Emergent Realities for Social Wellbeing

Environmental, Spatial and Social Pathways

Saviour Formosa (Ed.)

UNIVERSITY OF MALTA
L-Università ta' Malta

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Edited by
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Emergent Realities for Social Wellbeing: Environmental, Spatial and Social Pathways

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Imagery is published in greyscale. Where the Figures are replicated in colour at the end of the publication, the greyscale version is designated with the following icon.

To the ones we left behind, those new poor without access to the digital worlds and who might fall through the new social divide unless we create something familiar.

To the ones who are lost in real and virtual space, lest we forego to bridge the veritable gap between these two distinct worlds

And to all those who maintained vigil whilst waiting for SIntegraM to morph from an idea into a grounded project

To them I dedicate the finding of
l-Għariebel,
Proof that the era of exploring and discovery
is very much alive

l-Għariebel

Discovered by Saviour Formosa on
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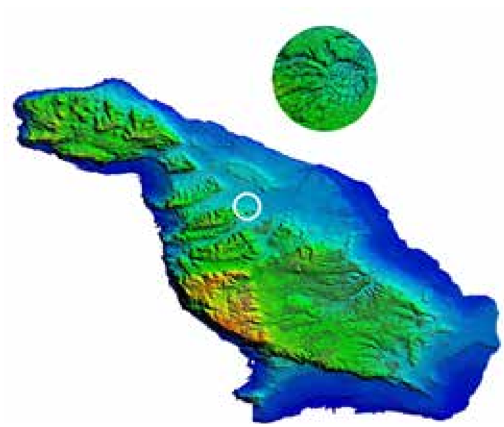

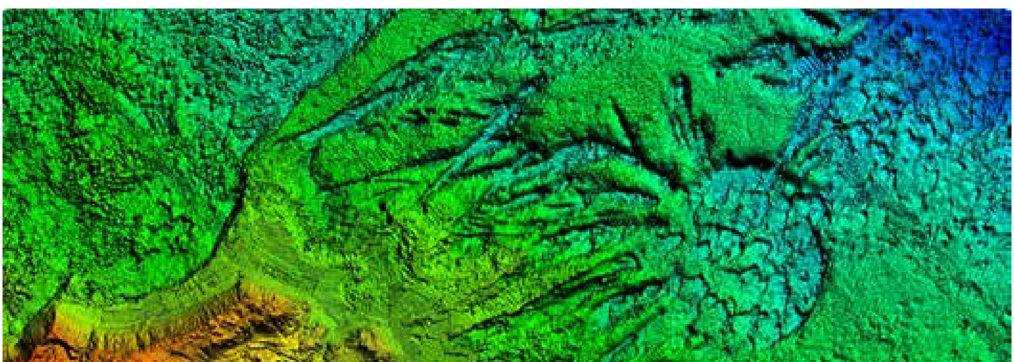

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Thanks also goes to Professor Alfred J. Vella - Rector of the University; Professor Godfrey Baldacchino - Pro-Rector; Professor Louis Cassar, Dr Timmy Gambin, Perit Vincent Cassar - PA Board Chairman, Johann Buttigieg - PA Executive Chairman, as well as the dedicated staff from the Information Resources Unit at the PA and those from the University IT Services staff, particularly Dorian Borg. A special thanks goes to Dr Janice Formosa Pace for her continuous review and Dr Andrew Azzopardi, Dean of the Faculty for Social Wellbeing. Final thanks go to Dr Ian Borg and Jonathan Vassallo for believing in the utility of such an endeavour.

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Finally, a word of appreciation to those thematic experts who reviewed this publication.

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With the reorganisation of the Public Works in 1992 into the Works Division made up of a number of Departments, Perit Cassar was appointed as the first Director General, a position he actively occupied up till 2003.
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In 2013, James Foden was appointed R&I Deputy Director with the Malta Council for Science and Technology, later to hold an Acting Director position for Programmes, Policy, Strategy and Projects. In 2015 he was appointed Director of the R&I Programmes Unit, being his current role. He is also a national delegate for European Space Agency and a Council member for Eurisy.

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PROLOGUE

Maltese Steps Towards Integrative Data
A Lifetime Target

Vincent Cassar

Understanding how urban ecologies operate and how one can relate to the changes required for social change entails a deep understanding of the structures that make up that society. This scenario is evident when one tries to understand how policy makers present their studies for decision-takers to act upon. In an ideal world the decision taker would have acquired knowledge of what planning entails, the situation at hand, the acquisition of a mental image of the area under study and would theoretically be able to decide on an outcome as based on such knowledge. Reality shows otherwise, since this process entails the full knowledge of how the data process is handled, how that data delivers meaningful information, which results in knowledge and eventually an informed decision is taken. However, the entire enterprise is based on access to information or the lack of same, to acquisition of information on the urban/rural structures and the environment in its wider aspects. Dealing with advocacy groups, non-governmental organisations and interested parties requires that the planner has a solid understanding of the physical, natural and social parameters that society is permeated with. A planner debating a decision on how to mitigate on urban sprawl would be required to understand how such urban ecologies morph from small hamlets to town and cities and eventually to metropolis, in addition to an understanding of the interactivities that occur between the players as based on the sociological pillars: politics, religion, education, family and economy. Each part plays a crucial role in its attempts to sway a decision one way or another. Without basic information across the fields planners may find barriers being set up that may thwart informed decision-making.

With the advent of a plethora of technologies and information systems, such knowledge can be readily placed on the planner's desk. Technologies vary from digital replicas of analogue files and documents, to OCRing (extraction of text from scans) documents that allow searchable options, to real-time data capture and finally to dissemination to the interested and general public. The process enables the lessening of pressure on the planner in terms of potential accusations of withholding of information to the potential for the NGOs and interested parties to be equipped with the same information which would enable them to reach informed opinions and to debate change.

The Maltese Scenario

The case employed within the Maltese Islands was aimed at reaching these goals where the planning process would be enhanced by the digitalisation of the entire planning process and the subsequent structuring of information and eventual dissemination. This keynote is aimed at helping planners understand the processes required to virtualise cities and the steps Malta took to create data layers that help this process. It concentrates on the unique situation where the legislative and operational tools available to planners were taken up through to the conceptualisation of a function that integrates baseline and thematic datasets for effective future analytical processes. The process is ultimately aimed at acquiring knowledge leading to the implementation of a smart cities approach where the data on every item and the relative flows are monitored in real time and where scenarios can be built to reflect the outcome resultant from every variable tweaking. As an example, understanding the effects of a new tall building would entail the insertion of a dxf model in a city model, the pooling in of spatial layers from transport, utilities, infrastructure as well as social information, with the resultant output where the different datasets are integrated in a model-based system and the scenarios tested as based on infrastructure load, increase in traffic, a growing elderly component and a myriad number of different variables. Though the latter can reach unsustainable proportions for the model, the choice of variables would be based on the knowledge gained from the expertise on the ground and other planners' knowledge-base.

In Malta, this process entailed the foresight requirement to enable smart-cities implementation, bearing on the virtualization of the planning process, the vision of a paperless system, the creation of a physical ICT (Information and Communications Technology) structure, funding options and methodological approaches to virtualization. The ICT structure is essential for valorisation of the smart-city approach due to its capabilities in integrating disparate datasets, a realistic gather-once / use-many functionality and ready take-up by the planning discipline as governed by the need to base all development on the use of a basemap as its core, working from a centralised approach to governance but a bottom-up approach to creation and use.

The Malta experience depicts a scenario where data is held by the legally designated data-creation bodies, where data is made accessible through a web-service model that point the dataset toward a common-core server.

Limitations experienced in striving to achieve the goals

The concept of place is a not an easy one to understand. People struggle to visualise the ambience of a city when described by another person: they have to conjure their vision of what that street could look like, how it is structured, the dimensions and scale, the spirit of the place, a distinction atmosphere better termed genius loci. This, whilst at the same time trying to listen to the thematic aspects being described by the other person. Imagine an architect trying to describe how a new development would look like once completed. The planner rarely visits the area and might recall what it looked like some time back or if ever, thus communication at the stage is hindered by background noise. The Malta process sought to integrate various technologies to enable both parties and even more such as third interested parties to visualise the area through technologies. The integration of spatial systems through to a 3D model has helped the process greatly. The model was based on a Lidar scan of the island, averaging a point density of 4.3 pts/m², with a classification of ground and nonground, which resulted in a DSM (digital surface model – includes terrain and buildings) and DTM (digital terrain model – no buildings) of the islands.

This process is still hindered by various factors; the lack of an integrated information structure across all government entities, lack of protocols requiring standardisation as well retention of analogue systems only (paper-based) and the silo-effect mentality where data acquired by one entity is seen as the domain of that same entity and thus required protection and guardianship. This is currently being mitigated through a process driven by myself and Professor Saviour Formosa from the Faculty for Social Wellbeing, which process was initiated in 1995 and required a mentality shift prior to its implementational triggering – I can personally state that this has been one hard struggle and that only driven personalities and sheer perseverance made this happen.

Back to the theme, Malta is driving its efforts to digitalise these processes and has been successful in its initial phase to digitalise the planning stream through internal investment whilst also accessing external funding to implement various tools and data capture. This it did through the knowledge that online maps, GPS (global positioning system) devices and smart technology have now been around since the late-1990s such that the university generation and the subsequent generation, have been exposed to virtual tools to a level that has been unprecedented some years ago. The older generations may need further aid to reach this level through training programmes as a clear understanding of the spatial-awareness is required. In order to employ this process, Malta took up this process through a project aimed at creating a series of technologies and protocols aimed at generating a virtuality of the island. This process to move from analogue to digital systems entailed scanning, the digitalization of the application process, the submission of digital plans, a GIS-based (geographical information system) planning process and acquisition of technologies that enable data capture, input, analysis and output. One such project entailed the creation of Malta in 3d using Lidar (Light detection and ranging) technology and the ERDF (European Regional Development Fund) project entitled "Developing National Environmental Monitoring Infrastructure and Capacity".

The steps that MEPA/PA took to understand spaces include various iterations of its legislative tools, as regulated by the Development Planning Act (DPA) of 1992 and the Environment Planning Act (EPA) of 2001, which were replaced by the Environment and Development Planning Act (EDPA) of 2010 and the new Act that set up the Planning Authority in 2016 (Act VII of 2016 Development Planning Act, 2016). In addition to these main tools, MEPA is governed by a series of subsidiary legislation that regulate planning and sustainability as well as the public participation process. In fact, the uniqueness of the amalgamation of the planning authority and the environment entity created the scenario that other legislative tools where integrated within the parameters of the governance such that the planning side now has a series of protocols for the datacycle that will be retained in place once the two entities part ways. Thus, in conjunction with the EDPA and its subsidiary legislation, a series of other tools were integrated, such that planners now have a plethora of objectives to follow in order to ensure that the data cycle is tackled in its entire process. These tools relate to access to standardised processes for information-creation which is being tackled from various legislative loci such as the Data Protection Act, the Århus Convention, the Freedom of Information Act and the INSPIRE Directive, in addition to other guidance documents that are targeted to enable the smooth and free flow of effective information. MEPA through its Information Resources and Technology Unit (IRU) has created a series of protocols that ensure further governance through metadata structures, lineages, adherence to the European Environment Agency priority dataflows and its own ISO standardisation.

These tools enabled MEPA to create a process that focused on its core function as a creator and user of spatial data. The organisation uses geodata in almost all of its business processes and has invested heavily in spatial resources and capacity. Users have multiple-level requirements, such as those who need to create data within a defined application process, others who carry out spatial analysis and data creation and editing processes as well as casual users such as the general public who require view and occasionally download services. Thus MEPA sought to create systems that provided a system that ensures a "capture once use many times" policy, employs a data owner/custodian mind set, implements data and quality standards, introduces metadata and discovery tools as well as disseminates data to the general public in a mixed charging mode: free for environmental related datasets and chargeable for other datasets as per time taken to run such queries.

The method employed in the effort to integrate the different functions across the planning and technological fields is that termed the W6H, a concept that was taken up through another discipline; criminology, which through its spatio-temporal concepts and requirements to convert thematic data into a spatial format, initiated a process to convert analogue data into digital forms. The ability of employing spatial data to form an analysis based on a what, why, who, when, where, why not and how phenomena (W6H) outlined by CMAP has helped spatial planning tremendously. GIS analysts seek to investigate each of the W6H pivots to identify patterns to reach conclusions on whether correlations exist or not. The six pivots (Who, What, When, Where, Why, How and Why Not) concept was employed as a basis for integration whilst the effort is currently being upgraded to encompass all spatial data creators and users entities that have a role in the foresight activities of the Maltese Islands. The main trust of this model is to ensure that all the process involved in the identification of activities relating of GIS analysis as integrated with other thematic data, are understood.

GIS has enabled information to be mapped over time. This means that statistics, such as those related to crime levels, could be understood in spatial contexts. As indicated in the W6H structure any data that has a link to a geocoded system can be analysed. In this way GIS has brought to the fore situations where previously non-spatial data (attributes) can now be linked to a spatial dataset and that same data would be integrated into a new GIS layer. Such a structure enables the evolution of thematic data to geographical data (locational data based on points on the earth) to a spatial construct (relationship between entities based on the earth) and across a temporal dimension. MEPA's role in this process was to create the base data to enable this foresight process.

The Strategy employed entailed a series of procedures were introduced and which served as guidelines for the whole data management process. It aimed to identify sources of redundancy and multiplicity, and enhanced a streamlined dataflow methodology leading to a one-stop-datashop environment. Whilst the strategy covered the main data management issues, it delved into ancillary services such as data creation methodologies, GIS services and research & information practices. On a logistical side it also outlined document management, data acquisition process inclusive of scanning and digitising, as well as dissemination processes inclusive of pricing policy, archival services and dissemination processes.

The data management cycle investigated the processes required from design, data gathering, input, analysis and output as well as data dissemination procedures. A generic data model was identified for thematic data models that were implemented for the different processes. In addition, metadata and lineage system procedures and templates were drafted. This entailed the implementation of a document management solution in line with strategy that established guidelines for the setting up of a repository system that aids data management control and maintenance. This was reviewed in line with the electronic-applications process, a service contract and other projects. The process was followed up by a document digitisation and uploading activity. Parallel activities entailed a process implemented to review the spatial data structures and layers within MEPA. The process aimed to source all data layers and developed common storage locations. It identified the available resources and GIS skills as well as bringing forward the need to follow strict metadata and lineage procedures.

The final aspect employed a data dissemination policy in order to streamline its services towards a harmonised approach. It reviewed issues such as pricing policy, publication options, marketing of data services, and dissemination through webservers. The outputs emanating from the integration of various technologies, proprietary and open-source that integrated the spatial layers and disseminated such through a dedicated mapserver.

The output system showed that the limitations experienced through the use of tools that are not universal to all browsers, point to the need to create a system based on web map services that follow the INSPIRE dissemination rules, with the relevant security system put in place to ensure system integrity.

The method identified issues that related directly to operational and implementation operands inclusive of budgeting, resource requirements, capacity, tendering and post-project maintenance. Malta partook to these activities through various means: in-house business plans, national and international legislation transposition, acquisition of funding and capacity building exercises. The crux of such projects lies with the eventual management and retention of the knowledge gained and its extension to other entities; a process that would ensure knowledge gain across the nation. The initial costs were significant, running close to EUR5million, with maintenance envisaged at EUR50,000 plus retraining activities, which costings are mitigated through reduction of expert time on recreation or redundancy elimination.

The next phase that attempts to integrate the planning data with all other governmental entities' data within a central core has been initiated and is planned to take up the PA process and expand it to all entities enabling instant access as well as enabling societal benefits such as post-disaster management. The project entitled SIntegraM: Spatial Integration for the Maltese Islands: Developing Integrated National Spatial Information Capacity is aimed at satisfying three aspects: building the necessary infrastructure, enhancing the human capacity and ensuring a legislative and mentality shift in ensuring the free exchange of data and established dissemination protocols.

The outcomes from the infrastructure aspect include the development of a new Basemap for the Maltese Islands, the alignment of all spatial data in a common projection, the creation of an online dissemination and analysis spatial information system, the setting up of necessary infrastructure to enable the entire data cycle (design-input-analysis-output-reporting) and the development of the necessary infrastructure to future preparedness. The outputs from the new project will enhance the outcomes from a project funded by ERDF that enabled MEPA to create an entire nation point cloud, rendered full public access to the information and enabled 3D views to all. The move towards a smart city approach will employ these datasets, integrate them within new infrastructure and allow immersive interaction within the new datasets, literally ensuring that planners are able to view the effects of their decisions in realistic scenarios.

The second aspect will strive to building human capacity in the spatial themes across all governmental entities, whilst the third aspect will ensure adherence to the INSPIRE Directive and relevant legislation as well as the creation of a series of protocols that enable the free exchange of data and knowledge across the entities.

In conclusion, the creation of a spatial information system for the Maltese Islands was simply the first step at attempting to understand how to create systems for employment by planners in a realistic and achievable scenario. The project was successful in its attempt to bridge the gap between analogue information and spatial planning information that depends heavily on locational data. Through an analysis of the legislative tools and the implementation processes undertaken to initiate the process that will eventually lead to a smart city data construct, the results show that the base-data steps taken will ensure the eventual integration of baseline and thematic datasets for effective future analytical processes. The Malta case study was only made possible through the intervention of various initiatives as delineated by the different Directives and conventions as well as national legislation. As both planning and environmental data were readily available, these processes were easier to employ and the resultant project outputs showed that it was possible to create new tools and systems that planners could use in their day-to-day professional activities and knowledge development. The next step, that of integrative processes across all government entities aim to further widen this knowledge which will result in new data integration such as geological, underground infrastructure, street furniture, watersheds, road networks and hundreds of other currently stand-alone datasets.

Interestingly, the process is not without its successes and lesser achievements. The impact of such an activity in the Maltese state is not insignificant, with the resultant pressures effecting directly and indirectly the modus operandi of the entities that partook to the activity. Training, realignment of job descriptions, new staff intake, re-training and capital expenditure were experienced. The drive enacted by the entity running the process resulted in a cascading effect on other entities that might not have been ready for such a change and in turn bottlenecking occurred that might slow down the expansion of the process across other entities, leading to slower uptake of the national process. This said, the fact that the activity was successful in the driving agency and that the impacts have already been experienced have enabled the laying of the foundation-stone for information integration leading to smarter environments.

Working towards a common goal for integrative information management

INTRODUCTION

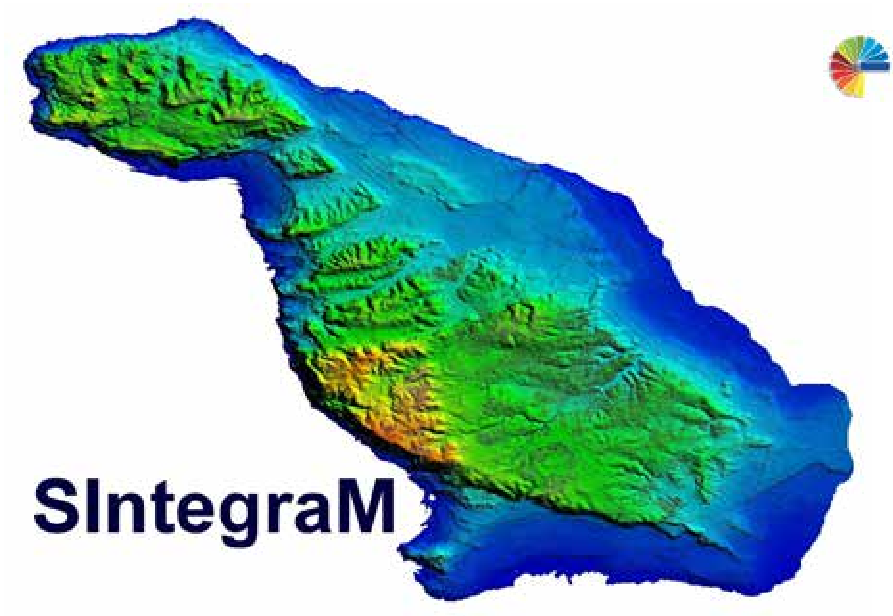
Patient Dilemmas in Fast-Tracking Technological Change

Saviour Formosa

Opening a window into the future is not an easy task. Attempting to open one in a generation after the initial launching step might seemed either idealistic, naïve or with hindsight plain driven. An idea that started off in 1995 by Formosa as paralleled by a similar but unconnected effort by Perit Vincent Cassar took two decades to take a semblance of form and structure within an achievable framework. These two steams of though came together in 2013 at the then MEPA which effort sought to push all spatial information within an integrated core that allows Malta to jump from a Data Phase to an Information Phase and over the next years to a Knowledge, Action and Wisdom phased approach. The two proponents converged and the effort took national significance through the SIntegraM concept: a concept that aimed to create a functionality targeting the Spatial Data Integration for the Maltese Islands: Developing Integrated National Spatial Information Capacity – hence the acronym SIntegraM.

Vincent Cassar in the preface depicts the difficulties in expressing such a vision into reality and with drive and a thirst for the achievement of a 'dream' as well as successes emanating from a previous ERDF project conceptualised and initially led by Saviour Formosa entitled "Developing National Environmental Monitoring Infrastructure and Capacity´. The lifetime experience on dealing with pitfalls and successes brought together these two persons and significant others resulting in the approval of SIntegraM through consistency and perseverance as well as the tackling of a bottom-up approach that saw all entities brought on board, whilst tackling the highest governmental echelons to ensure take-up and ensuring a cascading effect on project ownership.

However, in terms of on-the-ground acceptance, the process required a mentality shift to ensure readiness in data and information sharing, the abolition of data hoarding and the creation of collaborative protocols that ensure a gather-one/use-many scenario within a spatial construct, is coming to fruition. This process was required due to the need to ensure the elimination of barriers created through lack of access to data, the transposition of the INSPIRE Directive and a collaborative approach across all government entities.



Formosa initiated a conceptual process whereby data is built around a spatial-core and which resultant information could be used by both policy makers and academics to create knowledge and in turn action. The project will benefit Maltese Society due to its integrative process, a foresight perspective, governmental entities who can share and improve efficiency and effectivity, the industry and civic society as well as other social structure falling within the sociological foundations of society. In turn, this is an opportunity that such efforts empower the University of Malta due to its cross-thematic approach that spans all Faculties and Institutes both through access to data, access to data capture and analytical technologies as well as access to expertise.

The project will deliver a strategic approach to spatial data, integration of vital base datasets, new legislation as well as training, The main concept built around the creation of data creation protocols, information exchange, access to data, and inherently data protection and privacy, In terms of infrastructure, the project will acquire systems, equipment, data capture devices using aerial, terrestrial and marine technologies, in addition to analytical and dissemination tools that will ensure inter-governmental data dissemination, and national preparedness.

Examples of integrated research that span disciplines could include the analysis of air pollution as carried by air currents as affecting the health of children who live close to an amenity site or the investigation of potential development as it affects landscapes and skylines through a euclidean or viewshed approach, in turn resulting in the calculation of flooding that in turn alerts the Civil Protection and Transport entities to close off areas at risk. The project is set to change the way information is viewed, accessed and given academic value - added in turn enhancing the University's role in bringing about social change.

This publication seeks to help readers understand the efforts required to reach the integrative stage, mainly pushed by individual efforts that rendered the situation a lesser evil when pushing the spatial envelope. Those efforts are transmitted in the studies presented in this publication, spanning the physical, social and environmental domains.

The Technological Constructs as Foundations for Change

The first section focuses on the structural concepts and activities that impinge on the development of technological systems targeting the creation of foundation elements across the different entities..

Chapter 1 highlights another implementation project employing geographical information system (GIS) based applications. Brian Borg states that adopting this "spatial" strategy has enabled the WSC to determine how our core business can exploit location data to improve decision-making, reduce risks, and optimise operations. The WSC is as yet the first large local organisation to adopt GIS to manage, control, and plan internal projects. Over the years the corporation has built up a very comprehensive GIS capacity that includes the geo located points of all water meters, valves, taps, and pipes that exist on the Islands. Since the WSC is also responsible for Malta's wastewater, the company also has the same facilities in this sector too, complete with slope angle and elevation data. Borg describes the AquaDot AMM solution that can also provide users with information on which gateways have serviced a specific consumer meter over a period of time, rendered an enterprise-client interaction cycle closure.

Maria Gove, in Chapter 2, looks at the advances in technology that have made GIS more valuable in almost every field, not least of all transport, where Transport Malta is aiming to keep abreast with technology. As the GIS technology continues to evolve and our individual systems are becoming part of a larger interconnected platform, a platform to bring together all our data, technology, processes and people together was required. In view of this, Transport Malta implemented an EU funded project named STREETS - STRatEgia pEr un Trasporto Sostenibile to create a platform not only for the use of the public, and project partners but most imperative for the internal use across Transport Malta directorates. This project was developed in collaboration with academia and Italian partners under the Italia – Malta 2007-2013 programme was accepted as a strategic project under the Italia-Malta Programme. Transport Malta was given the task to create this platform. The GIS Platform supports the backbone infrastructure required to facilitate and streamline processes, integrate isolated datasets used by the different target groups. By consolidating operations within the directorates and facilitate transportation planning decisions by providing one common source to integrate, visualise and manipulate land, air and sea transport, this results in strengthened harmonisation required between the directorates.

In Chapter 3 Saviour Formosa envisages the initialising of a stepped approach towards access to spatial data never purports to offer a dull moment. Stepped approaches that aim to make sense of data and harmonisation are hindered by capital and recurrent issues that pertain to the creation and maintenance of systems and protocols whilst governance across a national landscape impinges stressors on any system. The SIntegraM concept was initiated in 1995 on a two pronged process, that pertaining to a simultaneous but independent bottom-up and top-down process that had striven to achieve success but were constrained by the early concept hiccups that did not empower the project due to failed uptake by diverse entities and a defunct base mapping system. SIntegraM saw the coming together of two project champions who spent four years to morph their conceptualisation, bring together all public entities, present a spatial data integrative approach and eventually apply for basal funds to implement change.

The result was based on an integrated approach to the data cycle, innovation concepts on data capture, integration and capture, the creation of a data-sharing protocol structure within a protected and secure environment and also the newly innovative action where hardware and apparatus will be shared by all government entities, under the gather-once / use-many philosophy. The stepped approach moved away from the vicious cycle of data hoarding and towards a spiral based on the need to use such resultant information eventually growing into a complex but readily available system that is driven by the Maltese Garigor interlocking but structurally sound.

Chapter 4 posits a treasure trove of spatial informational data and access to same date. Stephen Grixti and James Foden consider the extensive investments in satellite Earth Observation (EO) there is an ever increasing running archive of open satellite imagery over the Maltese Islands. This is primarily due to the European Union's Copernicus Programme, an EO infrastructure that collects data and generates geospatial services supporting numerous sectors amongst which environment, security, transport, energy, climate change and the management of natural resources.

However, only when these new services become well known and widely used by society will expected returns on satellite investments be fully reached. On a local context the uptake of services stemming from available EO data is still at an embryonic stage and the potential in supporting the various governmental entities is somewhat under exploited. This is in part due to lack of awareness regarding the availability and potential of locally relevant EO data, thus limiting demand and willingness to invest in preprocessing services. Through its membership of Eurisy, a consortium of European Space agencies aimed at bridging the gap between space technology and society, and the subsequent understanding of the potential of such imagery over the Maltese islands, the space directorate within the Malta Council for Science and Technology (MCST) is well placed to instigate the local uptake of such data. At the core of this reasonability, the directorate is undertaking a study to create a mind map connecting the various governmental entities to their data 'needs' or interests. The work provides the space directorate with an understanding of the status quo as far as the utilization of satellite-based information is concerned. This exposes the specific challenges the various entities face in fulfilling their respective remits and sets the foundation to appropriately stimulate the local uptake of satellite data/services.

The final Chapter 5 in this section, that penned by Omar Hili, acknowledges that Spatial Data Infrastructures (SDI) are undergoing development worldwide in various Geographic Information Systems (GIS) sectors. In this respect, the study gathered data and reviewed literature on SDIs to establish the design of a conceptual model for an environmental SDI in the Maltese Islands. The environment is a highly discussed topic at all levels in Malta. As the study the environment protection was entrusted to one National Authority – the Planning Authority (PA), which was also responsible for all national matters related to planning and also included the national Mapping Agency. With the separation of the environment function of the Authority from planning and national mapping, this study was undertaken with the aim of developing a new strategy for the conceptual model in relation to how the SDI impacts on such a change.

The study analysed in depth the Authority's data cycle: how data is acquired, transferred and reported, and then devised a new strategy for the conceptual model in relation to how the SDI impacts on such a change. Understanding how it works has assisted in providing solutions, such as the need for programmers, ICT infrastructure, more GIS theme experts, change in Governmental policies and ideas to better improve the conceptual model. The results clearly defined important issues such as: policies, legislation and reporting cycles to the European Union (EU).

Chapter 6 delves into the creation of the base layers for social analysis through the Census process. Maria Refalo, Silvan Zammit, Saviour Formosa and Ashley Hili focus on the focuses on the geographical information system (GIS) approach that was incorporated into the 2011 national census of population and housing. The GIS perspective adopted a methodology where census statistical data was integrated into the spatial element, giving visual interpretation more ease to be understood by the end user. The process employed was to create a more homogeneous and seamless study with statistical data based on hypothetical approach in absence of comprehensive set of georeferenced granular data in register form.

Spatial interpretation was created through an extensive process in plotting each enumeration area with their respective routes, which also represented a number of houses, formerly delineated. These routes consisted of a number of streets or parts thereof in a particular locality, totalling 1022 across Malta and Gozo.

The GIS application was a compelling arena in this respect as it was a recent introduction and analysis of the data that can be executed efficiently; creating a niche for further studies on the data compiled through the voluminous data collection of the census. In addition, the GIS approach was also used to represent census data in a series of 1km2 grid cells according to INSPIRE principles – a European-wide grid net of 1 km2 containing all grid cells intersecting the landmass of the countries concerned (EU27 + EFTA countries as at end 2009), including all inland waters.

Constructs for an Environmental Understanding

The second section of the publication looks at the wide range of domains expressed within the environmental domains as the authors attempt to understand what makes terrestrial and bathymetric zones tick.

Andrew Agius, Charles Galdies, Alannah Bonnici and Joel Azzopardi argue in Chapter 7 that several aspects of modern society have come to depend on accurate and regular weather forecasts which allow them to make strategic and informed decisions, in order to preserve and maintain their assets. Due to the extent of the calculations involved in meeting the accuracy and quality requirements, NWP models are used. One of the most commonly used NWP systems is the WRF model. However, the default boundary conditions provided by the model are considered to be course and contain data irregularities that limit the accuracy of the weather forecast. This is because surface features such as albedo, vegetation, land-sea mask, and moisture are able to affect the overlying meteorological variables and related atmospheric dynamics at various scales.

The aim of this paper was to demonstrate how such a surface boundary condition can be improved by inclusion of high spatial resolution land cover categories of the Maltese islands and quantify the resultant improvement of the weather forecast made thereafter. The land use categories, which were based on the USGS 24-category Land Use Categories as per WRF model requirements, were significantly improved on the basis of LANDSAT data by applying the ISO cluster unsupervised classification method.

To determine the effectiveness of these improved surface boundary conditions, the precipitation and temperature forecasts of a high rainfall precipitation event over the Maltese islands were generated and compared to observations from eight local weather stations distributed using both the default and improved land use categories. Model statistical measures showed an overall improvement in forecast accuracy.

An interesting topic, more toxicological by nature is found in Chapter 8 where Chiara Scicluna and Renald Blundell stated that although some debate exists as to the subject, elements which are classified under 'heavy metals' have come to be those which pose a threat to humans in terms of toxicity. Intoxication with heavy metals is not a typical diagnosis as it is fairly uncommon. This can impose a risk on people who fail to be diagnosed and removed from the source of exposure, increasing morbidity and mortality.

For the purposes of this chapter, in order of atomic weight, the following metals will be discussed: Aluminium, Chromium, Selenium, Silver, Cadmium, Mercury and Lead. A brief introduction of each element's chemical and physical properties will be given, as well as its sources in the environment and any uses. Each metal's toxicity was illustrated using several actual cases of poisoning. In instances were human cases are not available, animal studies are discussed. Any treatments for intoxication are explained at the end of each section.

In Chapter 9, Michelle Borg states that the land use planning system introduced in 1992 placed the coast as a resource meriting environmental protection particularly from tourism. Within a policy framework to constrain urban sprawl, the strategy in the Structure Plan for the Maltese Islands called for a coastal Subject Plan and protection of public access.

As an island nation our survival depends on the coast. Ports provide an economic life link, critical infrastructure provides energy and water, engineered landfills and sewage treatment plants manage our waste, while reprieve from the hot weather and urban areas is obtained through clean seas and scenic landscapes respectively. The quality of our coast determines the wellbeing of all those living here. Managing the coast and its users requires a comprehensive approach that recognises the dynamic nature of the land-sea interface. The challenge to implement this approach demands policy integration: the parallel processes introduced by the 1992 planning legislation that called for stakeholder consultation in decision-making proved essential. The extension of planning legislation to incorporate the sea in 1997 consolidated it further. Data collection improved the knowledge base on the coast, its resources and users.

Transforming exploitation into long-term stewardship remains a challenge, one that is further augmented by the predicted impacts of climate change. Based on coastal management principles and building on two decades of experience, the Strategic Plan for Environment and Development adopted in 2015 identifies the coast as a distinct spatial unit with an integral role to enhance climate resilience, where the ecosystems-based approach to spatial planning aims to guide socio-economic development.

Charles Galdies and Neil Mallia posit in Chapter 10 and argument that the world is experiencing a rising incidence of extreme weather events due to a number of different inter-related factors. This increase in extreme weather is affecting society directly through many fatalities and large incurred damages, as well as indirect impacts that affect industries and sectors in the long term.

The Maltese Islands are experiencing this burden imposed by extreme weather events and thus information is required to create strategies and to learn how to cope with such a situation. Three different historical extreme weather events that greatly impacted the Maltese Islands are examined by this paper. These were the supercell thunderstorm that occurred on the 29th of November 2011, the mesoscale convective system on the 2nd and 3rd of September 2012 and the hailstorm event of 15th of January 2013.

Analysis was done both from an atmospheric dynamics setting, as well as from an economic setting by assessing the monetary damages that they caused. The monetary damages on the basis of the number and amount of insurance claims presented by third parties as a result of these extreme weather events were examined and normalized in order to implement historical loss records that are more representative in today's context when one considers certain socio-economic factors. Using the data from IPCC's CIMP5 climate models, damage and loss estimations were generated. On this basis, solutions to the risks that future extreme weather events pose in Malta are reviewed.

The air monitoring networks and compliance to legislation were tackled in Chapter 11 by Francesca Tamburini and Ines Sanchez. Stating that Malta has gone through a significant economic, demographic and urban development over the last decade and though this had brought prosperity and new horizons to the island, it has also deploy the environmental conditions of the country. Due to the importance of its natural resources and its vulnerability to climatic change, Malta's governmental institutions ought to incorporate the protection of the environment to its national plans and programs. As part of this strategic line and due to the EU accession in 2002, Malta has started a long-term objective of coping with the EU requirements in terms of environmental monitoring network for air. Under this context,

MEPA had carried out a project funded by the ERDF entitled 'Developing National Environmental Monitoring Infrastructure and Capacity'. This article summarises the findings of this project that implied the analysis of the national environmental legislation and the comparison with the European Union directives, assessment of the current technical capacity and monitoring activities and the collection and evaluation of baseline data in order to determine the environmental status. Based on all these activities, the national monitoring network was evaluated and the level of compliance with the legislation requirements was determined.

Another insightful Chapter 12, was presented by Elaine Sciberras, George Buhagiar and Michael Schembri who look at the generation of and impacts of flooding through network analysis. The Maltese Islands are subject to sporadic flood events that have significant effects on the economic and social wellbeing, on transport and other infrastructure in affected areas. The derivation of hydrological networks in flood basins to establish the flow direction of runoff together with simulation of storm runoff volumes are key to identifying areas which are prone to inundation and flood risk. This paper reviews the hydrological networks derived from three separate studies to understand the generation of storm water runoff in four flood risk areas in the Maltese Islands. Hydrological networks were compared as derived from studies pertaining to the Storm Water Master Plan, the National Flood Relief Project and LiDAR topographic data.

LiDAR data were used as a high-end technology to derive Digital Surface Models, hydrological networks and to designate watersheds. A comparative qualitative assessment of the derived hydrological networks in the four catchments was carried out including the use of field data collected from the Marsascala catchment. The study identifies good similarities in the pattern of hydrological networks. Networks derived from LiDAR data demonstrate the use of such spatial technologies for hydrological studies. Shortcomings in the LiDAR-derived dataset were identified pointing to the need for on-site verifications to refine specific areas of the hydrological network. These relate to the location of man-made drainage structures and the removal of artificial pits. The use of GIS technology together with the rectified LiDAR-derived hydrological networks for modelling of storm runoff is foreseen as the next step for more effective assessment of flood risk scenarios.

On a parallel exploratory and in-depth analysis, Daniel Sultana in Chapter 13 looks at soil change quality. Soil monitoring and the early detection of changes in soil quality are essential to conserve soil for sustainable use. This study assesses various soil chemical properties for sites corresponding to those studied in the extensive 2003 MALSIS national soil survey (MALSIS). A comparison of both data sets may serve to highlight important changes in soil quality and potential ecosystem functioning, all of which are important for national sustainable agricultural management.

Soil bulk density results suggest that 59% of the locations assessed in 2013 had a greater average bulk soil density than the same locations in 2003 i.e. soil compaction is prevalent. Electrical conductivity results suggest that 67% of the locations assessed in 2013 had a lower electrical conductivity than the same locations in 2003. Organic carbon results suggest that 59% of the locations assessed in 2013 had higher organic carbon content than the same locations in 2003. Results for pH suggest that 65% of the locations assessed in 2013 were more acidic than the same locations in 2003. Soil moisture content results suggest that 61% of the locations assessed in 2013 had higher soil moisture content than the same locations in 2003. The average national soil depth was of 47.76cm.

Various soil management measures, falling under the description of "sustainable agriculture", have been proposed. These seek to maintain high crop yields whilst preserving soil quality in agricultural areas. Conservation tillage is considered as one of the most suitable management practices enabling sustainable agricultural production in the Maltese Islands.

Physicality and Realisms

Francesca Azzopardi tackles the functional elements of construction from an architect's viewpoint in Chapter 14, where society on a local and national level benefits from efficient time and team management in the construction industry. Collaboration, cross-functional teamwork, virtual technology and standardisation of data collation mechanisms encourage a 'team-think' approach, which encourages "inquiry, critical questioning, challenging behaviours (which) are all positive if they take place in a generally trusting and supporting environment" (Erdem, 2003). Adequate contractual selection, effective change management plans and definition of roles and responsibilities at the early stages of the project lifecycle boost time efficiency and aide team efficiency. They are supplemented by virtual methodologies and tools which facilitate time monitoring and control work advances in accordance with schedules established during project planning phases. These in turn facilitate a successful project lifecycle, to the advantage of the surrounding local communities who stand to gain on an economic and social level with the least societal nuisance associated with such construction projects.

Valerian Croitorescu and Alexiei Dingli, in Chapter 15 study the challenges and approaches for smart innovative transport system replication where the mobility of the future will represent an outstanding challenge for smart transport at least until 2050. The revolution of the mobility will be assured by vehicle electrification and concurrent autonomous driving. Smart innovative transport systems will be developed on the two technologies, being able to meet all travel needs, preservation for the natural environment, long-term viability and less harmful emissions. Cities all around the world must be well-prepared for the changes that will be initiated by these two fast developing technological fields in order to gain a maximum benefit towards sustainable mobility. Starting from developing the innovative transport system and familiarising the users with the newly autonomous driving technology, the challenge consists in offering considerable reduction on emissions, costs and traffic management.

The proposed solutions consist in electric autonomous vehicles for public transport, intelligent systems for vehicle to vehicle, vehicle to grid and vehicle to infrastructure communication systems for transport planning, autonomous-charging grids for higher energy efficiency and plans of measures for travel awareness by autonomous transport systems. The electric autonomous vehicles consist of modular platforms, equipped with electric machines and high capacity batteries. The intelligent communication transport system sets the transport planning and the vehicles behaviour. The approach to implement the innovative public transport covers several points of interests inside the studied areas, the proposed routes and the possible risks. The challenge consists in improving the currently transport system and to increase the community wellbeing.

Frans Mallia investigates the benefit that spatial planners glean when faced with better familiarity with integrated information systems in Chapter 16. He states that the planning process in Malta is one of the most important public administration activities and involves many environmental and socioeconomic considerations and interactions. Some of these are highly sensitive and in some cases may even escalate into nationwide controversies. He argues in favour of a rehaul of the modern planning process that should be evidence based; approached in a comprehensive manner; multi-disciplinary, participatory and inclusive in approach; transparent and systematic in execution; offering opportunities for public participation and redress; sustainable and making the best overall use of the available and envisaged resources; accountable; equitable; realistic and executable; taking into account socio-economic realities; and inspiring the confidence of all the involved actors and the wider society;.

A good number of these requirements are addressed through legislation whilst others are addressed through administrative and operational measures. Technology pervades every sphere of society. When judiciously applied, technology leaves benefits that can be enjoyed by many spheres within society. There are many areas in Maltese planning process which have employed technology to achieve a wide range of aims. The most evident tools include the wide use of digital technology which greatly assists the near real-time dissemination of information and promotes a higher level of public participation and transparency. Moreover, the geo-referenced presentation of spatial information greatly facilitates decision taking and decision making.

Concluding this section, in Chapter 17 Adriana Zammit depicts Sustainable Underground Development as a vital element in the understanding of physical domains. She states that the current realities of shifting demographics coupled with improved liveability and environmental protection standards is creating a strong demand for new and additional infrastructure, especially at underground levels. The use of the underground to support above-ground spaces is, in fact, becoming increasingly important. However, in several countries, inlcuding Malta, the development of subterranean spaces tends to be piecemeal. Most of the underground projects in hand being implemented ad hoc with no real long-term planning. Considering that the underground is a non-renewable resource, its uncontrolled development can add more pressures to the operations of cities rather than supporting them. To achieve sustainable development, urban planning should also consider the underground as an extension to the spaces above. This study shows that planning the underground nationally entails two main constructs.

The first takes into account the dimensions for underground urbanisation that include the underground space, geo-materials and groundwater for Malta. Energy could also be considered as another dimension as is the case in certain countries. The second focuses on the collecting, organising and analysing data to create a holistic perspective of what exists below ground in terms of geology, archaeology and existing infrastructure. This should be combined with data gathering on behavioural patterns of the population to meet their demands. It is thus imperative for decision-makers to appreciate the importance of underground as a resource that must be developed in a systematic manner. This is required to optimise resources, make cities more liveable and promote sound, sustainable development.

Social Wellbeing

Societal Wellbeing is a term seldom understood as it balanced between the concept of societal functionality and the human aspect within such a construct. Whilst studies focus on the sociological foundation of politics, religion, education, family and economy, these factors only become tangible once placed within a physical and environmental structure. These four chapters look at the preparation for disaster management, vandalism and damages, census base mapping for thematic analysis and finally a study into urban ecology and migration within a spatial construct.

John Agius, Marc Bonazountas, George Karagiannis, Elena Krikigianni and Chrysovalantis Tsiakos tackle risk assessments from a public policy perspective in Chapter 18. As the emergency management paradigm shifted from response to prevention in the 1980s, risk assessment progressively turned into a key requirement for civil protection authorities. European Union Member-States are required to draft National Risk Assessments, while State governments in the United States of America must also develop hazard mitigation plans based on disaster risk assessments. Existing methodologies fundamentally focus on analysing hazards and assessing vulnerabilities thereto. However, regulatory requirements are different in each country and the strategies for conducting disaster risk assessments depend on the type of decision-making support obligations. For example, risk assessments are hazard-based in the United States and scenario-based in the European Union. Similarly, disaster risk assessment methodologies are also diverse, with each national agency or international organization adopting its own variant.

This paper is meant as an overview of the diverse requirements for disaster risk assessments. First, we review the regulatory obligations for conducting disaster risk assessments in the European Union, the United States and elsewhere. Then, we outline the main strategies for assessing disaster risks, including the scenario-based and the hazard-based approach. Next, we present the variations in the existing methodologies and, finally, we discuss the role of critical infrastructure in disaster risk assessments.

Chapter 19 is dedicated to the study of a contextual analysis on the socio-spatial relationships of unauthorised graffiti and street art. Steve Fenech's study focuses on abandoned physical zones and how graffiti flows through the edifices, a phenomenon spreading elsewhere too, where graffiti and Street art have been under academic scrutiny for years by many researchers stemming from different domains, each with the intent to satisfy divergent curiosities. Although they are conceptually different, these phenomena have much in common, such as their nature of being committed in an unauthorised fashion leading to property damage, a term commonly coined as vandalism.

This chapter depicts the research findings of a recent study entitled 'Graffiti and street art: Location and dynamic aspects' that quantitatively investigated the spatial nature of the phenomena using geographic information system (GIS) applications to visualize the data points, captured at street-level, within the study zone. The study zone's locality context was chosen by the author and is made out of seven localities within the Northern Harbour Region, in Malta. The main aim is to investigate the incidence of the unauthorised graffiti and street art, and unravel any social, spatial and other relationships that may pertain to these forms of unauthorised art.

Through the use of GIS, the captured data points layer was visualised allowing for the creation of various hotspot representations using different proximity criteria. It was further queried by cross analysing it with other data layers obtained from Formosa (2015) to show if there is any link with the following themes: area, population, land use cover, poverty, total number offences and damage related offences. The paper will discuss the methodology applied and the research findings with the aim to provide further knowledge on the subject and shed further light on the geographical aspects of crime.

The final Chapter 20 investigates the theory of social disorganisation or urban ecology and depicts a detailed study on the ecology of migrants' ghettoization of Marsa. Clayton Xuereb employs GIS to study movements, patters, social change and impacts on the societal fabric. Marsa is often described as a ghetto by the media. It has been depicted as a no-go area to be avoided by the local population. This was brought about by the recent phenomena of migrants who either reside at the Open Centre, or are attracted to this context for social or work possibilities. This research was conducted to investigate urban decay, areas of social disorganisation and the presence of migrant segregation in this town. A unique time geography approach was employed in this spatio-temporal research to study the dynamic activities of migrants in Marsa. Data triangulation was possible as multiple research tools were employed, including geo-spatial data collection, observation methods and elite interviews.

Thematic and spatial evaluations were implemented and the findings elicited were presented in hotspot and choropleth maps based on Burgess' (1925) concentric ring model. The results implicated that the area surrounding the Open Centre, which is also the space mainly occupied by migrants, is socially disorganised and deteriorated. The ageing local population, their lack of education, cultural conflict and racist convictions may be the reasons why this migrant related area is avoided particularly after sunset. The findings suggest that this area, according to criminological literature can be referred to as a transitional multi-ethnic slum. However, it might also be serving the purpose of the migrants' unofficial capital city in Malta, since it caters to their needs including employment, shopping and recreation. The results of this study recommend that, in order to alleviate the negative connotations with this area, an alternative solution to the Open Centre should be sought, capable guardians employed and education needs are to be addressed.

A Word in Time

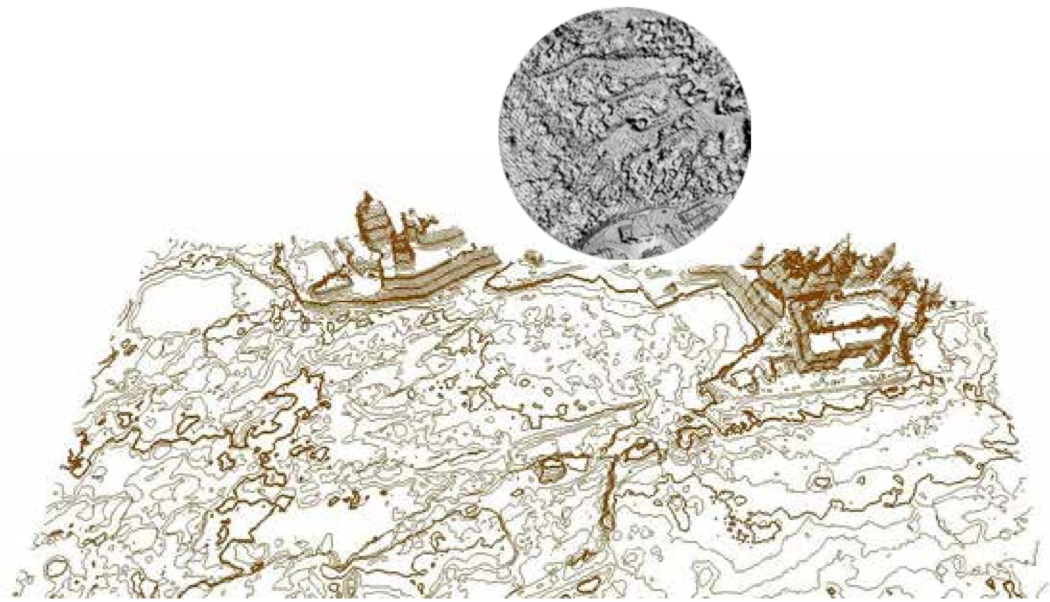
Timmy Gambin posits some thoughts on the next steps envisaged in Information Collaboration post-SIntegraM.

Societies have rapidly morphed into complex entities that are both fantastic and scary, both real and virtual, yet at the same time they are reflecting the result of years of debate and action in the physical, environmental and social worlds. The transition from a limited-information society to one that has rapid access, has morphed social structures into new forms in which the development and environmental disciplines played a critical role: in turn highlighting your specific input in such a transition.

The changes in the environment, development and social fields have wrought major changes in Malta's progress and knowledge gain, however few realise the implications of such a transitional change in wellbeing: whether at entire society or individual level. The resultant knowledge gain is yet to be fully established, as access to information, social, economic, educational and technological has outshone the actual transition, with most disciplines still struggling to understand the shift. In order to help such a shift, this book strives to enable readers to understand the transition of Maltese society within a rapidly evolving physical, environmental and social domains, each highly distinct but inherently intertwined. Spatial Information Integration plays a pivot role in the preparedness of a society for functional engagement in diverse changes within each of the same domains.

Pivot I

Technological Constructs as Foundations for Change



Ta' l-Għazzenin Rock-Cuts

Underwater rock-cut identified by Saviour Formosa on 15 June 2015
UTM 33N (ED50) (446211.297, 3978812.634, -8.006 m),
35° 57' 05.8990" N, 14° 24' 12.9159" E

CHAPTER 1

Using Brains Rather than Brawn: How the Water Services Corporation uses GIS-based Applications

Brian Borg

Introduction

Making sure that water continues to flow irrespective of population growth, increases in tourism numbers and other seasonal demands, requires a large infrastructure, sophisticated technology, and a dedicated organisation behind it. The Water Services Corporation (WSC) in Malta has evolved over the past two decades into a modern corporation adopting innovative technological solutions and sophisticated technology that has helped deliver the best-quality service to customers.

One way is by using geographic information system (GIS) based applications. Adopting this "spatial" strategy has enabled the WSC to determine how core business can exploit location data to improve decision-making, reduce risks, and optimise operations. The WSC is, as far as is known, the first large local organisation to adopt GIS to manage, control, and plan internal projects. Over the years the corporation has built up a very comprehensive GIS capacity that includes the geo-located points of all water meters, valves, taps, and pipes that exist on the Islands. Since the WSC is also responsible for Malta's wastewater, the company also has the same facilities in this sector too, complete with slope angle and elevation data.

An enterprise GIS solution is implemented and integrated throughout the organisation so that a large number of users can manage, share, and use spatial data and related information to address a variety of needs such as the creation, modification, visualisation, analysis, and dissemination of data in line with legislative (GoM, 2014; Cassar and Formosa, 2013). GIS benefits organisations of all sizes, and in almost every industry, because it allows strategic operators to visualise, question, analyse, and interpret data to understand relationships, patterns, and trends. There is a growing interest in and awareness of the economic and strategic value of GIS. Proper planning is the most important investment any organisation can make in building a GIS. Understanding one's GIS needs, selecting the right technology at the right time and establishing documented implementation milestones to measure the progress can ensure success.

In order to fully benefit from this solution and maximise return on investment, a long-term strategic plan was needed (ESRI, 2016). This chapter describes some examples of critical business functions where GIS plays a major role at the WSC (WSC, 2017).

AquaDot CRM

Within the customer care department incoming reports are geo-referenced directly on maps complete with accurate and fast search facilities. The objective of this newly introduced facility, is for so-called notifications i.e. reported technical issues, to be entered through a GIS application to SAP ERP, which is the standard information system. SAP ERP integrates the key business functions of the Corporation; which are mainly asset management, supply chain management, finance and accounting. Notifications are then automatically communicated to the relevant region and the officer in-charge of works.

The system has a number of features that would not be possible without a GIS. For example, searching for streets and locations, especially when reports are incoming over the phone, is certainly much simpler and visually verifiable. Switching between orthographic and street map views enables call centre personnel to confirm a reported location visually by giving back to the reporter on the other side of the line visual cues (Figure 1).

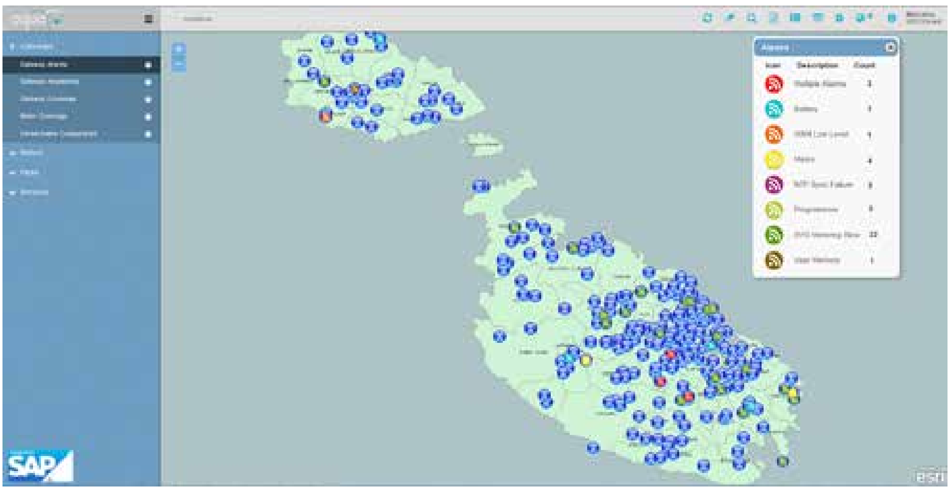
Figure 1: Customer care notifications

AquaDot AMM

The AMM AquaDot web-based solution has been developed with the primary scope of effectively managing and monitoring the WSC's smart metering system using GIS as the main driver. Given that the nature of the Smart Metering solution is essentially spatially-based, the AquaDot solution had to be a GIS-centric one. In order to obtain effective GIS interfaces and functionality, the solution was completely developed utilising the GIS spatial capabilities and functionalities which through its multiple tasks and methods proved to be extremely helpful.

The AquaDot AMM solution has become the main monitoring tool being used at operational level. To achieve this effective monitoring level, feature and geometry map services published through internal ArcGIS servers were used to monitor smart meter system components namely RF receiver gateways and meter module transmitters (Figure 2). Through visual aids users can rapidly identify the spatial location of, for example, a particular RF receiver gateway alarm (Figure 3). Users can also spatially locate meter-transmitter issues such as a meter-to-transmitter wire cut, tampering and low battery.

Figure 2: RF Receiver gateway monitoring



The AMM AquaDot solution also incorporates GIS in order to effectively monitor the radio reception between meter transmitters and receivers (Figure 4). By making use of appropriate geometry services, the reception area for every transmitter is stored and periodically analysed for any negative variations. Such variations are very often the result of antenna problems which give rise to requests for repairs. Stored reception area data in terms of metres squared is also providing information about overlapping reception areas.

With the use of GIS these overlaps can be identified and analysed for possible removal of redundant antennas which are very costly to maintain (Figure 5).

The AquaDot AMM solution can also provide users with information on which gateways have serviced a specific consumer meter over a period of time. Alternatively, users can specifically select a particular antenna to visually analyse which meters have been serviced within a specified time period. The GIS functionality within the AquaDot AMM solution also caters for the administration of meter-transmitter installation and maintenance management. Personnel can locate meters which require either a transmitter installation or an inspection. The planning of installations and maintenance have eased the operational construct.

Figure 3: RF reception comparison showing improvements in coverage through GIS based monitoring

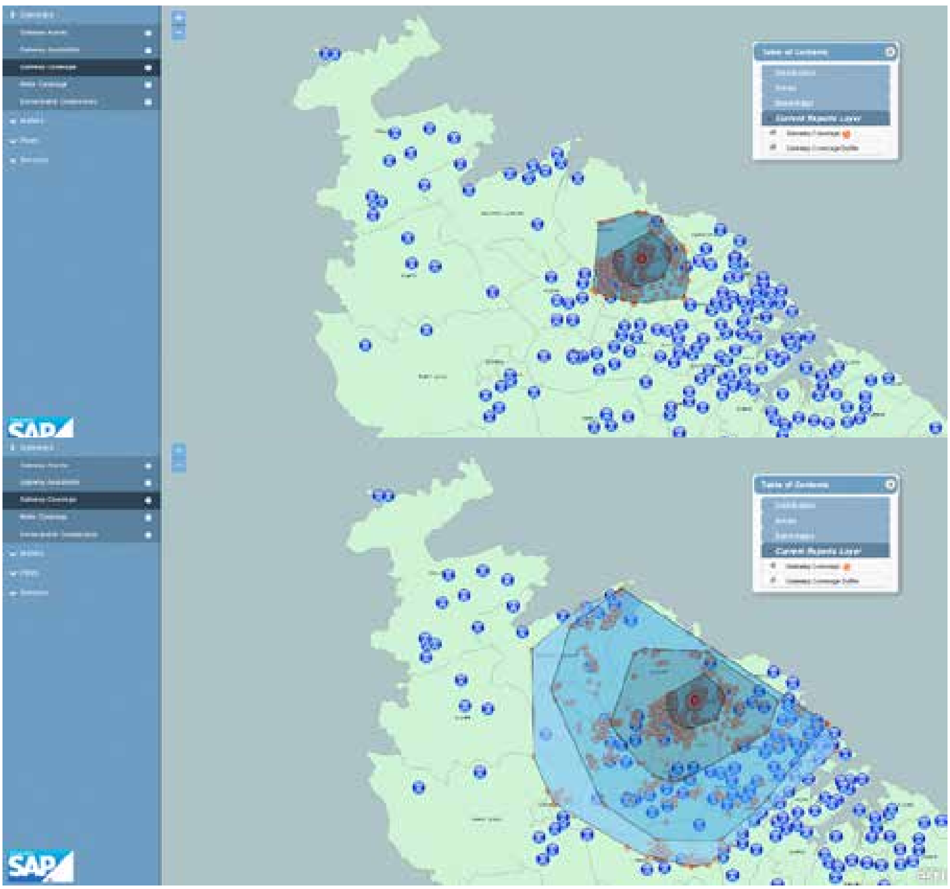


Figure 4: Meter to gateway reachability

Figure 5: Meter reachability spatial analysis

This solution makes use of the power of GIS to spatially analyse water leaks in predefined or on the fly selection of zones and to monitor water consumption versus water being pumped in the network to identify any possible water leaks in the system (Figures 6 to 8).

Figure 6: Water consumption analysis

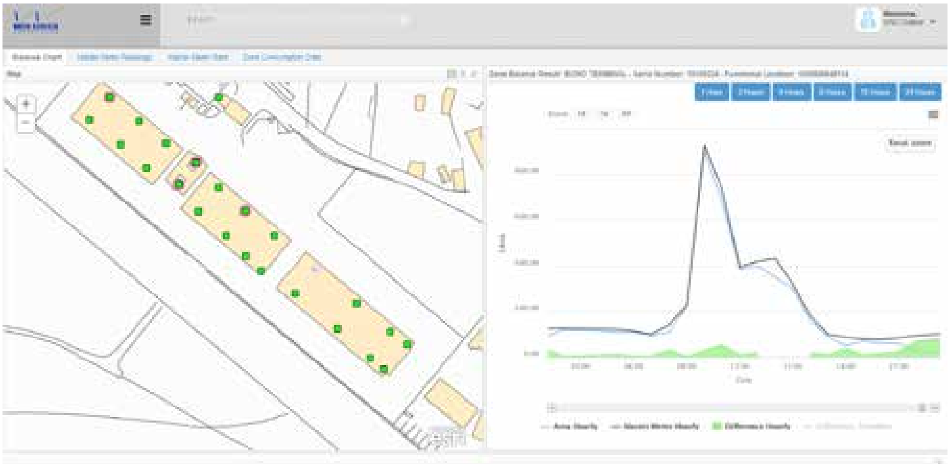
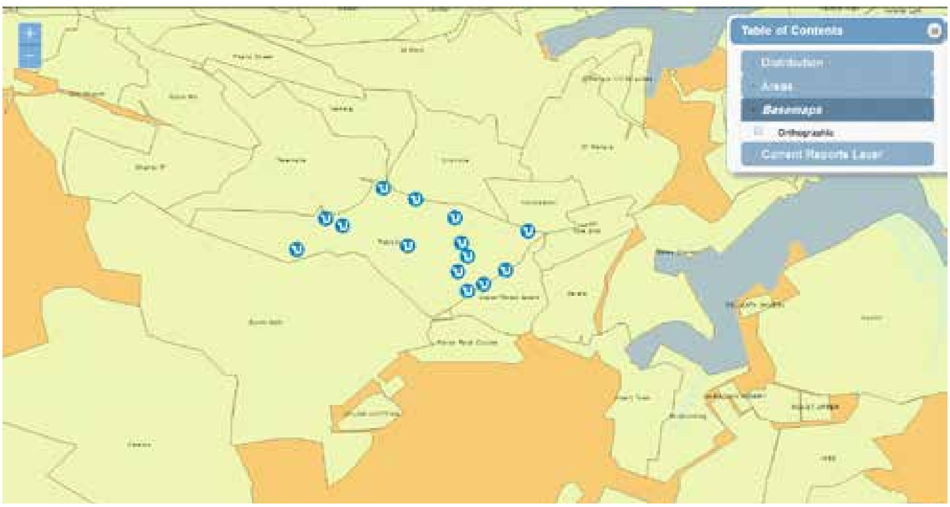


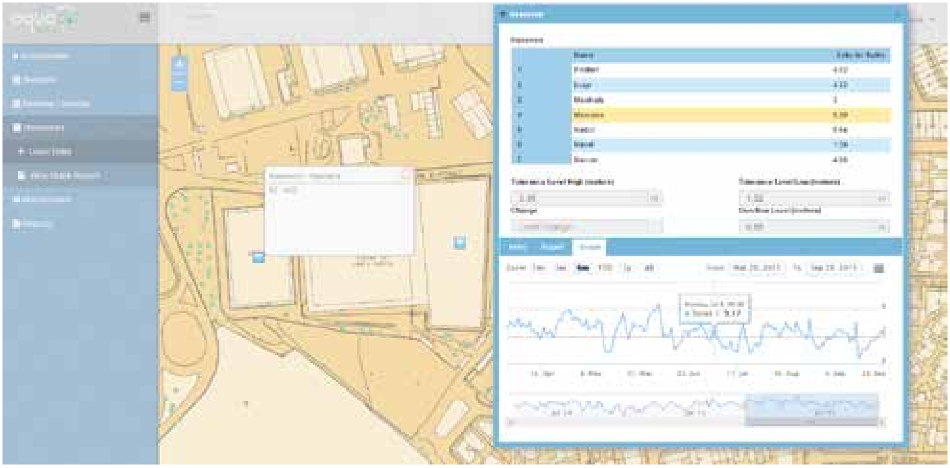
Figure 7: Meter reachability



AquaDot Projects

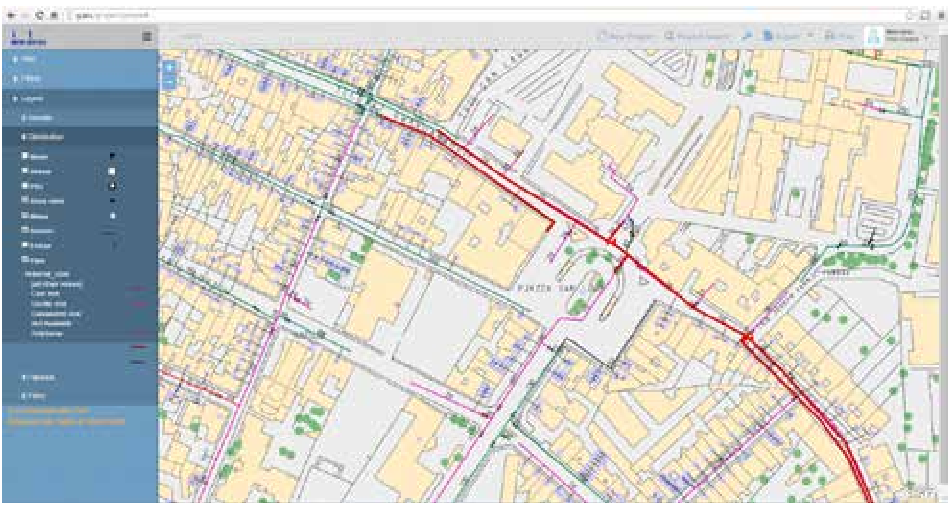
One of the main functions of the water services corporation is to undertake projects to maintain and extend the distribution and sewerage pipe network. The AquaDot projects system is a GIS centric in-house developed solution to manage these projects throughout their life cycle. Any planned project is system initialised through asset geocoding mainly pipes and other fittings. Consequently any attributes related to pipes and other assets such as pipe diameters and material types are stored with every geocoded feature.

Figure 8: Reservoirs monitoring



The GIS element within this solution has after a year of use proved to be extremely useful. Primarily it has become easy to locate the concentration of projects through heat maps. Moreover, as all projects are now being geocoded, various benefits provided by GIS tools are now being reaped. Amongst others, calculations of project pipe length, new service points and their costs, in the context of project locations can be carried out much more efficiently (Figure 9).

Figure 9: Geocoding of planned projects in red in conjunction with current distribution network



AquaDot Insight

AquaDot Insight is a Business Intelligence (BI) solution which provides high-level management reports and KPIs generated from data gathered by various solutions. Through the use of user-friendly dashboards, managers can effectively make fast decisions and evaluate trends. The GIS factor has been significantly integrated in order to provide relevant geographic information, such as specific dashboard provides managers with a visual display of a consumer meter transmitter percentage for every locality (Figure 10).

Figure 10: The red shading indicates local councils which have reached a meter transmitter installation percentage threshold

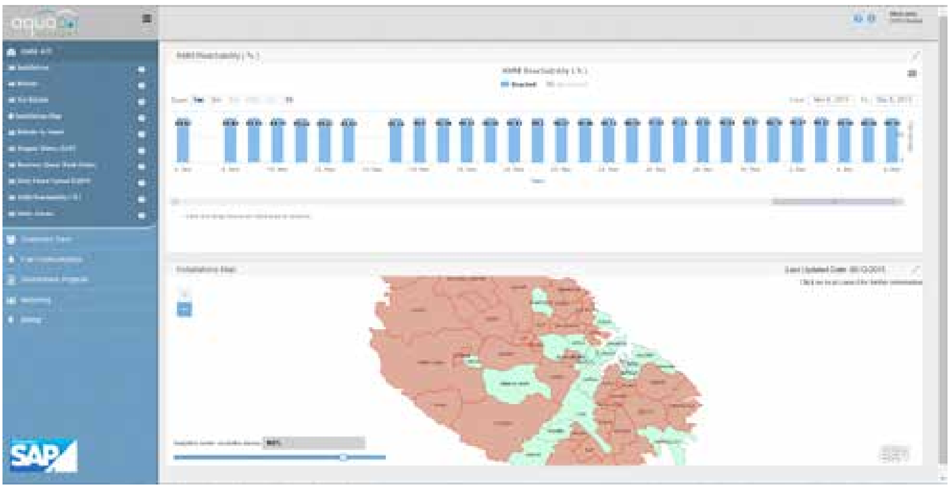


Figure 11: Heat map indicating customer notification concentrations

Another dashboard provides heat maps showing customer notification concentrations by notification types. Furthermore, spatial analysis is also being applied by generating heat maps based on the type of customer notification and their predetermined service level agreement (SLA). It is also being carried out to provide information about WSC projects through appropriate heat maps (Figures 11 and 12).

Figure 12: Heat map of notifications

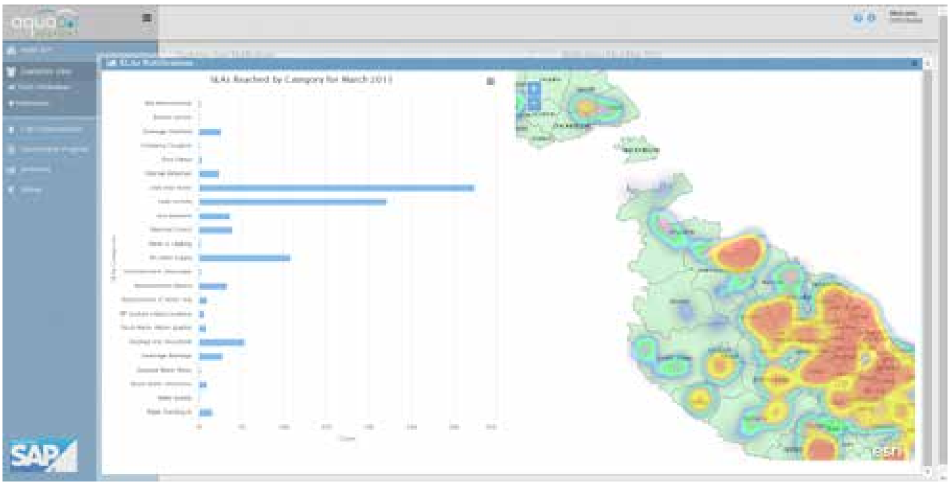
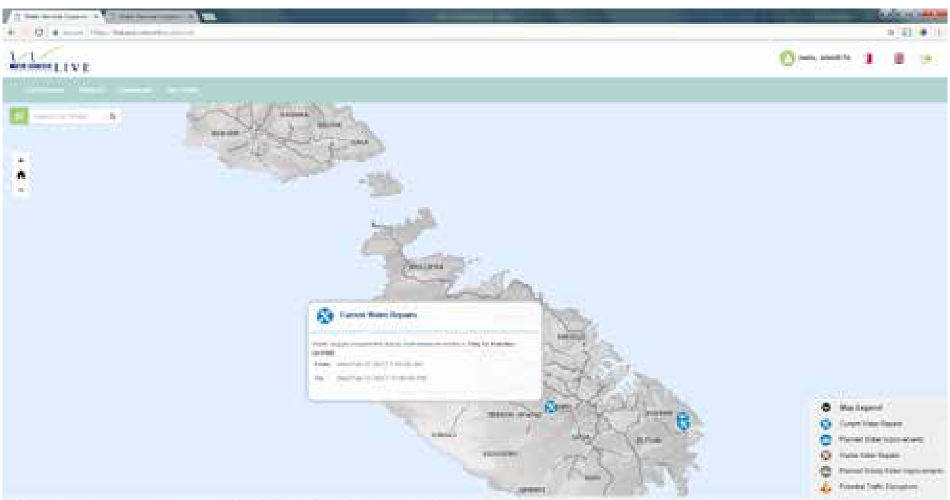


Figure 13: Water Quality monitoring

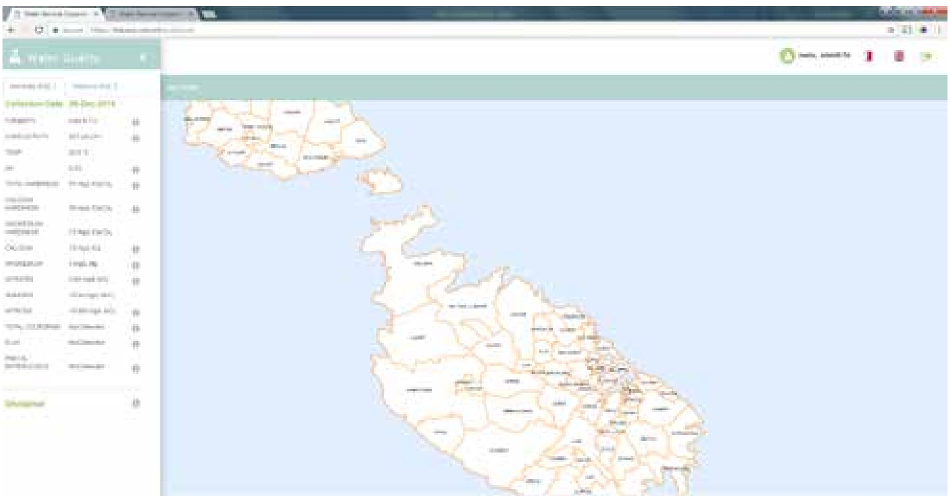


AquaDot WSC Live

The GIS-centric portal of the Water Services Corporation was designed and developed with the customer in mind. Maintenance works and planned future works and network upgrades are also depicted in Figure 13. A feature which is open to the general public, meaning that no registration is required, is the provision of water quality parameters. Water quality parameter values are obtained after meticulous tests on potable water taken from various sampling points are carried out.

Water is tested for various elements which may include amongst other chemical levels, possible bacteria and pH values. The portal makes it easy to view these values by simply clicking on a specific map zone whereby all the water parameters of that zone are consequently displayed. For knowledge purposes, water parameter descriptions are also being provided (Figure 14).

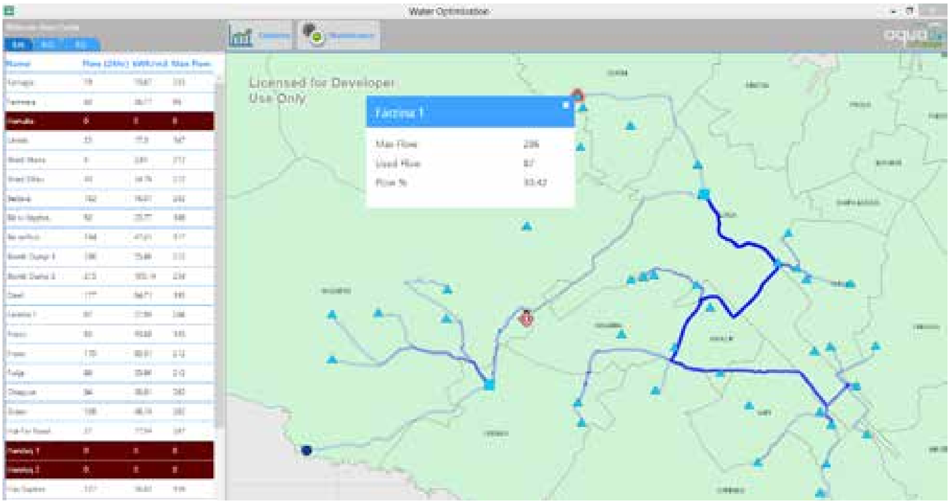
Figure 14: Water Quality monitoring - localities interface



AquaDot GIS Optimser

An area which greatly benefitted from GIS is the water production process. At present, the local management of water production is done manually without any formal consideration of optimisation. The Water Services Corporation integrated the GIS water hydraulic simulation model with Genetic Algorithms to optimise this process to meet demand, water quality specifications and minimise energy consumption. The results obtained from this model are very encouraging and indicates that there is room for drastic improvements (Figure 15).

Figure 15: GIS based water production optimiser



Conclusion

In conclusion, the system caters for the entire data cycle within a functional context that is governed by a core-GIS system, a decades-long activity to integrate systems and create a user interface that brings the input-output flow through a full-circle. The progressive applications described in this chapter have served as a case-study for the implementation of the integrated systems highlighted in Chapter 1 through the SIntegraM concept and project implementation. The WSC applications have enabled the spread of the spatial-information systems, as built around a central core, to other governmental agencies and entities.

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CHAPTER 2

Setting Up a Strategy for a GIS Platform to Empower the Transport Sector

Maria Gove

Introduction

In 2010, Transport Malta (2010) amalgamated the previous Malta Transport Authority, Civil Aviation Authority and the Malta Maritime Authority into a single regulator that is responsible for all the modes of transport in Malta. The role of Transport Malta is to plan and provide sustainable, high quality, safe, integrated and efficient transport service that will meet the travelling needs of commuters and the transport requirements for the movement of goods within the national framework.

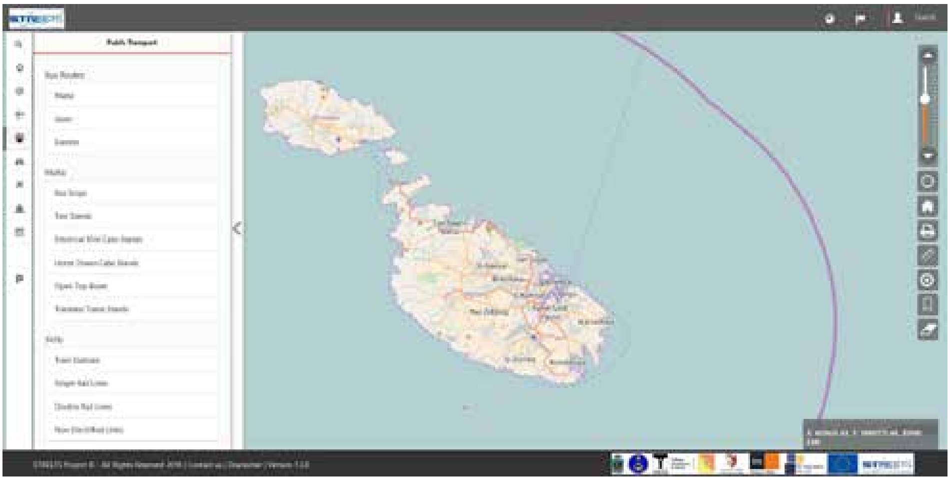
As the Authority is responsible for all the modes of transport, harmonisation between the directorates needed to be strengthened. Following an extensive Gap Analysis exercise across Transport Malta directorates to take stock of all the spatial data stored at the various directorates within Transport Malta and also to catalogue the operational systems, between 2011 and 2012, the Authority sought the means to justify the budget required to implement the platform required. A GIS Platform would consolidate operations within the directorates and facilitate transportation planning decisions in providing one common source to integrate, visualise and share spatial data.

In view of this, a proposal was submitted to implement STREETS project (2016) in collaboration with academia and also Italian partners under the Italia – Malta 2007-2013 programme (Figure 1). This proposal was accepted as a STRATEGIC PROJECT under the Italia-Malta Programme.

The Lead Partner of the project was Regione Siciliana Dipartimento Regionale Infrasstrutture mobilita e trasporti, and the other partners were Arces Collegio Universitario (Sicily), Transport Malta, University of Malta, Comune di Vittoria (Sicily) and Autorita Portuale di Catania (Sicily). This Strategic project had a total budget of €2.5M, of which was co-funded by ERDF (85%) and National Funds (15%).

In March 2015, the public interface of the GIS platform was launched. This platform is continuously evolving and internal services deployed across the Land, Air, Roads Infrastructure and Sea directorates plays a central role in providing a fully empowered solution that can manage all the different aspects of processes, infrastructure, software and data.

Figure 1: STREETS interface



Source: http://egis.transport.gov.mt:8030/egis

Rationale

The overall objective of this project was to strengthen the transport link between Malta and Sicily, identify bottlenecks and come up with a common strategy to provide an efficient transport link between Malta and Sicily. In order to strengthen the transport link required with its counterpart in Sicily, Transport Malta aimed to internally equip with the required infrastructure to reinforce its backbone infrastructure, by ensuring that processes, resources and isolated datasets are fully integrated in this platform. Through STREETS, Transport Malta embarked on implementing the required GIS Platform across all Authority focusing on building the platform to create and integrate GIS applications with other business systems deployed at Transport Malta.

Transport Malta's ultimate aim is to sustain a multimodal network to provide efficient connections between the ports, land and air transport models at all levels. The transport network is a key element and serves as an essential reference data to each transportation application providing spatial information on the Mediterranean Roads in Malta and Sicily as well as the maritime and aviation links between them. Thus, the resultant GIS Platform offers a common language for viewing transport features across all directorates, and also process geographic data from a variety of sources to integrates them with the GIS.

Project Deliverables

The project deliverables were structured around a series of hardware, software and protocol deliverables as detailed herein:

- Review and analyse requirements from all the partners of the project and also capture the requirements of all directorates for the GIS Platform, taking into consideration all relevant factors;

- Build the foundation transportation data model, infrastructure, and database for the GIS System within Transport Malta;

- Procure the Hardware and Licensing required for the GIS Platform;The delivery of the GIS Platform and providing Geospatial information and services; Use GIS data, and processes to capture all the transport lifecycle from planning, design, construction, operations, maintenance processes;The platform shall be interoperable with other Transport Malta business systems;

- The GIS Platform is developed using an ArcGIS Server Platform, expected to be modular and scalable system which is flexible to meet the varying demands of usage and applications;

- Create an internet and intranet, where each directorate shall integrate GIS applications with other Transport Malta business systems namely RPS (Road Permit System for Road Works and Diversions), Public Transport, AIS, TM IHO – Nautical Charts Data;

- An intranet portal that would provide accurate and reliable geospatial information and services to Transport Malta Directorates most importantly in land transport, aviation, Roads Infrastructure and maritime sector; and

- Amalgamate spatial data of Sicily and Malta onto the same platform and provide schedules of the Transport link provided through air and sea transport between Malta and Sicily.

The GIS Platform Activities

The platform was structured through the following series of Activities:

Activity 1 Requirements Review

During the first activity, the low level requirements of all parties involved were captured including Transport Malta directorates and also STREETS partners. This enabled Transport Malta and also the project partners to take informed decisions with respect to transport planning, operations, design and deployment of national wide projects in their respective fields. The proposed work plan sought to implement these requirements in the most technical feasible and efficient manner to address the requirements. During this activity, the project team met with key personnel of every directorate to capture the requirements from the respective directorate perspective.

Target Groups

The first deliverable of STREETS deployment pertained to the Public Service interface. The Public facing service shows the travel times between the two islands for different transport modes available on the two islands. Based on a Opensource basemap, the Public Portal provides information to the public and most imperative to commuters. To facilitate ease of use, the Public Portal has a simplistic interface providing the end users with the required information in one single source. End users can search for the public transport information from bus to sightseeing routes and stands, charging points. Interoperable with various solutions, provides link to live data, whereby road closures are automatically displayed on the GIS Platform. Also any events taking place in Malta are automatically captured and displayed on the portal.

Land Transport Service

The Land Transport service provides outputs for the surface and public transportation activities including the public transport route networks. The rendering and visualisation of spatial data captured from either hand held devices or directly on screen are interoperable with the Land Transport Service, thus keeping data up-to-date.

Maritime Service

The Maritime service includes the visualisation of AIS Automatic Identification System (AIS) in the port area and within the 12 mile buffer zone, where interoperability with automatic tracking services used on ships shall be viewable on the MAP and enabled through this platform. In addition, this service shall be interoperable with spatial datasets created in S57 format and rendered on the map service.

Transport Strategy Service

For this service, Transport Malta aims to provide a rich map service, with editing capabilities to cater for spatial analysis in order to maintain the data of the national transport system which brings together diverse expertise and resources from legacy organisations.

Sicily Government Portal

This service includes the same functionality as the public portal mentioned above with additional tools to help Sicilian government officials to perform spatial analysis. Detailed transport connectivity between the two islands of Malta and Sicily shall be included in the public portal to facilitate the transport link and help commuters in searching for internal and external mixed mode of transport link between the two islands. Apart from a rich map service, spatial analysis is also supported to generate an on-the-fly isochronous map of an area, level of service map, safety map and accessibility maps.

Road Infrastructure Service

This group provides a robust Map Service including reporting, printing, navigation with rich GIS functionality superimposed on referencing data that is the basemap, LIDAR data (Formosa, 2014) and orthophotos (MEPA, 2013).

The Road Infrastructure service is interoperable with the Road Closures and Diversions System currently implemented at Transport Malta. This system manages the permits for any Road Closure and Diversion in Malta, whereby any closures are processed through the system and given a permit in order to close and divert traffic accordingly.

The rendering and visualisation of spatial data captured from hand held devices is interoperable with the Roads Infrastructure service. Users have the facility to go beyond viewing information, whereby this service have built-in interfaces to enter and manipulate spatial datasets and their structures through web based viewers, and also attach multimedia objects. This service enable users to store ACAD drawings within STREETS eGIS databases and also facilitate the support of image geotagging within the database.

Activity 2 Transportation Data Model

This activity relates to building a robust Data Model holding all the transportation features. Through this model, we aimed to reduce data duplication, while improving the currency of data used for analysis and visualisation. Most imperative during this activity relates to the ownership of the spatial data to the respective directorate. The use of standards in data and development is trivial.

Activity 3 – GIS Platform Development

In parallel to the drafting of Transport Data Model, Transport Malta together with the developer focused on the development of the public portal. The subsequent deployments of the other services followed. The interfaces of each group is based on a Service Oriented Architecture, where each service launches GIS specific application and datasets in different sectors to cater for the transport modes. The proposed solutions have mixed modes of services to cater for specific needs of STREETS. The service specific for every directorate meets the key requirements, captured during the first activity of the project.

As this is an ongoing process, the GIS Platform of STREETS provides the backbone infrastructure required to streamline processes, and interpolate with other systems. Enterprise data warehousing, data services, and applications are centrally provisioned and available throughout the GIS Platform. Such interfaces listed features a group specific service for the provisioning of related specific data and tools required. This platform allow an authority-wide access to GIS data based on authorised content, whereby each directorate can visualise the data they own superimposed on vector and raster basemaps.

Transport Malta is continuously aiming to streamline the authority business process through visualising, sharing and monitoring transport related data. The end results signify and simplify data sharing whilst facilitating data access as part of an informed decision making tool.

Interoperability with other Transport Malta systems

A Service Oriented Architecture ensures that the platform supports standards that promote enterprise wide availability of GIS services. Exposing such web services ensures interoperability between the GIS based systems. Also, the interoperability to other current solutions implemented at Transport Malta is highly required and evolving.

Spatial Database Infrastructure

The GIS Platform is based on a Spatial Database Infrastructure (SDI), ensuring that data and resources available to the Authority and Stakeholders providing a clean institutional structure for the local organisation, storage, management and delivery of data.

The database leverages the full capabilities of a Spatial Database Infrastructure to centralise all spatial data of Transport Malta and other third party datasets whilst integrating isolated datasets of different directorates into a single spatial data warehouse encompassing the entity wide transport network.

Technology

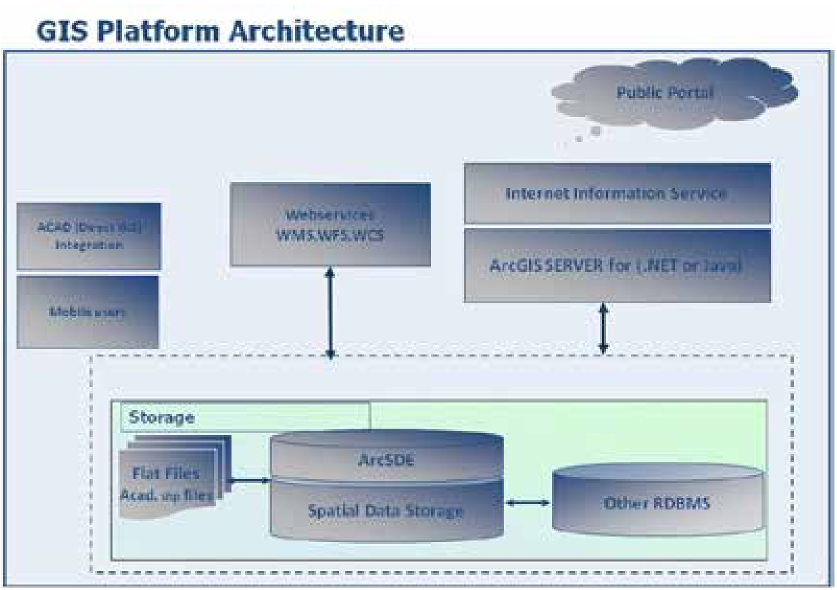
The GIS platform is plug-in free, cross browser and platform independent deployable also on kiosk based solutions. Thus the deployment of the GIS Platform is featured on two kiosks at the Virtu Ferries Terminal.

Following thorough research on the suitable GIS technology for a Transport Authority, the ESRI technology is most suited for Transport Malta needs and uses the following software:

- Microsoft SQL Server 2012 R2 Enterprise
- ArcGIS Server Standard Enterprise Edition

Figure 2 shows the architecture of STREETS where a detailed overview of each component is depicted below.

Figure 2 – GIS Platform Architecture



Mobile Solutions

Transport Malta procured three high performance hand held devices having submeter accuracy and one decimetre accuracy using Arcpad licences, in order to capture data directly in the field. Communication is facilitated between hand held devices by synchronising this output data from the handheld devices with STREETS GIS Platform.

Activity 4 Training

As GIS resources in Malta and at Transport Malta are very limited, the GIS Unit at TM embarked on providing various training sessions. Committed to increase the resources having this skill, basic GIS technology training was provided to every Directorate key personnel. Subsequently provided training was also provided on using hand held devices to equip field officers capturing data directly in the field and once back at the office plug data directly in the GIS Platform. In order for personnel to familiarise themselves with this technology, training personnel on GIS technology is an ongoing process

Benefits

GIS technology plays a central role to Transport Malta not only on merging all the technical components but in providing a fully empowered solution that can manage all the different aspects of processes, infrastructure, software and data.

This technology shall breaks down the barriers within the Authority, fluidly integrating different disciplines, and simplifies the ability for sharing within our directorates, authority, partners and entities. As the backbone infrastructure of the GIS Platform is based on a service oriented architecture, the services are continuously evolving to be interoperable with other business solutions and furnish spatial data to the service.

Conclusion

This GIS platform brings together operations on aviation, ports, roads infrastructure, land and sea transportation, through integration of isolated datasets and processes in one common platform. The information throughout an enterprise results in better decision making and also advancement of the transport sector in cooperation with neighbouring countries whilst providing a secure structure to store sensitive data for the use of internal staff and help in clean institutional structure for the local organisation, storage, management and delivery of data.

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CHAPTER 3

Sensing the SIntegraM: A Two-Decadal Endeavour for Spatial Data Harmonisation and Governance

Saviour Formosa

Abstract

Initialising a stepped approach towards access to spatial data never purports to offer a dull moment. Stepped approaches that aim to make sense of data and harmonisation are hindered by capital and recurrent issues that pertain to the creation and maintenance of systems and protocols whilst governance across a national landscape impinges stressors on any system. The SIntegraM concept was initiated in 1995 on a two pronged process, that pertaining to a simultaneous but independent bottom-up and top-down process that had striven to achieve success but were constrained by the early concept hiccups that did not empower the project due to failed uptake by diverse entities and a defunct base mapping system. SIntegraM saw the coming together of two project champions who spent four years to morph their conceptualisation, bring together all public entities, present a spatial data integrative approach and eventually apply for basal funds to implement change.

The result was based on an integrated approach to the data cycle, innovation concepts on data capture, integration and capture, the creation of a data-sharing protocol structure within a protected and secure environment and also the newly innovative action where hardware and apparatus will be shared by all government entities, under the gather-once / use-many philosophy. The stepped approach moved away from the vicious cycle of data hoarding and towards a spiral based on the need to use such resultant information eventually growing into a complex but readily available system that is driven by the Maltese SIntegraM's unique conceptualisation and implementation foresight.

Introduction

The process of data management and its transposition to spatial formats was conceptualised in an idea that started off in 1995 and required a mentality shift to ensure readiness in data and information sharing, the abolition of data hoarding and the creation of collaborative protocols. This process ensures a gather-one/use-many scenario within a spatial construct.

The ERDF project was conceptualised and driven by the author who spanned the diverse entities with collaboration from the Planning Authority and the Faculty for Social Wellbeing at the University of Malta which project was awarded €7 million. This initiated a process whereby data is built around a spatial-core and which resultant information could be used by both policy makers and academics to create knowledge and in turn action. This entailed a process that took 22-years to achieve fruition, Such was required due to the need to ensure the elimination of barriers created through lack of access to data (Formosa, 2010), the transposition of the INSPIRE Directive (OJ, 2007) and a collaborative approach across all government entities. The process was aided through the successful conclusion of a prior €5 million ERDF project that enabled the creation and dissemination of environmental and 3D terrestrial and bathymetric data (MEPA, 2009).

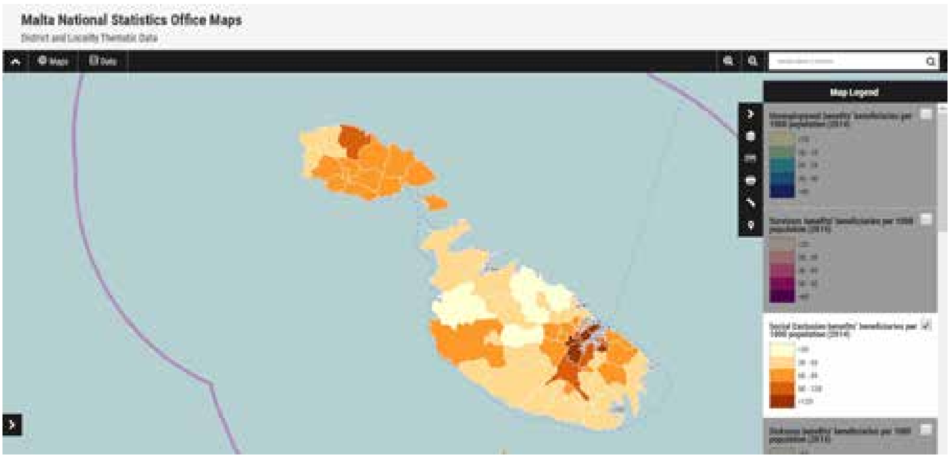
The SIntegraM (Spatial Data Integration for the Maltese Islands Spatial Data Integration for the Maltese Islands: Developing Integrated National Spatial Information Capacity) project, is being part-financed by the European Regional and Development Fund (ERDF) and is led by the Planning Authority with full partnership from all Ministries and their relative entities.

The project benefits the country as well as the University of Malta due to its cross-thematic approach that spans all Faculties and Institutes both through access to data, access to data capture and analytical technologies as well as access to expertise. The project delivers a strategic approach to spatial data, integration of vital base datasets, new legislation as well as training, The main concept is built around the creation of data creation protocols, information exchange, access to data, and inherently data protection and privacy, In terms of infrastructure, the project provides systems, equipment, data capture devices using aerial, terrestrial and marine technologies, in addition to analytical and dissemination tools that will ensure inter-governmental data dissemination, and national preparedness.

This concept of data sharing has been taken to another level where the protocols for sharing will span diverse domains through its philosophy to introduce an intra-government hardware and technology sharing. Such a concept will further break the ice towards ultimate ownership by all and removal of barriers to access to data.

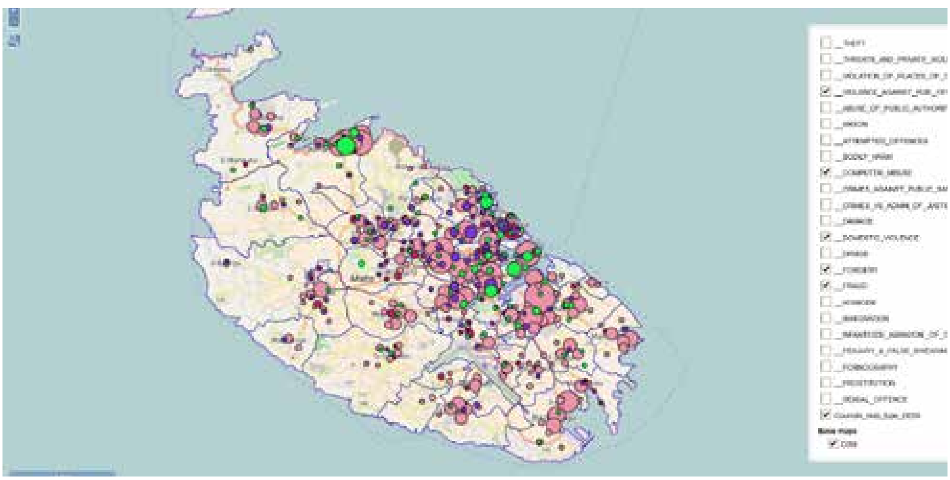
Examples of integrated research that span disciplines could include the analysis of air pollution as carried by air currents as affecting the health of children who live close to an amenity site or the investigation of potential development as it affects landscapes and skylines through a euclidean or viewshed approach, in turn resulting in the calculation of flooding that in turn alerts the Civil Protection and Transport entities to close off areas at risk. Population (Figure 1) and crimemaps also serve as a base service for safety and security (Figure 2). There are 22 years' worth of ideas in the pipeline.

Figure 1: NSO population maps



Source: (https://mangomap.com/nsomaps/maps/23649/malta-national-statistics-office-maps#)

Figure 2: Crime maps



Source: (www.crimemalta.com)

The project is set to change the way information is viewed, accessed and given academic value-added in turn enhancing the University's role in bringing about social change. As an example of an innovative data output, the project Cloudisle depicting 3D maps as emanating from the project will serve as a baseline for future 3D capture for analytical and operational management of national assets, predictive modelling and virtual tourism amongst other results. Figures 3a-b depict a topographic image (Figure 3a) of the Gozitan Ghajnielem cliff zone known as Xatt L-Ahmar which is depicted in Figure 3b as an elevation map showing the wreck of 3 sunken vessels named MV Xlendi (left), MV Karwela (centre) and MV Cominoland (left).

Proposals for Change

SIntegraM's drive towards geospatial DIKA (Data-Information-Knowledge-Action) was based on a conceptual to an implementational model, as defined from experiences that were garnered through various projects and case studies that helped build up a processed approach to spatial systems implementation. The following steps were undertaken as a procedural process (Cassar and Formosa, 2013):

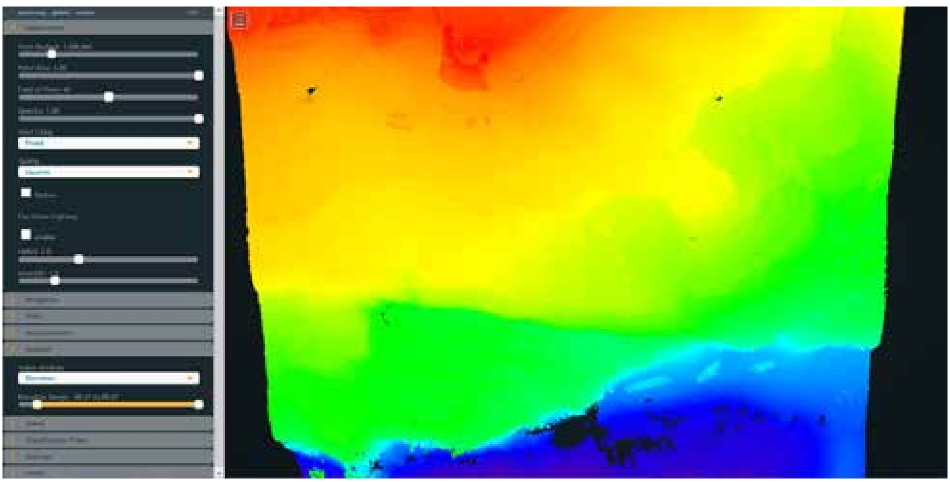
Concept: As most mapping data processing requires updated or near real time information, which is governed by concepts and technologies that evolve rapidly, it is imperative that a solid foundation is laid to ensure Malta's readiness in all areas that deal with base and thematic mapping. Currently the state of affairs depends on dated basemaps, inter-agency charging systems, inconsistent approach to the data-cycle process, dispersed expertise, various software and isolated non-networked systems.

Malta needs to bring together these entities to ensure the setting up of a central organisation that serves all the country's needs, the creation of base and thematic spatial information system, a regularly updated and enhanced information structure that serves all entities, and the integration of expertise.

This structure should ensure compliance with national and European/International legislation and commitments, simplification of procedures, free dissemination of information and inter-agency collaboration. Such a structure serves both for current requirements such as development monitoring, transport monitoring, infrastructural inventorisation, utilities' flows as well as deployment for foresight such as the real-time deployment of information in cases of emergencies. Only through an integrated information system can such be brought to a peak of excellence.

Figure 3: Cloudisle 3D

a) RGB map of Ghajnsielem cliff zone



b) Elevation map of Ghajnsielem cliff zone depicting 3 wrecks

Source: (www.cloudisle.org)

This proposal sought approval to develop a conceptual model and implementation process for the sourcing of EU ERDF funds aimed at creating the spatial entity, sourcing and integrating the players, creating information systems, acquiring in-situ and remote data harvesters, analysing the scenarios and implementing real-time and foresight contingency plans through scenario testing and disseminating the raw and processed information.

Technical: Spatial Data (or geographical information system) refers to those information streams that deal with location: data as it is related to a point in space. These are generally known as graphical information systems that allow one to view data in the form of a map or as online interactive systems. Systems in place include the PA mapserver, PA's SEIS (Shared Environmental Information System), Googlemaps and other similar systems. Since everything happens somewhere, the requirement for authoritative reference geospatial data is vital for all branches of central government. This necessitates the need for an increased awareness of the value of 'place' and 'location' as vital components in effective decision making and for linking public-sector information together. It is important to distinguish between levels of reference maps:- while free or web-based mapping are sufficient in locating the nearest restaurant, central government dealing with national and societal interests, and in some cases life-critical situations like disaster management, requires authoritative and quality-assured geospatial data at a national level.

Legacy: Malta is one of the forerunner countries that have attempted to gather, analyse and disseminate spatial (or geographical information) that cover the entire nation. The country's size is an aiding factor, however, Malta has the same relative human and material resource capacity as other states.

International Requirements: Malta's entry into the European Union has pushed the requirement to create these information structures towards locational analysis and reporting in over 70% of the Acquis. There has been an exponential growth in the use and proliferation of geospatial and location information in the past decade. More importantly this trend is expected to increase in the next five to ten years as technology-driven trends will impact geospatial data capture methods, making location information even more ubiquitous.

EU Legislation: Malta is party to the various legislations governing data (OJ, 1995; OJ 2003a, OJ, 2003b; OJ, 2003c; OJ, 2007) such as the Aarhus Convention, the INSPIRE Directive (EU Directive establishing an infrastructure for spatial information) and the SEIS initiative. All data reporting streams go through the EC (European Commission) and the EEA (European Environment Agency) and Malta has to report in spatial formats to these agencies.

Maltese Legislation: The production and maintenance of the national geographic database of Malta is defined as one of the functions and legal obligations of the Planning Authority laid out in Act No VII of 2016, Part V, Sub-article 38(e): "the carrying out of national mapping, including carrying out land surveys of specific areas and keeping up to date the national geographical database …"

Current Functionality: The PA's mapping unit is tasked with carrying out the national mapping function. The unit's core objective is to produce and maintain accurate, detailed, authoritative reference maps of the Maltese Islands, known as the large-scale topographic map (LSTM). This is composed of different layers that represent a collection of real-world features (such as buildings, roads, pavements), and abstract objects such as cartographic text. It includes a topography layer, an elevation layer, a Digital Terrain Model (DTM) layer, a geographic text layer, and the orthophoto map layer.

The national mapping function is a specialist function which benefits MEPA since the base map is intrinsically linked with several of the authority's business processes, such as forward planning, plotting, development control, environment and enforcement. However the LSTM is also the de facto national spatial reference data, a strategic dataset that is indispensable to the wider national requirements comprising utilities, civil protection, transport, communication, emergency services, agriculture and health, to name a few. Government is thus a major stakeholder in the need for accurate, detailed and up-to-date authoritative geospatial data which act as the basic reference layer over which many other government entities can overlay their own specific geospatial themes and layers of interest. The LSTM is thus the basic reference layer that underpins the national Geographic Information System (GIS), otherwise known as a National Spatial Data Infrastructure (NSDI). This NSDI is the vehicle through which geospatial information and public sector information can be shared in a standardised and cost effective manner by central and local government, public entities and indeed the general public. In turn a national GIS maximises the investment in information, ensuring that data are captured, maintained and managed once and shared by many. However a key element of an effective GIS is an authoritative and up-to-date reference database which brings together all the themes and layers of all the stakeholders in a standard, harmonised and interoperable platform.

The LSTM has a lengthy and specialist production process that requires the use of specialist suppliers, dedicated software and hardware, and specialist knowledge and skills. Topographic mapping represents the real world which is always changing. Therefore the challenge is to reflect the real world by constantly maintaining and updating the large-scale topographic map.

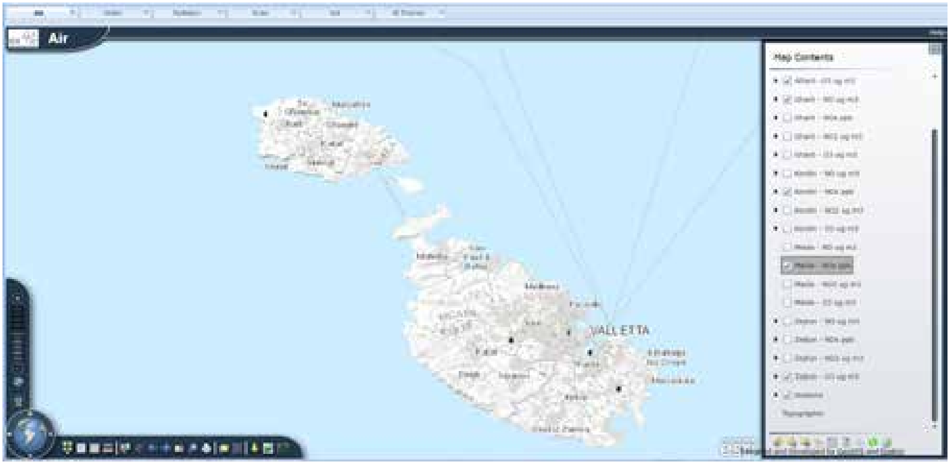
Issues at Stake: The technology and methods to produce and maintain digital geospatial data have undergone drastic changes in the last two decades since the Mapping Unit was initially set up in 1988. However, there has been no significant investment to upgrade the national mapping function in over a decade. The investment required to update and maintain the authoritative datasets and to upgrade the technology to exploit the new location-driven technology and trends is in the region of €1.5 - €2 million. This investment would entail a mixture of out-sourcing and in-house supply, data capture and quality control. While it is advantageous to out source certain elements of the data-capture and production process of the base map, total divestment of the entire undertaking is not recommended since commercial interests may undermine the authoritative nature and trust of the reference datasets which are critical to the national interest and security.

Free Access: An emerging trend in other European states is that as part of their eGovernment strategy, free access to high quality reference authoritative data is being granted to the public. Reference authoritative data in such cases could include: geospatial businesses information, addresses, real properties, land tenure, and digital map data. This is viewed as a driver for efficiency and interoperability in the public sector, a stimulant for economic growth, and an opportunity for the creation of innovative digital services in the private sector. Free access has already been made available through the establishment of the Aarhus requirements and through the SEIS system depicted in Figure 4, which MEPA launched on the 18th October 2013 (www.seis.org.mt). The concept of 'gather-once and use-many' should enable all entities in Malta to create information and distribute it for free to all entities and the public due to its base funding mechanism that ensure tax-payer's monies are returned in kind without the need to double charge for data that has already been paid for by the same citizens.

Resultant Recommendation: The above exposition, supported by and expounded further in the attached paper, are the main reasons for the urgency to establish a national Spatial Information Structure and to approve in principal the establishment of a national GIS function and authorise PA to set such a system in place. The authorities were also requested to entrust the structure to investigate the best modus operandi for the setting up of a functional entity, explore the funding mechanisms for setup and implementation as well as ensure the delivery of the data to all interested parties and the public.

ERDF Funding: In addition, approval was sought such that this process be implemented through the uptake of 2014-2020 funding with a specific mention in the proposal to this project as it entails a multitude of hardware, software and data gathering to enable its fulfilment. In turn the process cascaded through the Permanent Secretaries within each Ministry and the relative CIOs who partook to the implementation process.

Figure 4: SEIS Portal



Source: www.seismalta.org.mt

Strategic Need for Reform

The underlying strategy for the management of data should be based on a 'gather-once / use-many' approach, which ensures that data is gathered once but used by all without incurring further costs, access and implementation bottlenecks. This proposal looks at the setting up of an organisation through a two-phased approach:

Phase I: initially an entity is tasked with implementing the short-term targets, those of creating a base-data layer for all entities, such as the LSTM, currently held by PA;

Phase II: the long-term strategy looks at the setting up of a GI-dedicated entity that will be tasked with the integration of all these systems into one entity with dedicated thematic expertise across the diverse GI-enabled agencies.

Phase I should ensure the migration from the current isolated-entities system to one where the datasets are harmonised, aligned and prepared for the eventual integration that would be required in Phase II. The Phase I concept envisages a scenario where the setup would be similar to the current system of individual-entity ownership where the entities are defined as "owners of data" meaning that each Department, Authority, Corporation or organisation is responsible for collecting, maintaining and managing data relevant for the running of its activities and operations. This data will be shared with other Departments, Authorities, Corporations or organisations in a 'read-only' mode. The advantages lie in the fact that:

- the data is maintained by the owner of the information;
- updating of the system is done in an "informed" or more professional manner rather than straight forward data entry;
- the organisation itself and its officials maintaining the information are made responsible and accountable for the data;
- this system also allows the other entities to create their value-added data on to the same datasets which the 'guardian' entity can then decide to implement as part of that dataset;
- each dataset has to comply with INSPIRE implementation rules, even for those that do not fall under the diverse Directive Annexes.

It is very important that the data inputted in the system, once the necessary data collection exercise is carried out, will be almost completely error free. This is very important as the data, once input into the system is available to all those who need it for planning purposes. Any inaccurate data will definitely result in causing wrong decisions to be taken. Such occurrences would defeat the whole scope of the project.

Thus, it is of the utmost importance, that the project is set in the right perspective and that there are clear guidelines and standards to which all participants within the system would have to abide by. It is thus important that a proper set up is established which will have the authority not only to oversee the whole development, make the necessary guidelines and standards and see to their enforcement but be responsible also for the periodic auditing of the data in respect of its validity and accuracy.

The project targets its main responsibility as that pertaining to the development of a strategic approach and establishment of a plan for the successful implementation of both Phases of the project. In this respect the project deliveries include key tasks such as those of:

- Sourcing the best-technical expertise in Malta and international scenario to be tasked with providing input to the process;
- Developing an NSDI (National Spatial Data Infrastructure) Strategy for the Maltese Islands;
- Developing and establishing an Implementation Plan for the introduction of an integrated GIS;
- Co-ordinating with other arms of Government in developing a data collection system and organising and monitoring such data collection in accordance with agreed priorities;
- Setting up and carrying out a pilot collection project, monitoring, reviewing and

amending policies as and where necessary;
- Identifying and training staff;
- Identifying, purchasing and installing the required software and hardware in order to enable the development of a GIS in an incremental and logical basis with the final aim of connecting all data owners and users onto a distributed system;
- Developing and agreeing the appropriate interfaces with agencies involved in GIS-based activities;
- Acquiring approval and sourcing ERDF funding for the major Phase II project;
- Drafting of the ERDF Tenders and implementation processes;
- Ensuring the roll-out of the diverse outputs and bringing on aboard all the entities to employ the systems;
- Disseminating the information to the entities and the public.

This fits within the Digital Malta Strategy 2014-2020, which highlights three vertical strategic pillars of which the third aims to "Enhance the delivery of Government" (GoM, 2014). Better application of digitisation will result in reduced bureaucracy, increased efficiency and transparency. The public service will be closer to civil society and enterprises, improving the government's decision-making processes. Open Government and eDemocracy will be facilitated. On-line government services will be more accessible through the use of smart devices and mobile-friendly applications as well as websites and social media. Government's technological capabilities will be widened to include open source, cloud computing and big data concepts. Information sharing across government systems and services will be promoted, as will be the re-use of public sector information by third parties.

Chapter 6, "Digital Government", of the strategy document outlines several goals aimed at making government services more user-friendly and less bureaucratic. It is stated that "public data, which government creates, designs and manages, should be openly shared across entities and authorities" (GoM, 38). The policy document highlights the importance of re-using public sector information, increasing the usage of government services, and also simplifying existing digital public services. Through the completion of this project it will be possible for government departments to more easily share data with one another thereby reducing the need to replicate existing data. It will also help to build a cooperative culture between public entities through the open sharing of their data. Furthermore the underlying technologies used in this project create the opportunity to make use of this data in order to improve the quality of certain services such as healthcare.

In the section on Guiding Principles, the document states that "Government systems will be regularly assessed for efficiency and, when necessary, be enhanced or replaced." (GoM, 2014; 39). The goal of this project is specifically to introduce the necessary ICT infrastructure required to enhance the efficiency and effectiveness of current government systems whilst enhancing such systems through spatial technologies and data-cycle implementation.

The reduction in unnecessary work to duplicate existing data will also serve to "reduce bureaucracy and implement leaner processes, with the aim of offering new and improved public services" (GoM, 2014; 43).

This project will also provide the backbone for government to be able to use its data to provide new services to the public. As stated in the document the government plans to facilitate "the sharing of data across public administration" (GoM, 44) and to make use of data to improve "decision-making in critical areas such as finance, healthcare, transport, utilities and the environment" (GoM, 44).

Targeted Results

In effect, SIntegraM will enable the implementation of an integrated process where the interface between government, citizens and the business community would be able to use updated information in real time and which information is reliable and verifiable, whilst offering the latest spatial data updates, consolidation of information, free exchange of data and the enhancement of informed policy-making and decision-taking through knowledge gain.

In addition, the inter-governmental efficiency issue will be fully taken up as this project will ensure that all government ministries and entities will be able to participate in the project, create new information through a gather-once / use-many system, drastically reducing data redundancies and multiplicity of information, elimination of data and information duplication, recalibration of non-aligned information that is resulting in hundreds of man-hours being lost when reporting spatial information to the EU and other national or international entities, ensure the elimination of unreliable data sourcing, as well as reversing the practice where each entity hoards its data in isolation, to the exclusion of the rest.

The project will also ensure that a mentality shift is achieved through the process where data is shared between all entities through secure data protection legislative and operational measures, information is rich and that knowledge gained by one entity is transferred to all entities. Also hardware, software and data emanating from the project will be shared amongst all entities leading to an operational shift where there is a collective approach to project implementation and execution at a national level, as against a single entity level where the entity acquiring or managing the project retains a sole use over the proceeds from the project.

The SIntegraM's outcomes are larger than the sum of its parts as it will enable government entities to start thinking in spatial terms, brings together policy-makers, on the ground experts and academics which process will eventually enable an evidence-based approach to policy making and eventual decision-taking.

This process requires a mentality shift as it takes a generation to achieve, which is why the time is ripe to effect such a project which process was initiated in 1995 through the Structure Plan Monitoring Programme (PA, 1997), the Data Protection Act, the Freedom of Information Act (FOI), the Public Service Initiative (PSI), the Aarhus Directive, the INSPIRE Directive, the SEIS Initiative and other such legislative and implementation tools such as the ERDF156 project.

The SIntegraM will ensure the holistic approach to e-governance, the integration of data services, an increase in national spatial knowledge, as well as ensure that expertise is shared between all entities and that in turn data is made available to all.

The project will enable a seamless DIKA transition from "Data to Information to Knowledge to Action" that will benefit government entities and in turn enhance e-services, data access and technological expertise as achieved through collaboration based on a unified approach.

Added Value

Over the years, a number of attempts have been carried out in starting off variants of this project, most of which were larger in scope, more complex and financially non-sustainable. In the light of this experience, the project sponsors identified the right balance between what can be realistically achieved whilst safeguarding and maximising on the project's intended results and impacts. This has been achieved by down-sizing the project scope and related investment costs whilst maintaining compliance with the various national and EU regulatory directives and obligations. At the same time, a significant amount of new information and data will be made available across the public sector in their roles as direct users of the system and to the a wider range of other indirect users.

The scope of the project as reconfigured would still require a certain level of investment and operational costs which would make it financially unsustainable if it were to be solely funded through national funds. Nevertheless, Government is still committed in backing this project by committing national funds to cover approximately 46% of total investment and operational costs required over the projects expected 18 year lifetime.

The project's main aims are to foster an ethic where the reduction of bureaucracy is verily achieved through a gather-once/use-many functionality. This relates to the modus operandi where the different government entities currently gather their data in isolation and rarely share. SIntegraM will ensure that any data gathered is shared between all thus drastically reducing costs, ensure up-to-date data availability, ensure the dissemination of data at no cost to other governmental entities/departments, which situation allows for real-time knowledge gain and each entity advanced in tandem as against the current situation where some entities are highly updated with real-time data and others are still working on 1988 datasets. In turn all will be updated on new legislation and can respond requests for information quicker and based on reliable and verifiable information. This concept will in turn enable policy-makers to develop informed evidenced-based policies that would be in turn taken up by decision takers to update legislation, take realistic action as well as ensure that the rules and obligations are followed across the thematic disciplines/activities.

The project will also deliver more value through its diversity in terms of the provision of hardware across the entities, where each entity can avail of the technology at any time, thus eliminating the need for every entity to buy its own hardware that would be sporadically used for ad hoc tasks. The investment that represents SIntegraM will thus change the 'ownership' context from an insular (isolated) one to a national one. SIntegraM will deliver a strategy that aims to integrate a currently sporadic data-cycle structure, ensure legislative review, review functionalities that would reduce bureaucracy-hoarding and data barriers. The project drives the process to ensure government entities will update their spatial-data related activities in a streamlined mode that would be aggregated into a unique system.

The additional added value relates to the betterment of operational aspects inclusive of the first time creation of a unique information system that will ensure that Malta will have a secure storage area network for spatial information that would ensure a situation, where should a disaster scenario be actualised, the immediate access to the core datasets would be available by the protection directorates as well as ensure that Malta has the data and information legacy to restart the systems and data cycles. The latter would enable real-time information management in conjunction with other critical systems such as those managed by CIP and MITA. The SIntegraM systems will ensure that the legacy is available.

In addition, the project ensure that Malta will be able to provide earlier functionality for both thematic and operational aspects through real-time and predictive modelling for both passive (ex. population change, sprawl) and drastic scenarios (e.g. flash floods, storm surges, direct action on enforcement).

SIntegraM is an instrument that will achieve all the three pivots pertaining to the provision of more data-information-knowledge-action functionality, achieve better delivery through efficient and effective processing and enable the earlier actuation of the analytical and legislative components while ensuring that thematic, operational and tactical deliverables are rendered in rapid modes. The project will offer a sea change in methodological structures through the achievement of conceptualisation, entitation, quantification and validation through to action.

Expected Results

The implementation of an integrated GIS would drastically improve interdepartmental efficiency services through ICT due to its pivotal focus on implementing a process to allow public authorities to collectively strategise, acquire knowledge and skills, gather new data, employ a shared approach to the data cycle, ICT and shared use of technologies. The project results will be reached through the implementation of processes where public authorities therefore adopt a 'knowledge based approach' to decision making rather than basing decisions/policies solely on data that is available on an ad hoc basis. By way of example, the police department, the civil protection department, the health department and others would be able to make use of real time data for establishing the potential location of individuals and assets as affected by disasters, transport rerouting, storm surge monitoring, as well as the identification of missing persons, amongst others. In addition, the data generated from the systems could be structured through model-based approaches rendering different scenarios of change analysis such as development spread, environmental protection and flow characteristics, resulting in further efficiency. Such will allow analysts and policy makers to make better informed decisions.

The project links to the expected results through its focus on inter-departmental/inter-entity drive as outlined in the project sections as detailed below:

i) a unified approach to spatial information, ICT and technologies will be delivered through the inter-entity review, analysis and development of a Strategy for NSDI, inter-linked Legislative Drivers review and changes and the identification of inter-entity spatial data flows;

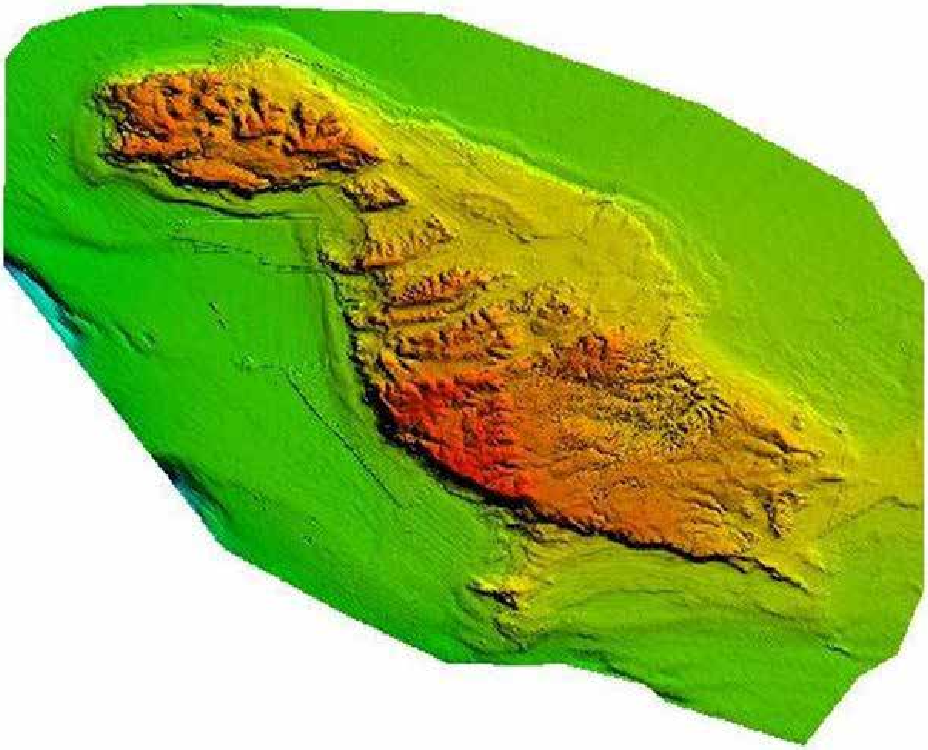
ii) the project's main pivot is to ensure that all entities are brought on board, a process initiated over the past years and through which the letters of intent were developed, which ensure that bureaucratic issues and information-barriers are reduced or eliminated through an integrated drafting of Protocols for data and information exchange based on a common approach to the data cycle. Such will include the drafting of policies for the free exchange of data across the governmental entities, knowledge again, access to ICT knowledge and ICT technologies as well as a national process enabling one unified and integrated information structure;

iii) all government entities will have access to the national basemap at zero cost as against the current system where each department would have to acquire a licence and in turn cross-charge the mapping agency for other services rendered. The creation of the basemap, which also includes data acquisition of imagery, LiDAR data, oblique imagery, infra-red data and other technologies will reduce the need for multiple data capture and expenditure by different departments as well as disseminate the resultant knowledge to all other entities, ensuring a smooth upgrading of both the effectivity and efficiency with regards to information and implementation processes. The issue of access closes the process initiated in 1995 and which outputs, such as the 3D baseline 2012 terrestrial and bathymetric scan) served as a testcase and an icebreaker, which showed that the free dissemination process is a doable construct (Figure 5);

iv) the project will ensure that time wastage and process redundancies are eliminated through the activity that target the re-projection of all spatial data from the current 1988-induced non-earth projection that is slowing down the data process as well as causing major capacity issues through a cross-departmental process to reproject all datasets to a real world map;

v) services rendered through the project that encompass all entities detailed with spatial information will be delivered through the acquisition of systems covering the management of spatial data (basic and advanced software tools) as well as the acquisition of highly advanced analytical tools targeted for real-time systems and real-life investigation. This will be made possible through the setting up of a collective system of processes, software and hardware that ensure that entities are equipped with predictive tools, analytical models as well as immersive environments. The latter functionality equips inter-departmental and inter-disciplinary focus teams to interact in real and virtual worlds ensuring that instant decision-taking is made possible through scenario building or instant access to streaming information (a case could be the immersion of a crisis group of specialists who can remotely view a developing situation such as a fireworks factory explosion and direct paramedics, CPD personnel, detour traffic, manage data capture drones, monitor dust/ chemical plumes from a remote site, amongst other inter-connective activities);

Figure 5: Terrestrial and Bathymetric Scanning



Source: MEPA, 2013

vi) the project in turn helps improve interdepartmental efficiency services through ICT as it delivers a rolling out of dissemination tools for the distribution and reporting of data to the public, scientific domains and EU/international reporting structures. In turn, this eases pressure on interdepartmental work as information would be instantly available through online and mobile systems both for the public but even importantly for service personnel who would be carrying out fieldwork, data capture through to the implementation of services on-the-ground and remote sites;

vii) one concept that ensconces the new concept that is paramount in this project and which aims to reduce public spending whilst ensuring a national approach to interdepartmental efficiency relates to the acquisition, installation, commissioning and testing of equipment that will be used by ALL entities through a time-slotted triage-like process, which process ensure that high-priority activities such as emergency services would be given precedence to ongoing projects or ad hoc initiatives. Such systems include ICT infrastructure that include immersive environment technologies, aerial-based technologies such as drones and specialised cameras (IR, thermal, LiDAR, rgb), terrestrial-based technologies that aim to scan streets, infrastructure, buildings and underground facilities, land survey and GNSS/GPS/GPR technologies as well as marine-based technologies.

Conclusion

The process of morphing an entire state's spatial data serves as an ambitious project but a realistic one that leaves a sense of tangibility on the ground that can be accessed by various entities and the general public. Social wellbeing is only served if the deliverables pertain to access to data, ease of use of information, knowledge gain and operation action. The process entailed in this Chapter identifies the struggles that were partaken to ensure the transition of such a process as well as the maintenance of conceptual scope and targeted delivery. The project enables the launching of a process eliciting a need for cooperation, integration and dissemination of information systems as well as a unique government effort to enable a homogenous process to the data cycle and its functional implementation.

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CHAPTER 4

A Study on the Exploitation of Satellite-Based Information in the Maltese Islands

Stephen Grixti and James Foden

Introduction

The subject of Space is often perceived as abstract. Yet, our communications infrastructure, navigation on land, sea and air, surveillance, border control and security, agriculture, meteorological observation, monitoring of natural disasters and early warning systems all rely on Space. Furthermore, the understanding of our planet, the solar system and beyond through space science, all rely on investment in the space sector. Space is not a luxury, but it is indeed essential for our daily lives.

Malta and the Current Cooperation with ESA

The European Space Agency (ESA) is Europe's flagship entity for the space sector and often seen as Europe's gateway to space. Key European Programmes in Space, such as Copernicus and Galileo are implemented by ESA, providing Europe with Earth Observation and global navigation infrastructures respectively. ESA's primary objective is to develop and boost European space capability and to ensure continued investment in space such that societal challenges can be overcome through the help of space applications. The Cooperation Agreement which Malta signed with the ESA in February 2012 (ESA, 2012), granted Malta an Observer status enabling it to follow discussions within an ESA context on ESA–EU matters and to learn first-hand about the processes involved in ESA decision-making. Additionally, the cooperation agreement resulted in new training and research opportunities for Maltese students and researchers, access to state-of-the-art equipment and facilities, as well as the possibility of networking with ESA researchers.

Raising Awareness and Jump Starting the Sector

Malta's cooperation agreement with ESA led to the setting up of the directorate for Space Technologies within the MCST. The directorate focuses on building relationships with foreign space agencies, the Maltese government, industry and educational sector and aims to explore the use of space-applications for businesses and the educational sector amongst others. Being the National Contact Organisation for Space-related matters, MCST maintained an active attendance to ESA Council meetings and other related fora, such as the Copernicus Committee, Copernicus User Forum and the Space Surveillance and Tracking Committee. Considering their remits involving the use of Space applications, a number of space-related fora are also attended by other governmental entities, namely: the Malta Communications Authority (MCA), the Armed Forces of Malta (AFM), the Planning Authority (PA) and the Environment and Resources Authority (ERA). MCST meets these entities in quarterly space governance meetings that help ensure proper communication between the Maltese entities having an interest or responsibilities within the local space sector. This aids establishing a common front in tackling joint issues and helps avoid duplication of effort.

MCST also represents national interests through Malta's Observer status with ESA. Through its motivation to pursue relevant opportunities with ESA, in October 2015, MCST organised a technical visit in Malta during which an esteemed number of Maltese SMEs and academic institutions where interviewed by ESA experts. The objectives of the visit where twofold: to facilitate the identification of areas that a national space strategy should specifically address and to help map the existing local capabilities or potential in contributing to such areas.

As identified through the Satellite data user uptake study (European Commission, 2016b), performed by the European Commission to help formulate a user engagement strategy for its Earth Observation programme, the Maltese user community has an overall low awareness of the potential of satellite based observation services, such as those emanating from Europe's Copernicus Programme (European Commission, 2016a). Consequently, MCST has embarked on a number of initiatives to help raise awareness and bridge the gap between society and satellite technologies. One important step in this direction was taken when MCST became a member of Eurisy, an association of space agencies that raises awareness of emerging satellite applications (Eurisy, 2016). The first tangible result of such a membership came along in November 2015, when the Council together with Eurisy co-organised the 'Satellite Solutions for Smarter Island' international conference in Malta (Eurisy, 2015).

With the participation of high profile entities, such as ESA, the European GNSS Agency and the Space Policy Directorate of the European Commission, the one-day conference discussed how island economies can leverage Europe's investments in satellite services to boost their economy and live up to current challenges. Case studies from private and public sectors exhibited the potential of satellite applications in various sectors such as tourism, transport and maritime. The conference was very well attended with over 100 participants converging from some ten countries. During the conference, the Council in collaboration with the Malta Information and Technology Agency (MITA) and the Malta Environment and Planning Authority (MEPA), today known as the PA and the ERA, launched the 'Satellite Solutions for Smarter Islands App Challenge'. The application challenge invited competitors to propose creative ideas for apps that could help solve environmental and socio-economic challenges in Malta.

As a follow-up to the conference, this initiative was aimed at raising awareness about the potential of exploiting open data, including European satellite datasets over Malta, for the benefit of Maltese citizens. Within the framework of this App Challenge, in February 2016 MCST organised an Earth Observation training day delivered by experts from ESA and Airbus Defence and Space. The training was primarily composed of a hands-on session using a free ESA toolbox and guided participants to download free satellite datasets over Malta and extract information related to a multitude of themes, amongst which agriculture, environment, land-use and maritime. The event was oversubscribed with around 35 participants turning up on the day. Another similar hands-on workshop organised in Malta was an ESA-sponsored course on Synthetic Aperture Radar (SAR). Lecturers from ESA and foreign universities provided an intensive week-long course covering SAR theory, polarimetry/interferometry, vegetation applications, land cover mapping, GIS/GPS integration, marine applications and archaeology applications.

The course was open to the public and was well attended by various public sector entities, academia and private researchers and SME's. Apart from raising awareness through conferences and workshops, MCST issued a number of calls for Maltese nationals to follow one-year placements at ESA establishments. Through the International Research Fellowship scheme and the National Traineeship scheme, Maltese students and researchers had the opportunity of training in state of the art establishments such as those in European Space Research and Technology Centre (ESTEC), otherwise known as ESA' s technical heart (ESA, 2016).

Such capacity building measures where made possible through Malta's current 5-year cooperation agreement with ESA, which is due to expire in February 2017. Considering results of the ESA technical visit and its willingness to further jump-start the local space sector, MCST is currently looking into possibilities of closer cooperation between Malta and ESA. This could be done through concrete research and education projects which will aid local capacity-building in line with Malta's current and immediate priorities.

Satellite Data Use in Malta

While the immediate general perception is perhaps that EO-satellite based services are underutilized in Malta, Maltese authorities directly benefit through satellite-based EU services within numerous applications and domains. The following sections intend to 'bring space down to Earth' by providing an overview of how satellite technologies are utilized in the day-to-day function of Maltese public authorities. This helps create a mind-map of satellite data use in Malta, particularly the utilization of imagery derived through satellite-based Earth Observation (EO), which is made possible through imaging satellites usually orbiting between 500km and 800km.

The main objectives of the following study are as follows:

1. Creating a review of satellite data use in Maltese public authorities with a primary focus on EO. This work not only captures entities which have the capacity of actual satellite-data preprocessing, but also reviews the utilization of services emerging further downstream the satellite data-flow process; and
2. The study feeds into processes that help identify gaps in satellite-data usage and hence support targeted capacity building measures. This is in line with efforts that help ensure Maltese public entities are maximizing Europe's investment in satellite technologies, particularly those related to EO.

While somewhat comprehensive, the following review is not an exhaustive list of Maltese entities utilising satellite technologies. The study focuses on public entities making use of satellite based EO services within their mainstream activities and does not delve into public bodies that utilize satellite information on an ad-hoc or ancillary basis. Additionally, it does not discuss services delivered by privately owned entities. Apart from EO, numerous other authorities and businesses rely on the other two satellite-based technologies, namely Satellite-based communication (SATCOM) and Satellite Based-navigation (SATNAV). As an example, Malta's Air Navigation Service Provider (ANSP) and the Maltese telecommunication service providers, rely on such technologies on a day-to-day basis. Such technologies are however outside of the scope of this study.

Satellite EO and Land Applications

Agricultural Control with Remote Sensing

As part of the infrastructure supporting Europe's Common Agricultural Policy (CAP) which, amongst other programmes, implements a system of agricultural subsidies, national authorities are required to operate an Integrated Administration and Control System (IACS). The system uniquely identifies each farmer together with the agricultural parcels of land and helps ensure that payments are made correctly, irregularities are prevented or identified, followed up and amounts unduly paid are recovered. Locally, operation of the IACS falls under the remit of the Agriculture and Rural Payments Agency (ARPA). Within the 'Ministry for Sustainable Development, the Environment and Climate Change', the agency is responsible for regulatory compliance of land parcels versus EU aid requested, together with any associated inspections. As a matter of fact, at the heart of the IACS is the Land Parcel Identification System (LPIS), a supporting tool for the generation and upkeep of a spatial register. This system, which is operated by a dedicated unit within ARPA, allows for the registration of agricultural "parcels" by farmers, intending to apply for EU aid. Farmers are entitled to receiving such aid subject to the fulfilment of criteria that is assessed through checks carried out on-the-spot. When combined with traditional checks physically carried out at the particular land parcel, the use of remote sensing helps making the control process more cost-effective and efficient.

In Malta approximately 15,000 agricultural land parcels are controlled annually through satellite remote sensing very-high resolution satellite imagery (VHR) to check farmers' declarations, and verify the compliance of their farming practices with CAP rules (Agriculture and Rural Payments Agency, 2016). Such satellite imagery is provided by the European Commission's Joint Research Centre as part of its Control with Remote Sensing Programme (CwRS) which makes available two VHR 400km2 datasets per year to be used in supporting the local implementation of CAP. The sub-metre resolution imagery through satellite sensors such as GeoEye-1 (0.46m) and WorldView-2 (0.46m), provides for the definition and identification of land types, features and relationships between these through the digitisation of polygons. Here, the use of satellite data through remote sensing is not only resource-efficient when compared to on-site inspection visits, but also cost-effective when compared to aerial photography of the land parcels. This provides a significant advantage for that part of inspection pertaining to land eligibility and cross compliance checks.

Land-Use Planning

The Mapping Unit within the PA is the National Mapping Agency of Malta, being responsible for large and small scale topographic mapping of the Maltese Islands. The unit maintains an archive of high quality aerial photography and is responsible to producing the national orthophoto map every two years. The centimetre resolution digital orthophotos taken through a specifically equipped surveying aircraft, form the basis of all planning undertaken by the authority. While RGB orthoimages are sufficient for the delineation of polygon mosaics associated with planning processes, the use of multispectral satellite imagery is crucial in ensuring a holistic spatial planning analysis.

The additional number of optical channels within the satellite dataset, help add value on a multitude of different themes, particularly when substantiated by other datasets such as elevation information collected through LIDAR imaging. An example of satellite imagery preprocessing done by the PA in this domain is the watershed analysis shown in Figure 1. Such an analysis, undertaken using RapidEye (5m) imagery, enables an understanding of soil and road erosion potential together with mapping of floodplains and stream pour points into the sea: all of which are useful parameters to consider in the processing of the planning applications. The PA also coordinates with the ERA in producing land cover maps for the CORINE Land Cover (CLC) inventory, which is coordinated by the European Environmental Agency (EEA). Updates have been produced in 2000, 2006, and 2012 (Copernicus, 2012) and involved the preprocessing of EO satellite imagery obtained through the EEA in conjunction with other ancillary datasets such as topographic maps, habitats, agricultural datasets, and development planning parcels. (Planning Authority, 2016).

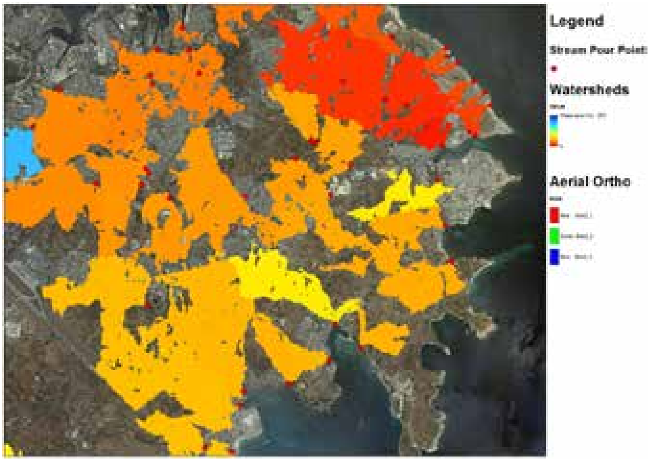
A snapshot of the CLC 2012 dataset, produced through preprocessing IRS P6 and RapidEye datasets (Copernicus, 2012) is shown in Figure 2. Through its proficiency working with Geospatial and Remote Sensing software packages such as ESRI ArcGIS (ESRI, 2016) and the ERDAS Imagine toolset (Hexagonal Geospatial, 2016), the PA has on various occasions, been commissioned by other entities or departments to orthorectify and preprocess EO optical imagery.

Apart from preprocessing satellite imagery to fulfil part of its remit, the PA has been also heading a number of processes to maximize the availability and usability of spatial information systems emanating from both aerial and remotely-sensed data. Through the PA, Malta undertook to integrate the requirements of the international activities and prepare a physical structure for data collection, input, storage, analysis and dissemination. Such was created through the acquisition of ERDF Funds through a project entitled "Developing National Environmental Monitoring Infrastructure and Capacity" (MEPA, 2013), which complied with dataflow requirements stipulated by the EEA. This process ensured the free dissemination of data to the public inclusive of spatial, environmental and physical data.

The initiative was based on the concept that the thematic disciplines will have available a comprehensive infrastructure that will enable NGOs, academia and the general public to upload thematic data and carry out cross-thematic analysis without the need to create their own systems. Such efforts are continuing through a follow-up project entitled SIntegraM: Spatial Integration for the Maltese Islands – Developing Integrated National

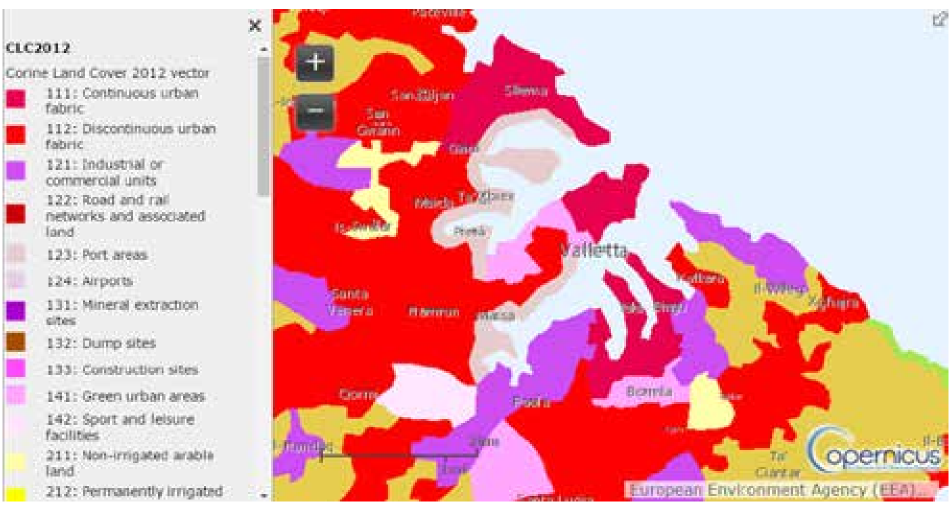
Spatial Information Capacity (refer to Formosa, Chapter 1), which involves building the necessary infrastructure, enhancing the human capacity and ensuring a legislative and mentality shift towards the free exchange of data. Furthermore, considering its interest in satellite-based EO, the PA represents Malta in a number of related fora and committees, amongst which are the Copernicus User Forum and the Copernicus Committee.

Figure 1: Watershed Analysis using RapidEye (5m) Imagery



Source: PA

Figure 2: Snapshot of Malta Dataset as part of CLC2012



Source: (Copernicus, 2012)

Environmental Monitoring

Previous academic research on the use of satellite imagery over the Maltese Islands, such as (Drago, Sorgente, & Olita, 2010), (Deidun, Drago, Gauci, Galea, Azzopardi, & Mélin, 2011) and (Azzopardi, Deidun, Gianni, Gauci, Pan, & Cioffi, 2013) has demonstrated the usefulness in using EO to study and monitor the local coastal and marine environment. The availability of satellite-derived data with snapshots (in some cases available several times daily), offers great potential in monitoring the temporal evolution of sea surface parameters such as surface currents, temperature variability and chlorophyll concentrations, amongst others. Since publication of the above-mentioned research, the availability and accessibility of satellite derived information over the Mediterranean sea has been significantly improved through Europe's EO programme, Copernicus.

Figure 3: Example of Copernicus Sentinel-2A imagery, 13th April 2016

Source: (ESA, 2016)

Apart from offering an elaborate satellite-derived information portfolio covering various ocean parameters (Copernicus Marine, 2016), the programme also exposes the lower level Sentinel-series satellite datasets through its Sentinels Scientific Data Hub (Copernicus , 2016). Such freely available datasets, which are accessible through fast registration, enables researchers and scientists to preprocess and derive additional parameters. As an example, the Sentinel-2A imagery in Figure 3 has been downloaded through the Sentinels Scientific Data Hub (ESA, 2016a) and processed using the SNAP toolbox (ESA, 2016b), which is also freely available from the ESA portal in support of the Copernicus Programme (ESA, 2016). The 10m resolution RGB image, dated 13th April 2016, shows clearly shows sediments, possibly combined with phytoplankton growth, flowing off the Sicilian coast towards Malta.

Considering the potential such imagery has to offer, ERA considers the use of satellite-derived information, substantiated by in-situ measurements for coastal and maritime environment monitoring as required by the Marine Strategy Framework Directive (ERA, 2016). Additionally, ERA also considers utilising EO for assessing ecosystem land cover in fulfilling actions related to the National Biodiversity Strategy and Action Plan (ERA, 2016a) and the EU Biodiversity Strategy to 2020.

Maritime Applications

Data from Earth observation satellites offer a systematic and unique perspective of our oceans, seas and coastlines. Apart from the multitude of satellite derived datasets, which when combined with in-situ samples provide invaluable information on marine ecosystems, satellite based solutions also contribute to maritime safety. In fact, the European Maritime Safety Agency (EMSA), an EU agency providing support to Member States in the development and implementation of legislation on maritime safety and security, provides services supported by satellite systems at their core. The European Commission has delegated EMSA with the implementation of satellite services dedicated to maritime surveillance as part of the Copernicus programme (European Commission, 2016). The following subsections provide an overview of three such services together with an outline of Maltese authorities that contribute and stand to benefit from such programmes.

Maritime Vessel Tracking

Vessels of a certain class or tonnage are mandated by international maritime law to be equipped with an Automated Identification System (AIS). The system continuously transmits messages containing, amongst other information, the ship identity and positioning information acquired from the shipborne Global Navigation Satellite System

(GPS) receiver. The radio frequency signals are instrumental as a collision-avoidance aid when picked by other nearby vessels and help enhance maritime situational awareness when picked up by land-based receiving stations when close to the coast. As a matter of fact, in line with European and International legislation Members States have developed national Vessel Traffic Monitoring Systems (VTMS) to track vessels along their coastlines.

Locally, the entity responsible for the implementation and operation of the Maltese VTMIS is Transport Malta. The system, which is linked to eight coastal radar sites in addition to AIS receiving stations (Transport Malta) significantly enhances the surveillance and monitoring capabilities available to the maritime departments within Transport Malta, the Armed Forces of Malta (AFM) and the Fisheries and Aquaculture Department. Apart from enhancing day-to-day vessel monitoring activities, the VTMIS has been instrumental in a number of operations which have led to the interception of craft carrying illegal migrants or engaged in the smuggling of controlled substances and contraband items.

In addition, as with the larger majority of EU countries, the Maltese VTMIS interfaces to the European Maritime Safety Agency's Safe Sea Net (SSN) Index Server, which harbours a complete network of AIS receiving stations monitoring vessels and their cargoes. The SSN National Competent Authority in Malta, which has the role of administrator at a national level is the Port and Yachting Directorate within Transport Malta (EMSA, Procedures for Requesting EMSA Data, 2014).

Overall, SSN monitors over 12,000 ships per day in EU waters and offers an interface for approved users to provide and request current and historical datasets (EMSA, How SafeSeaNet Works). Hence the Maltese Authorities may easily request information on a vessel that originated elsewhere in European Waters. Additionally vessels outside the range of coastal AIS receiving stations relay information to the SafeSeaNet network through Low Earth Orbit (LEO) Satellites equipped with AIS receivers (ESA, SAT-AIS factsheet). Research in satellite-based AIS systems, commonly referred to as SAT-AIS, is currently ongoing as part of a partnership between ESA and EMSA and while be instrumental as a back-up to the terrestrial SafeSeaNet information while extending its range to become a worldwide system (ESA, SAT-AIS Overview).

Apart from SSN, within the maritime surveillance domain, EMSA also manages the European Union Long Range Identification and Tracking Data Centre (EU LRIT DC). The LRIT system, devised by the International Maritime Organization (IMO), provides for the global identification and tracking of ships through an international data exchange with a data distribution plan that converges on the participation of contracted governments (International Maritime Organization). In contrast with the broadcast protocol used for AIS, LRIT information is only sent to specific recipients for confidential treatment. LRIT shipborne equipment, which is mandatory for certain vessels classes, utilises Telecommunication satellites such as the INMARSAT and IRIDIUM constellations (EMSA, 2014), to transmit identification and positioning information to data centres. As a participating state, contributing to the EU LRIT DC, the Maltese authorities may request real-time information on the location on Maltese-registered vessels around the world, vessels that are within 1000 nautical miles of the Maltese coast or vessels that are destined to a Maltese port. Additionally, in its role in the surveillance of Maltese waters, providing search and rescue operations and aiding other governmental entities, AFM's accesses to LRIT information aids a timely and effective operation.

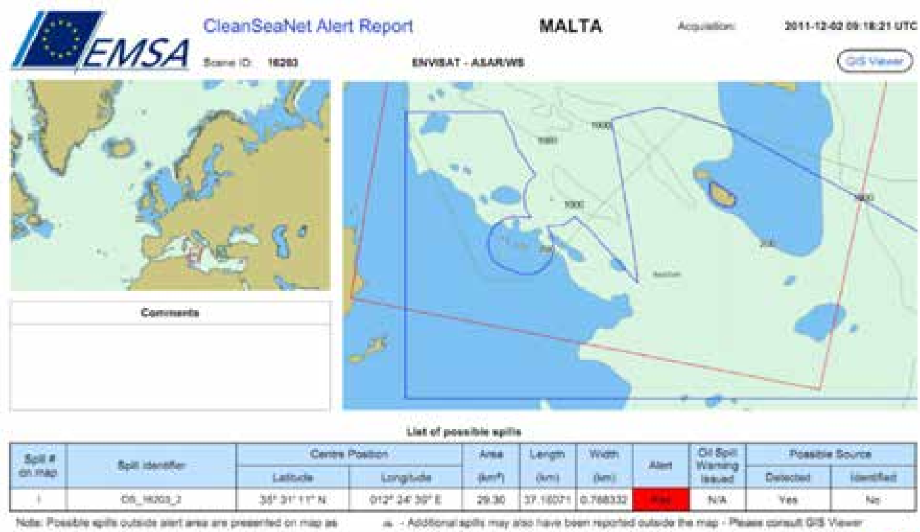
Oil Spill Detection

The Pollution and Incidence Response Unit (PIRU), falling within Transport Malta remit, is responsible for on-site assessment of small-scale maritime-related incidents. Following incident assessment, they often liaise with other authorities including the Civil Protection Department (CPD), the AFM, the ERA, and others. As with the tracking of maritime vessels presented in the previous section, such activities are well-substantiated by aids from satellite applications. In fact, PIRU is the national contact authority on CleanSeaNet, a near-real time satellite-based oil-spill detection service provided by EMSA (EMSA, 2010). This is possible through imagery taken through a number radar satellites orbiting in LEO (usually between 500km and 800km) and providing coverage of EU waters several times per day. Radar satellites, as opposed to optical satellites, have the inherent advantage of not being impaired by cloud formations and can operate during day and night. Oil slicks are distinctly visible in SAR imagery as characteristically dark features (Sentinel 1 Team, ESA, 2013).

Following a satellite pass, the imagery is downloaded through a network of ground stations and passed for rapid processing. Should expert analysis detect a possible oil spill, a CleanSeaNet report is sent to the locally relevant authorities, namely PIRU, AFM and the University of Malta Physical Oceanography Research Group, which has developed oil spill models for the Maltese Islands (Figure 4). A standard report usually includes the satellite images, the oil spill detection analysis result and, if visible, the identity of the likely polluter. (EMSA, 2010). Timing is of course critical in ensuring an appropriate operational response to accidental or deliberate shipborne oil spills. As a matter of fact, time from data acquisition by the satellite to the receipt of processed information by the local authorities is usually kept under 30 minutes (EMSA). To verify the reports received, as part of the

Emergency Response Control team, AFM utilises its own sea or air assets or contacts vessels navigating in the incident area.

Figure 4: Example of a CleanSeaNet Alert Report received by the Maltese Authorities



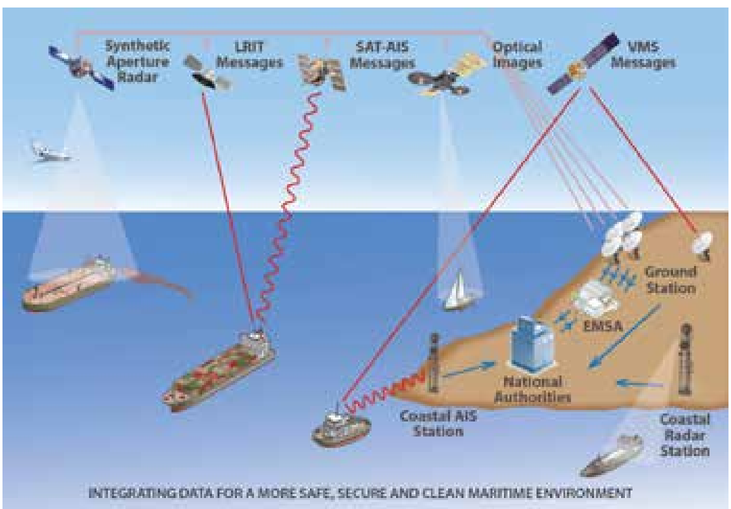
Source: (EMSA, 2012)

A 2014 performance audit to help measure Malta's level of preparedness to deal with an oil spill at sea concluded that oil spill detection mechanisms are primarily based on satellite imagery provide by the CleanSeaNet service (National Audit Office, 2014). Additionally, the report mentions a number of limitations in this regard, namely: the frequency and coverage of available satellite imagery, and the incidence of false alarms. Considering the European Commission investments in the Europe's flagship Earth observation programme, Copernicus, the frequency of imagery availability has improved significantly since publication of the audit report. As part of the Copernicus programme, radar satellites Sentinel-1A and Sentinel-1B, launched in 2014 and 2016 respectively, help ensure a revisit frequency of approximately 2 days over Malta (Sentinel 1 Team, ESA, 2013). Additionally, apart from the Sentinel series of radar satellites, EMSA's CleanSeaNet programme is supported by other radar satellites, such as the Canadian Space Agency's RADARSAT-2 (EMSA).

This helps improving revisit frequencies even further. Considering the incidence of false oil spill detections, this is also improving particularly as a result of the ESA's open data policy on Copernicus Sentinel datasets (ESA). This means that researchers from around the work have free access to Sentinel datasets, improving research prospects in all Earth Observation domains, including the science of oil spill detection through radar satellites. While the CleanSeaNet service identifies oil spills, it is usually complemented by the previously mentioned vessel tracking services, which are also substantiated by satellite technologies. Considering the fact that most oil slicks are caused by ships illegally emptying their bilge before entering port, slick detections through CleanSeaNet can be correlated with AIS information gather through SafeSeaNet to determine the source and gather evidence to prosecute the offenders (Sentinel 1 Team, ESA, 2013). As with most satellite EO based applications, the potential of such systems can be only fully exploitable through its integration with other sources of information.

Such satellite data-driven initiatives truly provide a timely and remote visualisation of the potential incident to enable initial assessment before deploying resources for on-site monitoring. The advantages here are not only optimisation of resources by more focused action, but also the latent advantages of a cross-border cooperation platforms and the speed at which incidents may be dealt with through the use of satellite data. Both SafeSeaNet and CleanSeaNet are put to good use by Transport Malta and AFM since such satellite-based solutions are instrumental in supporting the relatively small local resource in monitoring the considerably large Maltese Search and Rescue area (Figure 5). Hence, the need for more intelligent-sources for early detection and resource optimisation is clear.

Figure 5: Integrated Maritime Services using Satellite Technologies



Source: (EMSA, 2013)

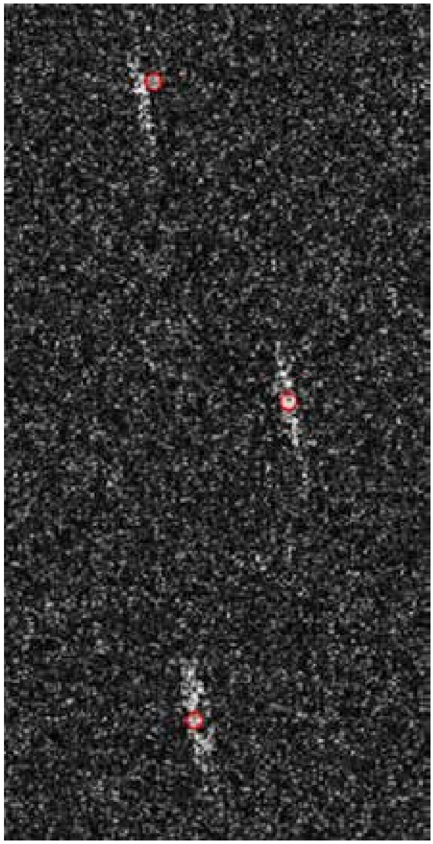
Security Applications

In December 2015, FRONTEX, the European Union Agency managing the cooperation between national border guards signed a delegation agreement with the European Commission to implement satellite services dedicated to border surveillance as part of the Copernicus programme (Frontex, 2015). As a result of this agreement, Frontex has access to Copernicus Sentinel imagery in addition to other VHR Copernicus contributing missions. Additionally, through its association with the EU Satellite Centre (SatCen), the agency utilizes sub-meter VHR radar and optical imagery through satellite sensors such as SAR-Lupe, COSMO Sky-Med, Pléiades and Spot6 /7.

In fact, Frontex is able to support authorities from EU countries in rapid response capability, assisting Member States with an enhanced situational awareness and providing an information sharing environment including satellite-based information gathering services. The collection of these services, called Eurosur Fusion Services, some of which are delivered in cooperation with the European Maritime Safety Agency (EMSA, 2014a) and the EU Satellite Centre (SatCen), include automated maritime vessel tracking and detection capabilities and software functionalities allowing complex calculations for detecting anomalies and predicting vessel positions. Previously mentioned EMSA services, such as SafeSeaNet, feed into Frontex coordinated services to help realise an EU-wide recognised maritime picture. While SafeSeaNet was primarily established to enhance maritime safety and efficiency, Eurosur services are more aligned to improving the reaction capability in combating cross-border crime, tackling irregular migration and preventing loss of migrant lives at sea.

Consequently, maritime-related Fusion Services use optical and radar satellite technology to locate vessels requiring search and rescue operations or those that are suspected of being engaged in criminal activities, such as illegal trafficking of migrants, drug or weapon smuggling (Frontex, 2016). While vessels involved in illegal activities would most likely be invisible to traditional vessel monitoring services such as AIS and SafeSeaNet due to a switched off or absent shipborne VMS, they may still be detected through Earth observation satellite scans. The Synthetic Aperture Radar (SAR) imagery from October 2015 shown in Figure 6, shows three rubber boats off the Libyan coast, identified as part of an operation involving experts from Frontex, EMSA, EUNAVFORMED and the Italian authorities. The identified vessels where migrant boats in distress and the timeliness identification led to the rescue of 370 migrants.

Figure 6: Radar image with the rubber boats spotted near Libyan coast, October 2015



Source: (Frontex, 2015)

Through its mandate to reinforce and streamline cooperation between national border authorities, Frontex provides Maltese border authorities with access to information regarding emerging risks and the current state of affairs, particularly in Maltese and neighbouring waters (Frontex, 2016a). The designated Maltese border authorities, namely the Malta Police Force, the AFM and Malta Customs (Frontex, 2016b) contribute to EU-wide information sharing infrastructure while benefitting from services such as Eurosur, particularly considering the fact that Malta is notably located within transit route of irregular migration.

Emergency Applications

As mentioned in previous sections, apart from making openly available large amounts of Earth Observation datasets, Copernicus delivers a number of services addressing various thematic areas. One such service is the Copernicus Emergency Management service (Copernicus EMS, 2016c) which, provides all actors involved in the management of natural disasters, emergency situations, and humanitarian crises with timely and accurate geo-spatial information derived from satellite remote sensing substantiated with other data sources (European Commission, 2016). Imagery is provided through the Copernicus Sentinel satellites or through any of the Copernicus contributing missions, which include VHR optical and radar satellites. The service, which is available to authorised users, consists of two components:

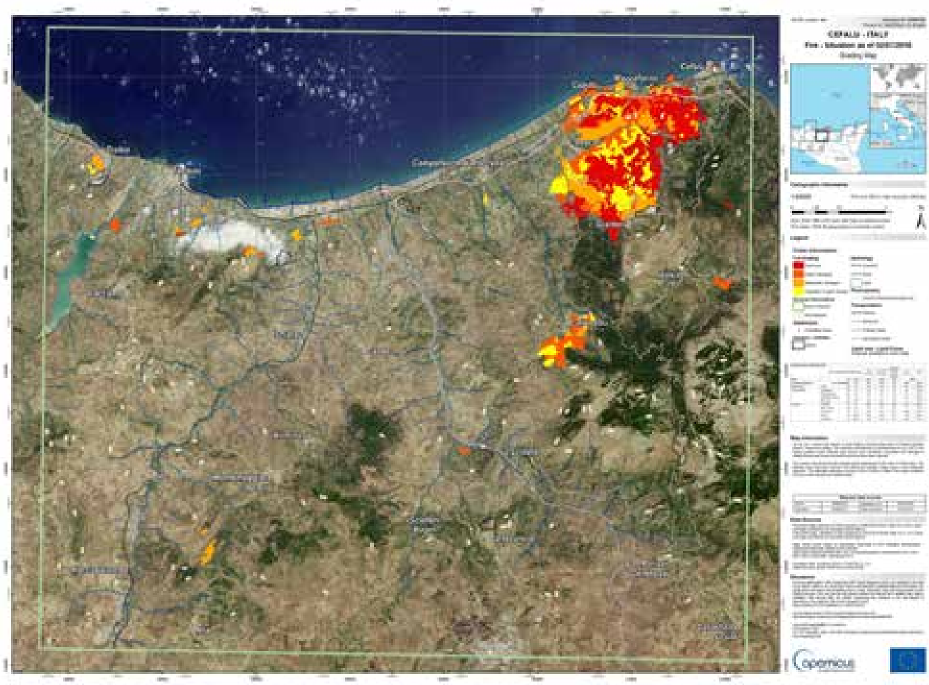
- •Rapid Mapping involves the fast provision of on-demand geospatial information intended to support authorities immediately following an emergency event. Timeliness of the information is critical and is made available within hours or at maximum a few days. When placing a service request, the authorised user specifies the required parameters. The service delivery consists of three standard products: Reference Maps, Delineation Maps that provide an assessment of the event extent, and Grading Maps (Figure 7) that include an assessment of the damage grade and its spatial distribution (European Commission, 2016).

- Risk and Recovery Mapping consists of the on-demand provision of geospatial information in support of activities not requiring immediate response. This applies in particular to activities dealing with prevention, preparedness, disaster risk reduction and recovery. Within this component, the three standard product categories are: Reference Maps, Pre-disaster Situation Maps and Post-disaster Situation Maps (European Commission, 2016).

The service may be triggered by Authorised Users by sending a service request form directly to the European Response Coordination Centre (ERCC). In Malta, the authorised user is the CPD which falls under the Ministry for Home Affairs and National Security (MHAS). Other associated users, such as the AFM amongst others, coordinate with the CPD in order to trigger the service. While such a satellite-based service might be considered as only marginally useful to small states such as Malta, a few application scenarios immediately come to mind.

Examples of emergencies related to naturally occurring disasters include incidents involving land subsidence or extensive flooding; tracking of volcanic ash plumes affecting airline traffic, phytosanitary emergencies affecting agricultural goods or algae blooms affecting the local coastal and marine environment. Examples of man-made emergency situations relevant locally might include amongst others, maritime incidents resulting in oil spillage or other forms of sea pollution, which would link to services delivered through EMSA.

Figure 7: EMS Grading Map covering the June 2016 Forest Fires in Sicily



Source: (Copernicus EMS, European Commission, 2016)

Conclusion

Satellite technologies and particularly the services rendered through remote sensing, have reached fruition through the entire data cycle, from gathering to analysis to output, enabling the mitigation of physical and social parameters towards social wellbeing as well as safety and security. When integrated within governmental polices and services, such technologies help deliver smarter and more effective solutions, ultimately benefitting the economic, academic, social and public domains.

While certain satellite application areas in Malta are well established and regulated, it is recognised that the remote sensing sector harbours additional potential which is currently not appropriately exploited. The identification of utilization gaps is a necessary prerequisite to embarking on appropriate capacity building measures, which help enable a resourceful approach to tackling societal challenges. Additionally, tailored awareness raising campaigns are instrumental in enabling a mentality shift; a shift in the conceptualisation and implementation of the technologies, data and information within a knowledge and action scenario. The review provided in this chapter is a step in this direction.

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CHAPTER 5

Conceptualisation of the Design of an Environmental GIS System in Malta

Omar Hili

Introduction

When Malta joined the European Union (EU) in 2004, it was obligatory to adhere to the Union's rigid environmental regulations. As a consequence, to date, most environmental data requires reporting in spatial formats, thus conventionally distinctive focus was given to the Geographic Information (GI) environmental aspect (EEA, 2014).

In 2002 the need for integration stemming from EU obligations resulted in the amalgamation of the then Environmental Protection Department (EPD) and Planning Authority (PA) to form the Malta Environment and Planning Authority (MEPA). Prior to this merger, the PA had its own Geographic Information System (GIS) whilst the EPD did not. Throughout the years to come the EPD as part of MEPA (now called the Environment Protection Directorate, bearing the same acronym [EPD]) sought a GIS system and constantly requested data thus consuming a considerable amount of time from the GIS professionals of the Authority.

In effect, the implementation of GIS structures within MEPA were located in two main departments:

- the Information Resources Unit (IRU), which caters for the thematic GI aspects of environmental and planning data, involved in various efforts to bring the environmental sector online (Farrugia, 2006; Formosa, 2010; Formosa, 2012); and
- the Mapping Unit (MU), which caters for the large-scale and small-scale topographic data and plotting services.

MEPA provided GIS reporting for both the EPD and the Planning Directorate (PD). Other main GI-related responsibilities of the Authority include the EU environmental reporting and the Environmental Impact Assessments (EIAs) collated from planning applications. Furthermore, the Government consulted with MEPA on GIS reports involving new national projects; case exercises, having been initiated in 2013, being land reclamation, wind farms and solar farms, (Government Property Department, 2013).

In March 2013 the Maltese Islands underwent a change in Government, with the Government aiming to and implementing a split of functions into two separate entities in line with the pre-election Manifesto (Labour Party, 2013). Due to its history of amalgamation as discussed above, albeit MEPA was externally perceived as one entity, EPD and PD structures were internally still relatively divided, with the PD remaining the main provider of IT related hardware and GI technical expertise to assist the EPD in their Information Technology (IT) / GI related needs.

Further to the above, data within the organisation was dispersed within several departments and servers. Moreover other governmental organisations hold their own GI data within their systems with third party entities not having access to such data. This data fragmentation results in difficulty to collect data, duplication and versioning control within different governmental organisations.

In summary, the following issues were faced with the above scenario, where this study chapter aims at conceptualising a centralised Shared Information System (SIS) where all environmental GIS data for government authorities are gathered and are accessible to all. All data needs to be in a central repository, in a standardised form, and on one platform; a situation brought to the fore in view that the split between the PD and EPD was under discussion, thus the new debate to which GIS as a core function is being studied. Thus this study also identifies the evaluation of synergies between the different GI environmental systems.

Such a case study will also assist GIS in Malta as such a proposal would result in a clear, centralised and sharable environmental GIS infrastructure. The main challenges comprise an SDI implementation, interoperability and system integration.

Methodology

The investigation of the potential SDI requirements resulting from the split of the Authority requires an analysis of what is entailed in the creation of an environmental SDI GI system for Malta. This was carried out through the understanding of the state of environmental information in Malta in terms of data lacunae, legislation, operational issues, structure, access and dissemination.

This posed questions on what and how the environmental GIS can be integrated within a strategic work frame based on EU Directives and through the examination of SDI systems implemented in other countries. A challenge of this study related to the functionality and design of the framework and the integration of feedback received from focus group interviews.

This process entailed an investigation of the methods best used in such a study, which focus on a triangulation method through the quantitative approach necessitated by the data gathering process, and the qualitative approach employing a focus group. Each of these are discussed in more detail below. Table 1 gives a description of both the qualitative and the quantitative approaches used.

Table 1 Qualitative and Quantitative Approaches and their outcomes

Qualitative Approach	*Quantitative Approach*
To grasp knowledge of subject and underlying reasons about the subject.	To quantify and generalise results from samples taken.
To analyse the issue in discussion and formulate ideas, hypothesis.	To cross reference values and measure incidence of various views.
Outcome: Finding is not conclusive but assists in creating a course of action to further decision making. Assists in creating a current setup and provides a future theory in conceptualization of models.	**Outcome:** Results will lead to a planned course of action to assist decision making.

The Qualitative Approach

A Qualitative Approach is a different method for the gathering of in-depth data about specific topics. Whilst researching a topic, qualitative approaches can assist in deriving extra topics which will assist the results of the study. This approach allows the flexibility to adopt unstructured interviews and content analysis whilst also permitting the collection of a variety of different opinions and ideas. Jung and Elwwod (2010) discuss new and extended qualitative approaches in GIS and stress that efforts are being pushed towards improving this type of approach. The latter is also considered as an explanatory approach, meaning that data gathered is analysed and theories are generated over the subject of study (Jung& Elwood, 2010).

A wide variety of innovative software solutions are available which assist in such an analysis. This approach has its limitations, such as those imposed by the level of knowledge and awareness of the subjects by the participants due to: low periods of time spent in GI-related work, (even if managing relevant units/teams); and limited choice of participants in a relatively-small organisation. Discussions between experts still define different views on the different approaches to adopt. Leszczynski (2009) describes the quantitative approach vs. the qualitative engagements in GIS as the diverse opinions between critical theorists and GI scientists. Taking the above into consideration, focus group interviews /

discussions with managerial staff in both Directorates within the Authority were carried out with fifteen experts over a period of four months. The aim of the focus group was to collect data and information on the current state and structure of the organisation, while the interviews with the Authority's Managers analysed the current interoperability between the different units, their views on the current structures, and the potential for an SDI implementation.

The Quantitative Approach

On the other hand the Quantitative Approach in GIS offers more numerical analytical techniques and numerical quantifications of values (Cope & Elwood,2009). A quantitative approach is the analysis of sociological data in numerical and statistical formats. By gathering numerical data, results can be illustrated in charts which can simplify a visual representation. A quantitative research is sometimes assisted with a qualitative research post quantitative results. Whilst delivering large volumes of objective data, the quantitative approach can be limited through various means such as the access to very specific datasets that are accessible to a few persons, issues related to nomenclature, non-clean datasets and dated data (Formosa et al., 2011). IBM (2012) SPSS statistics package is the tool used to derive such results from the quantitative data collected. It is mainly a predictive analytics software. For the data gathering and analysis of this study, the SPSS Data Collection package has been used to help generate frequencies. Other SPSS data collection capabilities are::

- Interviewing - tools for easy deployment, compiling and managing of surveys;
- Reporting - develop professional and interactive reports in online or desktop environments; and
- Authoring - facilitate the creation of surveys using intuitive interfaces comprising of sophisticated logic, to better completion rate and ensure good quality data.

Excel and SPSS assisted in cross-tabular analysis of the data gathered. This is the process to examine the relationship between two variables of data. Quantitative data was collected via questionnaires. The questionnaire was devised and constructed in such a way that results reflected the current knowledge on environmental spatial data use of GIS in Malta, and feedback on the proposal to conceptualise a design of an environmental GI System in Malta. Reja(2003) present the advantages and disadvantages for both open-ended and close-ended surveys. Open-ended questions promote a more spontaneous and freely deliberated reply, whilst the close-ended questions reduce the bias in reply by suggesting the choice or results (Reja., 2003). Reja (2003) also describe that open-ended questionnaires may be more difficult to analyse whilst close-ended replies might reduce the chance for theme experts and other interviewees to correct, or constructively adjust, the pre-given multiple choice answers.

Taking the above into consideration, the questionnaire utilised in this study was semi-structured, in that certain results were gathered online, whilst others were collected through a one-to-one meeting with key informants. Whereas the online version was a multiple choice with no open-ended questions, the one-to-one version used the same questions and allowed open-ended results and opinions. The choice for adopting such a method was to vary the results and to allow participants, in prime key positions, to express their opinion.

The Triangulation Approach

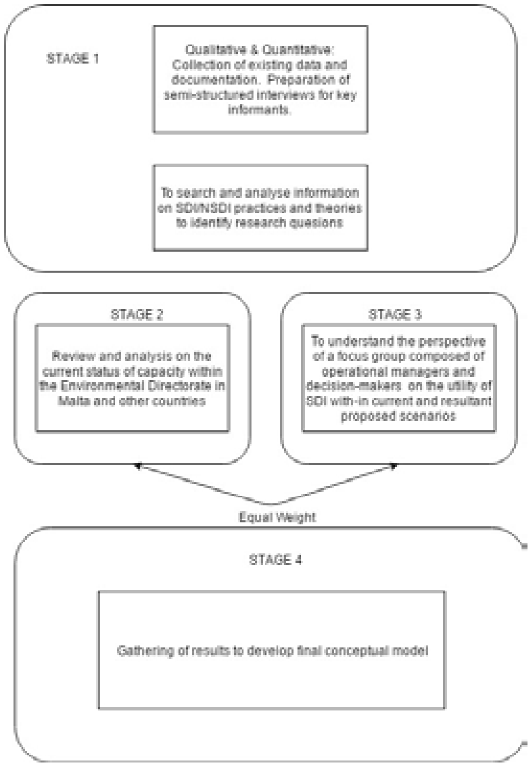
This study adopted a mixed-method approach, also called as a Triangulation Method. Tashakkori and Teddlie (2003) identify reasons that promote a mixed-method approach superior to the single-approach designs. A mixed-method approach can provide a more consolidated and better conclusion, whilst also providing the opportunity to gather information for wider and more diverse views and opinions. This research methodology was adopted since all interview experts formed part of the same organisation.

Table 2 describes the stages of how data collection was divided. Each stage does not reflect primary and secondary data but is in a chronological order for ease of data collection, resultant in the research methods and techniques as depicted in Figure 1. Figure 2 provides the mixed method design and implementation approach adopted.

Table 2 Individual description of the four stages in the research design

Stage 1	Qualitative: Collection of existing data and documentation. Preparation of semi-structured interviews for key informants.
Stage 2	Review and analysis on the current status of capacity within the Environment Directorate ED in Malta and other countries.
Stage 3	To understand the perspective of a focus group composed of the operational managers and decision-makers on the utility of SDI within current and the resultant proposed scenarios. To research and analyse information on SDI/NSDI practices and theories to identify research questions. Quantitative: Design of questionnaires and structured interviews. Analysis of response from questionnaires and interviews.
Stage 4	Gathering of results to develop final model and acquire feedback from the experts on whether such a model is acceptable.

Figure 1 Research Methods and Techniques



Primary Data

Primary data comprises of questionnaires and focus group interviews; presenting that an unstructured and a semi-structured approach has been adopted. The focus group follows a sequence of unstructured interviews with key elements that will allow the strengthening of results from questionnaires, thus having a triangulation of data in order to strengthen results.

The study's discussion was an open, semi-structured discussion highlighting the scope of this study aimed at gathering feedback and opinion. This was held at management level so as to gather key data on the responsibility of each unit and the way they operate. One of the major aims was to gather latest information, from top management, with regards to decisions on how the new environmental entity will operate, collecting information on new policies and environmental operations. Table 3 presents the approach adopted for the focus group interviews.

Figure 2 Mixed Method Design and Implementation Approach

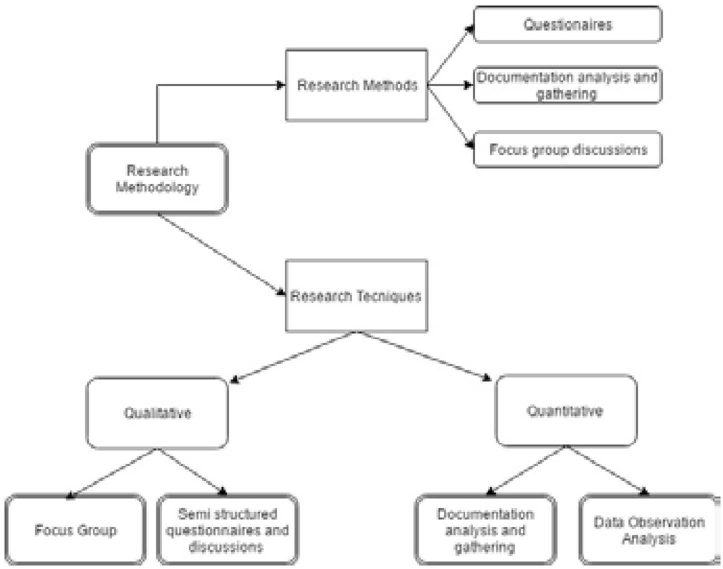


Table 3 Main focus of structured interviews

Identifying key participants	**Gathering of information on all officers working in IRU, MU and environmental units that are directly related to GIS and the ERDF156 Project. Such information will be gathered from the Human Resources (HR) department and clearly stating ethical issues that the proposal is bound by.**
Formulating questions needed	**Preparation of a set of standard questions that are focused directly on the current setup and the participants' opinion on an ideal setup. Direct questions to higher management and direct sub-ordinates.**
Inputting data whilst interviewing	**All information is relevant for future analysis so that information that is not directly related to the questions will be recorded.**
Transcribing data	**Creation of a standard template on how to transcribe data. Data must be standardised in order to assist its analysis in table format.**
Preparing and organising focus group for discussion and data collection	**Organisation of extra sessions with Technicals directly responsible of data acquisition and to gather information on how a proposed system will assist in their work.**

The second form of primary data collected was through the structured questionnaires, which data was later analysed. The key members were selected mutually with the consent of their respective managers during the focus group discussions. For every environmental theme (i.e. for every unit) one key expert was identified.

Secondary Data

The secondary data was collected from the IRU and the four environmental units forming the ED being: Environmental Permitting and Industry Unit (Unit A), the Environmental Assessment Unit (Unit B), the Ecosystems Management Unit (Unit C) and the Waste, Air, Radiation and Noise Unit (Unit D). Table 4 describes the secondary data sources used.

Table 4 Secondary sources of data

Within MEPA	*External Organisations*
Data gathering from (SEIS) within the ERDF156 Project, MEPA (2009). This is currently on beta version and incomplete.	**Data that is non-GI (non-spatial) from diverse agencies such as Malta Resources Authority (MRA), Ministry for Sustainable Development, the Environment and Climate Change (MSDEC, 2013).**
	Data gathered from European entities. The European Commission 'EU Shared Information System – Implementation Outlook', (The European Commission, 2013).
	Information from the EEA, and the EIONET Central Data Repository (CDR) (The European Commission, 2013).
	Various Papers and Journals.

Most of the secondary data sources were identified through the focus group interviews held with the unit heads and environmental experts, with an additional focus for those related to the 'Water' theme. Secondary data analysis was not restricted to data acquired by MEPA but also by other Maltese governmental authorities that house environmental data. Other sources of secondary data covered research and analysis of other European countries within the context of SDI, water theme, and data gathering and manipulation within the INSPIRE Directive.

Results

The following section will display results from the interviews held with various experts within the Authority. The aim of the first question was to cross reference how and who was conversant with spatial data. The response was that only a few respondents between the age group of 35 and 44 years were not conversant. These were mainly persons who were the ones at decision level within the Environment Directorate. Their role in the entity does not entail them to be conversant with the data but simply to be presented with statistics and to take key decisions within the same Directorate.

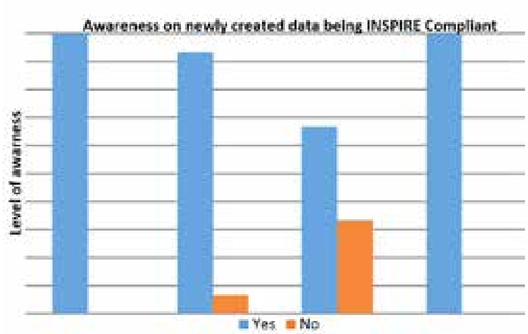
A cross-variable analysis was carried out in order to identify whether the respondents who replied positively on SDIs knowledge, were also aware of metadata. Respondents, who had a very good knowledge of the structure, user and operation of SDI, exhibited very high awareness of metadata. In fact, 40% stated that they had 'Very High Awareness' and the rest stated 'High Awareness' (Figure 4). Those who answered that they had a 'Good Knowledge' were less aware of metadata (17% - very high) and there was an increase in less aware persons when they answered that they had a 'Fair Knowledge' (20% 'Low Awareness'). Another finding shows that they still considered themselves to have a high level of awareness.

Figure 3 displays results of the cross reference between knowledge of metadata and the awareness that all new created datasets must adhere to the INSPIRE Directive. Results, clearly denote that 100% of the people who had knowledge of metadata, also had an awareness of INSPIRE compliance. 33% of respondents who were not aware of metadata, were also not aware that new datasets must adhere to the INSPIRE Directive. The same amount of respondents who answered 'No' had low knowledge. The respondents indicated that a centralised system is required where all data would have to be compliant in order to minimise the communication between diverse units, sections or ministerial departments. This is preferred by respondents, as it offers one strong hold of having one entity housing all environmental spatial datasets.

The desk study showed that GIS within the environmental sector of MEPA and ministerial departments was widely used, mainly for analysis (85%). Participants agreed with the consolidation of one entity housing all environmental data, as such analysis will be less troublesome. They indicated that all data will be available without interoperability issues between the units. An interesting fact is the low results in EU reporting. This was noted whilst commencing the open-ended questionnaire with the IRU, which as already stated is the National Focal Point (NFP), being responsible for the uploading of the content, after it is structured and prepared by the respective environmental experts.

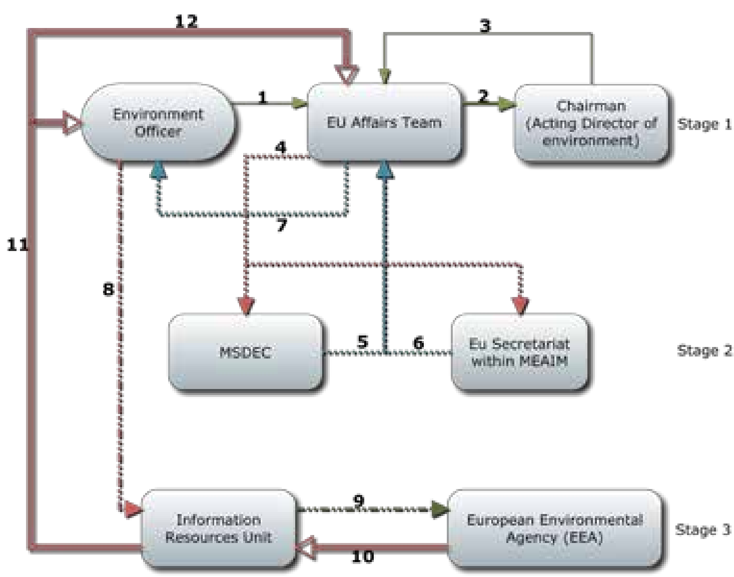
The respondents argued that the process from the Environment Officer to the EEA is a long process of correspondence and approvals were required from different entities, further stating that such process is necessary to grant approvals from different institutions. The unit responsible for such a flow was the EU Affairs Team within MEPA. Figure 4 displays the dataflow diagram together with the appropriate step by step explanation of the data flow before it reaches the EEA.

Figure 3 Level of awareness on newly created datasets being INSPIRE compliant



The reporting workflow developed following discussion with the EU Affairs Team resultant from discussions with the respondents decsirbes the process adopted by the Authority in order to finalise any reporting before uploading to the EEA.

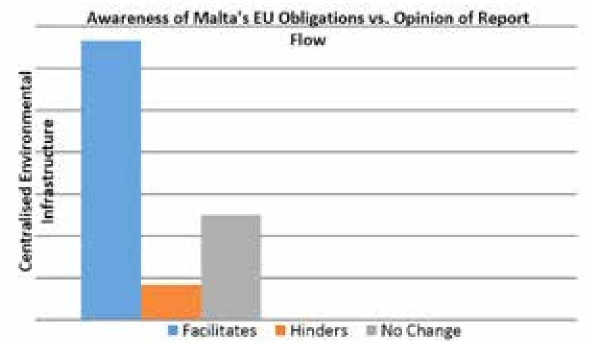
Figure 4 Dataflow between report originator to the EEA



1. The Environment Officer originates the data which after completion of report is sent to the EU Affairs Team;
2. The EU Affairs Team sends the report to the Environment Acting Director (currently MEPA Chairman) for the necessary approvals;
3. Once approved by the latter, the report is sent back to the EU Affairs Team;
4. The EU Affairs Team forwards the Environmental Director's approved reports to the (MSDEC) and to the Ministry for European Affairs and Implementation of the Manifesto (MEAIM), more specifically to the EU Secretariat, which coordinates matters and refers them to the Permanent Representation;
5. The MSDEC reports back to the EU Affairs Team;
6. The EU Secretariat also reports back to EU Affairs Team;
7. Reports from MSDEC and EU Secretariat are also forwarded back to the Environment Officer;
8. The Environment Officer forwards the approved reports to the IRU;
9. The IRU uploads the data on the EEA's portal being the European Environment Information and Observation Network (EIONET);
10. The EEA sends an automatic receipt of upload and any other relevant feedback to the IRU;
11. The IRU forwards any feedback to the responsible Environment Officer and the EU Affairs Team; and
12. The Environment Officer will then reply back to the EU Affairs Team.

As per discussions held with the IRU and the NFP, Malta must adhere to strict deadlines in uploading this data. 85% of the respondents who were aware of such obligations, also thought that a central environmental SDI will facilitate such reporting processes. Also, 4% thought that it will hinder such reporting. This is further explained in detail in Figure 5. The same percentage also illustrated that the theme experts who are in charge of preparing such reports had the perception that they will lose control of their data. The same respondents also thought that they will have to go through other individuals / entities to report data and also feared that the dataflow will be slowed down due to bureaucratic processes or political / operational indecisions. This was an ongoing concern, where dataflows had previously been slowed down at political / ministerial level and therefore data was always uploaded late. The IRU respondents stated that they had striven to reduce this problem through direct 'restricted-access' uploading to the EEA, which restrictions were then removed once the ministerial approval was gained.

Figure 5: Awareness of EU obligations and impact of centralised SDI on reporting



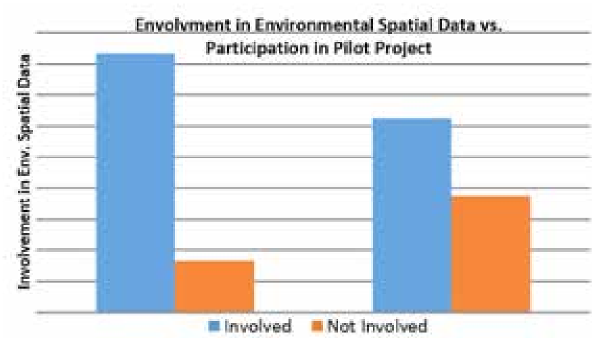
One interesting fact is that 25% of respondents thought that it will not make any difference in having a centralised system (Figure 8). The findings show that these respondents pertain to those who do not fully appreciate the GI work carried out. As demonstrated in Figure 6 with reference to the problems encountered by data share-ability between environmental departments within MEPA and other environmental entities throughout the governmental departments, all comments by respondents led to report a problem in this area. The results show that 38% of the respondents, who think that data sharing is a problem, still lacked the desire to participate in a pilot project for the conceptual model of a consolidated SDI, thus promoting data sharing between Governmental entities.

Figure 6: Data sharing vs. participation

The results show that when discussing lack of interest, it was noted that due to the fact that some employees have been employed for over 10 years with the organisation, their motivational drive has been reduced substantially. They stated that this was due to overloaded workloads, fear of unbalancing the status quo or a lack of willingness in striving against management and other governmental departments in their quest for new enhancements to the output.

Figure 7 depicts that a total of 23% of the respondents who are not involved in environmental spatial data, still showed interest in participating in a pilot project. On querying the reason for such a drive, younger participants and with recently acquired introductory knowledge of GI, showed more interest in learning more about SDIs and what is achievable with such consolidation of data. Once again, a large part of the respondents who were aware of environmental spatial data were still reluctant to participate in a pilot project, for the already mentioned reasons (63%).

Figure 7: Involvement in environmental spatial data vs. participation



Participants were also asked to give their opinion on the current GI environmental infrastructure, and their response was cross-referenced with the idea of a conceptual model for the environment entity (Figure 11). 56% considered GIS from an Information Communication Technology (ICT) perspective to be advanced but perceived having a centralised SDI to be highly essential in order to function better. Still, a very high percentage of those who thought that the system was adequate 'Passable', considered this to be 'Highly Essential' or 'Essential'. The respondents stated that whatever the current situation in environmental GI is, it is of essence to group all environmental data into one consolidated spatial infrastructure.

Participants were asked whether the idea of having a conceptual model of a centralised environmental SDI, was achievable. The response is a very positive one with 85% of the respondents confirming that it is achievable and that it will facilitate work within the new environmental authority, once it will be formally set up. 4% thought that a consolidated SDI might hinder, whilst 12% thought that it will not change the current situation. However, whilst investigating why such response was given, the same problem emerged, being that the respondents who have seen governmental changes and different reforms in the Authority still thought that at governmental level, there will be major barriers for the implementation. Respondents also highlighted that since this is a new proposal by a newly elected government, and was also part of the party's Electoral Manifesto, the change was more likely to happen now, thus the positive response.

Results from the choice of one thematic area: Water

Results from the 'Water' theme, show that respondents stated that each governmental entity is responsible for the collection of data that pertains to their respective department, which in turn is the data that MEPA has to try and gather for the compilation of the reports for the EEA. Table 5 describes the role of each governmental entity within the two directives as identified through this study.

Table 5 Relevant entities with respect to the WFD and MSFD Monitoring Programmes

Monitoring Programme	**Entities**
Ground Water (GW)	Unit A (MEPA) – responsible for water quality analysis and reports.
	Environmental Health Directorate – must oversee the quality of GW within the Maltese Islands.
Inland Surface Waters (ISW)	Unit A (MEPA) – responsible for water quality analysis and reports.
	Unit C (MEPA) – responsible for Biodiversity.
	Environmental Health Directorate – must oversee the quality of GW within the Maltese Islands.

Monitoring Programme	Entities
Coastal and Transitional Waters	MEPA – responsible to link with the MSFD Directive. Must also oversee Bathing Water Quality and Transitional Areas. As per Figure 4.11, Transitional Area is that area that overlaps with the MSFD within the OSPAR Convention laws of the sea.
Bathing Water Data (BW)	Department of Health – sample beaches and Coastal Waters (CWs).
Non-Indigenous Species (NIS)	MEPA - monitoring within hotspots (e.g. Protected Areas, Harbours) and Action Plans.
	Transport Malta (TM) -shipping is one of the main vectors of non-indigenous species, Ballast Waters (Ballast Water Management Convention).
	Fisheries Department - aquaculture can be another source of NIS - Council Regulation EC 708/2007 concerning use of alien and locally absent species; Fisheries also have the opportunity to contribute to monitoring by the collection of specimens through the International bottom trawl survey in the Mediterranean (MEDITS).
Eutrophication	MEPA (E-PRTR – monitoring of nutrient input; WFD – monitoring status in the marine environment).
	Water Services Corporation (WSC) – Sewage Treatment. Plants (Urban Waste Water Treatment Directive) (UWWT).
	Agriculture – Nitrates Directive – Nitrates Action Programme.
Hydrological Changes	MEPA (link to development applications), TM (harbour development).

Monitoring Programme	**Entities**
Contaminants	MEPA (WFD: monitoring of input loads, monitoring of status).WSC (monitor contents of effluents).
	TM (oil spills, bilge waters, bunkering).
	Continental Shelf Department – oil drilling.
	Fisheries Department – contribute to monitoring of contaminants in biota.
Contaminants in seafood	Environmental Health Directorate – monitor contaminants in food (EC Regulation 1881/2006).
	MEPA and Fisheries Department – contribute to sampling of biota and assessment of contaminants in biota.
Litter	Cleansing Services Directorate – beach cleaning which can generate data on litter on the beaches.
	Malta Tourism Authority (MTA) – Blue Flag Beaches including criteria for monitoring beach litter.
	Fisheries Department – contribute to monitoring of litter on the seabed.
	TM – main source of litter is shipping and they can contribute to monitoring of litter on the surface.
	MEPA – Oversee monitoring programme and compiles report for EEA.
Energy, including Underwater Noise	MEPA – to include MSFD data requirements in EIA process.
	Continental Shelf Department - licensing of seismic surveys (one of the main source of impulsive underwater noise).
	TM – shipping lanes – main source of increase in ambient noise levels.

Monitoring Programme	**Entities**
Biodiversity - Birds	Wild Birds Regulation Unit – Birds Directive.
Biodiversity – Mammals and Reptiles	MEPA (Habitats Directive).
	Fisheries Department, TM, Armed of Forces of Malta can contribute to monitoring; Fisheries Department will be collecting data on by-catch of turtles.
Biodiversity – Fish and Cephalopods	Fisheries Department – collect data on fish and cephalopods – Common Fisheries Policy.
	MEPA – data analysis.
Biodiversity – Commercial fish and Shellfish	Fisheries - Common Fisheries Policy
	MEPA – data analysis.
Biodiversity – Seabed Habitats	MEPA.
	Pressures: Fishing Intensity (Fisheries); Anchoring & Bunkering (Transport Malta); Aquaculture; Waste Water.
Biodiversity – Water Column Habitats.	MEPA – data analysis.

The mother directive, the WFD, is divided into two main programmes; the Inland Surface Waters (ISW) and the Coastal and Transitional Waters. Both have overlapping data, such as contaminants, eutrophication, hydrological changes, biodiversity seabed habitats and biodiversity in water column habitats. Each programme is responsible for the collection of data related to the underlying subsets.

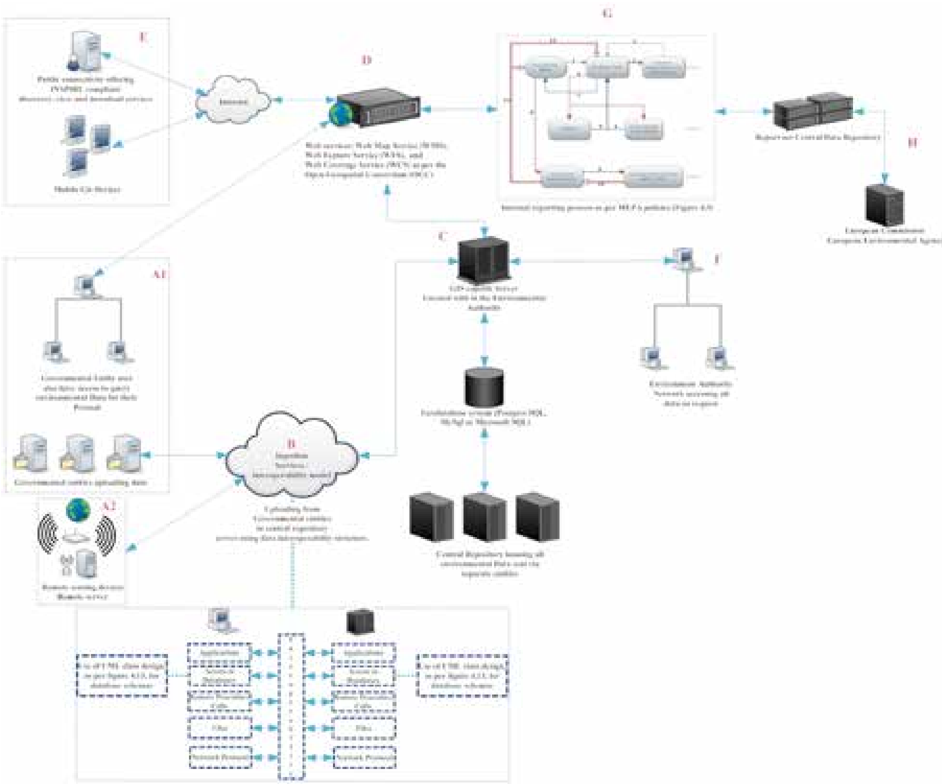
The conceptual model

The Conceptual Model (Figure 8) has been developed following an analysis of the qualitative and quantitative data presented above. The model was designed to facilitate communication and data gathering from different entities and to be able to be more productive in a better and more efficient way. As Tóth (2012) describes, providing a system with standardisation, will ease the interoperability between entities and also provide a base for a design of an environmental SDI (e-SDI) unified platform.

Figure 8 depicts the final conceptual technical model for an e-SDI resultant from the findings, which model was created post feedback on the current system and querying on whether the concept of a central repository would facilitate in the data collection, storage, reporting, ease of access, assistance in governmental decision making, and public dissemination.

The model provides the three main important features of an SDI, the core servers and respository, the dissemination services and finally the prodcedural data uploads and security. The scope is provide a solution capable of ingesting data from governmental entities directly into the system to disseminate to public thus reducing human interaction. The 'Results' section demonstrates positive feedback and depicts willingness in constructing such a system.

Figure 8 Conceptual Model for an environmental SDI



Conclusion

This study, in its strive to understand the status of environmental information in Malta, whilst initially reviewing the different environmental themes, focused on one main thematic aspect related to water as a case study. Findings showed that in terms of data lacunae, environmental themes suffer from the lack of spatially-structured information, legislation has been transposed (INSPIRE) but not every thematic expert is knowledgeable on this score. In terms of operational issues and structure, the findings show that there is a lack of interoperability between units, systems and information-sharing. This is highlighted even more through difficulties encountered in access to data and in being knowledgeable of dissemination modes of data.

The exercise to review, analyse and draft the process as well as to construct a conceptual model, which can be employed for an SDI's concept in Malta and findings show that the current ED does house knowledge and capabilities to convert a conceptual model into a full implementation. However there are issues that need to be tackled on various domains before such a system goes through to fruition. The process requires time and substantial finances but implementing the system in a staggered manner can assist the success of an SDI (Janssen & Dumortier, 2007). Throughout the process of data gathering, a number of concerns and issues have been highlighted, and these open new pathways for further investigations and studies.

The findings also show that the model is an achievable goal and its results are of great advantage to the authority that deploys it. The model covers new technologies and an independent upload system that will ease much of the work in digitising data. Furthermore, the system offers traceability, security and most importantly, data governance. Another important note is the enthusiasm shown by few, relatively new to the organisation, in implementing such a system, but also disappointingly, the large amount of people who are not willing to participate, mainly because of the years and numerous reforms MEPA went through. It is of vital interest to comprehend that such a system can simplify, and at the same time, build a robust architecture for the authority that is responsible for the care of the environment we live in. This is the scope of the conceptual model for the environmental SDI.

The main limitations of this study emanated from the state of flux that the change in the Authority's split brought about and as such, the experts interviewed could have been wary of the scope of this study, particularly due to a perceived fear that such a process may complicate / increase their work load or serve as the basis for additional functions. However, the experts were forthcoming, especially since the study was conducted prior to the actual launch of the change process.

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CHAPTER 6

A Geographical Information System used in the 2011 Census of Population and Housing

Maria Refalo, Silvan Zammit, Saviour Formosa and Ashley Hili

Introduction

The National Statistics Office is Malta's National Authority entrusted to carry out the census. The population statistic is only part of the whole exercise, thus the purpose of the census has evolved. The exercise has evolved over time with questions creating a spectrum of the Maltese society situation. The fact that it is carried out every 10 years, it allow for comparisons to be systematically arranged and within a time frame which is not short nor long. The census on its own is an extensive project to carry out, nevertheless the information gained from this national project provides data which needs to be turned into information, giving more value to the data gathered.

The national census being a vast data source, if integrated with GIS can produce several beneficial statistical outputs. The decennial count of residents, households and dwellings is a pool for statisticians to create progression, differences and a comparison between the different census years. Having GIS to analyse the data through its several tools can create a more systematic, efficient and clear results. The polygonisation process of the Enumeration Areas (EAs) was the next to be created, specifically for the purpose of the census statistics to be incorporated and thus can be spatially visualised. The process to create the polygons was made systematically so as to have a clearer way to visualise exactly how the plotting should be made. Plotting the EAs will not be a static map as it could be used further on with other census outputs, or if changes are necessary, amendments will be needed to be done.

Being able to integrate data from the census can be further on used to analyse the distribution of the questionnaire, giving a more representative output for policy makers. Furthermore, having the census with a spatial aspect was a must to relate to the contemporary needs.

The Population and Housing Census in Malta and the EU

The Census of Population and Housing provides an official count of residents, households, and dwellings in a country. It is normally a decennial exercise that allows for comparison of information over relatively fixed periods of time and presents a rich socioeconomic profile of the population as well as the dwelling stock characteristics, covering occupied and vacant property.

Every census exercise is specific and exhibits its own special characteristics. The last census in Malta was undertaken in 2011 and was the seventeenth of its kind since 1842. It was part of a European-union-wide round, since all Member States conducted their own national censuses. As in almost half of these countries, including Malta, the census is carried out the traditional way, whereby primary data is systematically collected by field officers (or enumerators) directly from individuals through questionnaires. Computer assisted and mixed data collection modes are gaining in popularity across the European Statistical System over time and some countries (particularly the Nordic) have a long tradition in undertaking fully register-based censuses. Mixed-mode data collection methods, involving a mix of different approaches, are also quite popular.

The census has a solid legal basis, underpinned by the provisions of the Maltese Census Act of 1948. Additionally, a number of Regulations of the European Parliament and of the Council establish common rules for the provision and dissemination of comprehensive census data in terms of methodologies and metadata.

The Census Questionnaire

The census provides a snapshot of a country's population at a particular point in time known as 'census night', which, in case of the 2011 census in Malta, corresponded to midnight of 20 November. This means that all information collected in the last census process had been recorded relative to this instance. This minimised problems of counting vacationers, newborns, seasonal labourers and other seasonal population in the country.

Census variables, concepts and definitions which are of general European interest are mandatory as stipulated by Eurostat's Regulations although countries are free to include any additional variables for national interest and use. In case of the 2011 round, (EC) No 763/2008 and (EC) No 1201/2009 applied. National issues were also addressed following a series of consultation meetings held with a number of organisations months before the official launch of the census, and the questionnaire was also piloted among a random sample of households for evaluation. In addition to aforementioned Regulations, census questionnaires must also ensure continuity as well as conformity to the recommendations, concepts and definitions on population censuses of the United Nations Economic Commission for Europe (UNECE).

The same questionnaire was used to collect information from private and institutional households, and respondents were able to request either a Maltese or English-language version. It was split into two parts, with the first focusing on socioeconomic characteristics of the population and the second part dealing with housing.

Constructing Enumeration Areas

For operational issues, Malta was divided into six districts according to the Local Administrative Unit (LAU) classification which comprises all the 68 localities (equivalent to local councils) in the country. All localities were further divided into 1021 geographical units called Enumeration Areas. Each EA was composed of a number of streets, or parts thereof, in a particular locality whilst taking into consideration both the number of dwellings included in each EA as well as the geographical area covered.

The initial step for delineating EAs was to identify the count of private dwellings in each street in Malta. A list of unique streets was extracted from the 2011 government's corporate database known as the Common Database (CdB), which contains details about Maltese residents in possession of a Maltese identity card. Other auxiliary databases available in the country were also consulted to ensure that a final comprehensive list of streets is created together with an estimate of occupied and vacant property in each street. This list was then provided to the Malta Environment and Planning Authority (MEPA) who constructed the EAs and represented them as maps in electronic format.

Each map was inspected in detail for any possible overlap, gaps and other inconsistencies. Particular attention was given to streets which spanned over multiple EAs to ensure that boundaries were clearly and distinctly marked.

Census Operations

Over 153 thousand census questionnaires were mailed to all households in Malta about two months before census night. About 93 per cent of all questionnaires were collected throughout the official data collection phase, which spanned from 7 November to 4 December 2011. Any remaining questionnaires were collected during the follow-up phase, until a final 96 per cent coverage rate was reached.

Throughout the process, almost 1200 persons, headed by the Census Officer and two deputies, were recruited for data collection purposes. A group of six district managers were responsible for ensuring the smooth running of the enumeration process within each district. In addition, five area supervisors were responsible for the transportation of all census questionnaires from 41 schools across Malta and Gozo which provided logistical support to enumerators during the census period to the premises housing the census office prior to the keying-in of data.

Each enumerator was required to completely canvass the assigned area and record all persons, together with private and vacant dwellings in the allotted EA. Enumerators were requested to record all tenements in their assigned area, by listing them systematically in a number of administrative forms which were provided. Each tenement was assigned a three digit serial number which, together with the locality MGC code and EA number, formed a unique identifier for each dwelling. Information about institutional households was collected by the Census Office.

Methodology

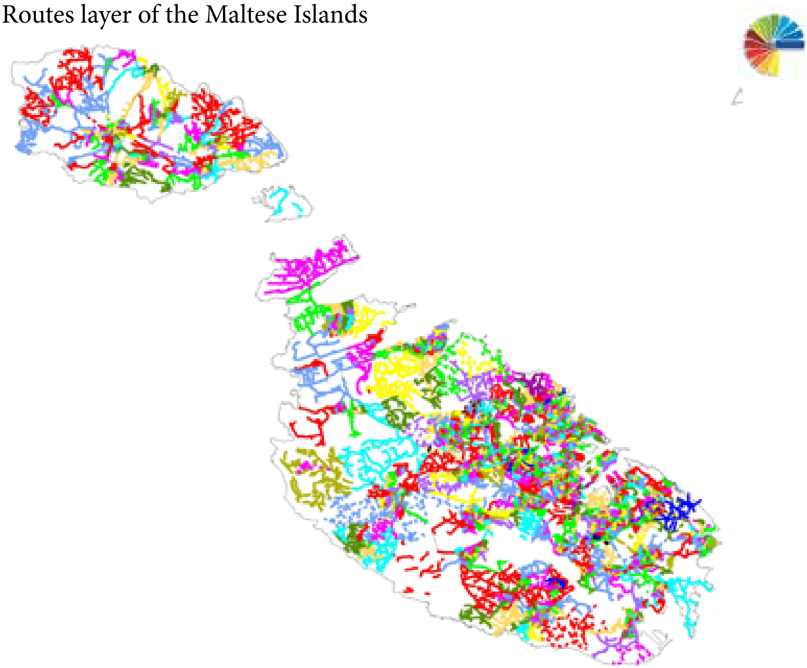
The process entailed the identification of street centrelines as linked to an electoral register that had been geocoded employing a street-centerline methodology. Each previous Census enumeration area was reviewed for its population consistency and an adherence to the maximum population allowed in each area. Issues identified in this process were related to the process that instead of identifying a homogeneous area. An enumeration area that had less population was adjoined by another area, which sometimes was at a distance from the main area. This issue introduced some error and in cases eliminated the possibility for inter-Census analysis. However, for the purposes of data capture and population take, the entire population was served, As a potential future Census runs, a street centreline or a point-based analysis could eliminate this issue.

Polygonisation of the Enumeration Areas

The spatial element of the census was brought in through the polygonisation of the Enumeration Areas (EA) an exercise which was carried out for the census in Malta. An enumeration area code represents a series number of streets or routes which make part of the whole council. The Maltese Islands are divided in EA as it is obligatory that every household complete the questionnaire while it is also made feasible for the enumerator to complete all the EA in her/her responsibility in a reasonable time-frame. A registered enumerator is given an EA so that s/he can help the household owner or family to complete the questionnaire in the correct way, if help is needed. Each council was divided into several numbers of EAs, as this is directly affected with the number of habitable households in the streets. Such distinction can be clearly noticed with the North and North-west areas of Malta with the Southern, Centre and Harbour region of Malta. This was deemed an important step towards a more spatial view on the resulting statistical outcomes. The process incorporated in obtaining such result is presented through the application of the Geographical Information Systems (GIS) knowledge, with the use of MapInfo program.

The routes of the census as used by the enumerator were uploaded and a thematic map for each council was created in order to visualise much better the different routes. In the thematic map is was necessary to have each route number in the council in different colour in order to be easily distinguishable from each other. The preparation of the route map, makes it more feasible and detailed enough to have a systematic approach while plotting the polygon around each EA. The delineation of the polygon needs to be accurate as there could be more than one straight line which needs to be grouped together. Another step before starting the polygonisation was to create a new MapInfo layer, precisely in which the delineation of the EA was plotted.

Figure 1 - Routes layer of the Maltese Islands



Source: Planning Authority

The attribute table of the latter layer included three fields in integer type; Council, Eas_Code and CounEas. These became useful in the process of polygonisation and identification. Finally, once the above preparations were completed, the user must load all the three layers together in one session and save them as a workspace. This will help the plotter to have all the layers aggregated together while it saves where the plotter would have stopped before closing, since this exercise requires a certain amount of time to complete all the coverage of the Maltese Islands. In the workspace, the order of the layers were as follows; routes layer, the thematic map for the polygonisation, the council layer and the orthophotos. The council layer, was necessary for reference of the local council boundaries.

For a more systematic approach to the polygonisation it was better to start from the Northern area moving towards the South of Malta. This helped in the visualisation when delineating the polygon. Once the polygonisation is initiated, it was important to take note of the routes that have the same number, in order to group them together. One must also take into consideration the dynamics of the area, this was aided through the addition of the orthophotos in the workspace. This helps to indicate things such as the width of the road and the building environment amongst other features. Including such layer keeps the perspective of the EA in a more realistic scenario.

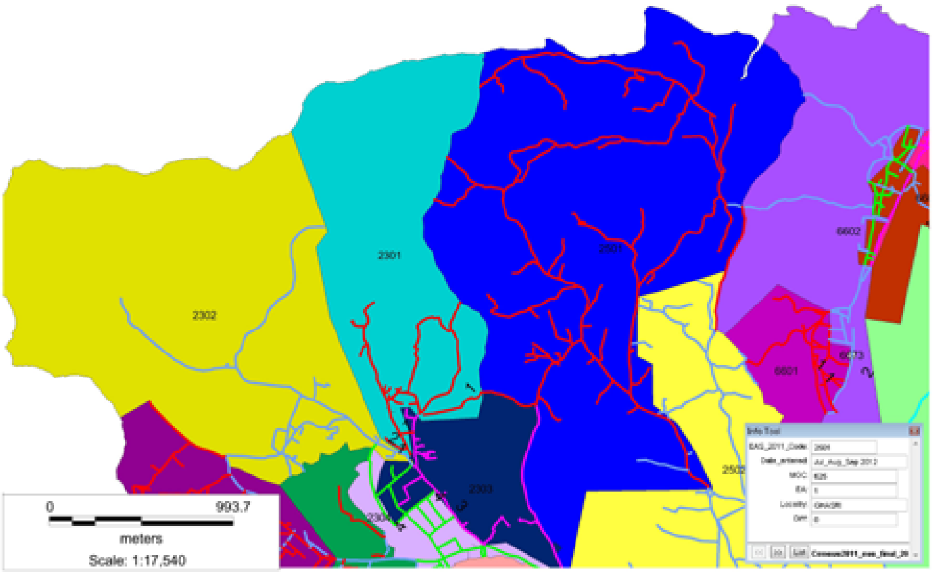
When creating the polygon it was very important to be vigilant with the exact roads that indicated the number of the EA upon the roads themselves. The number upon the roads was made visible through the label feature found adjacent to street layer in the control layer. This was an aid in the process so that one can continue delineating the polygon with more ease and technological facility. While doing this exercise, it was also crucial to see where each point was being plotted, as the polygon was plotted matching with both the outline of the base map and the council layer.

In completion of the polygon, it was important to fill in the information required for each polygon so that each polygon has a unique identifier, whilst no information will be lost. This identification is important to be done while carrying out this process as it will appear in the information tool. Every route polygon includes two components. These are the EA and the council code. After creating the polygon these two identification numbers combine in order to produce the enumeration area system 2011 code. Every enumeration area system 2011 code is unique for every polygon created. Taking as an example, Table 1 shows local council Attard, in the attribute table of the polygonisation layer, one need to input the information accordingly.

Table 1 - An example of the information to be inputted for the polygon

Council	EAS_Code	CountEas
12	**01**	**12001**

Figure 2 - Inputting the information of the polygon

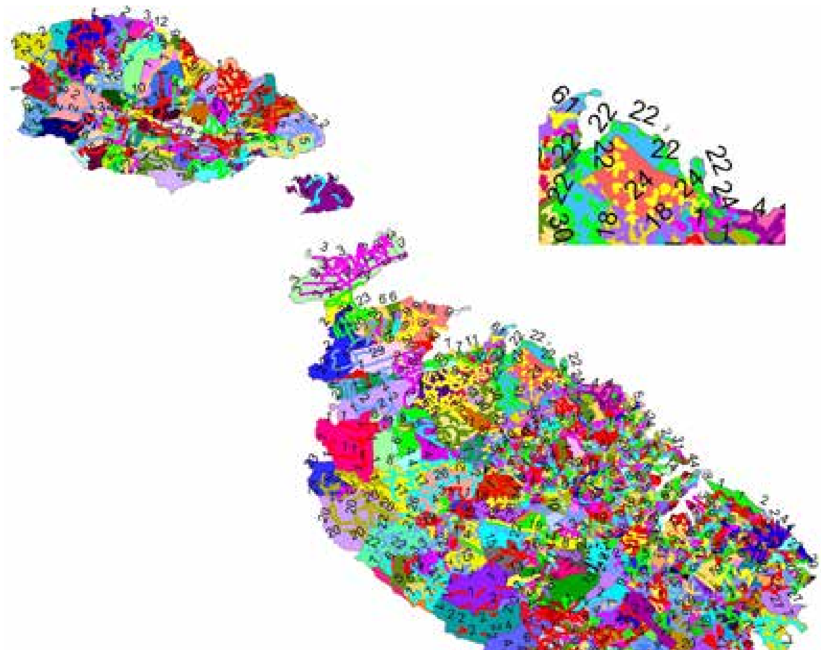


Source: Planning Authority

The information can be obtained from the different reference layers in the workspace. By selecting the information tool from the toolbar of the Mapinfo and clicking on the council, one would be able to see the council number, in this case it is 12. The council number is always constant throughout the council. The EAS_Code, is the route number for the enumerator, each route hold a different number, therefore this will be a unique identifier for the council, and the range of the EAS_Code will vary from one council to another. Finally the CountEas is the Council number and the EAS_Code combined together with a 0 in the middle, this will produce the above mentioned enumeration area system 2011 code.

The process entailed the importance of making sure that proper backups are made regularly, so that if an error occurs during the polygonisation, the plotter would have the latest copy to refer to. An important step in the overall process was error checking. Throughout the process it was important to constantly check the total number of routes from both layers, confirming that the enumeration areas and routes are corresponding to each other. The checking process was repeated for every council. It was important that the main workspace was being updated with every council correctly.

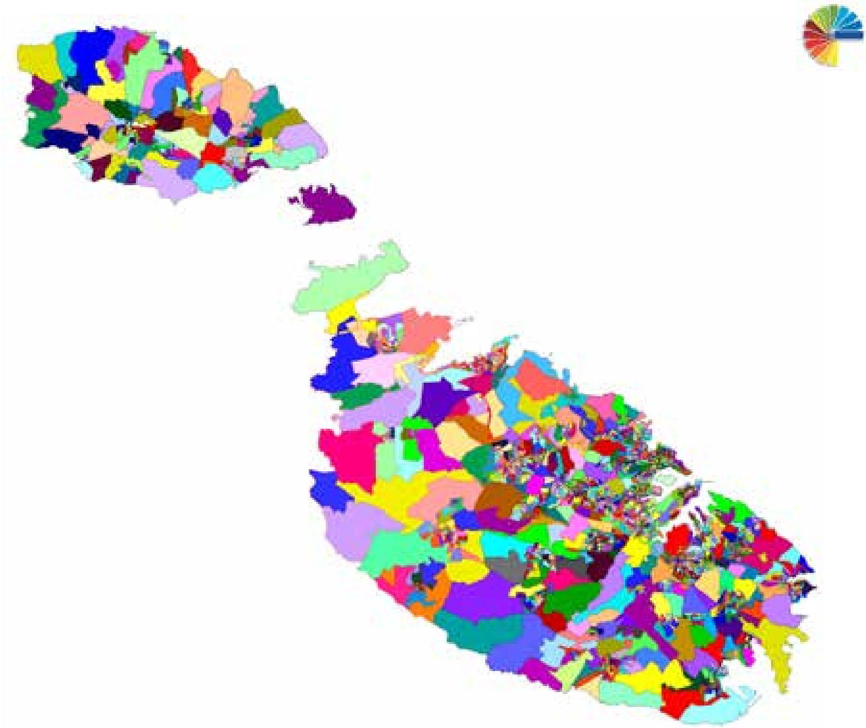
Figure 3 - Delineated EA's Final Map



Source: Planning Authority

The final result was a visual display delineating 1021 polygons representing all the enumeration areas of Malta and Gozo, furthermore the output can be a valuable aid to coordinate more professionally with what happens during the census year. In defining such information the process can be further on utilised by governmental entities to carry out further studies and research.

Figure 4 - Final Census 2011 EA's Map



Source: Planning Authority

Integration of textual data was carried out through a join function with SQL that enabled the tabular data extracted from the Census database, which data (flat table) was amalgamated with the spatial data, in turn allowing for both dataset integrity analysis and eventual analysis across the thematic areas (Formosa, Census 95, 2002).

Data on population and housing could be thus analysed in terms of both descriptive statistics and also spatial statistics, where the data was given an added-value where locational data was generated into choropleth maps, graduated maps and should the point data be available, heat maps (Formosa, Malta National Statistics Office Maps, 2014). Each of these categories was related to the map.

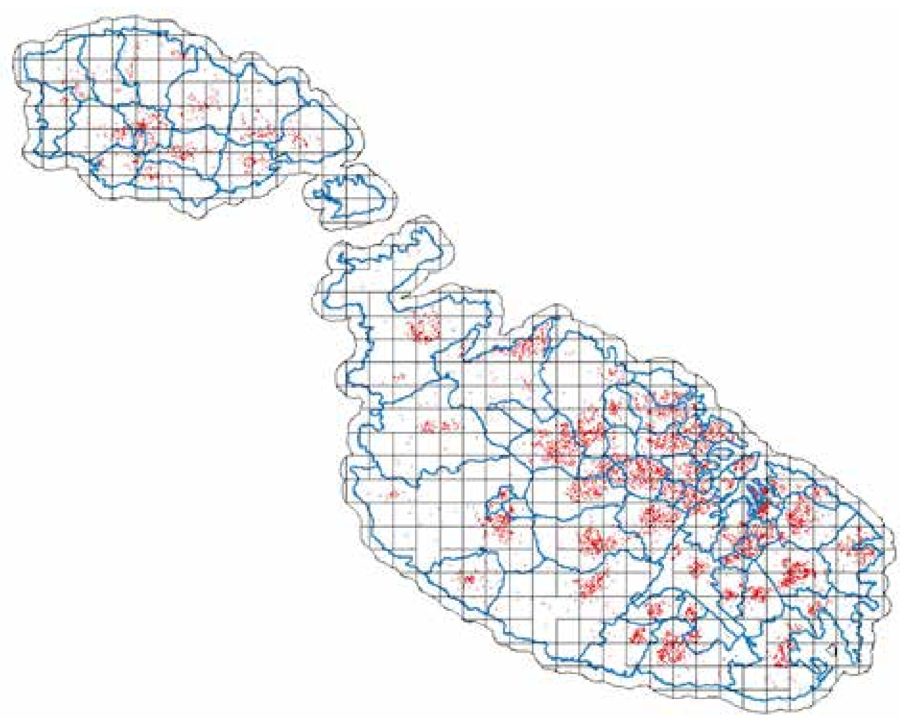
Variables for Analysis

The next step for Census data analysis pertains to the creation of various data structures that would enable the analysis through various methods: mainly the current polygon based structure, a grid-based structure and a point-based structure.

Whilst the polygon-based structure has its advantages in terms of being organic such that the polygons show change over time in terms of population change and movements, it has its limitations in that each Census take requires either a full redraw or major amendments and editing due to change on the ground (Formosa, Censiment 2005, 2005). The grid-based structure as debated at EU-level strives to create conformity across the countries in that it is based on a 1km squared base that would not change over time as it is based on a geographical construct as against a population construct (Figure 5).

This each cell would house a number of streets or households. Should data be only available at street level, then one should be aware that a number of cells could have no population, whilst others could acquire more than their real share. This is due to the context of centroidal function, where each street is designated a central point called a centroid and all population in that street is located in that areal point.

Figure: 1Km Grid base layer



The other method would be based on a point-based spatial layer where each dwelling unit would be located in real space and where the grid-analysis would be easier to conclude and as each unit is located in its point in space, then aggregation of all points in that street in a centroidal location is eliminated. This way the analysis would be carried out in a veritable methodological process as the data is correct in terms of where people live and where buildings are located. In addition to grid map analysis, heat maps could also be created for each parameter (attribute) that is designated to that point and analysis can be built up for any layer type and aggregate. This method spans boundaries as designated by local councils or districting as each point can aggregate to an adjacent point should they be of mutual structure and composition. A collection of points could span a number of streets or localities, thus creating new areas of analytical interest. The Census methodological process is taking a new step forward in that it is analysing new forms of thematic activity.

The next stepped approach to GI and Census

The NSO applied and was awarded a project entitled "GEODE: DataCycle process for the Spatialisation of Fundamental Spatial Elements for Census Implementation ", which aims to achieve an undertaning of the realities pertaining to the creation of a fundumental dataset based on address point data that would be geocoded and offer a basis for the creation of more aggregated data that would allow for inter-thematic analysis ranging from Census through to national and international data analysis.

The main aim is to study, understand, mindmap and map the existing and proposed geocoding processes employed and how they are currently employed and in turn could be used for future data integration based on Census and relative dataset creation. The study will take up the recording of the different data structures that exist in non-spatial and spatial formats inclusive of point, line and area vector data or rasterised data structures.

The project will identify the main datasets, mainly from Census 2011 and other key spatial datasets that could be identified as case studies for the mapping of a point address point dataset, as against the current random creation of boundaries pertaining to unique and at times insular pourposes, such as the creation of a new administratice council boundary. The project would study how far one can go in order to create the base addresspoint dataset, review the current datasets, identify methods to integrate and where non-existent, create new datasets. The process will investigate how the datasets could be integrated, how that integration would aid the data transposition process, map the addresspoint datasets, enable the creation of higher-level polygonised data layers and in turn identify the best technologies the creation, conversion and retention of such a base dataset and point towards the creation of polygonised or raster-based models.

The project structure ensures an investigation into the spatial data availability and implementation processes of the systems currently in place and new ones created or integrated within the project. The project is expected to deliver an implementation-oriented document based on the datacyle lineage structure that will focus on the DIKA model (Data-Information-Knowledge-Action) that would enable the NSO to create the basis for its geocoding Census knowledge and human capacity as well as empower persons to create, use, interpret and publish. The results will create a series of procedural, methodological, visual and analytical data aids for the entities creating the geocoded layers and which will partake to the inter-thematic analytical approaches.

The results will create a knowledge-based guidance document highlighting the best datasets to employ in such a system through the delivery of: a) the creation of a geocoding process and structure for the base Census data. Another result entails the creation of a GIS-based system in the NSO and training thereof; and b) a series of process lineages, implementation manuals and training sessions. The results will enable the NSO to build a spatial-based capacity and the general public to access data in a visual dimension.

Conclusion

The NSO is Malta's national authority responsible to carry out the census every 10 years, the process requires certain amount of time to be prepared, disseminated, collected and then manually inputted to carry out the statistics as a result of the collected questionnaires. This national exercise deliver huge amount of valuable data which until now was only limited to the hardbound books created as a final product, once the statistics are finalised. Technological advancement showed that a far more valuable use can be made from the data acquired in the census. GIS was the answer to introduce census data in a spatial platform.

GIS has clearly demonstrated its relevance in such process producing results which were generated from the NSO data. The stages taken into consideration along the polygonisation was a chain reaction of all the other datasets. The preliminary review of the data needed and availability reduced the time taken to arrange the datasets as they were already created. As such, the methodology employed in the exercise served as an aid for the whole process to be plotted clearly while making sure to take into consideration the boundaries of the other reference datasets. The resulting map visualised the polygonisation of the EAs. The utilisation of the output later is not limited only to the GIS users but also experts in other fields, serving them as an aid for a more local representative perspective. The importance is referred to the fact that incorporating their data to the EAs layer, will inherently have a higher level of detail than the regular local council boundary.

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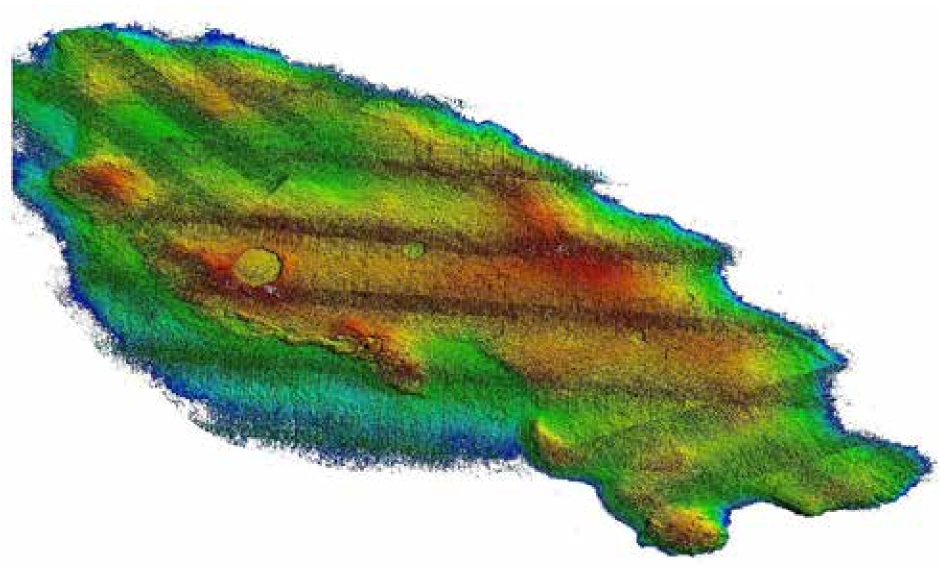
Pivot II

Constructs for an Environmental Understanding



Sikka l-Bajda Dolines

Underwater dolines identified through ERDF156 in 2012

GEO (WGS84) (14.3921986161, 36.0020301927) - -22.3 m,
36° 00' 07.3087" N, 14° 23' 31.9150" E

CHAPTER 7

Improving Weather Forecasts by Updating the Surface Boundary Conditions of a Numerical Weather Prediction Model for the Maltese Islands

Andrew Agius, Charles Galdies, Alannah Bonnici and Joel Azzopardi

Introduction

Multiple sectors of modern society have become dependent on accurate and regular weather forecasts. These allow them to make strategic and informed decisions in order to preserve and maintain their assets. Weather forecasts have also become an integral part of various systems and services, such as Decision Support Systems and Early Warning Systems, all of which play a crucial role in modern societies.

Numerical weather prediction (NWP) models are used to accurately compute synoptic weather conditions. One of the most commonly used NWP atmospheric simulators is the Weather Research and Forecasting (WRF) model (Lu, Zhong, Charney, Bian, & Liu, 2012; Evan, Alexander, & Dudhia, 2012), (Evan, Alexander, & Dudhia, 2012); Giannaros, Melas, Daglis, Keramitsoglou, & Kourtidis, 2013)). This model is a collaborative design effort between research and operational meteorological communities. It offers a state-of-the-art system which is continuously maintained to represent this critical body of knowledge within the scientific community. The WRF model is freeware with a wide variety of applications and which can be transferred and downloaded onto a variety of platforms. It is often used for both research and operational applications (Skamarock, et al., 2008).

Before simulating atmospheric conditions, an NWP model must first be initialised. There are two main types of input datasets which are mandatory for the model to be capable of performing a skilful simulation of weather synopsis: Estimated low resolution atmospheric data, to be used as input to the system's differential equations (such as Global Forecast System data which may be freely downloaded from the National Oceanic and Atmospheric Administration's (NOAA) data archives), and geographical land use categories. The higher the resolution and accuracy of these initial conditions, the more skilful the output forecasts. WRF provides a default global dataset which identifies geographically stable parameters. However, this land cover dataset, provided as part of the downloaded model default configuration, has a relatively low resolution. This causes inaccuracies that limit the skill of the model in accurately simulating weather conditions over the respective geographical area.

The purpose of this study was to improve the land use categories boundary conditions datasets for the Maltese Islands and identifying any improvements to weather forecasts made thereafter. Validation of the WRF model sensitivity with the improved land use dataset is done by comparing the default simulation configuration output to the output run with the improved land use categories. In order to quantitatively compare the skill of the forecasts, statistics are computed to quantify their error and bias. For this study to be a success an improvement in forecast accuracy had to be observed.

NWP Models and High Resolution Weather Forecasts

Advances in NWP were possible with improvements in computer technology that led to higher accuracy, better spatial resolution of model simulations, the ability to make predictions for longer periods and a wider diversity of environmental simulations. The information generated has numerous applications, such as the identification of developing extreme weather events for risk and disaster management (WMO, 2013). Other applications include military operations, climate change monitoring and forecasting, agricultural production, economic trends and scientific research (Chang, Peña, & Toth, 2013). NWP models are able to take into account a wide range of variables whilst analysing how they relate and influence each other, allowing for weather forecasts with a higher level of information (Coiffier, 2011).

High resolution data allows models to identify micro processes that influence the development of weather phenomena and their characteristics (Geertsema & Schreur, 2009). High resolution forecasts, whose resolution can range from 5 km to less than 1 km, offer a more realistic and accurate indication of meteorological developments for regional forecast (Montmerle, 2014). The WRF model is one such high resolution forecasting NWP model(NOAA, 2016). With the computational capacity used within the context of this study it was possible to push the horizontal resolution of the output down to 1 km.

The Influence of EO data on NWP

EO (Earth Observation) systems are instrumental in the scientific analysis of earth systems and improved environmental management. They provide the information required to monitor phenomena such as air pollution, oceanic salinity, meteorological developments and forest fires over long periods of time. The level of information recorded is limited by the designed observation spatial resolution of the instruments used (ESA, 2014). In weather forecasting, EO data collected can be used to determine initial and boundary conditions for the NWP model being used. These conditions include atmospheric status and composition, radiation fluctuations and atmospheric interactions, boundary layer atmospheric interactions with the Earth surface, and topographic information that identifies elevation changes, surface type and terrain composition. EO data is also used by meteorologists as a means of validating forecast accuracy. Data variables, such as temperature or precipitation, are validated by comparing numerically generated forecasts with EO data. A statistical assessment can numerically establish the accuracy of the simulation (Coiffier, 2011).

An Overview of the WRF Model

The WRF model is one of the most modern and frequently used NWP models (Collins, et al., 2013). It is an open source software with which users may simulate future atmospheric conditions (WRF, 2004). The modelling process is split into several phases: preprocessing which includes initialisation of the model's differential equations, the computation equations and physics settings within the model itself, and post-processing where data is manipulated through external software packages so as to obtain information (WRF Users, 2014).

Preprocessing steps occur in the WRF Preprocessing System (WPS), which is made up of three executables (Table 1) that are controlled through a variable list file called namelist. wps and then run (Figure 1):

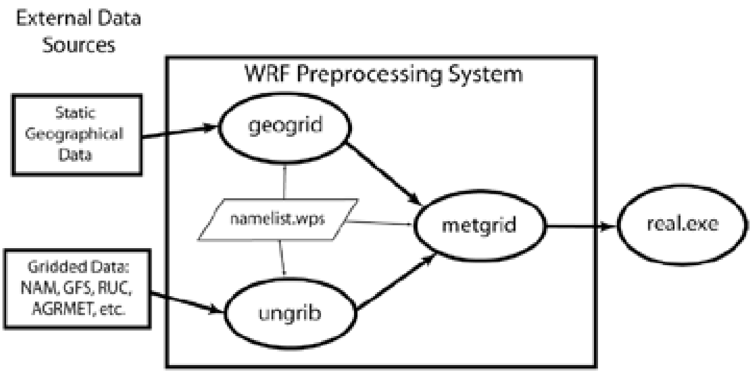
Table 1: The three WPS executables

WPS Executable	Function
geogrid	Defines the domains, grid resolution and applies static geographic data to the grid
ungrib	Converts meteorological input data from GRIB format to an intermediate format which can be interpreted by the model
metgrid	Interpolates the converted intermediary output files from ungrib executable onto the grid defined within the geogrid executable

Source: (NOAA, 2013).

Preprocessing prepares individual domains, or regions of Earth, for real data simulations in the WRF model (NOAA, 2013). The WPS is completed when the metgrid executable supplies its output to the WRF real program for further manipulation (Wang, et al., 2016).

Figure 1: The WPS process



Source: (Wang, et al., 2016)

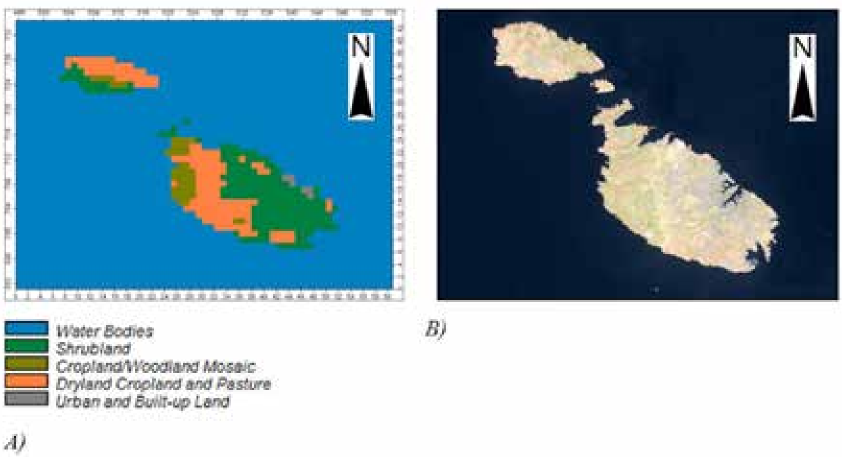
The following phase pertains to model initialisation, where the processed output from the WPS becomes the input supplied to the WRF model. The data is generated by a low resolution global forecast model and represents an estimation of the atmospheric conditions at 3 hourly time steps from the start of simulation. The supplied data is then prepared and processed for either a real or ideal simulations (Wang, et al., 2016).

Once initialised, the WRF model begins computing simulations. There are a number of different post-processing procedures available. Successfully completed simulations should undergo a validation procedure to quantify the skill of the forecasts. The user can also make use of tools to create visual representations of the output, such as time series graphs, forecast weather charts and 3D forecast representations (Wang, et al., 2016). Some of these data visualization tools come as add-ons to WRF or through external software packages such as MATLAB, SAGA, or ArcGIS. Another post-processing feature is called data assimilation for which the WRF model contains a package called WRF-DA. The very successful data assimilation process nudges the computed forecast variables with EO data to improve the estimated forecast (Skamarock, et al., 2008).

The WRF Geogrid Program and Land Use Categories

The WPS geogrid program establishes domains and grid resolution based on user specifications. This process initialises a number of variables at each grid point, including the longitude, latitude, surface albedo, terrain slope categories and elevations, and land use categories. Upon download the WRF model comes with default global datasets for each of these characteristic fields at 30 second, as well as 10, 5 and 2 minute resolutions (Wang, et al., 2016). One drawback of these datasets is that they may have low resolution and/or incorrect information. For example, the default land use categories dataset for the Maltese Islands (Figure 2a) limits the land use categories to four. On the other hand, an analysis of the Landsat 8 true colour image (Figure 2b) reveals a significantly higher number of categories and different distribution patterns.

Figure 2: The default WRF USGS 24-category Land Use Categories data set featuring the Maltese Islands (2a), generated with Saga version 2.1.1 and the true colour image of the Maltese Islands acquired via Landsat 8 on the 25th July 2014 at 09:36 hours (2b). Landsat Scene Identifier: LC81880352014206LGN00. Original image acquired from USGS EarthExplorer and edited with Picasa version 3.9.138.



WRF provides two default land use categories datasets: the USGS 24-category Land Use Categories, which is automatically selected by the geogrid program and the IGBP-Modified MODIS 20-category Land Use Categories. The latter, however, should only be used with the WRF Noah land surface model (Wang, et al., 2016). The USGS 24-category Land Use Categories follows the Anderson land-cover classification system published in 1976. This system splits classification into four levels based on data resolution, with Level I being used for data acquired through the LANDSAT project. This level is further subdivided into the Level II classification system which deals with increased levels of information provided by higher data resolution. A detailed description of these land use categories can be found in 'A Land Use and Land Cover Classification System for use with Remote Sensor Data' (Anderson, Hardy, Roach, & Witmer, 1976).

EO Data Acquisition and Land Use Categorisation

For the purpose of this study an EO dataset for the Maltese Islands was downloaded from the USGS EarthExplorer website. This dataset was LANDSAT Scene Identifier: LC81880352014046LGN00, generated on the 15th of February 2014 at GMT 09:37 hours. LANDSAT 8 data was selected due to its relatively high quality, frequent passes over the same area, its reliability and its free to use policy. This image was selected because it was one of the few images where the Maltese Islands was not obscured by cloud cover (Figure 2b). It also provided a clear distinction between urban and rural areas due to the flourishing vegetation cover which is typical of the local mid-winter season.

The image bands used for this study have a 30 m resolution. LANDSAT 8 was selected as the data source due to its free to use policy and its image resolution of 15m, 30m and 100m (depending on the spectral channels selected). In addition, the LANDSAT data distribution policy ensures data dependability and compliance with the National Spatial Data Infrastructure (NSDI) managed by the US Federal Geographic Data Committee (FGDC) which, in turn, ensures data compatibility with a wide range of applications (Ryan & Freilich, 2008).

The default WRF dataset for the islands was also acquired and downloaded from the NOAA National Centers for Environmental Prediction (NCEP) Central Operations website (http://www.nco.ncep.noaa.gov/pmb/codes/nwprod/hwrf.v8.1.0/fix/hwrf_wps_geo/landuse_30s/), region 22801-24000.14401-15600 as per the WRF 1km resolution global grid system. This dataset was then visually compared to the LC81880352014046LGN00 image and deemed inaccurate. To improve this dataset, LANDSAT 8 image bands were analysed, processed and converted into the WRF geogrid format. This phase of the study was conducted with SAGA version 2.1.1 as it was freely available and due to previous experience with software usage.

The conversion process began with classifying the 30m resolution image in accordance to the USGS 24-category Land Use Categories with the Unsupervised Classification method. Bands B2, B3, B4 and B5 of image LC81880352014046LGN00 were imported into SAGA as raster images and cropped to show only the Maltese Islands (Table 2).

Table 2: A description of bands B2, B3, B4 and B5

Band	Description	Wavelength
Band 2 (B2)	Blue	0.45 - 0.51
Band 3 (B3)	Green	0.53 - 0.59
Band 4 (B4)	Red	0.64 - 0.67
Band 5 (B5)	Near Infrared (NIR)	0.85 - 0.88

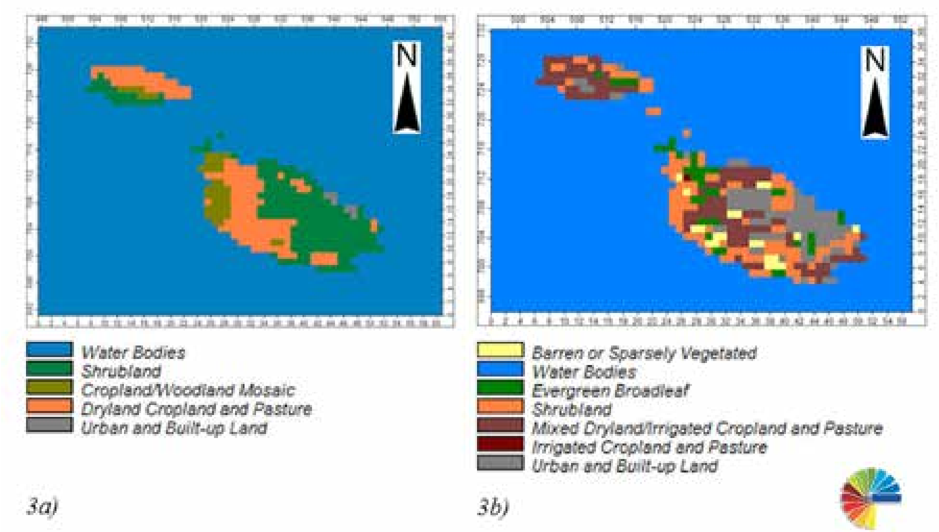
Source: (USGS, 2014).

This set of bands was selected to create a natural colour RGB image with enhanced vegetation cover (Butler, 2013). The statistical clustering method used for the unsupervised classification was the Hill climbing (Rubin 1967) method, with a limit of 24 clusters in accordance to the USGS 24-category Land Use Categories. The clustering process was followed by resampling which reduced the resolution from 30 m to 1 km in order to meet the data requirements of the geogrid.exe program (1 km resolution is considered as very high resolution in NWP research). Resampling was performed with the Majority interpolation method where a majority algorithm was used to determine the new 1 km resolution cell value based on the most popular 30 m resolution cell values (ArcGIS Resources, 2013).

Some regions, such as the urban areas and sea region, were automatically assigned more than one cluster due to multiple bands of light reflected from their surface. This resulted in 20 different clusters. Since the Maltese Islands have a limited number of applicable land uses, due to their geographical properties, it was necessary to change the assigned cluster values to those which gave the best representation according to the applicable USGS 24-category Land Use Categories. When determining the ideal category to be assigned reference was made to Google Earth imaging dated 15/04/2013. The Saga Change Grid Values module was used for this task with the default replace condition 'Grid value equals low value'. This module allows replacement of all the cells within a target cluster. The resultant data set contained 6 land use categories and the Water Bodies category. However, some areas were still deemed to be misrepresented, namely: The Valletta area, which was indicated as water bodies; and the Birżebbuġa area, where the sea within the mouth of the bay was indicated as urban and built-up land. To adjust this, the 'Change Cell Values' [interactive] module was used with the 'set constant value' method to properly categorise the grid cells.

Once this process was complete it was necessary to plot the improved categorisation image onto the original image, supplied by NOAA, with the Change Cell Values [interactive] module. The existing NOAA grid was altered by using the 'set constant value' method. Due to the projection differences between the two images it was also necessary to modify the improved image through image processing, before it was re-plotted onto the original one. The image was then converted into binary format by using the Export WRF Geogrid Binary Format module in 'Mercator' projection (Figure 3).

Figure 3: The default land use classification (3a) and the improved land use classification (3b) for the Maltese Islands at 1km resolution and according to the USGS 24-category Land Use Categories



Accuracy Assessment

To assess the accuracy of the product image classification, an error matrix was produced. The process involved taking 60 sample points, within the terrestrial boundaries of the archipelago, and comparing their actual composition (through Google Earth) with that generated by the unsupervised clustering. Point coordinates were identified with a random coordinate generator (www.geomidpoint.com/random). The area of influence was restricted to Malta (centre point at 35.937496o latitude and 14.375416o longitude), the number of points was limited to 250 and the maximum distance from the centre point set at 22 km.

An error matrix was then generated by comparing the observed land cover at each sampling point against the one generated with unsupervised clustering. A Producer's Accuracy assessment was conducted, followed by a User's Accuracy assessment and an Overall Accuracy assessment. While the Producer's accuracy provides an assessment of how ell a certain area has been classified from a data producer point of view, the User's accuracy or reliability is indicative of the probability that a pixel classified on the map actually represents that category on the ground (Story and Congalton, 1986). On the basis of these two accuracies, the error matrix generates an Overall accuracy. This process was repeated for the default WRF 30s land use dataset in order to quantify the increase in accuracy of the improved land use categorisation scheme.

Running WRF and Generating a Real Scenario

Once the static geographical data had been updated, the WPS had to be re-run to produce new updated grids. This involved directing the WPS to the updated land use data files by updating their path in the namelist.wps file. The WPS section was completed by running the three executables and obtaining the updated output data files. The WRF model was re-run by directing it to the new updated WPS output files which were used as input.

Since the aim of this study was to determine whether improved boundary conditions would improve the skill of a NWP model output, a real forecast was generated using the improved statistical geographical land use data in order to compare it to real observation data. It was expected that the generated statistics would show an improvement in the accuracy and skill of the simulated forecast. The WRF core executables, real.exe and wrf.exe were executed and a wrf.out output file was produced.

Data validation techniques were applied to identify any differences between the observed data, the simulated forecast using the original geogrid data and the simulated forecast using the new geogrid data. Visual representations of the data validation procedure were produced using MATLAB, namely time series plots for the final 3 datasets at the different stations where real observations were available. Real observation data was available from the following 8 Met Office weather stations: Dingli, Luqa airfield, Bengħajsa, Birkirkara, Selmun, Valletta, Xagħra and Xewkija stations. The variables validated as part of this exercise were variable 'T' (which provides perturbation potential temperature) and variable 'RAINNC' (which provides accumulated total grid scale precipitation).

These time series also identified the root mean squared error (RMSE) and bias ratio of the forecast plot using the improved land use categories and the forecast plot using the default scheme. The RMSE value provides an indication of the overall forecast offset from the overall observed trend (the closer an RMSE value is to 0, the more accurate the forecast is). On the other hand, the bias ratio provides an indication of how much the forecast values vary from the observed data, with the observed data having a bias ratio value of 1. These overall indications are based on the average RMSE or bias ratio generated by each hourly forecast.

Improving the WRF 30s Land Use Categories for the Maltese Islands

The land cover classification identified the different types and distribution of terrestrial features that affect the local climate, such as vegetation, urban and agricultural land cover. Depending on their properties, these land cover types have an influence on the local humidity, temperature, evaporation, evapotranspiration, albedo and wind profiles. These influences are taken into account by the WRF model numerical calculations. Therefore, the accuracy of the land cover categories that is supplied to the model influences the model output accuracy. The default WRF 30s land use classification dataset for the Maltese Islands was limited in terms of the categories assigned and their distribution. Not only were categories assigned incorrectly, they were also distributed inaccurately. An error assessment based on a 60-point sample revealed an overall accuracy of 10%. On the other hand, the improved land use classification had an overall accuracy of 70%.

WRF Simulation Output Analysis

The precipitation and temperature time series plots showing the default and updated outputs, as well as observations for the 8 meteorological stations between 24/10/2010 at 00:00hrs and 26/10/2010 at 00:00hrs, identified changes in the RMSE and the bias ratio of the forecast plots. The results show that the improved land use classification led to an overall improvement in forecasting accuracy. The average precipitation onset forecast accuracy (Figure 4) was improved by 1.12% while the average precipitation quantity forecast (Figure 5) was improved by 3.35%. The average forecasted onset of the temperature fluctuation (Figure 6) was improved by 3.04% and the average predicted temperature values (Figure 7) were improved by 0.17%. The lack of significant improvement can be attributed to the numerical settings that were not adjusted to take into account the improved boundary conditions. By adjusting the default settings one may be able to compensate for the increased bias ratio and improve the overall accuracy. The inaccuracy level can also be reduced by improving other boundary conditions, such as terrain slope categories and elevations, surface albedo properties and soil categories. Since the land use categorisation was the only dataset improved, a number of discrepancies may have developed between this dataset and the remaining terrestrial boundary conditions.

It is also interesting to note that changes in RMSE value accuracy did not always correspond to changes in the bias ratio when applying the improved land use classification. While this occurred only once (13%) for surface temperature forecasts, in precipitation forecasts 63% of the outputs for the group of stations (1 per station) showed either an improved RMSE accuracy but a decreased bias ratio accuracy or vice versa. Further in-depth analysis which refers to the identification and application of more suitable numerical schemes embedded, but not active, within the WRF model is therefore required.

Figure 4: The precipitation onset forecast RMSE value of the outputs using the default and updated land use classification for each of the stations, and their relation to the ideal RMSE value (0).

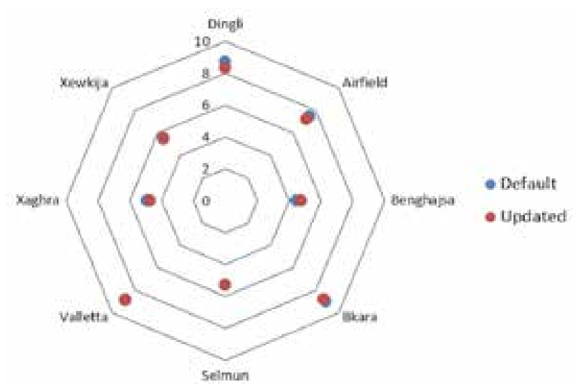


Figure 5: The precipitation quantity forecast bias ratio of the outputs using the default and updated land use classification for each of the stations, and their relation to the ideal bias ratio (1.0).

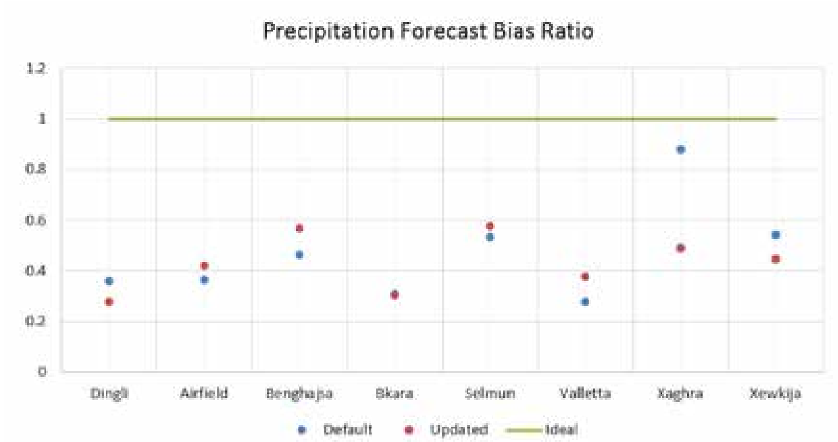


Figure 6: The surface temperature onset forecast RMSE value of the outputs using the default and updated land use classification for each of the stations and their relation to the ideal RMSE value (0).

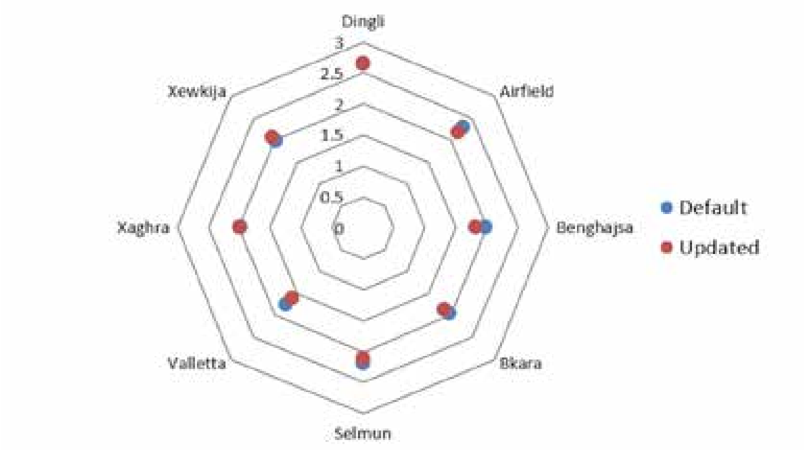
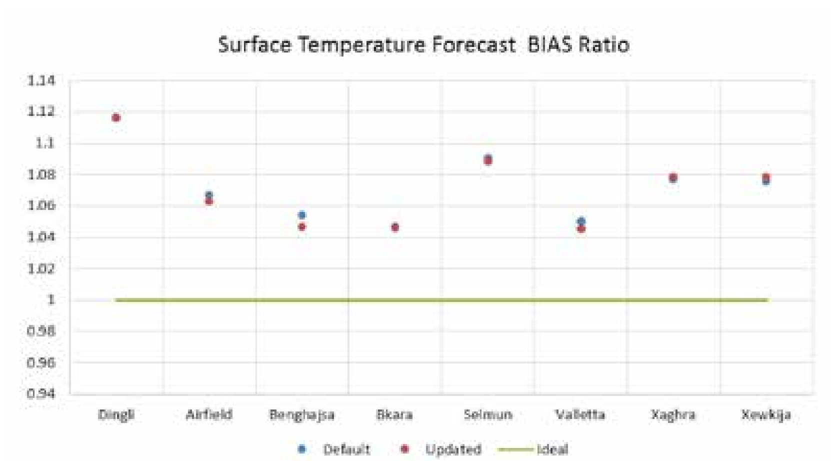


Figure 7: The surface temperature value forecast bias ratio of the outputs using the default and updated land use classification for each of the stations and their relation to the ideal bias ratio (1.0).



Limitations and Recommendations

The Mediterranean climate of the Maltese Islands means that the concentration of precipitation during the winter season causes the local vegetation to flourish, producing a greener land cover during the month of February. This was when the LANDSAT image was acquired. On the other hand, the summer season is dry resulting in a reduced vegetation cover (Aguado & Burt, 2007). In consequence, the differences in vegetation cover results in a discrepancy between the LANDSAT 8 image and the October land cover. Ideally, the terrestrial image selected provides the nearest representation of the conditions at the time of the simulation.

Further discrepancies may have been generated during the resampling process where, following the unsupervised classification procedure, the 30m resolution image was converted to 1km resolution. During resampling, pixel contamination may have occurred which would have had altered the land use categories distribution. These discrepancies contribute towards an increase in RMSE and bias ratio values of the WRF model output using the improved land use categorisation.

The model output may be further improved by making adjustments to the WRF model itself so as to find the best combination of numerical schemes responsible for skilful forecasting. It is also recommended that other default input datasets are updated. This would further exploit the improvements made by the improved land use categorisation. It is also recommended that WRF users improve the surface boundary conditions of their areas of interest in order to increase output accuracy.

As a continuation of this study, additional case studies are to be carried out in order to validate the impact of the improving the surface boundary conditions of NWP models.

Conclusion

The precipitation and temperature time series plots identified RMSE and bias ratio values of the default and updated WRF outputs revealed a minor improvement in forecast accuracy. The overall RMSE generated by the precipitation forecast indicates that the WRF output using the improved land cover categorisation boundary conditions produced a more accurate prediction in terms of precipitation onset. The bias ratio also indicates an improvement in the predicted precipitation quantity. Similarly, both the RMSE and bias ratio generated by the temperature time series plot indicated that the forecast generated using the improved boundary conditions was more accurate in terms of predicted temperature fluctuation onset and intensity.

One can therefore conclude that the improved land use categorisation led to an overall improvement in the WRF model 1km resolution output. However, further in-depth analysis is required to further exploit the information provided by the improved boundary conditions and thus increase the forecast accuracy. Furthermore, these analyses should identify and apply more suitable numerical schemes which are embedded, but not active, within the WRF model.

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CHAPTER 8

Heavy Metal Intoxication

Chiara Scicluna and Renald Blundell

Introduction

Although some debate exists as to the subject, elements which are classified under 'heavy metals' have come to be those which pose a threat to humans in terms of toxicity. Intoxication with heavy metals is not a typical diagnosis as it is fairly uncommon. This can impose a risk on people who fail to be diagnosed and removed from the source of exposure, increasing morbidity and mortality.

For the purposes of this chapter, in order of atomic weight, the following metals will be discussed: Aluminium, Chromium, Selenium, Silver, Cadmium, Mercury and Lead. A brief introduction of each element's chemical and physical properties will be given, as well as its sources in the environment and any uses. Each metal's toxicity will be illustrated using several actual cases of poisoning. In instances were human cases are not available, animal studies will be discussed. Any treatments for intoxication will be explained at the end of each section.

Aluminium

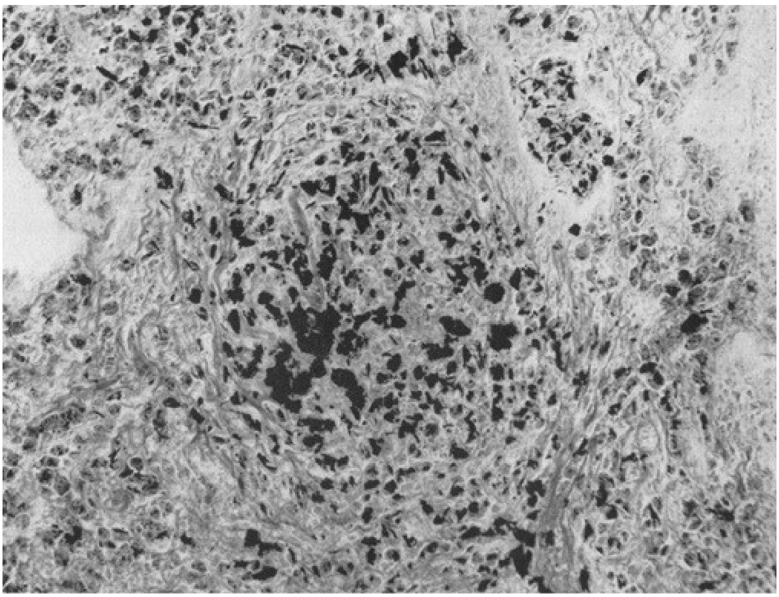
Aluminium (chemical symbol Al) is a member of Group III and can be found in the second period. As a metal, it is silver-white in colour, ductile and malleable. An aluminium oxide layer forms on its surface when it is exposed to the air, protecting it from further reactions. Al in compounds can be found in its +3 oxidation state (Keith, Jones, Rosemond, Ingerman & Chappell, 2008). This element is broadly distributed throughout the earth's crust and it is the most profuse of the metals. In nature, it is found bound to other elements as it is highly reactive. Industrial extraction of Al utilises the mineral bauxite (Keith et al., 2008).

Uses span crockery like pots and pans, as well as beverage cans, airplanes, roofing, siding and foil. Its compounds are used in fireworks and explosives, as well as alums and alumina. Consumer products with Al-compound content include astringents, additives to food, antacids, buffered aspirin, cosmetics and antiperspirants. Human exposure to Al compounds typically occurs from food items or consumer products (Keith et al., 2008).

Toxicity

The reports regarding the health effects of Al are mixed. In a case report by McLaughlin, Kazantis, King, Teare, Porter, & Owen (1962), the deteriorating health of a 49-year old man who had worked in a ball-mill room of an Al powder factory for thirteen and a half years was described. The man showed notable lung fibrosis (Figure 1) caused by inhalation of Al particles from his workplace, but his symptoms were largely neurological.

Figure 1: Photomic ograph of a histological preparation of lung tissue with fibrous tissue in concentric circles visible around particles of Al



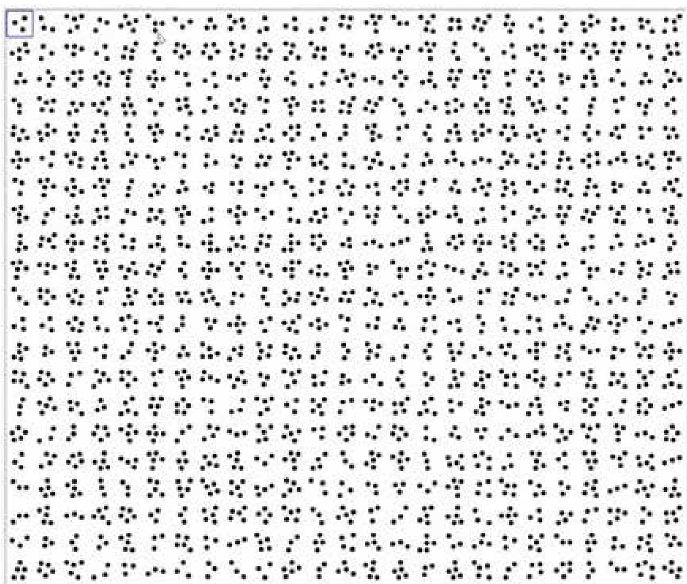
Source: McLaughlin et al. (1962)

The man's symptoms started with clonic jerking that progressed from the left leg to the left arm, during which attacks he was not capable of speaking. Other symptoms were moderate nominal aphasia and spastic left hemiparesis of the face, arm and leg. His condition progressed with multiple focal convulsive attacks with total aphasia, full convulsions and coma. A minute right embolus in his lung developed, increased mental deterioration and death. His cause of death was bronchopneumonia (McLaughlin et al., 1962).

In this case, the patient's encephalopathy was believed to be the result of Al poisoning. Particles of Al may have been taken up largely from the lungs the partly from the gastrointestinal tract (McLaughlin et al., 1962).

In a study by Akila, Stollery, & Riihimäki (1999), some neurodegenerative effects were observed in Al workers. Al exposure was quantified from its concentration in the urine of each individual. These individuals were then classified in one of three categories; reference, low and high exposure. They were asked to perform several tasks to establish if there was any neurodegenerativity. Scores indicated no issues with all of the tasks except for two; the Bourdon-Wiersma Dot Cancellation Task and backward counting. The Bourdon-Wiersma Dot Cancellation Task comprises of rows of black dots in groups, of which groups of four dots need to be identified and struck out (Figure 2).

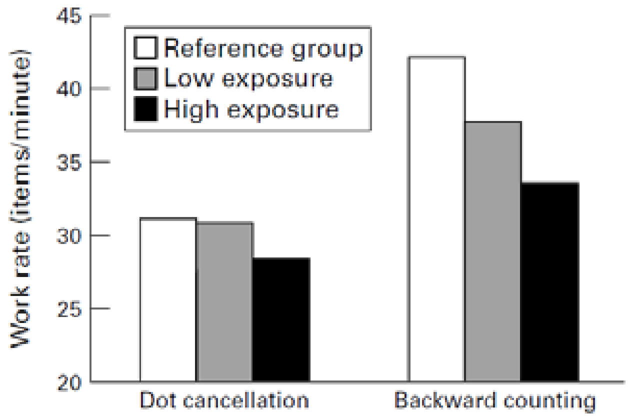
Figure 2: Appearance of the Bourdon-Wiersma Dot Cancellation Task Sheet



Source: Gresham (2012)

In the second task, the individual is given a three-digit number and he or she needs to count backwards in decrements of one. The tasks are both timed at one minute. Workers who experienced the lengthiest exposure to Al scored the lowest (Figure 3).

Figure 3: Bar charts showing the performance (work rates) of different groups of workers classified by the length of their exposure in two tests: the Bourdon-Wiersma Dot Cancellation Task, which comprises in looking for and crossing out groups of four dots among rows of groups of two, three and more dots; and backward counting tasks, which comprises in counting backward from a three digit number in decrements of one.



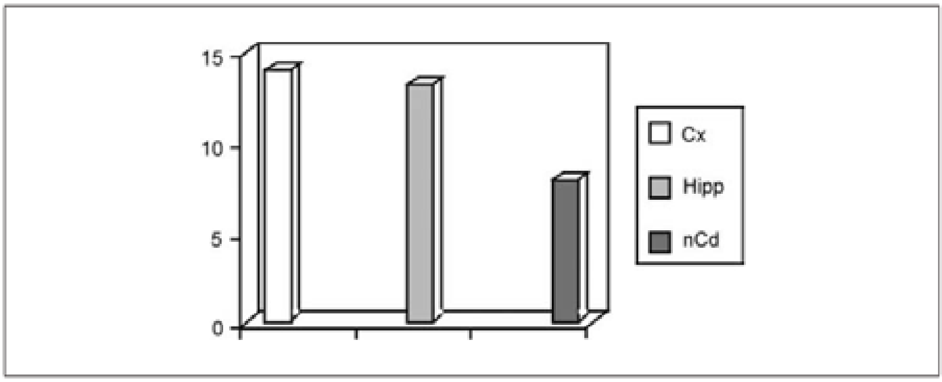
Source: Akila et al. (1999)

These results seem to indicate that Al exposure leads to the detriment of specific cognitive functions, specifically those involving visual-spatial efforts and processing within a time limit.

In a study performed on desert mice, acute intraperitoneal injections of Al caused oxidative stress on the brain. This was deduced from the reduction in activity of the enzymes Superoxide dismutase (SOD) and Glutathione reductase (GR). Both SOD and GR function by breaking down compounds which would otherwise cause oxidative stress on cells. A larger decrease in mitochondrial SOD was noted, in comparison to the decrease in tissue SOD. An increase in malondialdehyde (MDA) proportional to the dose of Al3+ was also noted. MDA is a biomarker of oxidative stress (Milovanović et al., 2013).

Figure 4 depicts the index of maximal damage (IMD) which was calculated for the effects of Al. It takes into consideration the reduction of SOD and GR as well as the increase in MDA (Milovanović et al., 2013).

Figure 4: Graph showing the IMD to the cerebral cortex (Cx), hippocampus (Hipp) and nucleus caudatus (nCd) caused following intraperitoneal Al injection in desert mice



Source: Milovanović et al. (2013)

Treatment

The literature was limited with regards to chelation or any treatment for Al poisoning, especially as any pathophysiology of Al intoxication is not yet fully understood.

Chromium

Chromium (chemical symbol Cr) is a transition metal which exists in a number of oxidation states, varying from -2 to +6. The most prevalent are the trivalent and hexavalent forms. In nature, elemental Cr is not found, but it can be mined from its chromite ore with the help of aluminium, silicon or carbon, after which it is purified. Chromite ore can be roasted with soda ash to produce the chromate and dichromate salts of sodium, which are then used to produce other compounds of Cr (Wilbur et al., 2012).

Cr (III) is thought to be a vital nutrient in the human metabolism of fat, protein and glucose. It is believed to function by potentiating insulin. There is some controversy surrounding its status as an essential nutrient as its mechanism of action is unknown (Wilbur et al., 2012).

The industrial uses of Cr include metallurgic, chemical and refractory uses. Stainless steel, nonferrous alloys and alloy cast irons all contain Cr. Refractory applications of Cr include magnesite-chrome bricks, chrome-magnesite and chrome. Chemical industry uses of Cr compounds include pigments, metal finishing, leather tanning and preservatives for wood.

A dietary supplement called chromium picolinate is given with the intention to lessen the symptoms of hypoglycaemia and type II diabetes. This compound consists of trivalent Cr in a complex with picolinic acid (Wilbur et al., 2012).

A meta-analytic study by Bailey (2014) concluded that given Cr supplements has no benefit except in populations who are vulnerable to Cr deficiency, such as patients relying on parenteral nutrition. No effect on fasting glucose levels was found.

Toxicity

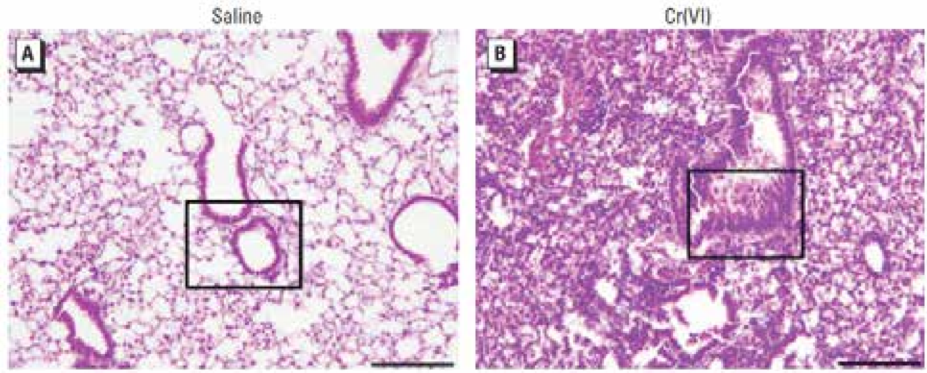
In a number of studies, people living in areas contaminated with Cr (VI) showed haematological, respiratory and gastrointestinal issues. Changes in the complete blood count included a heightened red blood cell count, decreased mean corpuscular volume and decreased platelet count. These results are in agreement with the results of exposure studies conducted on rats (Sharma et al., 2012).

In relation to gastrointestinal issues, reports mention abdominal pain, reduction in appetite and diarrhoea, as well as reports of increased incidence of stomach cancer deaths. Cr (VI) has also been reported to worsen cases of existing dermatitis when taken orally; also, almost twice of dermatological complaints came from females rather than males, possibly due to the regular exposure from polluted sources while performing everyday household tasks. Workers who were exposed to Cr at the workplace complained of eye problems. Populations living in areas contaminated by Cr (VI) also reported respiratory disease and death related to lung cancer (Sharma et al., 2012).

Repeated exposure to Cr (VI) particles was shown to cause chronic inflammation in lung tissue, resulting in neutrophils, macrophages and lymphoid cells aggregating in the epithelial tissue to correct the damage. Reactive nitrogen and oxygen species released by these cells are thought to create a microenvironment that promotes the direct damage of DNA or alternatively hinders DNA repair mechanisms (Beaver et al., 2009).

Chronic inflammation has been linked with the development of cancers, including cancer of the lung. Since repeated exposure to Cr (VI) results in chronic inflammation, this may lead to the development of lung cancer (Beaver et al., 2009). In a monograph about Cr (VI) and its compounds, issued by the International Association of Research on Cancer, the exposure of Cr (VI) is associated with a definite increase in lung cancer risk. Figure 5 shows uncontrolled cell growth following repeated exposure to Cr (VI). Reports regarding nasal cancers seem to indicate that there is a link, however this is less clear (Aitio et al., 2012).

Figure 5: Lung histological sections after the fifth administration of saline (A) and Cr (VI) (B). In the case of B, there is a visible increase in the number of cells, which confirms the likelihood of the carcinogenicity of Cr (VI)



Source: Aitio et al. (2012)

Treatment

Lee et al. (2015) investigated the possibility of treatment for Cr (VI)-induced dermatitis with N-acetylcysteine (NAC). Cr (VI) injected in guinea pig skin resulted in hypersensitivity mediated by an increase in cytokine-dependent reactive oxygen species (ROS). Therefore, the use of an antioxidant such as NAC could prevent hypersensitivity by attenuating ROS production. The effects of NAC include the inhibition of several kinases which in turn results in gene-suppression of a number of cytokines including Interleukin-1. Another pathway by which NAC could mitigate hypersensitivity caused by Cr (VI) is through the prevention of apoptosis and autophagy. This is mainly due to the highly regulated nature of these processes and their uncontrolled occurrence in pathophysiological conditions. Cell death of epidermal keratinocytes is an important mechanism in the development of cutaneous inflammation. Apoptosis and autophagy were both confirmed to occur in Cr (VI)-treated keratinocytes.

Despite these findings, Lee et al. (2015) concluded that although NAC has promise in the prevention of the progression of Cr hypersensitivity, further studies are required to assess cost-effectiveness, compliance and desensitization from prolonged use. The exact mechanism of action of NAC is not fully understood and more research would be required for better comprehension.

Selenium

The non-metal Selenium (chemical symbol Se) can be found in Group VI on the periodic table. It is a necessary micronutrient which can be found throughout the environment. Anthropogenic processes like coal combustion release Se; the natural weathering of Se-rich rocks and soils, as well as volcanic eruptions are also responsible for Se release (Risher, McDonald, Citra, Bosch, & Amata, 2003).

Since Se occurs in the diet, exposure to it happens mainly by ingestion of its compounds, which are both organic and inorganic. The organic components are largely the amino acids selenocysteine and selenomethionine, which can be consumed in cereals, forage crops and grains. Inorganic dietary Se includes selenate and selenite, although the gastrointestinal uptake of these compounds is less efficient than uptake of organic compounds (Risher et al., 2003).

The functions of Se are various. Most Se-containing proteins have antioxidant roles, with some having more precise functions such as thyroid hormone metabolism, Se-protein biosynthesis and spermatogenesis (Roman et al., 2014). In China, Se deficiency has been known to cause a form of cardiomyopathy termed Keshan Disease, as well as a dystrophic osteoarthrosis and spondylarthrosis called Kashin-Beck Syndrome (Müller & Desel 2010). Not all Se-proteins have an understood role. Se insufficiency is associated with diseases such as cancer, cardiovascular problems, diabetes and immune disorders. The consumption of excess Se leads to toxicity; in some cases, even sub-toxic doses may result in a negative impact. An example is the increased risk of type II diabetes (Roman, Jitarub & Barbante., 2014).

Toxicity

The symptoms of Se poisoning have been described as nausea, vomiting, dizziness and headaches lasting for a number of days; followed by substantial hair loss after two weeks and fingernail discolouration (Figure 6).

Müller & Desel (2010) described a case of Se poisoning in a 46-year old woman who was otherwise healthy. After consuming a handful of paradise nuts at a work outing, she developed the aforementioned symptoms in addition to cramps, restlessness and fatigue. Lecythis ollaria, known as paradise nuts, typically have a very high seleno-cystathionine content as a result of their growth in soil rich in Se, which can be found in South America. In this case, there was no particular therapy performed and the patient's symptoms subsided after 12 months, although she suffered from distress and anxiety due to her symptoms.

A similar case reported by MacFarquhar et al. (2010) listed the same symptoms. Here, a liquid supplement containing excess Se resulted in 201 cases of poisoning in people who consumed it. As in the other case, the persistence of symptoms was noted a long time after exposure ended. Examples of persistent symptoms included hair loss and nail changes, but mood swings, loss of memory, weakness, musculoskeletal problems and garlic breath were also reported.

Figure 6: Discolouration of the fingernails in a greyish tone due to Se intoxication

Source: Müller & Desel (2010)

Treatment

The current literature does not offer any treatment options in cases of Se poisoning, other than removal from the source of exposure.

Silver

Silver (chemical symbol Ag) is a transition metal with several uses in its elemental form. These include decorative jewellery, ornaments, and silverware such as cutlery and cups. Photographic material using Ag was a leading source of this metal's delivery into the environment. Ag and its compounds are also found in sites for hazardous waste, in combination with soil and water (Abraham et al., 1990).

Great quantities of Ag are liberated into the environment from the natural wearing of rocks and soils bearing Ag, facilitated by processes like wind and rain. This can be carried for a considerable distance and can contaminate groundwater (Abraham et al., 1990).

Ag has been historically used as an antibiotic in various applications. Early writings describe its use in the purification of drinking water. Current uses include bone prostheses, cardiac devices, wound care, orthopaedic surgery involving reconstruction, surgical appliances and catheters. Ionizable Ag is utilised in the clinical setting by incorporation into fabrics to prevent nosocomial infections and improve hygiene (Lansdown, 2006).

Ag exists as two isotopes; 107Ag and 109Ag. Of its three oxidation states, only compounds of Ag+ are medically relevant. This ion shows interaction with a variety of anions including proteins and receptors on human, bacterial and fungal cells. Ionization of Ag occurs in the presence of tissue exudate and other body fluids, facilitating antibiotic action and absorption (Table 1).

Table 1: Examples of compound containing Ag and their relative capability to ionize

Compound	Ionizing capacity
Metallic silver (incl. nanocrystalline forms and silver coatings)	low (<1 $g{\cdot}ml^{-1}$)
Phosphate	moderate
Nitrate	very high
Chloride	low
Sulphate	moderate
Zeolite	?
Sulphadiazine complex	high
Colloidal silver preparations	moderate to high
Allantoinates	?
Oxide (Ag_2O)	low

Source: (Lansdown 2006)

Ag+ shows strong binding to biological ligands containing sulfur, nitrogen and oxygen (Lansdown 2006).

Silver in wound care

Ag is used in antibiotic prophylaxis or treatment for skin infections such as those in wounds and burns, as well as in transplant surgery. Ag-impregnated wound dressings utilize elemental Ag, silver nitrate and silver sulphadiazine. Wound bed preparations ensure adequate balance between pathogen control and the patient's natural flora, especially in cases of chronic wounds. Free Ag ions are released in response to the presence of tissue exudates and other wound fluids. These ions then execute their antimicrobial function and also absorbed into tissues (Lansdown, 2006).

Dressings impregnated with Ag nanoparticles (AgNPs) have been studied to assess their potential for reducing bacterial biofilm formation. Biofilms are consortia of bacterial growth which offer the colony a much larger survival advantage when compared to planktonic bacteria, which are bacteria floating as single cells in water. A biofilm can be defined as a colony growing within a secreted matrix; advantages of this modality include metabolic cooperation, a larger gene pool and passive resistance. Biofilms exhibit a significant increase in resistance to antibiotics (Velázquez-Velázquez et al., 2015).

A study regarding the utilisation of AgNPs in wound dressings and its potential to control bacterial growth showed that biofilms of Pseudomonas aeruginosa could be successfully eliminated by the use of AgNPs. The proposed mechanism of action of AgNPs is the inhibition of extracellular matrix formation in the biofilm (Velázquez-Velázquez et al., 2015).

Silver in catheters

According to a study, Ag-alloy hydrogel urinary catheters were useful in lessening the occurrence of catheter-associated urinary tract infections, known in short as CAUTIs. This study was conducted in acute care hospitals. In comparison to standard catheters, Ag-impregnated catheters reduced infection by 47%, and also reduced the amount of time patients needed to be on antibiotics for CAUTIs (Novotney 2014).

Conversely, in a study by Bayston et al. (2009), Ag-processed catheters used in neurosurgery did not show much promise in bacterial eradication. At high inoculum, Ag had no effect on strains of Staphylococcus epidermidis, Eschericia coli and methicillin-resistant Staphylococcus aureus (MRSA). At low inoculum there was eradication of S. epidermidis, incomplete eradication of E. coli and no effect on MRSA. The suggested reason for this is the low amount of Ag ions which are available. The possibility of cytotoxicity may result if the quantity of Ag ions in increased.

Toxicity

Repeated consumption or inhalation of preparations containing colloidal Ag result in silver sulfide particles depositing in several organs, such as in the skin causing Argyria and in the eyes causing Argyrosis. The effect of Ag deposits is not dangerous but produces undesirable cosmetic effects (Lansdown, 2006).

Ag is transported via metallothioneins and elimination occurs through the liver and kidneys. Allergic reactions to Ag are a possibility, and therefore the use of antibiotic textiles and medical devices containing Ag is contraindicated in sufferers (Lansdown, 2006).

A case of persistent cyanosis which turned out to be in fact Argyria was reported by Travis (2010). The patient was a 48-year old man who was involved in a car accident which resulted in him being thrown from his motorbike. Following initial stabilization and transfer to the trauma surgical intensive care unit, the patient retained a blue skin tone on his face, torso and arms, with greyish extremities. As vitals and blood gases normalised, this condition persisted and was later diagnosed as Argyria by an experienced trauma surgeon. The levels of Ag in the patient were also thought to have lowered his seizure threshold following intracranial haemorrhage.

Further follow-up with the patient's sister concluded that his Argyria was caused by an Ag-containing preparation and vitamin supplements. The possibility of cyanosis as a diagnosis was excluded (Travis, 2010).

A similar case occurred with a 38-year old man who ingested colloidal silver supplements to treat his joint aches. He went to clinic to address the gray discolouration of his skin (Figure 7).

Figure 7: Greyish-blue skin discolouration (left) compared to normal (right). The patient suffered from Argyria due to his ingestion of colloidal silver to treat joint aches

Source: Wadhera & Fung (2005)

Argyria was confirmed after a punch biopsy of skin taken from the patient's neck was obtained and analysed. The biopsy results showed 1mm granules which were gray-brown to brown-black in colour. These grains were distributed outside cells within the dermis, with concentrations increasing close to the adventitia of eccrine glands (Wadhera & Fung, 2005).

Ag was not believed to result in toxicity in the immune, reproductive, nervous or cardiovascular system, and carcinogenicity was also excluded (Drake & Hazelwood, 2005). However in a more recent study, the cytotoxicity of AgNPs was brought into consideration. It was demonstrated that AgNPs reach the cytoplasm after being phagocytosed by macrophages with the aid of scavenger receptors. Degradation of these nanoparticles releases free Ag ions which hinder mitochondrial function and trigger apoptosis in cells. The results suggested that AgNPs pose a toxicity risk and increased the incidence of inflammation when exposed to mammalian cells (Singh & Ramarao, 2012).

Treatment

The literature was limited with regards to possible ways to prevent Ag toxicity. However, a study performed on Sprague-Dawley rats showed promise in preventing the effects of Ag with concomitant administration of Vitamin E. The effects of AgNP-administration were noted to be prevention of body weight gain and glial-scar formation in the cerebellum (Yin, Yao, Zhou, Faiola, & Jiang, 2015). The results showed that in comparison to control groups, rats given AgNPs gained less weight over the course of 12 weeks. The effect was ameliorated in groups who were also given Vitamin E in combination with AgNPs (Yin et al., 2015).

AgNPs were also observed to cause blood-brain barrier inflammation as well as heightened permeability in the endothelial cells of microvessels. The activation of glial fibrillary acid protein (GFAP) is considered to be an indicator of upcoming biological effects and is related to astrocyte activation. It becomes elevated in situations such as neurodegeneration or acute infection. An increase in GFAP levels was noted in rat cerebella which had undergone nasal instillation of AgNPs, inducing the activation of neuroglial cells together with the degeneration of the granular layer of the cerebellum. These findings suggest that AgNPs demonstrate neurotoxicity in vivo (Yin et al., 2015).

Vitamin E is lipid soluble and acts as an antioxidant; it is therefore thought that it can safeguard the brain from oxidative stress. The study showed that Vitamin E treated rats had less GFAP expression and therefore lessened the damage caused by AgNPs. Further studies would be required to assess to what extent Vitamin E can be used to reduced the toxicity of AgNPs (Yin et al., 2015).

Cadmium

Cadmium (chemical symbol Cd) is a transition metal element. Although the pure metal is not typically found in nature, it is associated with zinc ores, and to a certain extent to the ores of lead and copper. For this reason, it is difficult to eliminate the by-product of Cd from the metallurgy of the aforementioned elements. Other industrial sources of Cd include smelting of other metals, combustion of fossil fuels, incineration of waste and the utilization of phosphate and sewage sludge fertilizers (Alexandar et al., 2009).

The uses of Cd in industry include the productions coatings, pigments, plastics, plastic stabilizers, batteries, photovoltaic devices and nonferrous alloys. When it is released in the environment it can contaminate the air, water and soil. Cd is released from natural mechanisms including forest fires, marine aerosol production and volcanic eruptions among other natural phenomena (Faroon et al., 2012).

Typically found in its +2 oxidation state, Cd ions exist in their hydrated forms as well as complexed to organic or inorganic substances. The more soluble forms have the ability to migrate in water, whereas insoluble forms tend to adsorb to sediments and become immobilized (Faroon et al., 2012).

According to data collected in the European Union (EU), it is estimated that 90% of Cd exposure in non-smokers occurs from food, particularly cereals and vegetable crops. Plants can take up Cd salts from the soil. This uptake depends on factors such as the type of soil, the solubility of Cd in it and the species of the plant in question. Other sources of exposure include meat and fish, although these are less significant. However, consumption of organs such as liver and kidneys from exposed animals contributes a more noteworthy source of Cd, as the element tends to accumulate in these organs. For non-smokers, air and water pose negligible threats in terms of exposure as very low levels are present (Alexandar et al., 2009).

Data collected in the United States (US) complies with the report issued by the European Food Safety Authority. Exposure to non-smokers in the US is largely from the diet, with females exhibiting a larger uptake of Cd from their gastrointestinal tract than males. The highest amounts of Cd were found in leafy vegetables such as spinach and lettuce, and in staple foods like potatoes and grains. Naturally high levels of Cd can be found in peanuts, soybeans and sunflower seeds (Faroon et al., 2012).

Smokers showed an overall high mean blood Cd compared to non-smokers. This could be measured as high as 1.58μg/L, compared to the average value for adults, 0.38μg/L. The reason for this markedly high value is the fact that tobacco leaves naturally accumulate Cd more readily than other plants. It was also noted that non-smokers exposed to second-hand smoke were also at risk for Cd accumulation (Faroon et al., 2012).

Cd biomarkers are typically detected in blood, urine, hepatic tissue, faeces, renal tissue, hair and other tissues (Faroon et al., 2012). Blood Cd levels tend to be more closely related to recent Cd exposure, whereas urine Cd levels reflect body burden over lengthy exposure, and tend to increase with renal tubular dysfunction. Liver Cd levels are also related to duration and intensity of exposure regardless of renal function (Roels et al., 1981).

Toxicity

This metal ion can pose numerous health risks. Cd2+ does not have any known use in animal or human biology, however its divalent nature can assimilate roles performed by other essential metals. It can cross membranes using metal transporters. When it gains entry within the cell, Cd2+ can bind ligands with a particularly high affinity. Clearance is difficult, explaining the long term storage of Cd in intestinal, hepatic and renal tissues. The biological half life of this metal is estimated to vary from 10 to 30 years. Its toxicity stems from its interference with iron, calcium or zinc homeostasis, which are necessary for basic cellular functions (Alexandar et al., 2009).

Acute effects

Metal fume fever is a condition which develops within 48hr of exposure to metal fumes and is typically caused by cadmium oxide, although other metal oxides can also cause it. Patients present with flu-like symptoms with resolution within 24-48h of onset. The pathogenesis is not fully understood; however it is hypothesized that upregulation of proteins releases in response to stress occurs. An example could be heat shock proteins, which are chaperone proteins released in response to hypothermia and other environmental stresses. The advised treatment is immediate removal from the source of Cd exposure, bed rest, antipyretics and treatment for osteoporosis (Malaguarnera et al., 2013).

Chronic effects

Metallothioneins are sulfur-containing proteins rich in the amino acid cysteine, which typically bind metal ions in the body; with the example of haemoglobin. These chelators have numerous important functions including transport, detoxification, sequestering and metabolism of metal ions. Metallothioneins bound to Cd are reabsorbed in kidney tubules (Nordberg & Nordberg 2009). Renal cortex Cd accumulation results in tubular proteinuria with measurable loss of low molecular weight proteins. These include retinol binding protein, α-1-microglobulin and β-2-microglobulin. Progression of renal damage results in glucose, amino acids and minerals being lost in the urine. Long term exposure eventually damages the renal glomeruli and results in a drop in glomerular filtration rate. Uraemia can develop in serious cases. Reversibility of Cd-induced tubular dysfunction depends on the severity of proteinuria, which is quantified by the amount of β-2-microglobulin (B2M) in the urine (Table 2) (Nordberg 1998).

Table 2: Levels of B2M in the urine compared with the level of damage achieved and the possibility for reversal (Nordberg 1998)

B2M in urine (μg/g creatinine)	Clinical interpretation
<300	Within the reference interval.
300-1,000	Incipient cadmium tubulopathy, possibly reversible upon cessation of exposure or forerunner a) of accelerated decline of GFR; increased incidence of renal stones.
1,000-10,000	Irreversible tubular proteinuria. GFR may still be normal.
> 10,000	Overt cadmium nephropathy and usually decreased GFR.

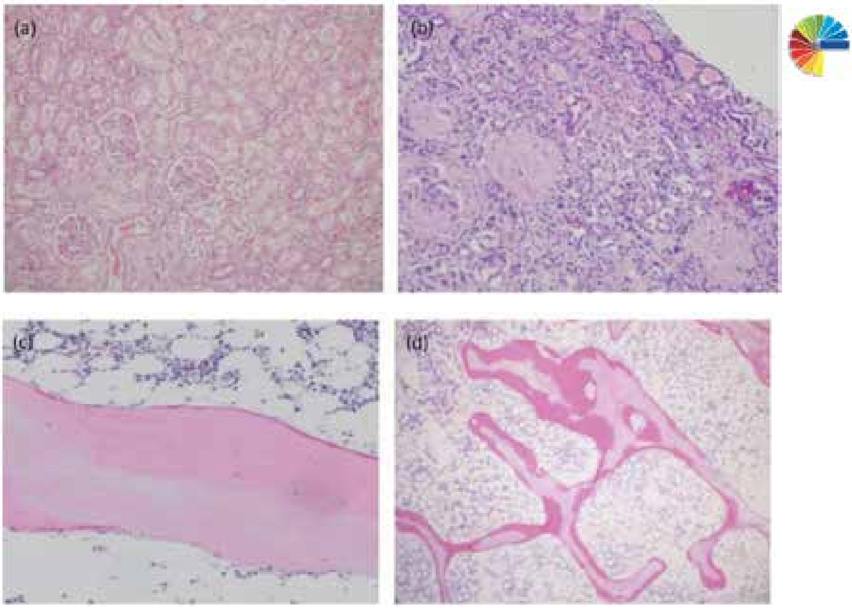
[a] this refers to values that have been confirmed in the same subject at least twice in two repeated measurements over a six-month period.

Itai-Itai disease (IID) is a painful disease which presents with multiple distortions and fractures of the long bones. It is the most severe form of chronic Cd poisoning by ingestion. Due to a zinc mine located upstream from Toyama Prefecture, the Jinzu River was contaminated with Cd. People who lived in the river basin showed the symptoms of Itai-Itai (Baba, Tsuneyama, Kumada, Aoshima, & Imura, 2014).

A study conducted on post-menopausal women living in this area. The aim of the study was to link osteomalacia with renal tubulopathy. Two methods for cause of development of osteomalacia were considered; a direct and an indirect pathway. In the direct pathway, osteomalacia is thought to be caused by the direct interference of Cd with bone metabolism. In the indirect pathway Cd causes Fanconi syndrome, which is the damage of the renal proximal tubule resulting in loss of calcium and phosphate in the urine and the subsequent development of osteomalacia. Although the study does not entirely dismiss the direct pathway, histopathological analysis showed that osteomalacia development was linked to the Cd concentration in the renal cortex but not in bone. Figure 8 shows the damage caused by Cd; in comparison to the normal subjects, there is notable atrophy in the renal cortex of IID patients, as well as osteoid lesions in their bones (Baba et al., 2014).

Cd exposure by inhalation has been linked to lung cancer in studies based on men who were exposed to Cd at their workplace; however these studies did not account for other significant factors such as the possibility of other carcinogens or the smoking habits of the subjects. A different studies, it was concluded that Cd was not a cause of lung cancer; rather, cigarette smoking and exposure to arsenic were to blame (Faroon et al., 2012).

Figure 8: Histological sections of normal renal cortex (a), IID patient renal cortex (b), normal iliac bone (c) and IID patient iliac bone (d). Renal cortex atrophy in (b) and iliac bone osteoid lesions in (d) can be observed following prolonged exposure to Cd



Source: Baba et al. (2014)

Treatment

Treatment of Cd exposure is largely symptomatic. Patients exposed to oral Cd salts should be given a gastric lavage or induced to vomit. Inhalation exposure treatment consists of removing the subject from exposure and giving oxygen as necessary. Chelating agents are contraindicated as they are nephrotoxic in combination with Cd (Nordberg, 1998).

In a study using a rat model, administration of Chlorella vulgaris was observed to increase excretion of Cd in the urine and faeces, as well as preventing its uptake from the gastrointestinal tract. The precise mechanism by which excretion is increased is unknown. Prevention of Cd uptake is thought to be due to dietary fibre found in Chlorella, which traps Cd in the intestinal epithelium. Epithelial cells are then lost in the faeces by desquamation (Shim et al., 2009).

Mercury

Mercury (chemical symbol Hg) is a transition metal which occurs in three variations; the elemental form and in inorganic and organic compounds. In its elemental form Hg is a liquid at room temperature. Depending on how high the temperature, colourless and odourless vapours are emitted (Risher & DeWoskin, 1999).

In its inorganic form, Hg occurs as salts of chloride, sulfide or oxides. A large majority are white salts, with the exception of cinnabar. Cinnabar is mercury sulfide, a red salt which converts to black following light exposure. Organic Hg compounds are also known as organomercurials. The most common organomercurial is methylmercury, a crystalline white solid. Other compounds include dimethylmercury, a colourless liquid, and phenylmercury, a white solid (Risher & DeWoskin, 1999).

In nature the commonest forms of Hg are elemental, mercuric chloride, cinnabar ore and methylmercury. Liquid elemental Hg has multiple uses, such as the production of caustic soda, gaseous chlorine, as well as the extraction of gold from it ore or gold-containing items. Elemental Hg is used in measuring devices like thermometers and barometers, and also batteries and electric switches. Inorganic Hg is used in fungicides, skin-lightening creams, paints, tattoo dyes, topical antiseptics as well as disinfecting agents. Prior to 1991, organic Hg compounds were used in antifungal agents, but this use was discontinued after it became known that Hg vapours were released from these products (Risher & DeWoskin, 1999).

Hg constitutes about 50% of the components of dental amalgam. Other metals include silver, copper, tin and trace metals. Dental amalgam is used to treat dental cavities. Its continued use until today is mainly due to its quality and the fact that most dentists are trained to use it, as opposed to other modern substitutes. These fillings leach Hg when they are being inserted, removed, as they deteriorate with time and from the buried or cremated remains of people who had these fillings. According to the final report prepared for the European commission, the phasing out of Hg-containing dental amalgam would be difficult for a number of reasons, including the expense of dental amalgams that do not contain Hg. Also, dentists would require training to insert these amalgams as well as new equipment with it. Health services in the EU do not always cover these costs; dental fillings are not covered by the national health insurance schemes in Malta (Mudgal, Van Long, Mitsios, Pahal, De Toni & Hylander, 2012).

Toxicity

Hg poisoning in the clinical setting is largely due to suicide attempts by ingestion of mercury cyanide or other compounds. Accidental poisoning is not usual, although reports of Hg exposure by youngsters from broken mercury thermometers and barometers have been reported. Inorganic Hg compounds in their pure powder form are the cause of non-fatal poisoning in adults (Triunfante, Soares, Santos, Tavares, Carmo & de Lourdes Basto, 2009).

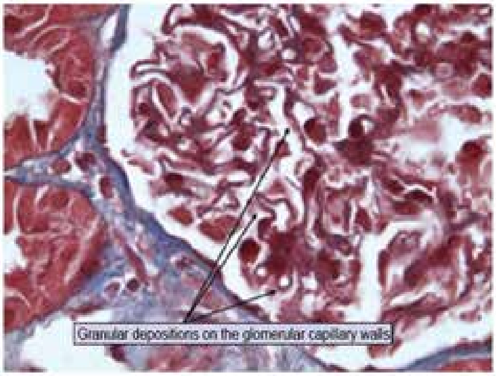
Chronic exposure of methylmercury from bioaccumulation in fish is a cause of concern (Triunfante et al., 2009). Hg in trace amounts dissolves in water and is converted into toxic methylmercury, which is absorbed by fish through the gills and by consuming smaller aquatic organisms contaminated by Hg. Larger fish carry the largest amounts of Hg due to predation. A study conducted in Ghana analysed the content of heavy metals including Hg in several canned fish products. Canned tuna brands showed the highest Hg levels from the fish analysed (Okyere, Voegborlo & Agorku, 2015).

Intoxication from inhalation of metallic Hg vapour typically results in respiratory distress which can result in death if severe (Triunfante et al., 2009). When Hg is inhaled, 74-80% of the dose is absorbed via the alveolar membrane in the lungs. It is then transported to a number of tissues including the liver, central nervous system and especially the kidneys. In a case report by Gul Oz, Tozlu, Siddika Yalcin, Sozen & Sain Guven. (2012), a family of four suffered varying degrees of Hg poisoning after one of the children brought home a minute piece of Hg in a glass from school, which broke and was vacuumed up by the mother in a non-aerated room.

Nephrotic syndrome due to Hg intoxication developed in the mother following 3 months from exposure. Kidney malfunctions present with proteinuria, which can be for one of two reasons: antigen-antibody complexes that form as a result of excess Hg are not effectively cleared and result in damage to the glomeruli (Figure 9); alternatively Hg ions cause direct damage in renal tubules (Gul Oz et al., 2012).

The initial effects of Hg poisoning are flu-like symptoms within 1 to 3 days of exposure. These effects include excess salivation, oedematous gingiva, fever, dry cough, diarrhoea, nausea and vomiting. Later effects include noncardiogenic pulmonary oedema as well as pneumothorax. In post-mortem analyses of Hg-exposed lungs, damage such as intense corrosion of the bronchiolar epithelium and necrotizing bronchiolitis with fluid accumulation in the alveoli and the interstitium. Dysfunctions in other systems such as the kidneys, liver, blood and skin have also been reported (Gul Oz et al., 2012).

Figure 9: Histological section showing depositions on the capillary walls of glomeruli made up of granules formed by antibody-antigen complexes that did not clear successfully



Source: Gul Oz et al. (2012)

The final phase of Hg poisoning is typically a progressing hypoxic state which can lead to death. If the patient survives the intoxication, there may be residual damage in the form of gingivostomatitis, tremors as well as erethrism, which can manifest as loss of memory, emotional instability, insomnia, depression and shyness (Gul Oz et al., 2012).

Injection of metallic Hg with the intent of suicide is also reported. Intravenous injection leads to pulmonary embolization by globules of Hg, and patients present with chest pain, dyspnoea, fever and cough. Other signs include changes in the patient's electrocardiogram, impairment of renal function and dermatological symptoms. Subcutaneous Hg injections results in inflammation that is localised, granulation tissue and the formation of abscesses. Eventual systemic involvement is also expected (Alhamad, Rooney, Nwosu, MacCombs, Kim & Shukla, 2012).

In case of methylmercury poisoning, effects on the cardiovascular system may be reported. This can be easily confused with pheochromocytoma, a catecholamine-secreting tumour which also presents with hypertension and tachycardia. The common factor is accumulation of cathecholamines. In case of inorganic Hg intoxication, Hg incapacitates the cofactor of catecholamine-O-methyltransferase, which is the enzyme that is responsible for catecholamine degradation (Gul Oz et al., 2012).

Tachycardia and hypertension can fall under acrodynia, which is a collection of symptoms resulting from Hg poisoning, that also include mental changes, swelling and irritation of palms and feet with skin desquamation, extreme sweating, pain localised in the extremities, photophobia, anorexia and fever (Gul Oz et al., 2012).

Treatment

British Anti-Lewisite, also known as BAL, was developed in warfare as an antidote to lewisite, which is an arsenical vesicant. BAL's chemical name is 2,3-dimercaptopropanal, and it is an oil which is freely absorbed by the skin. It binds lewisite to form a stable compound, therefore removing this toxin's effect on the enzyme pyruvate. BAL can also prevent the vesicant effects of lewisite if applied before exposure, but can reverse the initial symptoms up to two hours after exposure. The resulting compound is then excreted in the urine. This drug was also used to treat Hg poisoning (Peters, 1949).

In rats, intravenous BAL proved effective in preventing the acute systemic poisoning caused by mercury chloride. When BAL was supplied by injection as well as oral dosage, it also safeguarded the rats from fatal doses (Stocken, 1946).

In the 1950s, chemically similar dithiols which could also dissolve in water were produced; unithiol (DMPS) and succimer (DMSA). Treatment with these substances is required as early as possible following Hg exposure, as their effectiveness decreases with time. In chronic intoxication, DMPA and DMSA chelation appears to reduce the inorganic Hg burden on some organs. However, in morbidity and mortality terms, the benefit has not yet been concluded. Some observed side effects of DMPS and DMSA include allergic reactions with widespread rashes in 1 to 10% of subjects in certain studies. Other effects include gastrointestinal issues and reversible rises in hepatic transaminases and drops in white blood cell count (Kosnett, 2013).

Lead

Lead (chemical symbol Pb) is a group IV element of the periodic table. It does not occur in particular abundance, however its ores are easily accessible and found in several locations the world over. These ores include Galena (PbS), Cerussite (PbCO3) and Anglesite (PbSO4). Its physical properties include resistance to corrosion, relatively large density and low melting point. Pb's oxidation states include the elemental form, Pb2+ and Pb4+, with the (II) oxidation state being the most abundant in nature. Metallic Pb does exist but it is rare. Some organolead (IV) compounds also exist (Abadin et al., 2007).

Pb's uses include solder, weights, pipes and storage batteries. The largest availability for human exposure stems from the past use of Pb as a gasoline additive which caused a broad environmental dissemination. A second source of likely exposure comes from paints containing Pb pigments. In the US, the use of Pb in gasoline was phased out and stopped by 1995. The use of Pb paints became illegal in 1978, however older homes still had leaded paint. As this type of paint peels off, Pb dust is released and is a potential route of exposure to Pb. Some exposure from drinking water which has passed through Pb pipes and fittings also still occurs, although Pb content regulations in pipes were established in 1988 (Abadin et al., 2007).

People working in industries such as Pb smelting and refining, manufacture of batteries, construction, steel, printing, plastics, rubber, radiator repair shops and firing ranges are at a risk for Pb exposure. This is mainly due to flame soldering of solder containing Pb. In these cases, inhalation exposure can occur (Abadin et al., 2007).

Other possible exposure routes include the use of Pb in non-western folk medicine and Pb glazes on ceramic pottery which can leach into food or drinks stored inside them (Abadin et al., 2007).

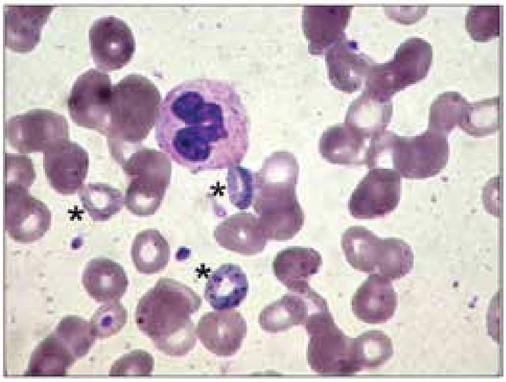
Toxicity

The acute form of Pb poisoning typically occurs by lead acetate. Instantly after being exposed orally to lead acetate, the patient suffers from throat stinging and thirst. This is typically followed by vomiting within 30 minutes. Worsening colic that is alleviated by pressure occurs. Abdominal examination reveals tenderness and contraction. The patient also suffers from oliguria as well as constipation; the stools are dark due to the formation of lead sulphide. The patient is weak with cold and clammy skin, and the pulse is typically fast and weak. Nervous symptoms include insomnia, vertigo, headache, drowsiness, muscle cramps, numbness and convulsions; in some cases also paralysis. Exhaustion can lead to death (Kadu, Nampalliwar, Pandey, Sharma & Gothecha, 2012).

When the poisoning occurs with tetraethyllead, symptoms are mainly nervous while gastric symptoms are less pronounced. Nevertheless, some patients suffer from nausea, vomiting and anorexia. Nervous symptoms are grouped under the umbrella term 'lead encephalopathy'. This includes irritability, anxiety, insomnia, nightmares, headache, excitement, vertigo, tremors, myasthenia, convulsions and delirium. Cardiovascular symptoms are usually bradycardia and hypotension (Kadu et al., 2012).

A case report by Yen, Lin and Weng (2010) describes a 23-year old male who suffered from Pb intoxication. His occupation was Pb battery recycling. The patient was referred due to intermittent and colicky abdominal pain that could not be relieved or worsened by any factors. His abdomen was found to be soft and tender, and no neurological symptoms were reported. The patient's blood results showed drops in haemoglobin level, haematocrit and mean corpuscular volume, which was diagnosed as microcytic anaemia. Stippling of basophils could be observed from a blood smear: a sign linked with Pb poisoning (Figure 101).

Figure 10: Peripheral blood smear showing microcytic erythrocytes with visible basophilic stippling, marked with an asterisk (*), a sign of Pb intoxication



Source: Yen et al. (2010)

In pregnant women and children, Pb causes a great deal of harm. Pb can traverse the placenta. Fetal Pb levels are usually 75-100% higher than those of the mother. Miscarriage, premature membrane rupture, preterm birth and delay in development are linked with elevated maternal Pb levels. Pb inhibits several enzymes required for the synthesis of haemoglobin, hinders the sodium-potassium pump and binds to the cell membrane of red blood cells, making them fragile (Kadu et al., 2012).

Children with high Pb levels suffer from mental retardation, seizures, coma and death. Lower levels can cause learning disabilities, colic, attention-deficit hyperactivity disorder, hindered growth, loss of hearing and weakness in the upper body. Chronic exposure damages the kidneys, central nervous system and causes blood changes. Syndromes which are Fanconi-like have been reported. In cases of severe, extended poisoning, patient's gums develop a purplish line, however this is not commonly seen. Another typical feature of Pb poisoning is the visibility of 'lead lines' on an X-ray; these areas signify cessated bone growth (Cohen, 2011). These lines were observed in the long-bone X-rays in a case report by Hildebrand (2011). The infant in this case was born after 38 weeks of gestation to a mother who regularly consumed ground Pb-containing pottery. High density bands could be observed in the child's tubular bone metaphyses, particularly in the distal ulnas and proximal fibulas (Kadu et al., 2012).

Chronic Pb toxicity results in anaemia, colic, constipation, gingival Pb lines, neurotoxicity, peripheral neuropathy, encephalopathy, renal toxicity, cardiovascular toxicity, menstrual problems, spontaneous abortion, developmental defects and carcinogenicity (Kadu et al., 2012).

Treatment

Treatment for Pb intoxication is given by chelating agents. These include 2,3-dimercaptosuccinic acid (DMSA), which is also known as succimer, an analogue of dimercaprol which can dissolve in water. Succimer has a broad therapeutic index which makes it superior to the other chelating agents, CaNa2EDTA and dimercaprol. The structure of succimer consists of four carbon atoms, two sulfur and two carboxyl groups. It clears Pb as the latter binds to the adjacent sulfur and oxygen atoms (Lowry, 2010).

Another chelating agent is DMPS, whose chemical name is racemic-2,3-dimercapto-1-propanesulfonic acid. This water soluble agent has some relation to dimercaprol and DMSA, but it shows less toxicity than dimercaprol. Its formulations include intramuscular, intravenous and oral. DMPS can treat a number of types of heavy metal poisoning, including Pb (Lowry, 2010).

Penicillamine is a degradation product of penicillin, specifically a D-B, B-dimethylcysteine. It is a fairly old drug which was the oral chelator of choice before the introduction of DMSA (Lowry, 2010).

Conclusion

Diagnosis of heavy metal intoxication is not one of the first which comes to mind when presented with a case, and therefore achieving a good standard of care requires understanding the sources of exposure of each metal as well as the pathophysiology of poisoning. This is also true from the point of view of researchers looking for possible prevention treatments.

Elements like Aluminium are used in daily items and exposure at subclinical levels occurs on a regular basis. Selenium and to a certain extent Chromium are micronutrients, although in excess they show toxicity. Silver has multiple uses as an antibacterial agent but can give undesirable cosmetic effects when used excessively or ingested in supplements. Metals like Cadmium, Mercury and Lead show no uses to the body and cause different degrees of damage to the human body depending on route and level of exposure.

Exposure can occur from medication, diet, environmental contamination and at the workplace. For this reason, a thorough history of possible heavy metal intoxication cases should be gathered and scrutinized before any attempt at a diagnosis is made. The importance is placed on the need for environmental data sensors and capture devices that help identify traces of these elements, which technology was introduced as part of the ERDF156 project that catered for environmental parameters but requires an additional series of element-capture devices spread across the islands to ensure a uniform approach. Such would enable a medico-spatial analysis linkinh=g trace identification, health and spread of incidents in relation to physical space.

When multiple patients present with similar symptoms, it can be advisable to further investigate any linking factors. The possibility of intentional poisoning as a means of suicide or murder cannot be excluded.

The primary treatment is removing the patient from the source of exposure as soon as possible. Further follow-up depends on the type of metal poisoning; chelating agents discussed in the essay are used at the discretion of the physician in charge, due to side effects and the chance of nephrotoxicity especially when the kidneys have already been implicated.

Future research should be based on the prevention as well as treatment. New and better chelators are a good avenue, however other studies have focused on substances like Vitamin E and NAC, as well as organisms like Chlorella vulgaris for preventing the toxic effects of specific metals when administered concomitantly. More studies would be required before any conclusions can be reached; however, current studies are showing promise.

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CHAPTER 9

Planning for a Dynamic and Resilient Land-Sea Interface

Michelle Borg

Introduction

It has been claimed that a country's economic performance is influenced by its physical geography and particularly in having a coastline which provides more opportunities through sea-trade (Sachs, 2005). Coastal economies have been noted to have higher income than the landlocked economies (Gallup and Sachs, 1998). For small island states isolated from the mainland economies on continents, the land and sea interface assumes an even more important role that in many instances is either taken for granted or overlooked. Over the islands' history the Maltese coast has accommodated uses that supported human life. Ports offer an economic life link through maritime trade, critical infrastructure provides energy and water, while reprieve from the hot weather and urban areas is obtained through clean seas and scenic landscapes respectively. The decisions to locate uses along the coast were largely based on operational and economic criteria, which for many years were the key factors that shaped government policy.

In a global scenario that has endorsed sustainable development, it is now evident that human quality of life depends on the natural environment. Therefore the quality of the coastal environment affects the quality of the ecosystem services it provides, such as clean waters that support fisheries and recreation, upon which we depend. In addition the healthier the coastal environment the stronger its resilience to the predicted impacts of climate change, particularly if supported through measures that reduce stressors on ecosystems (IPCC, 2007). Spatial planning is one such measure as it determines the long term status of the land-sea interface and its resources through the allocation of space for different uses. This paper presents a historical overview of how the national planning system in the Maltese Islands addressed the coast. It is argued that through adaptive management together with the application of coastal zone management principles Malta's land use planning system has transformed from the original instrument focused mainly on traditional urban planning to cater for the needs of a small island state, where the relatively larger maritime space has gained a much higher spatial significance (Government of Malta, 2015), and formally introduced the concept of maritime spatial planning.

Managing the Coast Sustainably

The coast brings together two very distinct environments to create a constant state of dynamic interaction that distinguishes this geographical area from any other areas on dry land or in the open sea. Coastal areas are among the most fragile ecosystems on the globe where traditional management approaches particularly applied to commercial fisheries and coastal conservation failed (Portman, Dalton and Wiggin, 2015). Given the diverse habitats and human activities taking place, conflicts amongst users either through competition for space or resource degradation, abound particularly where human settlements and populations are concentrated. The management approach recommended for coastal areas was one where all characteristics, uses and issues needed to be addressed holistically.

Integrated Coastal Zone Management (ICZM)

The chapter on ocean and coastal management in Agenda 21 called for new approaches to marine and coastal area management and development that are integrated (Adler et al, 1999). Such an approach is necessary for an area that encompasses a mosaic of natural processes and human activities. The terminology used for the coastal area to be managed is the 'coastal zone' and over time many definitions were proposed to identify where it is and what it is composed of. The concept of Integrated Coastal Zone Management (ICZM) as a tool saw its early beginning approximately four decades ago (Portman et al, 2015). Table 1 includes some of the definitions that have been put forward over time highlighting the basic common elements centred mainly on the physical environment and the interactions with human activities.

Experience in coastal management around the world has developed a series of common principles that constitute effective management. The European and Mediterranean regional experience which are of significant relevance to the Maltese Islands have also contributed to the development of this approach. The European Recommendation on Integrated Coastal Zone Management (2002/413/EC) lists a series of principles that European Member States are to follow in developing coastal strategies. Similar principles are included in the Protocol on Integrated Coastal Zone Management in the Mediterranean adopted through the United Nations Environment Program-Mediterranean Action Plan (UNEP-MAP).

Table 2 allows for a comparison to be made on the set of principles included in these two policy documents. ICZM as an approach benefits from the application of instruments such as urban planning and declaration of public domain; complementary approaches such as the ecosystems based approach; and the prioritisation of space allocation for certain uses. The concept of adaptive management referred to in the EU ICZM Recommendation is a means of linking learning with policy and implementation, when uncertainty exists (Stankey, Clark and Bormann, 2005). This approach still enables decisions on coastal use to be taken, on the basis of available knowledge to design policies and measures that once implemented will also enable knowledge to be gained. Ultimately the overarching framework embedded in both these policy instruments is sustainable development. This confirms the claim that sustainability emerged as the dominant paradigm for coastal management in the late twentieth century (Kay and Adler, 1999).

Table 1. Coastal zone definitions

Year	*Definition*	*Source*
1969	That part of land affected by the proximity to the sea and that part of the oceans affected by its proximity to the land	US Commission on Marine Science, Engineering and Resources (in Sorensen and McCreary, 1990)
1972	The band of dry land and adjacent ocean space (water and submerged land) in which terrestrial processes and land uses directly affect oceanic processes and uses, and vice versa.	Ketchum (in Kay and Adler, 1999)
1990	The interface or transition space between two environmental domains, the land and the sea.	Sorensen and McCreary, 1990
1995	Coasts are dynamic interface zones involving the meeting of the atmosphere, land and sea. It is taken to include the area between the tidal limits as well as the continental shelf and coastal plain	Viles and Spencer, 1995
1999	Contains both land and ocean components; has land and ocean boundaries that are determined by the degree of influence of the land on the ocean and the ocean on the land; and are not of uniform width, depth or height	Kay and Adler, 1999
2002	The coast is a narrow zone where the land and the sea overlap and directly interact. Its development is affected by terrestrial, atmospheric, marine and human processes and their interrelationships. The coast is the most varied and rapidly changing of all landforms and ecosystems.	Waugh, 2002

Table 2. ICZM Principles in EU and Mediterranean policy

EU ICZM Recommendation	*UNEP-MAP ICZM Protocol*
- A broad perspective that takes into account the interdependence of natural systems and human activities - A long term perspective taking into account the precautionary principle and needs of present and future generations - Adaptive management to facilitate adjustment implying need for sound scientific knowledge - Local specificity and the great diversity of European coasts - Working with natural processes and respecting the carrying capacities of ecosystems - Involving all partners concerned in the management process - Support and involvement of relevant administrative bodies at all levels - Use combination of instruments to facilitate coherence between sectoral policy objectives and between planning and management: - Developing contractual or voluntary agreements with coastal zone users, - Harnessing economic and fiscal incentives - Working through regional development mechanisms	- The natural dynamics and the interdependent nature of the land and marine parts shall be taken into account - All elements relating to hydrological, geomorphological, climatic, ecological, socio-economic and cultural systems shall be taken into account in an integrated manner, not to exceed the carrying capacity of the coastal zone and prevent the negative effects of natural disasters and of development - The ecosystems approach shall be applied - Adequate and timely participation in a transparent decision-making process by civil society - Cross-sectorally organised institutional co-ordination of administrative services - Formulation of land use strategies, plans and programmes covering urban development and socio-economic activities - Priority shall be given to public services and activities requiring in terms of use and location, immediate proximity of the sea - Allocation of uses throughout the entire coastal zone should be balanced, and unnecessary concentration and urban sprawl avoided - Preliminary assessments shall be made of the risks associated with human activities and infrastructure to prevent and reduce negative impacts - Damage to the coastal environment shall be prevented and appropriate restoration affected

Source: adapted from O.J. (2002) and UNEP/MAP/PAP (2008)

Adapting to Climate Change

The vulnerability of a country to climate change depends not only on natural factors such as geographical location, but also on the degree of preparedness being taken to increase resilience of natural and human systems in order to adapt. Coastal zones are considered vulnerable due to sea level changes and inundation from increased storm surge events that affect both natural coasts and human infrastructure present whilst increased sea temperatures are expected to modify marine ecosystems (EEA, 2012). For small islands, the expected climate impacts on coastal zones increase the risk to livelihoods of their inhabitants and economic stability more significantly in view of the limited land space available, particularly if no adaptation efforts are made (IPCC, 2007). In Malta, these risks are further compounded as the IPPC Fifth Assessment Report in 2007 also identified the Mediterranean region as being at high risk in terms of water scarcity and extreme heat events.

Malta's second Communication to the United Nations Framework Convention on Climate Change (MRRA, 2010) highlights the vulnerability of human activities and natural resources particularly in low lying coastal areas. However detailed evaluation of climate impacts on the Maltese Islands was hampered by the lack of relevant data available at the local scale. This is still the case as evaluations are limited to extrapolating assumptions from global and regional predictions linked primarily to weather patterns and long term sea level changes. Nonetheless planning efforts for adaptation need not be put off in the absence of all the required information: knowledge on the existing physical characteristics and climate change phenomena of the coastal area coupled with an insight of the expected related impacts can still assist in guiding adequate adaptation measures (NOAA, 2010).

In a similar manner where ICZM principles recognise spatial planning as a useful tool for coastal sustainability, evidence from academic literature and policy sources point towards the significant role that the planning system can also play in climate change policy agenda (Davoudi, 2009). Thus, adopting spatial planning as a leading instrument to guide sustainable use of the coastal zone can also pave the way to mainstream climate adaptation measures in the process.

Integrating ICZM into the National Planning System

Historical context

Malta is not the only small island in the central Mediterranean however it was the Grand Harbour that attributed a strategic importance to this archipelago that is not shared by other islands, like Pantelleria (Blouet, 1992). Defined as the best natural harbour in the Mediterranean (Karmon, 1980) it was this coastal feature that defined Malta's history. Its location may have also been considered as strategic since prehistoric times, given the concentration of megalithic structures along the coast of such a small land territory. Maritime transport already provided the life link for the islands at the time bringing in resources that were not locally present. The obsidian found in archaeological sites confirms such links (Trump, 2002).

During the 16th right up to the 20th century the focus on the coast centred around military defence with historic fortifications from this period still present. Local fishing communities concentrated along coastal embayments of Marsaxlokk, St. Paul's Bay, Mellieħa Bay and Marsalforn to exploit the surrounding sea which also served as reprieve in the hot summer months for the local population to cool off. For centuries the sea also served as a waste sink for untreated sewage.

With independence in 1964 a fledgling State sought alternative sources of foreign economic investment and increase employment opportunities. During this time the coast was perceived as a resource for tourism. Hotels were developed adjacent to every sandy beach, mirroring the sun, sand and sea tourism model already dominating the Mediterranean littoral. Industrial estates to support manufacturing were located at Hal Far and in the Xgħajra environs away from residential areas. As the tourism industry flourished over time, pressures on infrastructure were felt, with episodes of water shortages and increased incidents of sewage pollution in bathing areas. Innovative technology led to the development of desalination plants whilst more recently sewage treatment plants were constructed to eliminate the polluting effects from discharging raw sewage at sea.

Gradually, within a short time span in Malta's history, the services provided by the coast grew, with ports, harbours, power plants, waste landfills, hotels, industrial estates, desalination plants, agriculture, and recreation all seeking coastal space to accommodate the required needs. The multifunctional role of the coast for the social and economic well-being of the Maltese Islands was established. Yet it was not fully acknowledged by the time the land use planning system was undergoing a major over haul in the early 1990s.

The initial steps

The enactment of the Development Planning Act of 1992 and the adoption by Parliament of the Structure Plan for the Maltese Islands in the same year were the main instruments introduced at the time to counter the lack of systematic regulation of development. The ultimate aim of this new administrative system was to rein in the urban sprawl that was threatening the limited land resources, placing potential pressures on supporting infrastructure and degrading environmental quality in general.

The Structure Plan had a long term vision of twenty years. Foreseeing where to take the Maltese Islands and its population by 2020 demanded a break from the short-term and sectoral approach in policy development that was prevalent at the time. The preparation of the Structure Plan of the Maltese Islands was based on consultations and surveys resulting in a series of technical reports describing the land use issues at the time and presented policy options for the future. In 1989 a coastal zone survey was carried out by the University of Durham and the University of Malta to identify the natural and cultural assets and development related issues within a narrow coastal strip. On the marine side, the focus was on the identification of the marine park potential of the coastal waters (Planning Services Division, 1990).

During the preparation of the Structure Plan, the key strategic coastal issues that needed attention were three: (i) safeguarding the natural and historical environment; (ii) halting the impacts arising from tourism whilst recognising that the coast is an important asset for recreation; and (iii) promoting aquaculture as a new economic sector (Planning Services Division, 1990). The recommendations for the Structure Plan centred on the principles of coastal management, guided by the policy development advocated by the Mediterranean Action Plan at the time.

Recommendations called for the adoption of an integrated approach and to consider the coastal area as a unique environment with natural, ecological, aesthetic and historical value where the main goal was environment protection and conservation as well as adequate development (Planning Services Division, 1990). Recommended actions that could be taken to implement this approach included: (i) the identification of the coastal area on the basis of coastal ecosystems; (ii) the introduction of development control procedures on the basis of detailed plans; (iii) an integrated environmental zone to protect natural habitats on land and sea; and (iv) securing the rights of public access to shoreline and beaches. A tentative landward boundary for the coast based on visual and morphological criteria was presented as an initial attempt (Figure 1a).

The stated government policy considered the coast as a resource of which social and environmental use is to be made (Planning Services Division, 1990). Protection of agriculture, traditional settlements, recreation and fisheries was recommended whilst the promotion of aquaculture was recommended together with the restoration of seawater quality. At the same time active quarries, tourism development and industrial installations were identified as major serious problems on the coast together with waste, fly-tipping and the risk of coastal erosion. In the absence of robust scientific information at the time, recommendations linked with climate change were limited to raising awareness on the potential impacts of sea level rise.

These reports constitute Malta's first introduction to coastal management and the first attempts at adopting the ecosystems based approach to decision making. In the absence of human resources and information to guide the adoption of coastal management principles, the resulting strategic direction in the Structure Plan for the coast inevitably centred on capacity building, the preparation of a subject plan to provide detailed policy and one policy to safeguard public access. In addition, within the Structure Plan there were more than fifty policies that directly or indirectly had an impact on the coastal zone (Planning Authority, 2002). The key diagram accompanying the Structure Plan did not include any geographical definition of the coastal area, placing a challenge on how to interpret the applicability of coastal related policies. However most of the western coastline was classified as Outside Development Zone (ODZ) corresponding with one of the richest natural habitats in the Maltese Islands: the coastal cliffs.

Prepared during the same time as ongoing negotiations were taking place an a global level for the World Conference on Environment and Development in Rio 1992, the Structure Plan incorporated the concepts of sustainable development as understood at the time. Noting that the term was only coined a few years earlier in 1987 by the World Commission on Environment and Development, the attempt to align national strategy with emergent global development policy was an ambitious step.

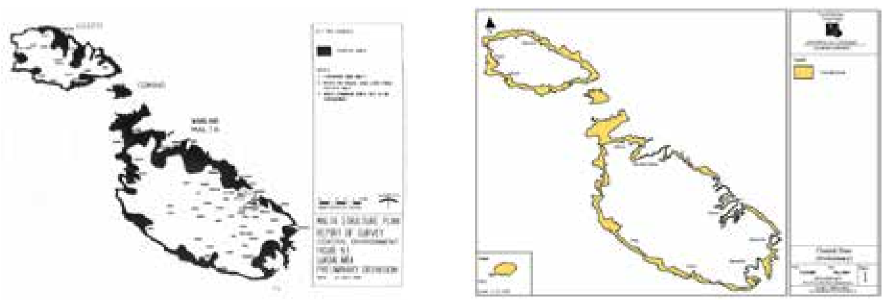
In parallel to the strategic policy framework, the planning legislation enacted at the time introduced another component that was in line with good governance and complemented the application of coastal zone management. The 1992 legislation introduced stakeholder participation through consultation at the decision making stage, both for policy development and decisions on individual development applications. On the policy front, this legal provision supported greater integration for a more comprehensive and co-ordinated approach particularly with government departments and agencies.

Developing a strategy for the coast

The impact of the Structure Plan policies and the planning legislation were comprehensively assessed in the Coastal Strategy Topic Paper prepared in 2002 as a stock-take proposing a new strategic policy framework in the Structure Plan review process. Changes to planning legislation in 1997 extended the planning system to the sea, bringing with it more experience through the development control process of coastal applications. Aquaculture and underwater recreation emerged as new maritime users enabling the testing of tools such as Environmental Impact Assessment and public consultations, to assist planners in decision making. In the absence of a defined geographical area policy implementation relied only on interpretation of potential impacts on a case by case basis. The potential risk for urban sprawl along the coast was augmented by the fact that the low lying rocky shoreline was classified as an opportunity area where some form of development may be considered without any distinction of what constitutes as acceptable development. This was further compounded by the fact that the limits to development for the Maltese Islands extended to the water's edge creating no distinction between the undeveloped shoreline and the hinterland (Planning Authority, 2002).

As a result, the first output of the Topic Paper was to introduce clarity by defining the coastal zone where coastal policies would apply. The intensity of activities and growing pressures on the coast, both on land and sea, required specific measures and therefore a coastal zone boundary to assist the development of a locations strategy was identified. The resulting landward limit was delineated on the basis of ecological, physical and administrative criteria and is limited to the first road aligning the coast in urban areas whilst in rural areas the boundary is characterised by ecological systems and extends further inland, corresponding as much as possible to the limit of identified coastal habitats (Planning Authority, 2002). As illustrated in Figure 1b, similarities with the proposed boundary of 1990 can be found, with the 2002 boundary resulting closer to the coastline in urban areas. With the amendments to planning legislation that extended the planning system to the maritime space, the seaward limit of the coastal zone was identified as the 12 nautical mile boundary of the Territorial Sea in where national sovereignty extends (Planning Authority, 2002).

Figure 1: Definition of the landward limit of the coastal zone in Malta



1a: tentative boundary (1990) 1b: proposed boundary (2002)
Source: Planning Services Division (1990); Planning Authority (2002).

The second scope of the Topic Paper was to outline a strategy for this geographical area that was based on an understanding of the ecosystems and uses present. More than a decade had passed since the preparation of the Structure Plan and through the Environmental Impact Assessment process and specific surveys carried out for the preparation of the Local Plans in particular, more data on the status of the coastal and marine environment was collated. The experience from development control processes of coastal projects indicated the potential risks and possible mitigation actions that could be taken to reduce environmental impacts and social impacts particularly through loss of space or displacement of coastal activities mainly linked with recreation.

The strategy presented in 2002 was based on a refined zoning scheme for land use. To protect the distinctive qualities of the coast, safeguard natural resources within and manage existing and future uses, the terrestrial coast was classified into two general categories, predominantly urban and predominantly rural, depending upon the prevailing characteristics and scale of uses present (Planning Authority, 2002). The strategy also set out the following objectives for development both on land and at sea:

- protect coastal and marine habitats and biodiversity;
- protect cultural heritage;
- protect coastal uses that necessitate a coastal location;
- promote and protect public access and use; and
- minimise existing and potential user conflicts.

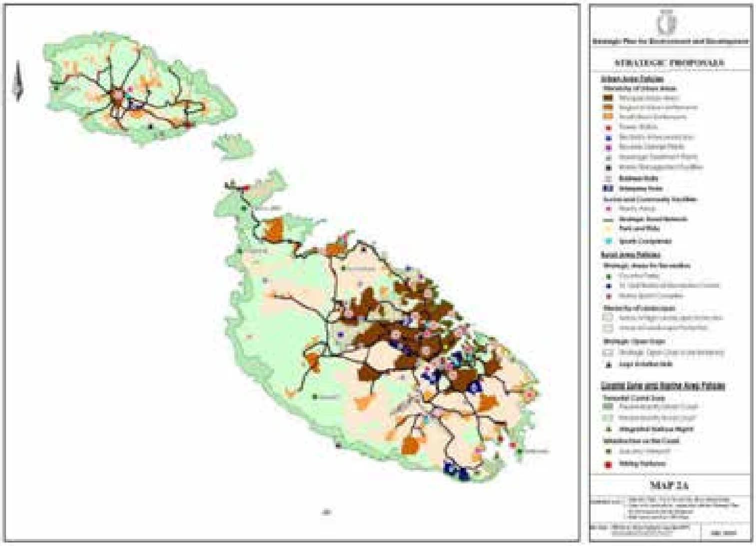
Adopting a Spatial Planning Framework for the Coast

The Strategic Plan for Environment and Development (SPED) was adopted in 2015 by the House of Representatives replacing the Structure Plan of the Maltese Islands as the national spatial plan. As a strategic document, it departs from the approach taken in the early 1990s on a number of counts. Firstly, as required by legislation, land use planning gave way to spatial planning, a significant step within the context of sustainable development.

With land use planning, as a public policy process, the aim is to facilitate and regulate the development and use of land and property (Taussik, 2007 cited in Smith Maes, Stojanovic, Ballinger, 2011). Spatial planning on the other hand links land use planning with social, economic and environmental development policies and promotes the concept of balance and sustainable polycentric development (Ballinger 2008, cited in Smith et al., 2011). The SPED views spatial planning as a process that translates economic, social, cultural and environmental policies into a geographical context (Government of Malta, 2015).

The second departure from the Structure Plan, as a consequence of adopting spatial planning, sees the SPED policy framework structured on the spatial context and therefore the geographical characteristics of the islands as opposed to the sectoral approach of the earlier document. Focusing on the spatial context facilitates the integration of social, economic and environmental objectives into a location strategy. The national spatial framework as adopted in the SPED identifies five spatial units on the basis of the natural characteristics present as well as administrative boundaries: the Urban Area, the Rural Area, the Coastal Zone, the Marine Area and Gozo (Government of Malta, 2015). Although distinct these spatial units are interlinked. Each spatial unit has a set of policies which are supplemented by a set of cross-cutting thematic policies that address socio-economic development, environment, climate change and travel patterns, applicable to all the spatial units, where relevant.

Figure 2: SPED strategic proposals on land

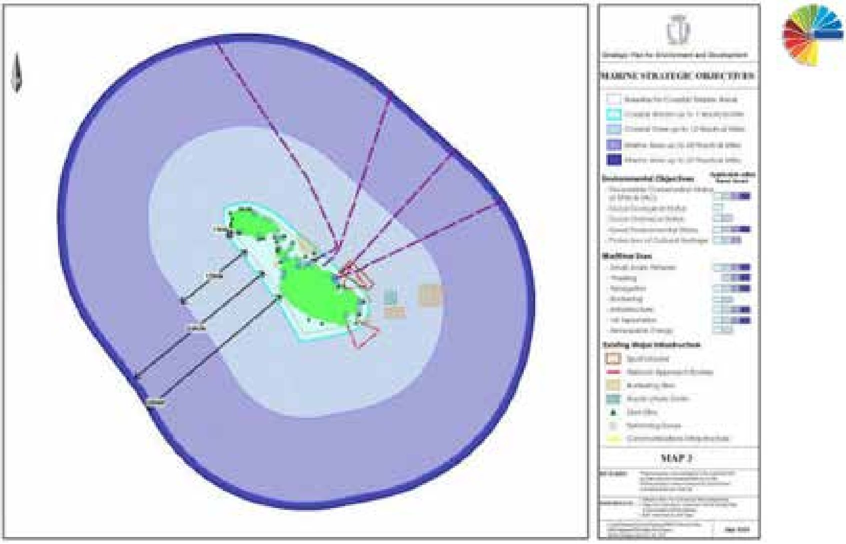


Source: Government of Malta (2015)

For the Coastal Zone the SPED adopts the 2002 coastal zone boundary and strategy for the predominantly rural and predominantly urban terrestrial coast (Figure 2). The policies for the Coastal Zone incorporate ICZM principles as they call for prioritisation in favour of legitimate coastal uses, i.e. uses that require a coastal location to operate; safeguarding not only public access but also use of the coast, and aim to prevent displacement of existing legitimate uses by safeguarding bathing areas, dive sites, fishing harbours from new activities. User conflict is also targeted particularly in coastal areas accommodating critical infrastructure related to energy and maritime transport by designated energy hubs and prioritising efficient use of land and maritime space in port areas.

The SPED policy framework incorporates the national objectives that emerged following accession to the European Union and links fisheries, energy, climate change, environment and growth of the maritime economy to provide a more detailed strategy for the maritime space then identified in 2002. The spatial strategy for the Marine Area extends beyond the limits of the coastal zone, up to the 25 nautical mile limit of the Fisheries Conservation Management Zone (Figure 3). Whilst directing the location of maritime uses, the policy framework lays out the respective environmental objectives which also need to be achieved, thus providing clarity for future investors. Effectively the SPED also constitutes the first maritime spatial plan of the Maltese Islands.

Figure 3: SPED marine strategic objectives



Source: Government of Malta (2015)

Being proactive and indicating locations were development can take place, regulating how different uses can be accommodated and ensuring strategic co-ordination through participation for enhance policy integration, enables spatial planning to contribute towards climate action, particularly adaptation (Davoudi, 2009). The SPED policies affecting the coast contain similar elements in their design.

The preparation of the SPED was complemented with a Strategic Environmental Assessment which further enhanced the take up of the ecosystems-based approach to the plan formulation process. With the available information at the time, and on the basis of knowledge gained not only through data on environmental quality and socio-economic trends, but also on emerging policy trends at a European and Mediterranean level, the strategic policy set out for the coastal zone in the SPED is expected to provide a sound basis to further sustainable development on the land-sea interface for the near future.

Conclusion

The approach adopted in the SPED is a result of the evolution that has taken place over twenty five years within the policy development process in the national planning system where a comprehensive and integrated policy framework has been developed that links the maritime territory with the hinterland in one policy document. From a peripheral role in the 1990 Structure Plan, the coast in the 2015 Strategic Plan for Environment and Development acquired its rightful place as a distinct spatial unit with a vital role to fulfil in securing the long term and sustainable socio-economic growth of the Maltese Islands and wellbeing of its inhabitants.

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CHAPTER 10

Losses, Damages and Return Period of Extreme Weather Events in the Maltese Islands

Charles Galdies and Neil Mallia

Introduction

Full range economic costing of weather disasters tends to be quite challenging. Complete and systematic data on such impacts are often lacking, and most data sets generally tend to underestimate losses. The best estimates made by Hoeppe (2016) for the average global cost of natural disasters worldwide between 1980 and 2014 have caused a total of 1.7 million fatalities and at least $4,200bn damages, including $1,100bn insured losses. Around 65% of the overall losses were due to convective and hydrological events. And what about future trends? Nineteen years ago, William Nordhaus (1997) expressed his dilemma that is still haunting both scientists and economists of today. It relates to the current significant knowledge gaps between the projected increase of temperature (now with high confidence) and its translation into future ecological, economic and social outcomes. Many important sectors still lack a proper description of their future growth dynamics in the presence of such impacts (Hallegatte et al., 2016) and economists often resort to the modeling of long-term economic growth on the basis of current time horizon and climate change scenarios. In doing so, they are neglecting the possibility of potential deviations from presumed model conditions of economic growth, irrespective of whether adverse impacts affect rich economies or those already weakened by various disequilibria or inertia in their readjustment process.

The insurance sector is society's risk management tool that is capable of encouraging risk reduction like no other economical instrument (Zurich Financial Services Group, 2009). This is reinforced by its ability to collect records of damages caused by major weather catastrophes. Based on data available from Munich Re's NatCatSERVICE database among others), Mohleji and Pielke (2014) showed that global losses have increased at a rate of $3.1 bn per year from 1980 till 2008, during which losses resulting from storms and floods in North America, Asia, Europe and Australia account for 97% of the increase. Based on past records, Fischer and Knutti (2015) managed to show that for every 2oC of warming, the fraction of extreme precipitation events increased by about 40%. Such a very important statistic is expected to increase non-linearly with further warming.

In terms of insurance losses, data shows that European storms rank amongst the costliest (Jahn, 2015). Schwarze & Wagner (2004) showed how the insurance industry was hit hard by a catastrophic flood event in Dresden, Germany in 2002. The damages handled by Allianz Insurance Group alone totaled €770m (equivalent to 0.04% of Germany's 2002 GDP). The European Environment Agency estimated that between 1998 and 2009 flooding and storms in Europe have caused some 1,126 fatalities in 213 recorded flood events, with an overall loss of €96bn, out of which €25bn were insured economic losses (European Commission, 2016).

Scope of this paper

Remarkably however, research on weather disasters and their after-effect is considerably limited (Chaiechi, 2014), especially in small island states. Briguglio (1997) showed how small countries tend to be associated with high per–unit costs making them economically disadvantageous. Consequently they are highly vulnerable to the pervasive impact of natural disasters on their population, environment and economy (Wright, 2013).

Similarly, research in the area of extreme weather events and resulting impacts on the Maltese islands are almost non-existent. The scope of this paper is to feed into the much-needed evaluation of local extreme weather events and their economic impact, and even more challenging, on their return period in light of a changing climate. This is done by researching the insurance loss and damage following a select number of Maltese extreme weather events that have occurred between 2011 and 2013. It is hoped that this knowledge will encourage further national risk mitigation and prevention measures.

Methodology

Detailed, long-term information on losses and damages caused by natural disasters can be found in countries with a high insurance penetration like North America, Europe and parts of Asia. Such information is considered to be the most reliable natural catastrophe loss data available which is often used for risk assessment by insurers and reinsurers, social scientists and climatologists alike (Hoeppe, 2016). It must be said, however, that the assessment tools used to quantify the direct total economic losses (including repair, replacement or reconstruction of damaged infrastructure and private material losses) comprise some degree of uncertainty and tends to increase as a result of unaccounted indirect economic losses (such as business interruptions, loss of labour etc.).

The term 'extreme' used by this study falls within the context of local meteorology on the basis of occurrence extremity (extreme values of meteorological variables) and not on impact extremity (magnitude of impacts). The occurrence of an extreme meteorological event is met whenever the values of particular variables go beyond pre-defined absolute thresholds. A similar approach is adopted by NOAA Environmental Centers for Environmental Information (NOAA, 2016).

Extreme events data

This study looks at different types of locally convective weather extremes, namely floods, hailstorms and windstorms (inclusive of storm surges). Local weather storms generally have a short duration but are capable of producing heavy rainfall accompanied by hail and strong gusty winds (Galdies, 2011). In the central Mediterranean region, extreme storms usually take the form of mesoscale convective systems and are not uncommon between the end of August and September. Supercell Mesoscale Systems for example, are convective weather phenomenon capable of causing severe weather with hail, flooding, and tornadoes thus leading to many casualties and significant damages (Morel & Senesi, 2002).

Three locally extreme, isolated meteorological events were examined, which were further subdivided into main events and sub-perils (Figure 1) so as to standardize them with other global natural catastrophe databases for inter-comparative reasons (Hoeppe, 2016). These extreme events included a severe thunderstorm (29.10.2011), a mesoscale convective system (2-3.09.2012) and a hailstorm (15.01.2013).

Figure 1. Meteorological events examined by this study, which were further subdivided into main events and sub-perils

Source: MunichReNatCatSERVICEdatabase; https://www.munichre.com/en/reinsurance/business/non-life/natcatservice/index.html)

Relevant information and data was collected from the insurance sector, official meteorological sources, news media, government reports and published scientific studies.

Analysis of extreme weather events

Meteorological data was gathered from various sources, including synoptic weather charts, satellite images and land observations. Land observations reported by the national climate station situated at the Luqa Airport (Malta) were collected, which included precipitation levels and rates, wind speed and direction, wind gusts and other relevant measurements. Information regarding the socio-economic impacts and damage to infrastructure and private belongings, incidents and fatalities were collected from archived local media sources.

Time-series trends

Surface synoptic meteorological observations published every 30 minutes by Malta's climate station (World Meteorological Organisation registered Climate Station Number: 16597) were reduced to one-hour intervals. The period 1973 till 2009 was analysed, generating 316,000 observations per hazard – equivalent to the processing of around 1 million local observations. Only the long-term trends of the occurrence of hail events (1973-2009) and the maximum hourly rainfall (1959-2015) rates were analyzed in view of space and time constraints.

Statistical analyses

Statistical analyses of weather data, which included data homogeneity testing, cumulative density functions, non-parametric correlation analysis and return periods, were carried out using Rainbow software (Raes, Willem and GBaguidi, 2006) on the basis of the reference meteorological and hydrological data.

Damages and losses

Information related to damages for the three events was gathered from the Ministry of Sustainable Development, Environment and Climate Change (for the thunderstorm event on the 29.11.2011) and from the Malta Insurance Association (for both the mesoscale convective system 09.2012 and the hailstorm on 01.2013).

The data collected from the Ministry included the damages reported by 185 local farmers (Dr. Justin Zahra, personal communication, 2015) as part of the government's effort to offer financial assistance to these farmers. The four different groups of damaged agricultural property available included crops, rubble walls, soil loss and structures.

The Malta Insurance Association (2017), which is tasked with the collection of statistical data from all of the insurance companies in the Maltese Islands (Adrian Galea, Director General of the Malta Insurance Association, personal communication, 2015), provided information on four major insured groups, these being home damages, commercial damages (shops, malls), pleasure craft damages (boats, yachts, ships) and motor damages (cars, buses, motorbikes). This data referred to payments made to insurants after submitting their reports. This information must be considered as partial since indirect losses are not normally accounted for (Kousky, 2014); moreover, the amount paid is often pegged to a predefined limit that is based on the insurant's premium and therefore could further lead to an underestimation of the total costs.

The monetary amounts were normalised by adjusting for wealth over time, as per Neumayer and Barthel (2011), in order to harmonize the damages brought about by all three events. No depreciation was made of the total amount stated. The approach is capable of highlighting the damages from any time period as relative damages with respect to the total wealth of a country, Nd_t=D_t/W_t , where Ndt is the normalized damage for year t, Dt is the total damage reported during t and Wt is the economic wealth (GDP per capita; source: NSO, Malta) estimated during year t. This approach does not require adjustment due to inflation as long as nominal damage in year t is divided by nominal wealth in the same year.

Results and Discussion
Description of events

29th November 2011

This weather event was triggered due to the descent of cold air over Northern Europe into the Mediterranean basin, resulting in the formation of a severe convective mesoscale system. This process led to intensive vertical instability, heavy precipitation, lightning, hail and strong winds. This intensive weather struck the Maltese Islands at approximately 06:00 GMT with moderate rain showers followed by a thunderstorm 6 hours later. At this point, the wind speed was at its peak with 33.4 km hr-1 (or 9.3 m s-1) gusting to 61.2 km hr-1 (or 17 m s-1). Figures 2a-d show the extent and severity of the mesoscale system at 18:00 GMT.

During this event, heavy precipitation was observed in Gozo, Comino and the northwest region of Malta with a total rainfall of 123.6 mm registered in Baħrija and 107 mm in Żebbuġ (Gozo) to name a few locations. In Mosta, a car was carried by floodwaters whilst a mother and her two children were rescued from a vehicle in Marsalforn (Gozo).

On that day, a number of arterial roads were damaged including the ones at Marfa, Rabat and Victoria (Gozo), while some homes were flooded in Rabat and Baħrija (Times of Malta, 2011).

Flooding event on 2nd and 3rd September 2012

This Mesoscale Convective System was triggered by a 'cut-off' low over the western Mediterranean basin which formed during the latter part of August 31st. This slow moving feature led to intense precipitation, thunderstorms, waterspout formation and strong winds over the region. This low pressure system continued to move eastwards and started affecting the Maltese Islands on September 2nd at around 18:00 UTC (Figures 3a-d). Strong winds peaked at 06:00 GMT the following day with gusts reaching 89 km h-1 (or 24.7 m s-1) at Luqa Airport. A woman was saved from floodwaters in Birkirkara by the Civil Protection Department, and in Munxar (Gozo) a heavy water tank was blown by strong winds and landed on the roof of a house that led to its collapse. According to Sansone (2012), a waterspout was spotted to the south of Dingli. On September 2nd, a total of 48.6 mm of rainfall was registered at Luqa Airport, which is equivalent to 121% of the normal precipitation amount for September (i.e. 40 mm).

Hailstorm event on 15th January 2013

This meteorological event arose due to the slow descent into the Mediterranean of cold, polar continental air mass originating from Siberia on 12th January. A vigorous hailstorm struck the Maltese Islands on January 15th. The size of the hailstones was relatively larger than usual and somewhat oblate. According to Dalli (2013), the size of these hailstones was observed to be between 40 to 50mm, equivalent to 'H6' on the TORRO Scale (torro.org.uk/hscale.php) and an impact force of more than 800 J m-2.

Local meteorological observations taken at 12:00 GMT show strong winds reaching 50 km hr-1 (or 14 m s-1) gusting to 77.8 km hr-1 (or 22 m s-1) in a west-northwest direction. These wind gusts increased up to 83.4 km hr-1 (or 23 m s-1) by 18:00 GMT. Cooke (2013a-b) stated that Middlesea Insurance received a substantial number of claims for damages to property, which included damage to solar water heaters, photovoltaic panels, glass panels and water pipes. Gasan Mamo Insurance was in receipt of more than 300 claims made to its Motors department. Media reports indicated that Baħar iċ-Ċagħaq, Burmarrad, Għargħur, Madliena, Mosta, Naxxar, Pembroke, Rabat, San Pawl tat-Targa and St. Andrews were mostly affected by this hailstorm.

Figure 2a-b. Left (a): Water vapour image showing dense accumulation over the central Mediterranean region; Right (b): Microphysics image showing extensive red patches over the Maltese islands, indicative of convective clouds with severe updrafts and ice particles. Case study: 29 November 2011. Source: EUMEtrain.org

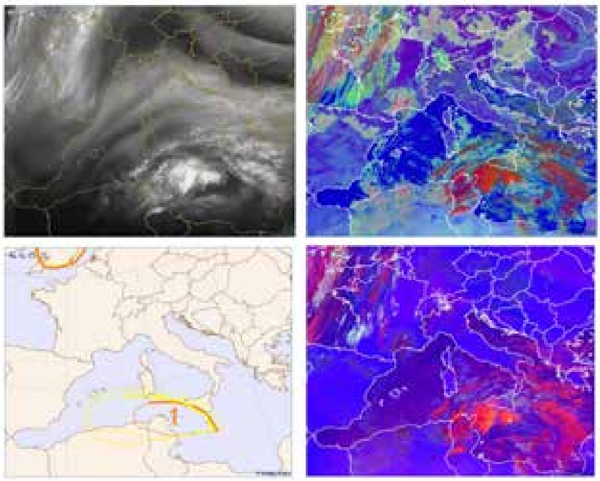
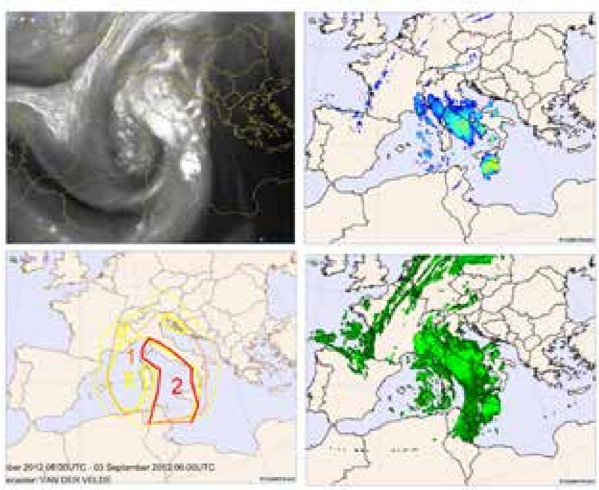


Figure 2c-d. Left (c): Area marked as '1' refers to probability of severe weather within highlighted region; Right (d) Magenta patches over the Maltese islands refer to severe convection with cold cloud tops associated with severe updrafts and fierce weather. Case study: 29 November 2011. Source: EUMEtrain.org



Reported costs

The damages reported following the event of 29.11.2011 only originate from the agricultural sector and therefore can be considered as a case study that highlights the impact of a single occurrence on this sector. According to reports collected from farmers coming from various localities in Malta and Gozo, the total damage caused by this thunderstorm event was €1,831,292.85 (table 1) from which €1,682,639.46 was due to crop damage, €42,621 from damaged boundary walls, €12,990 worth of damages to soil, €50,685 damages to infrastructure and €42,357.39 due to other unspecified damages. In the agricultural sector, destroyed crops can be a major source of losses in the short-term. Necessary dependence on imports might generate additional losses in the long-term; however this could not be quantified by this study. The soil quality can also be negatively influenced for years due to washed-in contaminants – an indirect loss which cannot be determined due to lack of data.

Table 1. Normalised damage on the basis of Malta's GDP per capita. The reported damage for the 2011 event is related only to agricultural-related losses (see text for further details on sub-categories).

Event	Reported damage (€)	Estimated wealth (€)	Normalized damage (€); based on Malta's GDP per capita	Percentage of year-specific GDP (Indexmundi, 2017)
29.11.2011	1,831,293	16,582 (2011)	110.43	0.02
2-3.09.2012	5,073,000	17,221 (2012)	294.58	0.05
15.01.2013	4,341,000	17,919 (2013)	242.25	0.05

The number of insurance claims received due to the September 2012 event amounted to 1844, with a total of €5,073,000 worth of damages (residential: €1,057,000; commercial: €3,259,000; pleasure craft: €81,000; motor: €640,000). These various categories reflect the type of incidents encountered during the event, which ranged from flooding, strong winds, to storm surges and rough seas.

Similarly, the damage total of €4,341,000 claimed for the January 2013 event (made up of 2,763 claims) can be subdivided into the following categories: Residential: €427,000; Commercial: €441,000; pleasure crafts: €1,687; motor: €3,472,000.

This data does not include any indirect losses or damages related to non-market goods and services, and therefore the costs identified here are an underestimation of the full economic impact of these three extreme events. Moreover, a degree of artificiality is assumed in the case of the November 2011 reports compiled by farmers who were in need of external financial assistance.

The results also show that between 2012 and 2013 the economic 'shocks' caused by similar convective weather extremes and economic impact (% GDP; table 1) have been somewhat dampened by increased wealth. Yet, in spite of Malta's small economy, the insurance losses in terms of %GDP estimated for these three case studies, are close to other major European disasters, such as windstorms 'Kyrill' (Germany, 2007; 0.09% of GDP; CEA, (2009)), and 'St. Jude' (UK, 2013; 0.01% of GDP; Willis Re, (2013)). If in the future adaptation measures are put into place, then the effects of such shocks are likely to become more temporary, with a short turnaround period in different sectors of the economy after their occurrence.

The analysis of just three extreme weather events is however, not enough to identify a trend resulting from climate change. On a wider geographical scale however, Hoeppe (2016) describes how the observed increases and variability of similar losses can be correlated with changes in the meteorological potential for severe thunderstorms, where the main driver of these changes have been changes in the humidity of the troposphere. In Europe, the largest annual aggregated losses registered between 1980 annd 2014 have reached about €7.5bn with a significant increase of the number of events ($p<0.001$) by a factor of 4. Moreover, a shift from about 30 events per year to about 120 between has been observed. The largest convective losses worldwide have occurred in 2013 when a large hail storm hit Germany, resulting in an overall loss of €3.6bn and insured losses of €2.8bn (equivalent to 0.1% of Germany's GDP in 2013).

On the contrary, Neumayer & Barthel (2011) observed no significant upward trends in global disaster damage over the period 1980-2009, suggesting that it may be still far too early to detect such a trend even though they are expected to gain momentum over time. Mohleji and Pielke (2014) are also of the same opinion. Crompton et al. (2011) concluded that an anthropogenic climate signal will not be identifiable in US tropical cyclone losses for another 120-550 years and urged extreme caution in attributing global weather-related natural disasters losses in the near future to anthropgenic climate change. Bouder et al. (2007) points to issues related to data quality, low frequency of extreme event impacts, limited length of time series, and various societal factors present in the disaster loss record (including lack of indirect costs) as factors that are not helping in the determination of such damages. This is likely to remain unchanged in the near future.

Weather trends and return periods

Maximum hourly rainfall rate

In figure 4, the cumulative deviations from the mean of the maximum hourly rainfall for the full time series 1959-2015 (n=52). In this graph the vertical axis was rescaled and lines presenting various probabilities with which the homogeneity of the data can be rejected. Since the values fluctuated around zero and are far off from the lines where homogeneity is rejected, the data of the time series is homogenous (at 99% CL) with no breakpoints.

Figure 4. Homogeneity test for the time series of hourly maximum rainfall rate for Luqa Airport (Malta, WMO Climate Station: 16597) for the period 1959-2015. Data homogeneity is acceptable at 99% CL. Data for 2006 and 2007 are missing from dataset.

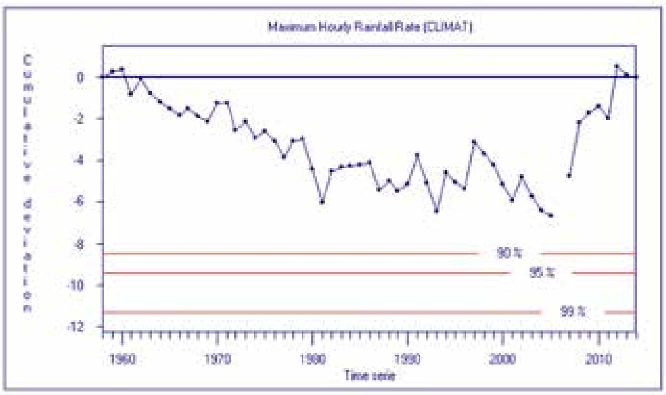
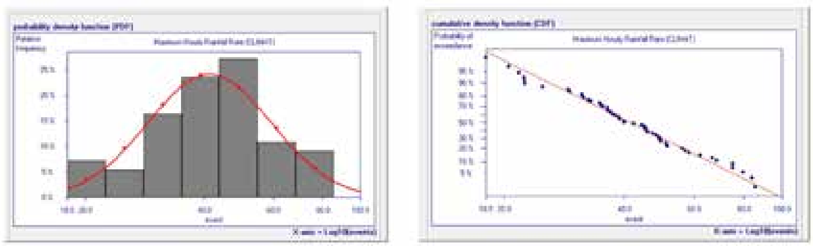


Figure 5 is the probability plot (PDF and CDF) of the maximum hourly rainfall rates versus their probabilities of exceedance. The scale of the event was transformed to log10 for best and most significant distribution at 95% level with an R-square of 0.98.

The extreme 2012 rainfall event showed an hourly rainfall rate of 84 mm hr-1. By plotting the value on the probability plot (Figure 5b), it is evident that the event was indeed the second highest throughout Malta's record period for this parameter. The return periods are shown in table 2. Statistically, the return period to reach or exceed the 2012 maximum hourly rainfall rate record is estimated to be around 41 years under current climatic conditions.

Figure 5a-b. Probability and cumulative functions (PDF and CDF; both significant at 5% level) of the maximum hourly rainfall rate for Luqa Airport (Malta, WMO Climate Station: 16597) on log10 probability for the period 1959-2014, with the highest hourly rainfall rate of 84 mm hr-1 recorded during the September 2012 event. Distribution of both PDF and CDF are acceptable at 95% CL.



(a) Probability density function of maximum hourly rainfall rate. *(b) Cumulative density function of recorded maximum hourly rainfall.*

Probability density function of maximum hourly rainfall rate.
Cumulative density function of recorded maximum hourly rainfall.

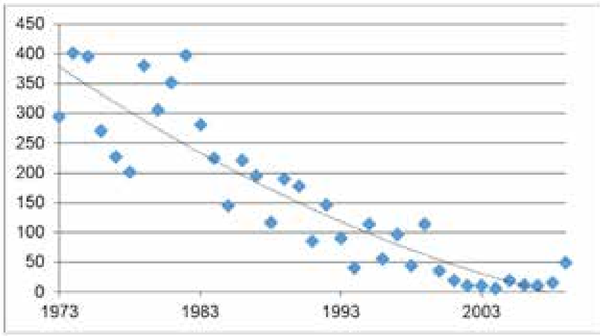
Table 2. Estimated hourly maximum rainfall rate for Luqa Airport (Malta, Climate Station: 16597 WMO) for selected probabilities and return periods from the probability plot (fig. 5).

Probability of exceedance (%)	Hourly rainfall rate (mm hr^{-1})	Return period (years)
1	95.8	100
2	86.8	50
5	74.9	20
10	65.6	10

Extremes of hail

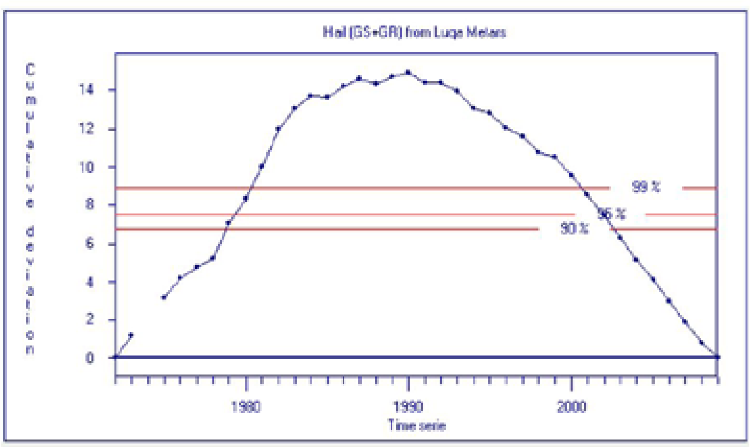
The total number of occurrences with hail during the period 1973-2009 is seen to be generally on the decline (Figure 6). The annual records varied between 400 (1974) and 5 events (2004). The average number of hail events for this 37-year period is 155.4 per year. The negative trend (which is significant at 0.05 CL) however, potentially reflects Malta's changing climate.

Figure 6. Total number of hail events recorded at Luqa Airport (Malta; WMO Climate Station 16597) for the period 1973-2009.



A shift is detected in the number of yearly hail occurrence throughout the study period. The homogeneity test shows a clear change of slope in the year 1990 (Figure 7). Over the period 1973-1990 the total number of yearly hail events was above normal while over 1991 – 2009, the opposite pattern can be observed. It is important to note that the estimation method remains the same for both periods. This is the best available local data we have for the occurrence of this meteorological phenomenon.

Figure 7. Rescaled cumulative deviation from the mean for the total number of yearly hail events for Luqa Airport (Malta. WMO Climate Station: 16597) for the period 1973-2009. The horizontal lines represent the 90, 95, and 99% probability at which the homegeneity of the data is rejected. (N=36; one outlier removed).



The reference period 1973-2009 can be therefore split up into two statistically significant periods different in their means: 1973-1990 with a mean of 265 hail events and 1991-2009 with a mean of 51 events. The jump in the mean between the years 1990/1991 separates the two periods. Based on best probability plot (R-Square=0.93), the return periods of occurrences of hail (and therefore a higher probability to record extremes) are shown in Table 3.

Table 3. Estimated return period of number of hail events for Luqa Airport (Malta, Climate Station: 16597 WMO) for selected probabilities and return periods derived from the probability of exceedance plot.

Probability of exceedance (%)	Yearly occurrence of hail	Return period (years)
1	451	100
2	*417*	*50*
5	365	20
10	318	10
20	262	5

The estimate return periods of between 50 and 65 years must be considered with caution. According to the official definition given by IPCC (2007), climate change is a change observed over a time period of 30 to 50 years or longer, and the time series used to derive the return periods might not contain a strong enough climate signal of such change (what Goodwin & Wright (2010) identified as a 'sparse' reference class for a typically 'chaotic' weather process). Moreover, being based on past values and records, statistically-derived return periods are mathematically possible on the assumption that the variability between past and future data sets remains stationary and that future time series will reveal frequency distributions similar to the observed ones. As the number of observations gradually increases, the error in determining expected return periods diminishes. Overall however, a period of 30 years and over is usually deemed to be very satisfactory for climate studies.

Conclusions

This chapter analysed the monetary impacts arising from direct damage to local infrastructure, property and services following three of the most recent weather-triggered convective events in the Maltese islands. It contributes unique research attempt to calculate the local economic losses due to weather-induced extreme events with an average return period of 58 years.

These results are tentative, but they indicate a research priority. Locally, empirical work on adaptation to future extreme events is scarce. This provides no reason for complacency. For the debate on climate change and its predicted increased occurrence of extreme weather events, our results should become part of an overall cost-benefit analysis on whether to increase or not our economic resilience by introducing certain adaptation measures. For example, more work is needed to ascertain future trends upon which appropriate adaptation strategies can be tailored. This paper has limited itself to empirical studies of the economic impacts of a select number of convective events. Parallel reviews of modelling studies, engineering estimates, case studies, and impacts of disasters on socio-political and health outcomes would be useful complements to this work. It also calls for actionable research by our local climate research community to make available tailored information and knowledge to strengthen the link between weather and disasters (van der Hurk et al., 2016). Such information is a rich source of inspiration to increase society's resilience to an unknown future.

Acknowledgements

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CHAPTER 11

Compliance of the Maltese Air Monitoring Network with the National and European Air Quality Legislation

Francesca Tamburini and Ines Munoz Sanchez

Introduction

This article summarises the results of an evaluation performed to the air monitoring network of Malta in 2012 where the following elements were evaluated in comparison with national and European legal requirements: the classification of zones and agglomerations in the island, the number, type and location of fixed monitoring stations, the data reporting and the reference methods used for the analysis of parameters.

Legislation Framework

The Directive 2008/50/EC is the most important European law together with the Directive 2004/107/EC relating the Arsenic, Cadmium, Mercury, Nickel and Benzo(a) pyrene that remains in force. Directive 2008/50/EC provides common standards and standardiseised measurement techniques at European level for the assessment of air quality and establishment of different zones that help identify dimensions and characteristics of ecosystems and populations subject to air pollution and also to predict magnitude and duration of exposure. The limit and target values for the concentration of ozone have not changed from Directive 2002/3/EC. The Maltese national legislation on air quality and emission control of pollutants transposes both European Directives to the Maltese regulation L.N. 478/2010.

The law is structured by defining three groups of pollutant which respectively correspond to:

- Group A of pollutants: pollutants of Directive 2008/50/EC except ozone (meaning sulfur dioxide, nitrogen dioxide and oxides of nitrogen, particulate matter (PM10 and PM2.5), lead, benzene and carbon monoxide;)
- Group B of pollutants: pollutants regulated by Directive 2004/107/EC except polycyclic aromatic hydrocarbons (Arsenic, Cadmium, Nickel and Benzo(a) pyrene;)
- Group C of pollutants: polycyclic aromatic hydrocarbons regulated by 2004/107/CE.Theme i / II, etc

Air Monitoring Network in Malta

The ambient air monitoring in Malta is formed by two networks: fixed stations (Gharb, Msida, Zejtun, Kordin and Attard) and diffusion tubes (about 134 monitoring sites). Figure 1shows the spatial locations of all the sampling points. Both the networks are managed by MEPA (i.e. Air Quality Unit) which is constituted by an air quality manager and four technicians.

The current network was analysed and compared the minimum requirements of representativeness (number and location of sampling stations, pollutants monitored, delineation of agglomeration, data capture and reference methods) established by the L.N.478/2010. The methodology and results of this evaluation is detailed in the sections below.

Maltese Agglomeration and Zone Classification

Based on the first requirements established by the Directive 2008/50/EC, as well as by the L.N. 478/2010, the competent authority shall divide the entire territory in zones and agglomerations. In Malta, this assessment was performed by Stacey and Bush (2002) and published in August 2002 through the document Preliminary Assessment of Air Quality in Malta, which complies with the legislation that was in force at the time (Council Directive 96/62/EC and subsequent Daughter Directives).

To delineate the agglomeration, Stacey and Bush (2002) applied a 100 m buffer around all the continuous urban areas present on the Maltese islands, in such a way that, the urban areas distant from each other more than 200 m, will not be encountered within the main agglomeration.

Stacey and Bush finally identified two main distinct zones in Malta:

- Valletta and Sliema agglomeration that include the main urban and industrial centres present in Malta
- Maltese zone: the rest of the territory not falling under the agglomeration

The Figures 1 and 2 show the classification performed by Stacey and Bush in 2002.

Figure 1: Urban areas with an indication of the 100m buffer zone made by Bush and Stacey for the identification of the main agglomeration

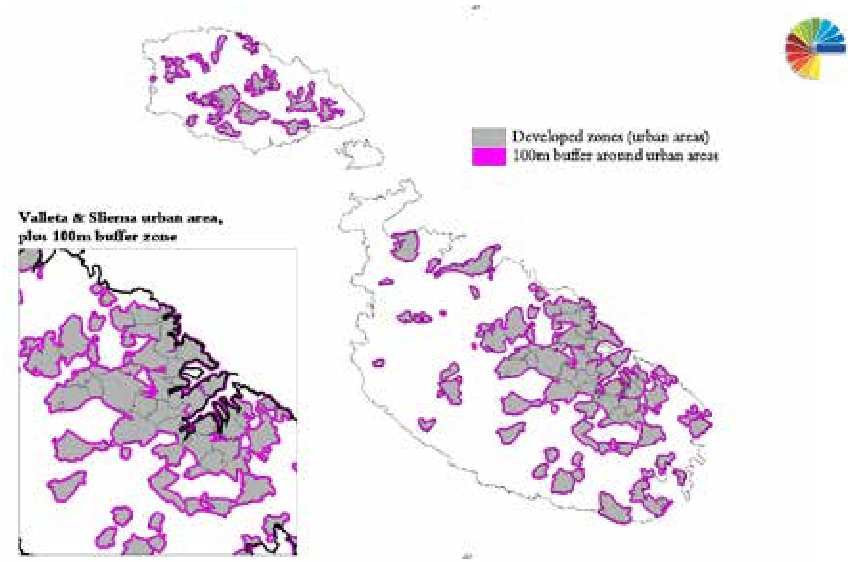
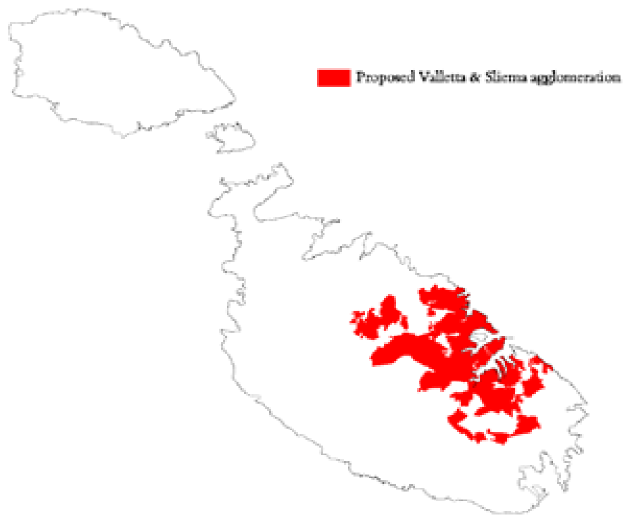


Figure 2: Final extension of the Valletta & Sliema agglomeration



Source: Stacey & Bush, (2002)

Type and Number of Stations

According the European Directives, there are two variables that determine the type of station to be established: type of area and emission

Type of area:

- Urban area: continuously built-up meaning complete (or at least highly predominant) building-up of the street front side by building with at least two floors;
- Suburban: largely built-up urban area. 'Largely built-up' is defined as contiguous settlement of detached buildings of any sise with a building density less than for 'continuously built-up' area; and
- Rural area: all areas that do not fulfil the criteria for urban or suburban areas. Rural areas can be subdivided further, based upon the distance to major sources or source areas:

o Near city area: within 10km from the border of an urban or suburban area (there is one only found in Malta);
o Regional area: 10-50 km from major source areas; and
o Remote area: >50 km from major source areas.

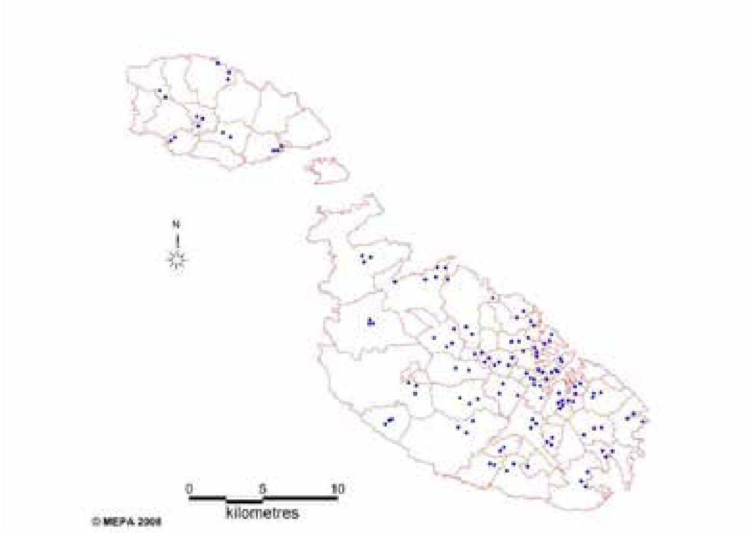
Types of station in relation to dominant emission sources:

- Traffic: located such that its pollution level is determined predominantly by the emission from nearby traffic (roads, motorways, highways);
- Industrial: located such that its pollution level is influenced predominantly by the emission from nearby single industrial sources or industrial areas with many sources; and
- Background: located such that its pollution level is not influenced significantly by any single.

The actual Maltese fixed stations network is based on the preliminary air quality study made by Stacey and Bush in 2002 and analysed during the project 'Developing National Environmental Monitoring Infrastructure and Capacity'. The classification, performed by Stacey and Bush in 2002, was based on data obtained on indicative measurements obtained from short term automatic campaigns, which took place in 21 traffic stations by using mobile laboratories between 1999 and 2001 and from the results of diffusive samplers campaign carried out between 2000 and 2001 in 28 different types of stations (traffic, urban, urban background).

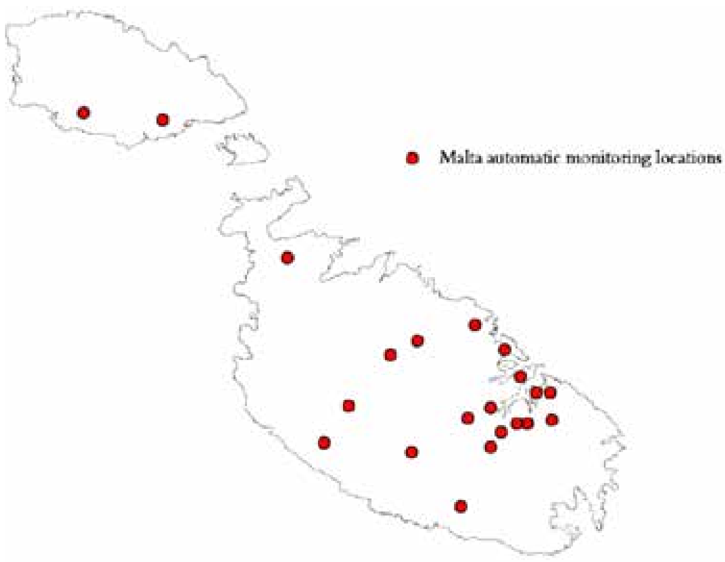
The locations of the indicative measurements and diffusion tubes are shown in the Figures 3 and4.

Figure 3: Malta diffusion tube network



Source: Mepa.org.mt, 2017

Figure 4: Malta automatic monitoring locations



Source: Stacey & Bush, (2002)

The results of the monitoring campaigns are summariseised below:

- Nitrogen dioxide: Exceedances of the Upper Assessment Thresholds (UAT) were obtained both from the diffusion tubes campaigns, (annual averages) and from the automatic monitoring (hourly averages) in the Maltese Zone and in the Valletta & Sliema Agglomeration. According to the legislation in force at that time, monitoring of nitrogen dioxide for the protection of human health was necessary in both the zones. Precisely, the recommendation results from this preliminary assessment were:
  - Two fixed NO2 monitoring stations are required within the Valletta and Sliema agglomeration; and
  - One fixed NO2 monitoring station is required within the Malta zone.
  - Benzene: Exceedances of the Upper Assessment Threshold (UAT) were obtained both from the diffusion tubes campaigns, (annual averages) and from the automatic monitoring (hourly averages) in the Maltese Zone and in the Valletta & Sliema Agglomeration. According to the legislation in force at that time, monitoring of benzene dioxide for the protection of human health was necessary in both the zones. Precisely, the recommendation results from this preliminary assessment were:
  - Two fixed Benzene monitoring stations are required within the Valletta and Sliema agglomeration; and
  - One fixed Benzene monitoring station is required within the Malta zone.
- Sulphur dioxide: Exceedances of the UAT were obtained only in the agglomeration and only from the automatic monitoring data since the limit value for this pollutant was based on the hour concentration; because of this, the diffusion tubes could not be used for this assessment. However, high concentration values were also measured in the Maltese Zone, on an annual basis, by using the diffusion tubes. The conclusion of this assessment suggested that, for the protection of human health, monitoring of this pollutant was necessary in both zones. Precisely, the recommendation results from this preliminary assessment were:
  - Two fixed SO2 monitoring stations are required within the Valletta and Sliema agglomeration; and
  - One fixed SO2 monitoring station is required within the Malta zone at a point identified as the location of maximum ground level concentration arising from Marsa power station.
- PM10: Exceedances of the UAT were obtained from the automatic monitoring station through the automatic beta-attenuation technique. Exceedances were recorded both in the Maltese zones and in the Valletta & Sliema Agglomeration. The recommendation results from this preliminary assessment were:

  - Two fixed PM10 monitoring stations are required within the Valletta and Sliema agglomeration; and
  - One fixed PM10 monitoring station is required within the Malta zone at a point identified as the location of maximum ground level concentration arising from Marsa power station.
- Lead: the necessity to monitor lead was estimated according to the Maltese inventory of pollutant emission, since data on this pollutant was not available at that time. A pro capita rate of lead emission was estimated and it resulted 300% greater than the rate estimated in UK. Moreover, the presence of many emission sources for lead (e.g. prevalence of cars fuelled by leaded petrol), recommended to install monitoring sites in both Valletta & Sliema Agglomeration and Maltese Zone. The conclusions of this assessment were:
  - Two fixed lead monitoring stations are required within the Valletta and Sliema agglomeration; and
  - One fixed lead monitoring station is required within the Malta zone.
- Carbon monoxide: Exceedances of the UAT were obtained, by using automatic infrared absorption monitor, in Valletta and Sliema agglomeration. However, the Maltese inventory of emissions showed a pro capita rate of emission of the pollutant greater that the rate recorded in the rest of Europe and particularly in UK. Thus, considering also the lack of long-term fixed monitoring within the Malta zone, it is proposed that, monitoring for the protection of human health is also required within this zone. The conclusions of this assessment were:
  - Two fixed CO monitoring stations are required within the Valletta and Sliema agglomeration
  - One fixed CO monitoring station is required within the Malta zone
- Ozone: From the indicative measurements provided by the diffusive sampler network, this assessment concluded that, given the magnitude of the annual average data measured, an exceedance of the Long-Term Objective (LTO) for ozone (8-hour average) is possible within both in the Valletta and Sliema agglomeration and the Malta zone. So, the Ozone monitoring was considered necessary in both the zones:
  - One fixed ozone monitoring stations is required within the Valletta and Sliema agglomeration at an urban background/suburban location; and
  - One fixed ozone monitoring station is required within the Malta zone at a suburban or rural location.

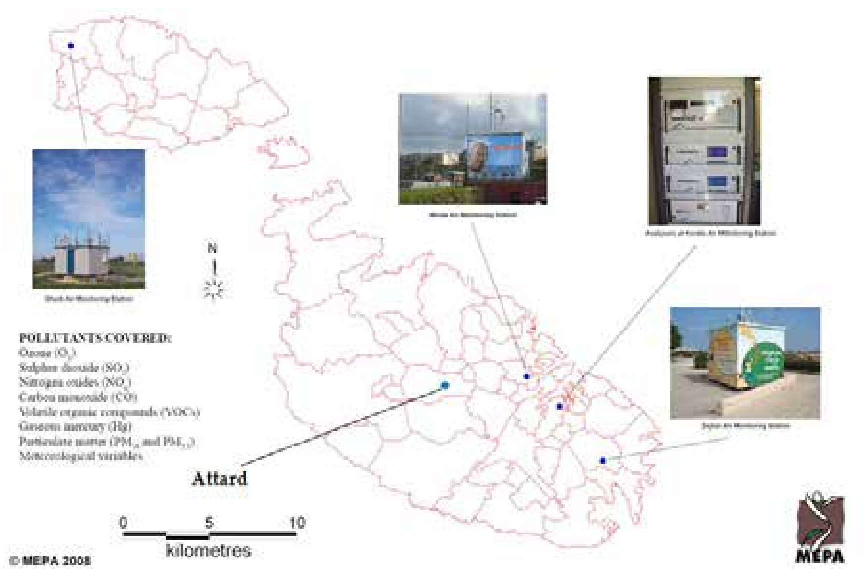
In accordance with the preliminary assessment study recommendations, suitability for installation and own judgment, MEPA identified five locations where to install fixed real-time monitoring stations. Tables 1 to 3 report the classification of each station according to the Directive 2008/50/EC and the monitored parameters.

Table 1: Classification of the real-time monitoring stations in Malta

	NAME OF THE STATION	*CLASSIFICATION OF STATIONS*
VALLETTA/SLIEMA AGGLOMERATION	Msida	Traffic location
	Żejtun	Suburban background
	Attard	Urban background
	Kordin	Urban industrial: (Point of max ground level concentration for plume from Marsa power station)
MALTA ZONE	Għarb	Rural background

Source: Stacey & Bush, (2002)

Figure 5: Location of the real-time monitoring stations in Malta



Source: Mepa.org.mt, 2017

Table 2: Monitored parameters at Valletta & Sliema Agglomeration

Żejtun *Monitored parameters*	***Attard*** *Monitored parameters*
PM_{10} and $PM_{2.5}$	O_3
SO_2	
NO-NO_2-NO_x	
O_3	
CO	
Metals (Ni, Cd, Pb, As)	
Metal (Hg)	
VOC	
PAHs	
Msida *Monitored parameters*	***Kordin*** *Monitored parameters*
PM_{10} and $PM_{2.5}$	PM_{10}
SO_2	SO_2
NO-NO_2-NO_x	NO-NO_2-NO_x
O_3	O_3
CO	CO
Metals (Ni, Cd, Pb, As)	Metals (Ni, Cd, Pb)
VOC	
PAHs	PAHs

Source: Mepa.org.mt, 2017

Table 3: Monitored parameters at Maltese Zone

Gharb *Monitored parameters*
PM_{10} and $PM_{2.5}$
SO_2
NO-NO_2-NO_x
O_3
CO
Metals (Ni, Cd, Pb)
Metal (As)
Ions
EC and OC
VOC

Source: Mepa.org.mt, 2017

Air Quality Assessment, Data Capture and Minimum Number of Sampling Points required

According to Regulation 8(2) of L.N.478/2010 "classification of the zones shall be reviewed at least every 5 years", Malta might not be in full compliance with the legislation requirements, however the following aspects have to be considered:

- The population of the Valletta & Sliema agglomeration and Maltese zone has been estimated in 2011 to be well below the threshold of 250,000 inhabitants (source MEPA personal communication) ; and
- The number of fixed stations are more than the minimum requirements for the current population, even considering the worst case scenario (max. concentrations > UAT).

In order to optimise the Maltese air monitoring network, a preliminary analysis of the pollutant levels measured by all the fixed stations in the past 5 years (2008 – 2011) was performed, as required by the law.

The main consideration, after this preliminary evaluation of the data collected by all the fixed stations, is that the minimum data capture, as defined by the directive for each pollutant, is almost never reached.

Table 4 depicts the respective thresholds for measurements in fixed sites are listed:

Table 4: Minimum data capture for the pollutants monitored

Compound	*Data capture (%)*
Sulphur dioxide	90
Nitrogen oxides	90
Carbon monoxide	90
Benzene	90
PM10 and PM2.5	90
Ozone	90 (summer) and 75 (winter)
Benzo[a]pyrene	90

Source: Mepa.org.mt, 2013

During the period 2008-2011, the percentage of valid data was calculated for each pollutant specified in the Directives.

Table 5: Data Capture by station between 2008-2011)

	Year	*PM10*	*PM2.5*	*NO2*	*SO2*	*Benzene*	*CO2*
GHARB	2008	85%*	89%*	89%*	97%	74%*	61%*
	2009	38%*	28%*	76%*	76%*	55%*	42%*
	2010	89%*	81%*	84%*	90%	76%*	95%
	2011	96%	93%	97%	87%*	84%	49%*
MSIDA	2008	65%*	83%*	33%*	65%*	64%*	72%*
	2009	86%*	86%*	56%*	81%*	89%*	86%*
	2010	93%	81%*	86%*	60%*	63%*	40%*
	2011	73%*	79%*	90%	53%*	63%*	79%*
ŻEJTUN	2008	42%*	27%*	21%*	64%*	69%*	48%*
	2009	88%*	67%*	-	63%*	86%*	58%*
	2010	88%*	86%*	-	75%*	69%*	4%*
	2011	61%*	87%*	90%	25%*	-	87%*
KORDIN	2008	-	89%*	-	-	-	-
	2009	50%*	28%*	49%*	42%*	-	69%*
	2010	11%*	81%*	69%*	39%*	-	63%*
	2011	49%*	93%	96%	60%*	66%	93%

Source: Mepa.org.mt, 2013

Table 6: Ozone data captures in the fixed stations over the period 2008-2011

Ozone		
	Year	*% Valid data*
GHARB	2008-2010	90%
MSIDA	2008-2010	90%
MSIDA	2009-2011	80%*
ŻEJTUN	2008-2010	92%
ŻEJTUN	2009-2011	81%*

Source: Mepa.org.mt, 2013

As can be noticed from Tables 5 and 6, the minimum data capture was not met for the majority of the pollutants, and in some cases, the percentage of valid data was very low (When the minimum data capture is not reached, the value is marked with an upper asterisk). Nonetheless, it is noticed a good improvement of the number of valid data in the last few years, especially in 2011. This consideration cannot be done for group B pollutants since no data are available for 2011.

However, analysis of the LAT, UAT and LTO was carried out in the Table 7 to have at least an indicative overview of the air quality in Malta in the most recent period

Table 7: Summary classification of zones and agglomerations on the basis of Lowest Assessment Threshold (LAT)T and UAT

	VALLETTA & SLIEMA AGGLOMERATION	*MALTESE ZONE*
GROUP A		
SO2	< LAT	< LAT
NO2	>UAT	< LAT
PM10	>UAT	>UAT
PM2,5	>UAT	LAT<value<UAT
PB	< LAT	< LAT
BENZENE	LAT<value<UAT	< LAT
CO	< LAT	< LAT
GROUP B	< LAT	< LAT
OZONE	>LTO	>LTO

Source: Mepa.org.mt, 2013

From Table 7, a compliance analysis is carried out to evaluate whether the minimum sampling points requirement is actually fulfilled or not (Table 8) Considering the poor dataset obtained from the fixed stations in the past 5 years, the worst case scenario was taken, i.e. the UAT are exceeded for all the pollutants in both zones. The other input information for the determination of the minimum number of fixed stations is the population, (is below the 250,000 inhabitants both in the Valletta and Sliema agglomeration and Maltese zone) in accordance with the last demographic survey performed in 2011 by MEPA.

Table 8: Comparison between the minimum numbers of sampling points (L.N.478/2010) and the fixed stations actually installed in Malta

	MINIMUM NUMBERS OF SAMPLING POINTS (NO2, NOX, SO2, BENZENE, LEAD AND CO)	*MALTA AIR MONITORING FIXED STATIONS*
VALLETTA & SLIEMA AGGLOMERATION	1	3
MALTESE ZONE	1	1

	Minimum numbers of sampling points PM[1] (sum of PM10&PM2.5)	*Malta air monitoring fixed stations[2]*
Valletta & Sliema agglomeration	*2*	*5*
Maltese zone	*1*	*2*

	Minimum numbers of sampling points[3]		*Malta air monitoring fixed stations*	
	As, Cd, Ni	*B(a)P*	*As, Cd, Ni*	*B(a)P*
Valletta & Sliema agglomeration	1	1	3	3
Maltese zone	1	1	1	0

Source: Mepa.org.mt, 2013

In the Maltese zone, there is no fixed station currently installed for benzo(a)pyrene monitoring but, as stated in the L.N.478/2010 that transposed Directive 2004/107/EC, this monitoring can be carried out even by random sampling provided the number of measurements is sufficient to enable the levels to be determined. According to this preliminary air quality assessment, the concentration levels of Group B pollutants are all below the LAT, except for Msida for Benzo(a)pyrene and Nickel in one year. However, considering the low data captures that do not allow a complete assessment and assuming the worst case scenario (concentration of at least one group B pollutant above UAT), Malta would need only one fixed station for the entire country since the population is below 749,000 inhabitants (as established in the Annex 3 section 4 of the Directive 2004/107/EC).

Location of Sampling Points

The fixed stations' locations, in addition to be in compliance with the minimum number of monitoring sites for all the pollutants within the agglomerations or zones, shall be in compliance with the criteria for macroscale and microscale locations of the sampling.

Criteria for location of the sampling points on a macro-scale

Group A pollutants

The first macro-scale siting criteria for Group A pollutants are the following (Schedule 3 part b-1 of L.N. 478/2010).

Sampling points directed at the protection of human health shall be sited in such a way as to provide data on the following:

- The areas within zones and agglomerations where the highest concentrations occur to which the population is likely to be directly or indirectly exposed for a period which is significant in relation to the averaging period of the limit value(s); and
- Levels in other areas within the zones and agglomeration which are representative of the exposure of the general population.
- Within the Valletta & Sliema Agglomeration
- Near Msida station, the population is mainly exposed to vehicular traffic pollution;
- Near Kordin station, the resident population is mainly exposed to pollutants derived from the presence of many industrial activities in the surrounding zone; besides this station has been chosen to monitor the max ground concentration of pollutants derived from Marsa power station; and
- Attard e Żejtun stations are urban background stations which means that its pollution level is not influenced by any single source or street, but rather by the integrated contribution from all sources upwind of the station (source Guidance

on the Annexes to the Decision 97/101/EC as revised by Decision 2001/752/EC, released by EC in 2002). Thus, this station represents well the average pollution level in the identified zone or agglomeration.

Thus, the fixed stations in the agglomeration are in compliance with the criteria mentioned above.

The situation is different in the Maltese Zone, where Għarb represents better the air quality in a rural background zone and thus it mainly assesses the background level of the different pollutants away from relevant pollution sources, but it is not representative of the maximum levels of concentration to which the population of the Maltese zone is exposed. However, as already explained previously, Żejtun station can well represent the average exposure of the population living in the main centres of the Maltese zone to the main air pollutants.

Group B pollutants

The Group B pollutants are monitored in 4 fixed stations (Għarb, Msida, Kordin and Żejtun) and furthermore MEPA performs spot campaigns to detect metal concentrations in different zones. This implies that Malta is more than complaint with the monitoring requirements even considering that the criteria for macro-scale localization are similar to those for Group A and thus considerations expressed above are valid.

The only differences are related to the monitoring station at the traffic-oriented site which must be representative of a 200m2 instead of 100m length of a street segment. The station in Msida can be considered a well representative monitoring station also for metals and B(a)P.

Besides, Group B pollutants are monitored in correspondence with sampling points for PM10, as recommended by the L.N. 478/2010.

Thus, it can be affirmed that the Group B pollutants respect all the criteria for macroscale siting.

Ozone

Regarding Ozone, the following classification for the determination of the different territorial zones and agglomerations should be followed (Table 9):

Table 9: Criteria for classifying and locating sampling points for assessments of ozone concentrations

Macroscale siting

Type of station	Objectives of measurement	Representativeness (1)	Macroscale siting criteria
Urban	Protection of human health: to assess the exposure of the urban population to ozone, i.e. where population density and ozone concentration are relatively high and representative of the exposure of the general population	A few km^2	Away from the influence of local emissions such as traffic, petrol stations, etc.; vented locations where well mixed levels can be measured; locations such as residential and commercial areas of cities, parks (away from the trees), big streets or squares with very little or no traffic, open areas characteristic of educational, sports or recreation facilities
Suburban	Protection of human health and vegetation: to assess the exposure of the population and vegetation located in the outskirts of the agglomeration, where the highest ozone levels, to which the population and vegetation are likely to be directly or indirectly exposed occur	Some tens of km^2	At a certain distance from the area of maximum emissions, downwind following the main wind direction/directions during conditions favourable to ozone formation; where population, sensitive crops or natural ecosystems located in the outer fringe of an agglomeration are exposed to high ozone levels; where appropriate, some suburban stations also upwind of the area of maximum emissions, in order to determine the regional background levels of ozone
Rural	Protection of human health and vegetation: to assess the exposure of population, crops and natural ecosystems to sub-regional scale ozone concentrations	Sub-regional levels (some hundreds of km^2)	Stations can be located in small settlements and/or areas with natural ecosystems, forests or crops; representative for ozone away from the influence of immediate local emissions such as industrial installations and roads; at open area sites, but not on summits of higher mountains
Rural background	Protection of vegetation and human health: to assess the exposure of crops and natural ecosystems to regional-scale ozone concentrations as well as exposure of the population	Regional/ national/ continental levels (1 000 to 10 000 km^2)	Station located in areas with lower population density, e.g. with natural ecosystems, forests, at a distance of at least 20 km from urban and industrial areas and away from local emissions; avoid locations which are subject to locally enhanced formation of ground-near inversion conditions, also summits of higher mountains; coastal sites with pronounced diurnal wind cycles of local character are not recommended.

(1) Sampling points should, where possible, be representative of similar locations not in their immediate vicinity.

Source: Council Directive 2008/50/EC. Annex VIII

Table 10 reports the minimum number of sampling points for Ozone according to the different types of zone classification.

Table 10: Minimum number of sampling points for fixed measurements of ozone

Table 10: Minimum number of sampling points for fixed measurements of ozone

Population	*Agglomerations (urban and suburban)*	*Other zones (suburban and rural)*	*Rural background*
< 250,000	0	1	1 station /50,000 Km^2

Source: Council Directive 2008/50/EC. Annex IX

All the 5 fixed stations are monitoring Ozone concentration and there are 2 urban stations (Kordin and Attard), 1 suburban background (Żejtun), 1 rural background (Għarb) and 1 urban traffic station (Msida). This latter is not included in the 4 types of station as defined in table 9 because it is located very close to traffic emissions which represent a characteristic to avoid when measuring ozone concentrations.

Zejtun station has been classified as suburban location following the Ozone criteria established in the Annex VII of the Directive 2008/50/EC (see and Table 10). The Directive for Malta (population below 250,000 inhabitants) imposes to install, since the Long term objective is not achieved in both the agglomeration and zone, at least one suburban and one rural background location, this latter requirement is achieved by the Gharb measurements. Thus, the Maltese fixed monitoring network results in compliance with the minimum requirements laid down in the Directive 2008/50/EC.

Criteria for location of the sampling points on a micro-scale

The criteria for Group A, B and Ozone are reported below:

- The flow around the inlet sampling probe shall be unrestricted (free in an arc of at least 270°) without any obstructions affecting the airflow in the vicinity of the sampler (normally some metres away from buildings, balconies, trees and other obstacles and at least 0,5 m from the nearest building in the case of sampling points representing air quality at the building line);
- In general, the inlet sampling point shall be between 1,5 m (the breathing zone) and 4 m above the ground. Higher positions (up to 8 m) may be necessary in some circumstances. Higher siting may also be appropriate if the station is representative of a large area;

- The inlet probe shall not be positioned in the immediate vicinity of sources in order to avoid the direct intake of emissions unmixed with ambient air; and
- The sampler's exhaust outlet shall be positioned so that recirculation of exhaust air to the sampler inlet is avoided.

All the current monitoring stations comply with the criteria mentioned above, as san be seen in Figure 7.

Figure 7: Monitoring Stations

Source: www.mepa.org.mt. (2013)

There are no obstacles that can influence the correct air flow sampling, and, in all cases the nearest buildings are located at adequate distances from the sampling probe. Moreover, there are no pollution sources in proximity of the inlet of the air flow. At the Żejtun, Għarb and Msida stations the heights of the sampling inlets comply with the established requirement (i.e. distance from the ground must be between 1.5m and 4m). In Kordin, the sampling inlet is located at a height of about 10m. However, Kordin is representative of a large industrial area (which includes the Marsa power station) and thus this height from the ground is justified by the micro-scale criteria.

Reference Methods

The reference methods to determine the concentrations of the pollutants listed in the Directive 2008/50/EC ("ambient air quality and cleaner air for Europe") and Directive

2004/107/EC (relating to Arsenic, Cadmium, Mercury Nickel and PAHs) are reported table 11 that reports whether the analyser is in compliance with the EU reference method (green cell) or not (red cell). Compounds that require both field sampling and laboratory analysis are divided in two phases. In case there is no reference method specified in the EU Directive, it is reported whether the chemical analysis is accredited (blue cell) or not (yellow cell). As shown in this table, the lack of compliance is only for the PM samplers.

The automatic instruments used by MEPA to measure PM concentrations work with different monitoring techniques (Beta ray attenuation and TEOM-FDMS) compared with the reference method (gravimetric method). These two monitoring techniques measure PM concentration in with high precise and reliable results and in facts they have been proven to be equivalent to the reference methods in other Country. For example, Beta-Ray attenuation monitoring technique is demonstrated to be en equivalent method in Italy. However, the Directive 2008/50/EC requires the Member State to carry out their own demonstration of equivalence because this test can vary and give different results in each different Country.

Conclusion

Based on the air quality assessment carried out three pollutants have been identified to be the most significant in terms of potential health effects on population:

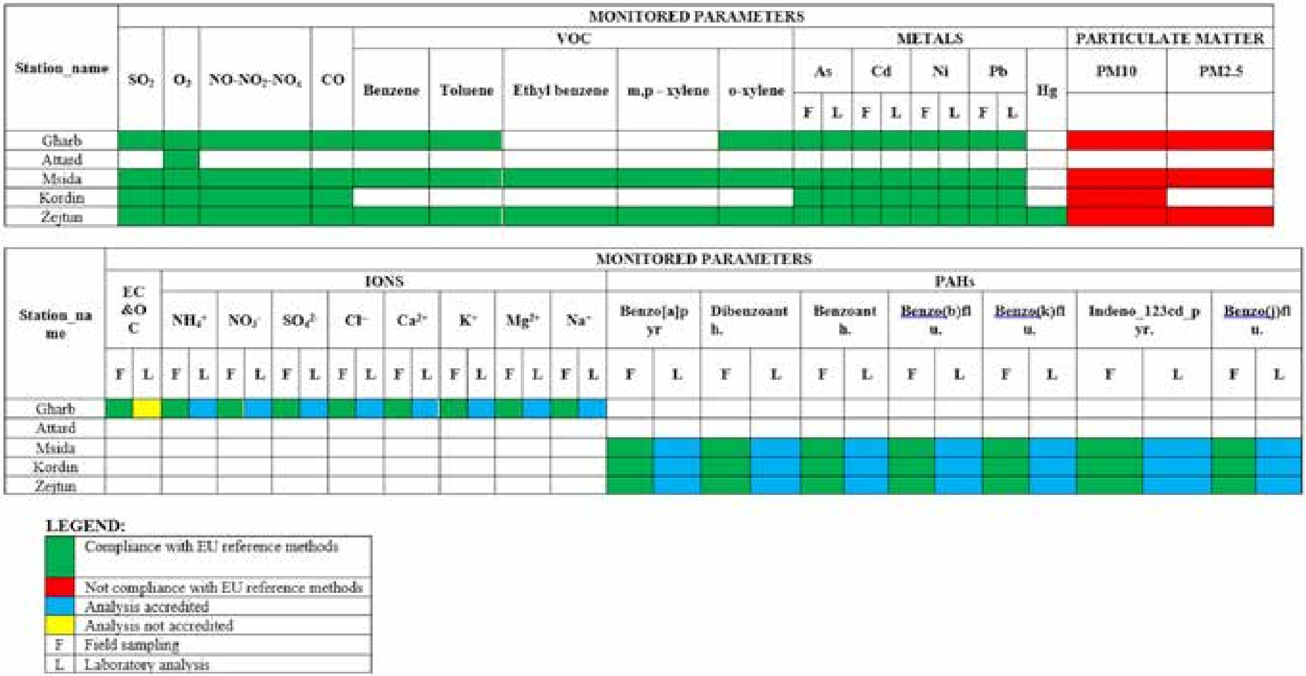
- Particulate Matter (both PM10 & PM2.5)
- NO2
- O3

These pollutants should be continuously monitored by reference instruments or equivalent and their measurements should meet the data quality objectives established by the L.N.478/2010.

The main issue found in the air monitoring networks is that the minimum data capture has not been achieved for many analysers in all the different fixed stations. Besides, the PM10 and PM2.5 automatic analysers currently installed in the fixed stations are not demonstrated to be equivalent for the site-conditions in Malta, and hence a demonstration for equivalence should be performed by an accredited body according to EN 17025.

For the rest, the Maltese fixed station network is in compliance with the monitoring requirements of the Directive 2008/50/EC regarding the sampling sites, pollutants monitored, sampling locations, zoning and air assessment of the zones or agglomerations.

Table 11: Overview of the pollutants monitored by MEPA real-time network. Source: Mepa.org.mt. (2013)



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CHAPTER 12

Deriving Hydrological Networks in the Maltese Islands for Flood Risk Assessments - A Comparative Study

Elaine Sciberras, George Buhagiar and Michael Schembri

Introduction

One of the most significant effects of urbanisation is the increase in impervious surface cover which reduces infiltration and increases runoff volume. Effective management of urban storm water runoff and water quality issues can only be accomplished once drainage area and flow networks are accurately identified (Parece and Campbell, 2014). Water resources cannot be properly managed unless their spatial distribution is known, in terms of quantity and quality, and how these variables are dependent on the parameters of periodic events, such as the intensity and duration of storms. Data from hydrological networks are used by public and private sectors for various applications, including planning of water management systems, the preparation and distribution of flood forecasts and warning systems, and the design of spillways, bridges and culverts (Stewart, 2015).

A good understanding of the hydrological functioning of suburban areas can contribute to reducing flood risks and improving the overall water management as natural land is urbanised (Jankowfsky, Branger, Braud, Gironas & Rodriguez, 2013). Reliable hydrological data and information are key inputs to the sound management of water resources. In particular, knowledge about the drainage system and contributing areas is relevant for drainage and storm water management (e.g. sizing and location of sewer pipes, and construction of hydrological models) (Jankowfsky et al., 2013). Furthermore, the quality and accuracy of data required for a specific hydrological application will depend on the requirements of the application area. For example, where there are life-threatening risks, greater confidence is required in the quality and accuracy of the data (Stewart, 2015).

Theoretical Issues

Deriving hydrological networks

Various methods have been used for the designation of watersheds and their respective water flow lines. On-the-ground surveys in an urban area produce a watershed boundary that is dissimilar to those of a natural watershed because they can account for grading and slope changes from impervious surfaces. However, such surveys cannot account for inflows or outflows due to storm water infrastructure. Furthermore, in large urban areas field surveys can be quite complex, expensive and disruptive to daily human activities (Parece and Campbell, 2014). Extensive research has been accomplished in modelling water flow with the introduction of Geographical Information Systems (GIS), (Rodriguez, Andrieu, & Morena, 2008).

Geospatial technologies include vector and raster analysis, the latter derived from aerial or satellite imagery. GIS techniques enable the user to analyse the spatial distribution of the hydrological data and to derive storm water networks through hydrological modelling. Nonetheless, ground assessments may still be necessary. This is particularly true in urban areas, where structures and landscaping, such as storm sewer networks and impervious surfaces, are designed to redirect water flow and create complex hydrologic geometries (Parece and Campbell, 2014).

Digital Elevation Models (DEMs) provide important datasets for hydrological analysis. DEMs can be used to produce critical topographic and hydrologic derivatives such as slope, aspect and flow accumulation. The accuracy of derived hydrological features is largely dependent on the quality and resolution of DEMs (Li, Tang, Li & Winter, 2013). DEMs may be derived from various height data sources in various forms and formats and can be represented as a raster or as a vector-based triangular irregular network (TIN). DEMs were traditionally acquired through techniques such as land surveying and photogrammetry with relatively coarse resolutions and low accuracies. As an emerging technology, Light Detection and Ranging (LiDAR) has been increasingly applied to produce a new generation of DEMs with higher resolution and accuracy based on laser technology.

LiDAR densely samples the ground surface and produces point clouds with highly accurate three-dimensional positions that can then be used to derive these high-resolution DEMs (Li et al., 2013). LiDAR is considered as a cost effective and accurate method of creating DEMs (Hill et al., 2000). LiDAR-derived DEMs possess higher horizontal and vertical accuracy thereby being more suitable to depict minor topographic variations that control surface water flow across low-relief landscapes (Jones, Poole, O'Daniel, Mertes & Stanford., 2008). For example, LiDAR-derived DEMs are capable of modeling low-order drainage lines and fine-scale headwater channels that were not present on topographic maps or even orthorectified aerial photographs (Li et al., 2013).

The combined use of DEMs and GIS has allowed the implementation of algorithms for automatic watershed delineation. The most commonly used is the d8 flow direction algorithm (O'Callaghan and Mark, 1984) in which the flow direction follows the steepest gradient towards one of eight neighbours. These algorithms are combined with routines to remove sinks, accumulate the flow, extract the stream network and delineate the watershed and subcatchments (Jankowfsky et al., 2013). However, since airborne LiDAR only reflects topographic features, the derived DEMs are topographic DEMs and drainage structures, such as culverts, underground pipes or areas below bridges cannot be detected (Jankowfsky et al., 2013). As a result, in such areas, the modelled water flow and flow accumulation over the land surface would not be an accurate representation of the on-site water flow during a storm event.

Collection of field data on drainage structures (culverts and bridges) has been found to be necessary for a more realistic hydrological modelling. Li et al. (2013) used such data to create hydrological breaklines to derive a hydrological DEM which allows surface flow through drainage structures that are generally unrepresented in a topographic DEM. Field verification for drainage structures is recommended along with DEMs derived from high resolution data such as LiDAR to estimate more reliable boundary and drainage areas in flat, low-gradient coastal plain landscapes (Amatya, Trettin, Panda & Ssegane, 2013).

The Maltese Scenario

The topography of the main island of Malta has a general West-East dip. The country does not have permanent rivers or streams and surface water runoff temporarily flows through valley systems that are completely dry throughout most of the year and are active only after heavy storm events. Urbanisation is most dense on the lower Eastern side of the islands and by time has encroached on the valleybeds of these natural valley systems with the building of roads and housing. Efforts to control urban sprawl in the last decades has further concentrated around these areas. Furthermore, flooding events in the Maltese Islands have become increasingly characterised by high intensity short duration rainfall events (Ministry for Sustainable Development, the Environment and Climate Change, 2013), which due to the inadequacy or absence of a storm water infrastructure, result in the accumulation of uncontrolled surface water runoff in areas where the valley channel has been urbanised.

This flow occurs for a very short period of time and is mostly concentrated in the valley channels which resume their original natural water conveyance function, irrespective of whether they have been urbanised or not. Fflood risks to life and property are most acute in those segments where the natural valley channel has been urbanised and developed into roads, which is a common situation. A Storm Water Master Plan (SWMP), commissioned in 2006, was aimed at providing sustainable solutions to local flood hazards and at establishing profitable multipurpose water utilisation systems (Tahal Group, 2008). During the SWMP, ten areas which are vulnerable to flooding due to uncontrolled surface storm water runoff were identified (Figure 1), with the largest watersheds (in decreasing size) being Marsa, Burmarrad, Birkirkara-Msida, Marsascala, Birzebbuga and Gzira.

Figure 1: Watersheds as designated in the STWP which are prone to flooding

Source: (Tahal Group, 2008).

Hydrological studies were carried out for each watershed using a rainfall-runoff application modelled on hourly and daily model rainfall inputs, as well as soil type and land use maps. A topographic map with 2.5 m interval contours was used to delimit the watershed area. Design discharge values were determined based on a 5-year storm with a duration of eight hours. Based on model output data engineering solutions, such various hydraulic structures were proposed to mitigate flood risks in areas susceptible to flooding. The Plan also provided alternatives for storm water harvesting from different catchments.

Proposals for a National Flood Relief Project (NFRP) were drawn up on the basis of more detailed technical and economic feasibility studies. The aim of the NFRP was to mitigate flood risk in the worst hit areas. The flood risk areas identified in the SWMP were shortlisted to specific localities in four catchments namely the - Marsascala, Birkirkara-Msida, Gzira and Marsa catchments. A dynamic rainfall-runoff simulation model (EPA-Storm Water Management Model) and a hydrological modelling system (HEC-HMS) were used to simulate the hydraulic characteristics of the uncontrolled surface water runoff resulting from a 1 in 5 year event. The simulation results for the 5 year storm events resulted in the assignment of flood water depths for main roads within each of the catchments. The aim was to optimize the design of the technical options considered under the NFRP for management of this runoff (EEA-EIONET, 2015). A flood damages assessment was also carried out for the 5-year flood simulation, estimating the total damages on a social level, economic losses and damages to buildings and infrastructure (Politecnica Soc. Coop. Consortium, 2010a). Given the extremely short temporal scale of flood events in Malta, no information on the hydrological characteristics of past flood events was ever recorded. Therefore, the probability of the events in the derived flood risk maps is based on rainfall return periods since no direct measurement were available with which to correlate these simulated flood events (EEA-EIONET, 2015).

Acquisition of LiDAR data over the Maltese Islands

The first LiDAR survey over all the Maltese Islands was carried out through an ERDF project entitled 'Developing National Environmental Monitoring Infrastructure and Capacity' (Hili, 2014). This technology was a novel source of very high resolution data for the topographic analysis of the Maltese Islands. Prior to this, Digital Elevation Models were derived from aerial orthophotography as provided by the then Malta Environment and Planning Authority. The use of photogrammetric capture methods to collect topographic detail is often laborious, work-intensive, lengthy and hence, costly (Agius & Brearley, 2014). Derivation of hydrological networks for the south-east area of Malta from contour maps and derived Triangular Irregular Networks (TINs) was carried out by Tabone Adami (2001) as part of a hydrological study to quantify storm water and nutrient flows into coastal waters. From the LiDAR data acquired during the topographic LiDAR survey of the ERDF project, Digital Surface Models (DSMs) and Digital Terrain Models (DTMs) were derived.

Methodology

Watershed and drainage networks delineations in the NFRP

As part of the NFRP and based on catchment delineations from the SWMP, the Consultants working on the NFRP drew the water flow lines within sub-basins in each catchment (Politecnica Soc. Coop. Consortium, 2010a). The boundaries of each sub-basin were determined based on the morphological characteristics of the land, natural or engineered canals and slopes and the presence of roads that can constitute a drainage canal, an embankment, or barriers to water flow. The flow direction was then established based on this road network. This process was carried out for the four flood priority areas: the Marsascala, Birkirkara-Msida, Gzira and Marsa basins. Hydrological models were simulated for each sub-basin estimating the peak value for different return periods including that of a 1 in 5 year flood (Politecnica Soc. Coop. Consortium, 2010b).

Watershed and drainage networks delineations from LiDAR data

The aerial survey for the topographic LiDAR scan, as part of the ERDF project, was carried out on the 17th February 2012. This included the acquisition of ortho imagery with a ground resolution of 15cm and a 30cm XY accuracy.

The LiDAR point cloud acquired had an average of 4.3 points/m3 and a height accuracy of less than 10cm. The resultant DSM had a 1m grid resolution and an equivalent height accuracy. This DSM was processed for the hydrological analysis in this paper using ArcToolbox processes in ArcGIS 10. The process using the ArcGIS geoprocessing tools is summarised in Figure 2 and is described further below.

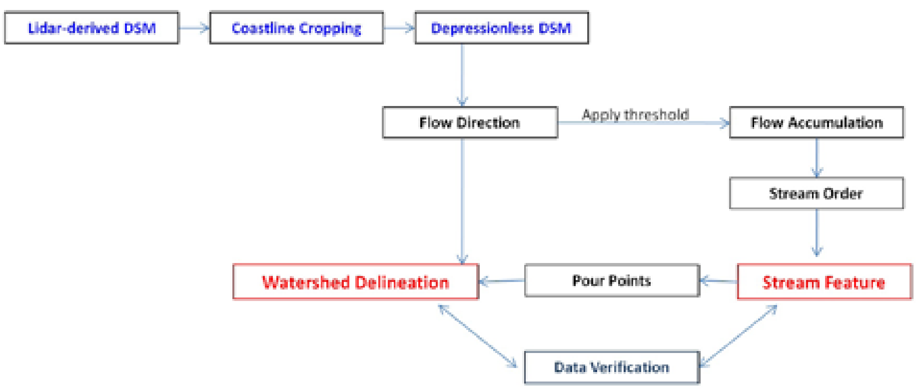
The following steps were implemented for the hydrological modelling:

- Crop sea areas using the coastline polygon as a mask;
- Prefill of spurious artifacts in the DEM to create a depressionless DSM. Small sinks were regarded as spurious artifacts resulting from errors caused by artifacts of DEM interpolation;
- Derive flow direction using the depressionless DSM as an input;
- Derive flow accumulation from the flow direction raster. A cell value in the flow accumulation raster is the number of upstream cells flowing into the cell;
- Apply a threshold of flow accumulation. Based on various outputs, a threshold value of 1500 was applied to realistically represent relevant parts of the hydrological networks. Any raster cell with an upstream area greater than the 1500 threshold

was selected as part of the network. The orthoimage was used as a reference background layer in the GIS to better interpret the location of the hydrological network;

- Create a stream order by assigning a numeric order value to the flow accumulation raster above. Streams with a high order have higher water flows. Six stream orders were derived with order 1 being the lowest accumulation level to order 6 with the highest accumulated water flows;
- Convert the stream order raster to a stream feature map. Each stream order feature was assigned a unique map symbology;
- Identify pour points to delineate the contributing watersheds. A watershed is the upslope area that contributes water flow to a common outlet - the pour point. Pour points were identified only for networks which contained orders equal or greater than 3;
- Delineate watersheds using the flow direction map and the location of the pour points; and
- Verify network with NFRP drainage networks and field data.

Figure 2: Methodological process for the derivation of hydrological networks from the DSM



Comparison and verification of networks

For the purpose of verification of LiDAR derived data, comparisons of the drainage network and corresponding watersheds were applied to the areas of the four catchments investigated in the NFRP. These pertain to the Msida, Gzira, Marsa and Marascala catchments. In the case of the Msida, Gzira and Marsa catchments, comparisons were made between the water flow routes depicted in the NFRP study and the LiDAR-derived networks. Furthermore, an additional field survey of the stretch of watercourse between Zabbar and Marsascala, was carried out during April 2016, as a case study for this chapter. The area of study included sections of the watercourse that are still in a relatively natural state, ranging from little or no vegetation cover to fully vegetated areas, together with other stretches that have been heavily modified by the construction of roads, culverts and sumps. The field survey included detailed site observations at specific locations where the LIDAR data derivations had been noted to be incomplete or incoherent with the overall hydrological network modelling of the catchment.

The field survey also included the gathering of local knowledge about water flows during storms and the identification and recording of physical features that clearly alter the flow of surface water flow, which features, can easily go undetected by the LIDAR data derivations. Such physical features included underground pipes, culverts and connecting sumps as well as low walls and outlets intended to keep water out, or divert it, where there are changes in ground levels. The site-specific survey enabled a comparison of the whole stretch of the network with the LiDAR-derived network and was instrumental in identifying and understanding the sources of errors more comprehensively. Underground and overhead hydrological features such as culverts and bridges cannot be identified solely by LiDAR data.

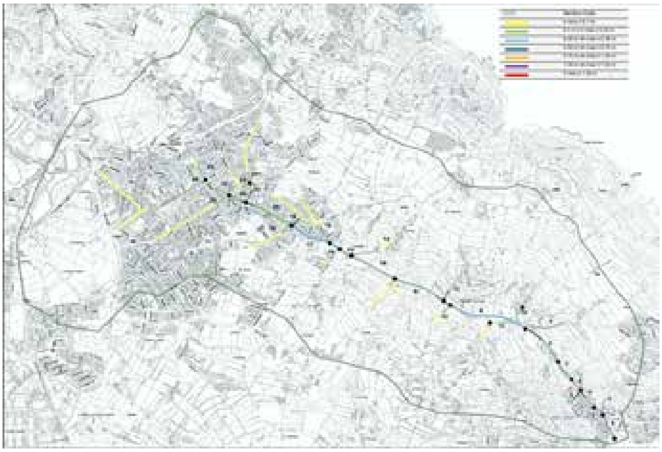
It was concluded that field surveys denoting such hydrological features are key to correct the LiDAR-derived hydrological network. Through the collected field data, including mapping of routes, the location of culverts, sumps and underground tunnels, and knowledge of the site during storm events, shortcomings in the LiDAR-derived network were identified. The LiDAR-derived hydrological network for the Marsascala catchment was then edited to conform to the verified flow as a remedial measure.

Results

Comparison of catchment networks

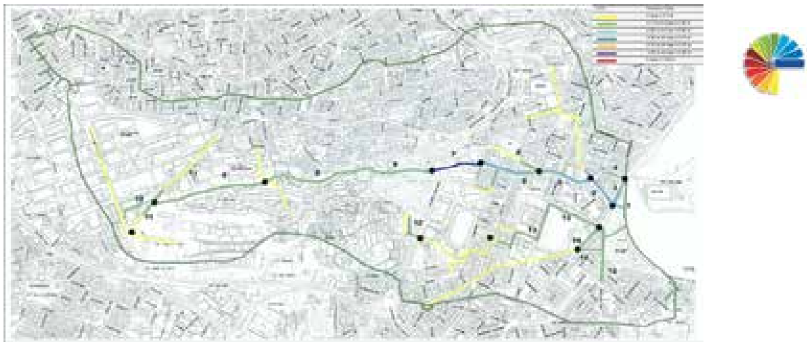
Maps of the watershed boundaries delineated during the NFRP study and the respective water depths of flooded routes are shown for the four catchments (Figure 3). Water depths represent the result of the hydrological simulations for a 5-year recurrent storm event. The simulated water depths for each inundated road and the survey code of each road section are indicated.

Figure 3: Watershed boundaries, flood simulation water depths and survey codes as delineated in the NPRP study for (a) Marsascala (b) Birkirkara-Msida (c) Gzira (d) Marsa catchments

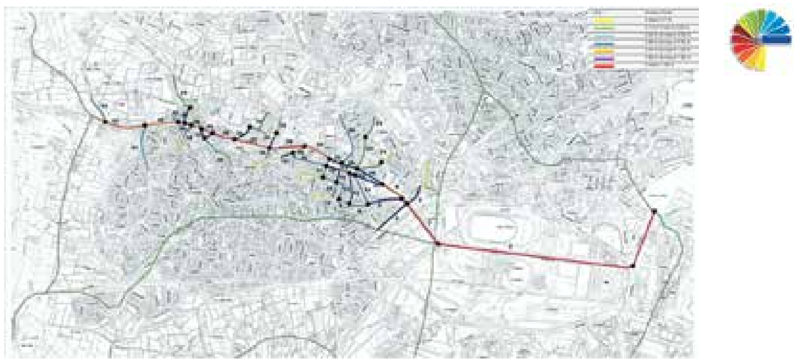


(a)

(b)



(c)

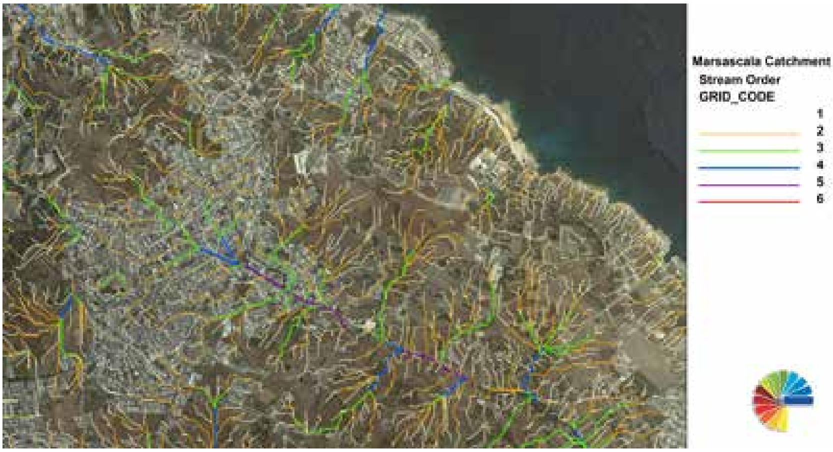


(d)

Source: (Politecnica Soc. Coop. Consortium, 2010a)

The stream networks derived from the LiDAR DSM for the four catchments are shown in Figure 4. Stream orders are colour coded. The maximum stream order achieved was order 6 in the case of the Marsa catchment, thereby being the most extensive network,

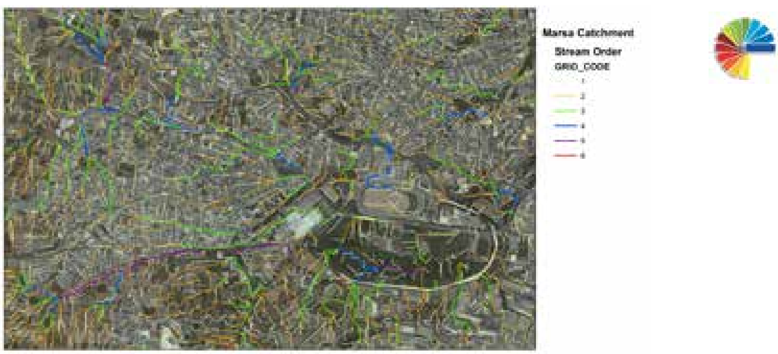
Figure 4: Stream networks derived from the LiDAR data for (a) Marsascala (b) Birkirkara-Msida (c) Gzira (d) Marsa catchments



(a)

(b)

(c)



(d)

Overall comparisons of the stream networks derived from the NFRP study and those derived from LiDAR DSMs demonstrated a good comparison overall with respect to the main flow directions. The networks derived from the LiDAR DSMs were more extensive given that each 1m x 1m pixel in the DSM was taken into account in the hydrological model. The NFRP networks were established only on those land areas for which field surveys were carried out and were based on expert judgement of the area.

Marsascala basin - The NFRP study estimated the Marascala basin to be about 4 km2 with the highest point of the watershed located in Zabbar, 57 m above sea level and the lowest site being Marsascala Bay at sea level (Figure 3a). (Politecnica Soc. Coop. Consortium, 2010a). The stream network derived from the LiDAR DSM denoted a stream order of 5 as the largest order commencing from Zabbar (Figure 4a). The main network derived from the LiDAR DSM follows the same overall route as that denoted in the NFRP study but is disjointed at some points along the Zabbar-Marsascala agricultural area. The LiDAR-derived network also derived the contributing tributaries since the model takes into account all the catchment surface area.

Birkirkara-Msida basin - Through the NFRP study, the watershed area of the Birkikara-Msida basin was estimated to be about 11 km2 with the highest point of the watershed located in Naxxar, 128 m above sea level and the lowest site being the Msida Marina at sea level (Politecnica Soc. Coop. Consortium, 2010a). In the case of a 5-year recurrent storm event, about 12 km of roads were calculated to be inundated starting from Valletta road and Naxxar Road in Birkirkara, along the main axis in Valley Road until Msida square (Figure 3b). Figure 4b shows the stream order created based on the LiDAR DSM. The main network follows the same path as that denoted in the NFRP study. A stream order of 5 was the largest order commencing from Birkirkara and ending at the top part of Valley Road due to the presence of a depression in that area. Beyond that area, the hydrological model from LiDAR data continues to follow the same route as that in the NFRP data and identifies the tributaries contributing to the main network up to stream orders of 4.

Gzira basin - The NFRP study estimated the watershed area of the Gzira basin to be about 2 km2 with the highest point of the watershed located in San Gwann, 100 m above sea level and the lowest site being the Sliema Creek at sea level (Figure 3c) (Politecnica Soc. Coop. Consortium, 2010a). In the simulation, 4 km of roads were calculated to be inundated starting from San Gwann industrial estate down to Gzira. The network from the LiDAR DSM (Figure 4c) denoted two main networks, one of which follows that located in the NFRP study. This LiDAR network had a maximum stream order of 4 commencing from San Gwann although the network is disjointed in the Gzira area after Wied Ghollieqa. The second main network in the upper part of the catchment, also with a maximum stream order of 4, coincides with the northern border of the Gzira basin delineated in the NFRP study. The LiDAR network also includes the presence of various smaller subsidiaries not connected to the main network of this basin.

Marsa basin - This was the largest basin investigated in the NFRP study with a watershed area of about 47.6 km2. It comprises two main watercourses (Kbir in the south and Sewda in the north) that join before entering Marsa with the largest part of the basin being agricultural land (Figure 3d). The highest point of the watershed is located in the Ġebel Ciantar area at 216 m above sea level and its lowest site is the Marsa Creek at sea level. The watershed's longest water course length running from southwest to northeast is about 12 km. Once again the stream network derived from the LiDAR DSM is extensive given that the non-urban areas are considered in the model (Figure 4d).

Two major networks with a maximum stream order of 5 are indicated. However, particularly over the Qormi and Marsa border (beneath the Marsa racetrack), disjoined networks are visible. Investigation into the LiDAR DSM data over these areas showed that these areas pertain to DSM pixel values of NO DATA in areas of low water reflectivity (Figure 5). These include areas of standing water such as swimming pools, open reservoirs and water retention areas following heavy rainfall, such as areas in Wied is-Sewda, upstream of Qormi (Figure 6a). The latter was the case given that the LiDAR survey was carried out after a recent storm. Pixels with NO DATA were not taken into account by the hydrological model, thereby deviating the real course of the hydrological network.

Figure 5: Stream networks derived from the LiDAR data for over the Qormi-Marsa area overlaid on DSM. White patches represent areas of NO DATA.

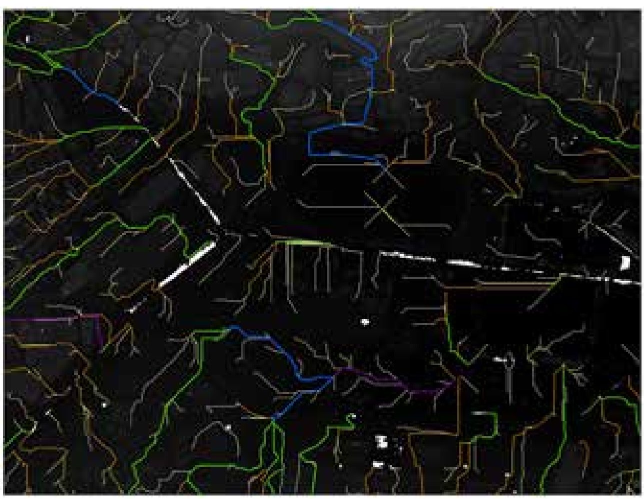
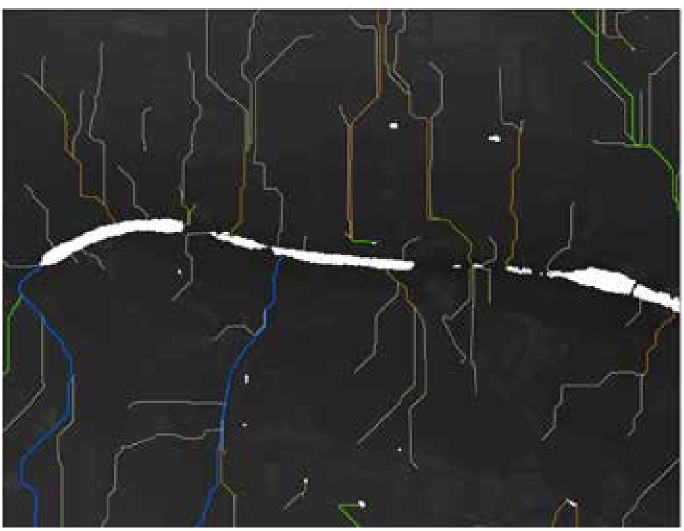


Figure 6: Effect of standing water areas on DSM (a) flooded areas in Wied is-Sewda Qormi, within the Marsa basin (b) corresponding areas of no reflectance of LiDAR data shown in white.

(a)

Source: Works and Infrastructure Department, Malta

(b)



Marsascala catchment - comparison with field survey

The field survey carried out along the Marsascala catchment helped to investigate the LiDAR-derived network in greater detail. Overall, the main network from the LiDAR data compared favourably to the field survey and knowledge of the watercourse from expert knowledge. However, the following shortcomings in the LiDAR-derived networks were identified.

1. Presence of false pits. As noted in Figure 7(a), the network is broken at points 1 and 2. The location of a false pit (a field below road level and a swimming pool in this case) and the presence of a physical barrier in the road-field boundary wall diverted the network to the pit. Therefore the two points had to be joined manually to continue the network along the road (where the water flows at a higher level from the adjacent land), as substantiated by the field survey. The subsequent stream orders reclassified to order 5 so as to continue with the same order downstream (Figure 7b).

Figure 7 (a): Diversion of stream network in the Marsascala catchment caused by a false pit (b) result of editing to join stream network along stream order 5 (shown in voilet).

(a)

(b)

2. Presence of canopy cover along the route. Through field data and on-site knowledge, it is known that the water is diverted into the valley bed through a manmade passageway enroute (Figure 8) at point 3 (Figure 9), moves along the valley vegetation, across a weir and flows into a sump. Water from the upper part of the Marsascala-Zabbar valley flows along the main road through point 4 and joins the flow from the valley vegetation.

Since a DSM includes both building and tree heights, the presence of the tree canopy implied increased height levels in the DSM. This precluded the hydrological model from routing the water along the grass under the tree cover (light blue route in Figure 9). For future use, the use of a Digital Terrain Model (DTM) data from the LiDAR survey, implying a bare-earth Digital Elevation Model, could be used in those areas for which water flows beneath tree canopies, potentially employing the last return emanating from the LiDAR scan.

Figure 8: Manmade passageway for the diversion of water flow from the road into the natural valley bed. Location refers to Point 3.

Source: Valley Management Section, Works and Infrastructure Department, Malta

Figure 9: Diversion of stream network into the valley bed and along man-made hydrological features. The edited route in shown in light blue.

3. Presence of hydrological features deviated water underground. Since underground hydrological features are not identified through the LiDAR survey, the location of these features is required through field knowledge. These include the presence of various culverts, sumps, bridges and road gratings (Figure 10). As remedial measures, the route network needs to be verified through a site reconnaissance exercise and then edited manually in these locations so as to reconcile the data with the relevant order network derived from the LiDAR DSM.

Figure 10: Man-made hydrological features present along route network (a) road gratings (b) sump

(a)

(b)

Source: Valley Management Section, Works and Infrastructure Department, Malta

4. Presence of NO DATA in LiDAR DSM. Since the LiDAR was carried out following a rainfall event, the presence of large puddles and flooded areas, particularly on impervious surfaces such as roads, led to corresponding areas of no reflectance of the LiDAR pulse. This resulted in areas of NO DATA in the resultant DSM. Therefore, the hydrological model routed the water networks incorrectly in this area (Figures 5 and 6b). The detection of points in water areas is difficult since a laser scanner does not have reflectance of the water, particularly when they are standing waters. Some reflectance of the water is possible when there are some waves or some objects above the water surface. Semi-automatic extraction of water bodies have been investigated to model water areas for DEM generation (Korzeniowska, 2012).

Due to these shortcomings, the route network was disjoined at specific locations. Hence this resulted in gaps within the watershed delineations due to disconnected networks.

Spatial datasets for future flooding models

The use of a hydrological network has extensive applications in terms of its use for simulating rainfall-runoff models. Once the LiDAR-derived network has been edited in locations where the shortcomings were identified, the derived product would serve as an input into the hydrological model. The use of a Geographical Information System (GIS) technology to analyse the datasets of such spatial data is crucial for running flood simulation models. This would include additional spatial data layers as model inputs including land cover and soil type. The use of satellite imagery for the derivation of these datasets provides synoptic data based on the reflectance characteristics of the ground. Overall the flood simulation models can be used to update the NFRP-derived economic and infrastructure effects of flooding.

Conclusion

This study investigated the use of a high-end technology such as LiDAR to derive hydrological networks for all the Maltese Islands by assessing data for four catchments. Overall the LiDAR-derived network compared favourably to the data for the SWMP and NFRP basins. Since the LiDAR survey was carried out for all the Maltese Islands on the same day, it enabled a snapshot overview of the hydrological network for the entire territory including smaller catchments. The use of aerial orthoimagery as a basemap in the GIS enabled the location of network areas under investigation.

Data assessment highlighted shortcomings in some of the LiDAR data. The use of on-site collection of data and site knowledge is a pre-requisite for understanding the network comprehensively and in detail. This is needed prior to applying any specific remedial measures to correct the LiDAR-derived data. Integration of spatial datasets to form a more robust model for flood simulation should be looked on as the next step. This would include the use of satellite imagery as well as future high-resolution and also oblique LiDAR surveys to provide updated digital datasets for hydrological modelling.

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CHAPTER 13

Soil Quality Change in the Maltese Islands: A 10-Year Assessment (2003 to 2013)

Daniel Sultana

Introduction

Soils constitute a significant non-renewable geo-resource. Soil resources produce various ecosystem goods and services, chief amongst which are food production and the recycling or assimilation of wastes and other by-products (Arrouays, Marchant, Saby, Meersmans, Orton & Martin, 2012; deGroot, Wilson and Boumans., 2002). Healthy soils are therefore the foundation of our food system and merit our attention (Bot & Benites, 2005). Over the past few decades, various anthropogenic factors have increased the pressures on soil systems and associated ecosystem services. Amongst these pressures is a growth in global population and standards of living as well as climate change. These factors have significantly increased the global demand for food and have led to a widespread process of land use intensification.

Agricultural land use intensification may adversely affect soil physical, chemical and biological properties. The intensification process has occurred throughout the entire world and has lead to a significant decline in soil quality (Van Camp, Camp, Bujjarabal, Gentile, Jones, Montanarella, Olazabal & Selvaradjou., 2004). Supporting this claim is Steer's (1998) work that demonstrates that approximately 23% of the Earth's agricultural lands, pastures, forests and wild native lands have been degraded in the last decades of the last century. Soil erosion is a significant contributor towards soil quality loss and has been identified as a major threat to European agricultural soils (Virto et al., 2015). It is estimated 12% (115 million hectares) of Europe's total land area is affected by water erosion, a major threat to agricultural soil quality.

Soil degradation, which is a decline in soil quality, constitutes a serious global problem with important environmental and socio-economic consequences. Soil degradation limits soil's capacity to perform various ecosystem services, namely the provision of food, water, biodiversity and energy (Brevik et al., 2015). Consequently, soil quality is inexorably tied to national and global food safety, human health and sustainable economic and social development (Cheng, 2003; Liu, Herbert, Hashemi, Zhang & Ding, 2006). The increased awareness that soil is of critical importance has led to an interest in evaluating and monitoring its quality (Glanz, 1995; Doran & Parkin, 1996). Soil quality and its monitoring are a useful management tool through which soil conservation and sustainable development may be achieved (Banwart, 2011).

Soil management: policy, monitoring and selection of crops

Various soil management measures, falling under the description of "sustainable agriculture", have been proposed (Matson et al., 1997). These fundamentally seek to maintain high crop yields while preserving soil quality in agricultural areas. Such measures include: organic farming (van Leeuwen et al., 2015); terracing (Zhao, Mu, Wen & Wangand Gao, 2013); crop residue retention (Pittelkow et al., 2014); diversified crop rotations (Bhattacharyya, Prakash, Kundu & Gupta., 2006; Pittelkow et al., 2014; Abdollahi, Hansen, Rickson & Munkholm, 2015) and conservation tillage systems that include no-tillage (Kahlon & Ann-Varughese, 2013). These practices have been successful in reversing declines in soil organic matter and increasing soil fertility, water infiltration and water holding capacity.

Conservation and no-tillage practices preserve the soil quality by reducing soil erosion (Lal, 1993) and increasing the soil organic carbon content (Zotarelli et al., 2012), aggregate stability (Alvarez & Steinbach, 2009), biodiversity (Adl, Coleman & Read, 2005) and biological activity (Anken, Weisskopf, Zihlmann, Forrer, Jansa & Perhacova, 2004; Babujia, Hungria, Franchini & Brookes, 2010). In view of these benefits, conservation tillage is considered as on of the most important management practices enabling sustainable agricultural production. McGarry & Sharp (2001) support this claim. The authors measured a 47 and 40% increase in organic matter in the 20 to 30cm and 50 to 60cm layer of a field that had been under no-till for 12 years, relative to an adjacent conventionally tilled field. The relative increase in organic matter was matched with a measured decline in bulk density (23%) and an increase in water infiltration on the 0 to 5cm layer.

Since 1999 there has been a 250% increase in the agricultural areas applying no-tillage management measures; from 45million ha in 1999 to 111 million ha in 2009 (Derpsch et al., 2010). The rapid rise in global adoption of no-tillage by farmers may be tied to a number of significant advantages, namely; a reduction in fuel and labour consumption and soil erosion control (Lal, 1993).

The effects of tillage on soil physical properties are time, space and management dependent. In view of this, despite wide investigations on the impacts of no-tillage and other tillage systems on soil physical quality, correlations are highly variable and at times contradictory (Alvarez and Steinbach, 2009; Tangyuan et al., 2009; Wang and Shao, 2013; Munkholm, Heck & Deen, 2013; Derpsch, Friedrich, Kassam & Hongwen, 2014). Excessive soil compaction in untilled areas is still a concern in various agricultural regions, such as Europe (Anken et al., 2004; Soane., Ball, Arvidsson, Baschd, Moreno & Roger-Estrade, 2012; Dal Ferro, Sartori, Simonetti, Berti & Morari, 2014; López-Garrido, Madejón, León-Camacho, Girón, Moreno & Murillo, 2014). Soil compaction is undesired in agricultural areas since it leads to a reduction in total porosity, water infiltration capacity and hydraulic conductivity (Silva, Reichert, Reinert & Bortoluzzi, 2009).

An increase in soil bulk density also hinders root penetration capacity (Moraes, Debiasi, Carlesso, Franchini & Silva., 2014), which in turn limits the volume of soil roots have access to and reduces access to water and nutrients (Li et al., 2007). These changes may reduce crop yields, especially in dry years (Franchini et al., 2012). In this context of uncertainty of tillage system of soil quality, the use of crop rotations including plants with high potential for shoot and root biomass production has been suggested (Calonego & Rosolem, 2010; Munkholm et al., 2013; Silva et al., 2014). Such measures will prevent the formation of compacted layers and improve soil physical quality.

Soil management: soil quality indicators

The multidimensional concept of soil quality emerged as a result of the growing holistic approaches to land management and sustainable use systems (Mairura, Mugendi, Mwanje, Ramisch, Mbugua & Chianu, 2007; Villamil, Miguez & Bollero, 2008). The evaluation of soil quality is based on the use of indicators (Moebius-Clune, et al., 2011; Toledo, Galantini, Dalurzo, Vazquez & Bollero, 2013). The selection of soil quality indicators and their associated threshold values, maintained for the sustained functioning of soil, provides an ability to monitor changes and identify trends of improvement or deterioration in agro-ecological zones at various geographical and time scales.

Soil quality indicators should be selected according to the scope of, the monitoring programme, the environmental context and the soil types of the region under study (Cantú, Becker, Bedano & Schiavo, 2007). It is essential to check the utility of soil quality indicators for each local agricultural ecosystem to prevent improper practices (Dalurzo, 2002). Productivity has traditionally been the indicator selected to quantify soil quality (Karlen, Mausbach, Doran, Cline, Harris & Schuman, 1997). Recently, however, soil quality indicators have been tied to aspects of soil sustainability. In particular, indicators should quantify the capacity of soil to absorb, store and recycle water, minerals and energy in such away that production of crops can be maximised and environmental degradation minimised (Tóth, Stolbovoy, V., & Montanarella, 2007). To this extent, typical soil quality indicators and monitoring programmes include soil organic matter, bulk density, electric conductivity, moisture content, pH, nitrates, phosphates and potassium, heavy metal concentrations and soil depth (Gao, Wang, Xu, Kong, Zhao & Zeng, 2013).

Soil monitoring and the early detection of changes in soil quality are essential to conserve soil for sustainable use. Soil quality monitoring are thus an effective method for evaluating the environmental sustainability of land use and management activities (Hamblin, 1991). Various countries have identified the benefits of soil monitoring and have introduced various monitoring programs. In fact, Europe has carried out a number of official soil monitoring frameworks for several years (such as the soil monitoring network, SMN). European SMNs include soil fertility monitoring, heavy metal monitoring, environmental soil surveys, soil erosion surveys, soil organic matter monitoring assessed through a variety of sampling strategies (Morvan, Saby, Arrouays, Le Bas, Jones & Verheijen, 2008).

In his report on Agriculture in Malta, Shepherd (1920) remarks that a precise national soil survey is not available. Lang (1960) later carried out a detailed survey where differences in soil chemistry, physical properties and biology constituents were mapped. The study by Lang (1960) provided a detailed description of the soils types and their distribution that aimed to facilitate agricultural planning.

Due to the rapid increase in urban areas since the 1960's and the shift of topsoil within and around new urban areas, the Lang (1960) map was considered as unsatisfactory for contemporary use. As a result, the Malta Soil Information System (MALSIS) project was carried out in 2003. Through MALSIS Malta – which until that point in time did not have a tradition of soil survey and monitoring – sought to describe, assess, monitor and manage National soils in a sustainable way (Vella, 2003). MALSIS consists of a national grid-based soil inventory at 1km intervals. A total of 280 sites were assessed between June 2002 and August 2003 in Malta, Gozo and Comino. The surveying methodology followed the FAO Guidelines for Soil Description. Sites were assessed in terms of agricultural land use, height of terrace, cropping pattern, irrigation, slope and soil chemical and physical properties. The MALSIS results identify six soil reference groups; leptosols, vertisols, calcisols, luvisols, cambisols and regosols. Calcisols were recognised as the dominant soil group. Results also demonstrate that National spatial patterns of soil types are very intricate. In fact, different soil types were often observed to occur within a single field or within a distance of a few metres (Vella, 2003). Refer to MEPA website (https://www.mepa.org.mt/soil-definition).

The study presented here assesses various soil chemical properties for sites corresponding to those studied in the 2003 MALSIS survey. The chemical properties – indicators of soil quality – obtained in this study may be directly compared against the MALSIS results. This allows a 10-year assessment in soil quality to be appraised. This information may serve to highlight important changes in soil quality and potential ecosystem functioning, all of which are important for National sustainable agricultural management.

Materials and Methods

Sampling methods and indicators

The sampling locations identified for this study are the same as those studied in MALSIS (2003) and are based on a 1km spaced grid distribution across Malta and Gozo. All grid points located within soil containing natural and agricultural areas were sampled in this study. The study present involved the survey of 280 sites across Malta and Gozo (Figures 1 to 6). The sampling of soils at the pre-selected geo-referenced target sites was initiated in June 2013 and was completed in September 2013. The timing of sampling is therefore similar to that of the MALSIS survey and corresponds to the Maltese dry season. Soil samples were gathered from a 0.2 meter depth below the soil surface. As with the MALSIS study, the soil survey methodology followed in this work follow the FAO Guidelines for Soil Description with minor adaptations to reflect local conditions.

The tools for assessing soil properties and health are taken from the VS-Fast methodology (McGarry, 1996) and selected VSA methods of Shepherd (2000). During field visits emphasis was placed on the qualitative and quantitative assessment of soil physical condition. The soil properties assessed in for each site in this study include the soil chemical measurements; organic carbon, pH, electrical conductivity and the soil physical measurements; bulk density, moisture and depth. The aforementioned soil properties were also assessed in the MALSIS study. Three results were calculated for each soil quality indicator in each site with the aim of obtaining average, range and standard deviation values. A justification for the choice of the aforementioned soil quality indicators is provided below.

Bulk density

Soil bulk density directly quantifies soil compaction and provides information on soil texture, organic matter levels, porosity and aggregation (Hernanz et al., 2000). In view of this, soil bulk density is a very useful parameter describing soil quality. Volumetric pore space is essential for sustainable soil use, both in terms of productivity and environmental well-being. Soil pores contain and allow the movement of water and air. Both of which are necessary for processes that produce and sustain the production of biomass. It is important to note that crop yields and the sustainability of farming families' livelihoods, are also closely linked with soil porosity (Shaxson & Barber, 2003). A change in bulk density is also a direct indicator suggesting change in other soil parameters. For instance, an increased soil organic carbon improves soil structure, which in turn leads to a decrease in bulk density, improves aggregate stability, increases pore size and increases the proportion of air and water filled pore space (Loveland & Webb, 2002).

Soil bulk density may increase when the total porosity is reduced. This may occur through a variety of compaction processes, either through direct compaction or through mechanical, chemical or biological breakdown of soil aggregates. The consequences of an increase in soil bulk density are numerous and significant. Severely compacted soil leads to a reduction in macropore volume, with a consequent reduction in water availability and poorer aeration. Compacted soils also slow drainage (hydraulic conductivity) which in turn reduces infiltration rates and water storage capacity, which increases overland flow, leads to the erosion of fertile topsoil and reduces crop production potential (biomass yields) (Li et al., 2007; Hernanz, Peixoto, Cerisola & Sanchez-Giron, 2000; Neves, Feller, Guimaraes, Medina, Tavares & Fortier, 2003). At the other extreme, soils with low bulk density and strength are susceptible to rapid soil erosion rates, a poor capacity to retain water and are subject to accelerated oxidation of soil organic matter with consequent loss of soil organic carbon (Sparling, Lilburne & Vojvodic-Vukovic, 2003).

The methods and standards followed in this study to obtain dry bulk density measures are that same as those adopted in MALSIS's (2003); Determination of dry bulk density British Standard 7755 – 5.6: 1999.

Electrical conductivity

Electrical conductivity of soil is a measure of the concentration of ions in solution. Electric conductivity is most often used as an indicator of salinity. It is however important to note that where soil nitrate levels are high, electric conductivity is also an indicator of soil nitrate status (Lewandowski, Zumwinkle & Fish, 1999).

The methods and standards followed in this study to obtain electrical conductivity measures are that same as those adopted in MALSIS's (2003); Determination of the specific electric conductivity ISO 11265 Soil Quality. This procedure specifies an instrumental method for the routine determination of the specific electrical conductivity in a water extract of soil samples. The determination is carried out to get an indication of the content of water-soluble electrolytes in a soil.

Organic carbon

Soil organic matter is soil material that originates from organisms that were once or are currently living (Magdoff, 2004). Soil organic matter is comprised of approximately 50% carbon and is rich in various nutrients including nitrogen and phosphorus. Soil organic matter content is dependent on a variety of parameters, namely; organic matter inputs and decomposition, temperature, aeration, physical and chemical properties and leaching. Soil organic matter strongly influences most of the functions associated with soil quality (Weil, Islam, Stine & Samson-Liebig, 2003). Organic carbon rapidly decreases with cultivation and cropping (Su, Zhao, Zhang & Zhao, 2004; Bot & Benites, 2005). A decrease in organic carbon has negative effects on various soil properties necessary to maintain soil quality and crop productivity and leads to an increase in bulk density, a decrease in water infiltration and water holding capacity and a decrease in aggregate stability (Matson, Parton, Power & Swift, 1997).

There are many advantages to increasing or maintaining high levels of soil organic matter, namely; reducing bulk density, increasing soil resistance to erosion and reducing green house gasses by carbon sequestration. Soil organic matter and agricultural productivity potential have also been directly and positively correlated. Soil organic matter and by extension soil fertility, is increased in most agricultural soils by retaining crop residue on the soil surface, by rotating crops with pasture or perennials, or by adding organic residues (Krull, Skjemstad & Baldock, 2004). Levels of soil organic carbon reflect the total quantity of soil organic matter.

The methods and standards followed in this study to obtain organic carbon measures are that same as those adopted in MALSIS (2003). Determination of Organic Matter according to Walkley & Black (Nelson & Sommers, 1982) quantifies organic carbon in soil samples according to a wet oxidation procedure. This procedure is applicable to all types of air-dry soil samples pre-treated according to PROT 003.

pH

The analysis of mixed soil pH is necessary in soil quality assessment. The chemical reactions that occur in soil are significantly influenced by soil pH. Nutrients demonstrate diverse ranges of pH thresholds within which the highest proportion of nutrients are in a plat-available form. Optimal pH ranges exist for each crop and soil inhabiting organism. Various parameters influence soil pH, key amongst these are climate, parent material and fertiliser use. pH significantly influences various soil processes, key amongst these are; nutrient availability, biogeochemical cycling, contaminant sorption, structural stability and biological activity (scho0306bkiq-e-e pp14). Base saturation quantifies the percentage of the total cation exchange capacity occupied by the basic cations, calcium, magnesium, potassium and sodium. Base saturation is positively correlated to pH; with an increase in pH there is an increase in the amount of basic cations (Lewandowski et al., 1999). The methods and standards followed in this study to obtain pH measures are that same as those adopted in MALSIS (2003). The procedure followed is an instrumental method for the routine determination of pH using a glass electrode in a 1:5 (V/V) suspension of soil in water (pH-H2O); ISOIDIS 10390 Soil quality - Determination of pH.

Moisture content

Plants can use water holding capacity is the quantity of water soil can retain that. Water holding capacity is influenced by soil texture, structure and organic matter (Lewandowski et al., 1999). The amount of water present in soil is referred to as soil moisture content. Soil moisture is not constant with time and may vary. The management of soil moisture is important for sustained and improved crop productivity and water supply (Shaxson & Barber, 2003). The methods and standards followed in this study to obtain soil moisture measures are that same as those adopted in MALSIS (2003). The procedure followed is the determination of moisture in soil by oven drying; PROT 003, preparation and pre-treatment of soil samples for physico-chemical analysis.

Soil depth

Soil depth measures the depth from soil surface to a root restrictive layer, typically stone, water table, or hardpan. Shallow soils reduce water holding capacity and root development (Lewandowski et al., 1999).

The soil depth indicator was not assessed in MALSIS (2003). In this study, soil depth measures depth from surface to bedrock. The depth was measured at a grid distribution of between 0.5 to 1km (Figure 6) using soil augers in a total of three hundred and thirty locations. Due to significant differences in soil depth within the same sampling location, soil depth was measured three to four times; each measure was spaced 1meter east of the previously sampled point. The soil depth vales for each location are presented as an average of the four soil depth values (Figure 6).

Results Andand Discussions

Bulk density (g/cm3)

The average soil bulk density for the 254 assessed Maltese soils in 2003 (MALSIS 1) fell within the following ranges; ≤0.5g/cm3, 0%; 0.51 to 1.00g/cm3, 16%; 1.01 to 1.25g/cm3, 65%; 1.26 to 1.50g/cm3, 18%; 1.51 to 2.00g/cm3, 1%; ≥2.01g/cm3, 0%. The average soil bulk density for the 109 assessed Maltese soils in 2013 (MALSIS 2) fell within the following ranges; ≤0.5g/cm3, 0%, 0.51 to 1.00g/cm3, 11%; 1.01 to 1.25g/cm3, 70%; 1.26 to 1.50g/cm3, 18%; 1.51 to 2.50g/cm3, 0%; 2.51 to 3.00g/cm3, 1%; >3.00g/cm3, 0% (Figure 1a).

Change in soil bulk density was also assessed for sites where measures in bulk density were carried out in 2003 (MALSIS 1) and 2013 (MALSIS 2). MALSIS 2 values were subtracted from MALSIS 1, such that a positive change demonstrates an increase in soil bulk density and a negative change suggests a fall in soil bulk density. Bulk density change has been calculated in 97sites and exists within the following ranges; ≤ -0.40g/cm3, 1%; -0.39 to -0.2g/cm3, 6%, -0.19 to -0.01g/cm3, 32%; 0 g/cm3, 2%; 0.01 to 0.20g/cm3, 58%; 0.21 to 0.40g/cm3, 6%; 0.41 to 0.60g/cm3, 3%; 0.61 to 1.00g/cm3, 0%; >1.00g/cm3, 1% (Figure 1b). Results suggest that 59% of the locations assessed in 2013 had a greater average bulk soil density than the same locations in 2003 i.e. soil compaction is prevalent. It is worth noting that 82% of the locations subject to compaction have an increase in soil bulk density within the range of 0.01 to 0.20g/cm3; 0.01 to 0.1g/cm3, 44% and 0.11 to 0.2g/cm3, 38%.

Figure 1a: Average bulk density values for M1 (2003) as the smaller circles and M2 (2013) values as the larger circles surrounding the smaller (M1) circles

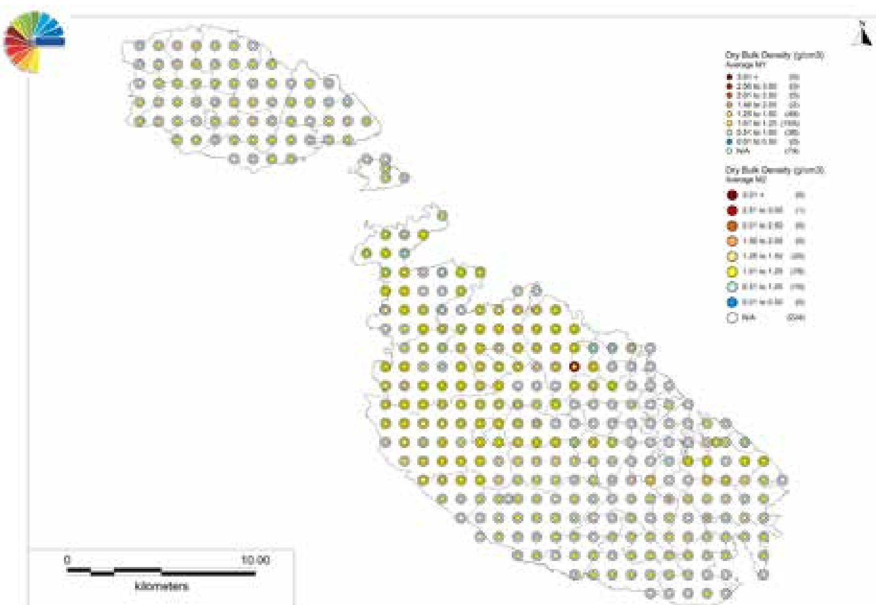
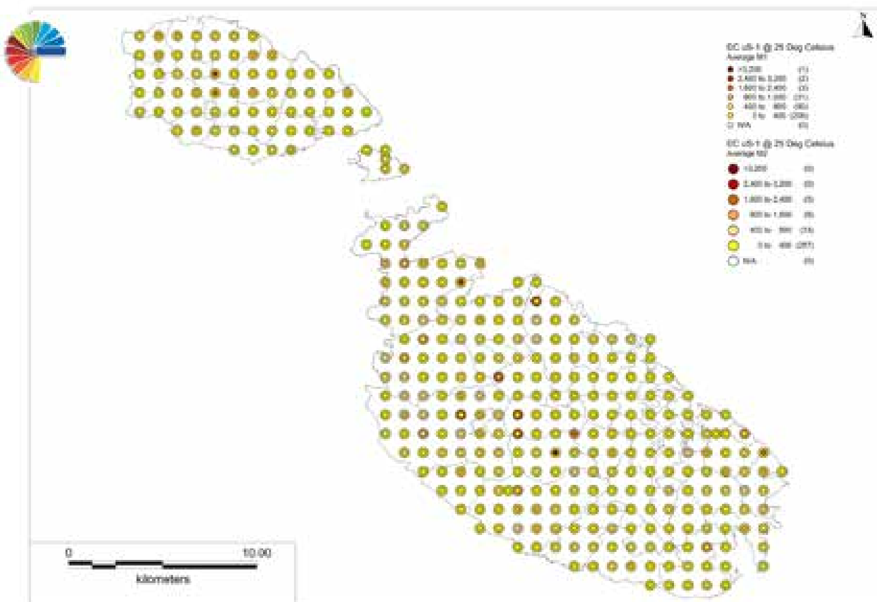


Figure 1b: Change in bulk density between 2003 and 2013 (M2-M1)



The average bulk density of all the sites assessed in 2003 is 1.14g/cm3. The average soil bulk density for the sites assessed in both 2003 and 2013 (97 sites in total) was of 1.12g cm3 for 2003 and 1.17g cm3 for 2013. In view of the national average soil bulk density, the increase in soil bulk density observed in 59% of the studied sites is significant. An increase in soil bulk density over time signifies soil compaction. This leads to a decrease in total soil porosity (macro-porosity in particularly) and hydraulic conductivity which influences the water release curve. Various chemical and biological parameters, namely soil organic carbon and mineralisable nitrogen, are also influenced by a change in soil bulk density (scho0306bkiq-e-e pp36).

3.1.2. Electrical conductivity (uS-1) (at 25°C)

The average electrical conductivity (uS-1) for the 270 assessed Maltese soils in 2003 (MALSIS 1) fell within the following ranges; ≤400uS-1 (non-saline), 53%, >400 to 800uS-1 (slightly saline), 33%; >800 to 1600uS-1 (moderately saline), 11%; >1600 to 2400uS-1 (moderately saline), 1%; >2400 to 3200uS-1 (very saline), 1%; >3200uS-1 (extremely saline), 0%. The average electrical conductivity for the 143 assessed Maltese soils in 2013 (MALSIS 2) fell within the following ranges; ≤400uS-1, 69%, >400 to 800uS-1, 22%; >800 to 1600uS-1, 6%; >1600 to 2400uS-1, 3%; >2400uS-1, 0% (Figure 2a).

Change in soil electrical conductivity was also assessed for sites where measures in electrical conductivity were carried out in 2003 (MALSIS 1) and 2013 (MALSIS 2). MALSIS 2 values were subtracted from MALSIS 1, such that a positive change demonstrates an increase in electrical conductivity and a negative change suggests a decrease in electrical conductivity. Change in electrical conductivity has been calculated in 141 sites and exists within the following ranges; ≤ -2500uS-1, 1%; >-2500 to -200uS-1, 0%, >-2000 to -1500uS-1, 1%; >-1500 to -1000 uS-1, 1%; >-1000 to -500uS-1, 9%; >-500 to -250uS-1, 13%; >-250 to -1uS-1, 42%; 0uS-1, 0%; 1 to 250uS-1, 20%; >250 to 500uS-1, 7%; >500 to 1000uS-1, 3%; >1000 to 1500uS-1, 0%; >1500uS-1, 3% (figure 2.B). Results suggest that 67% of the locations assessed in 2013 had a lower electrical conductivity than the same locations in 2003. It is worth noting that 82% of the locations subject to reduced conductivity levels have a decrease in electrical conductivity within the range of -1 to -500uS-1.

Figure 2a: Average electrical conductivity values for M1 (2003) as the smaller circles and M2 (2013) values as the larger circles surrounding the smaller (M1) circles.

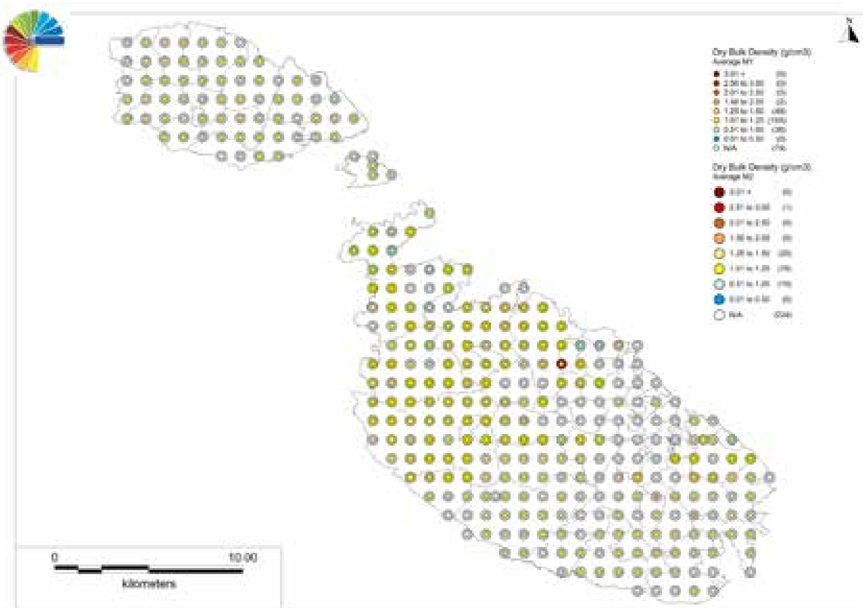
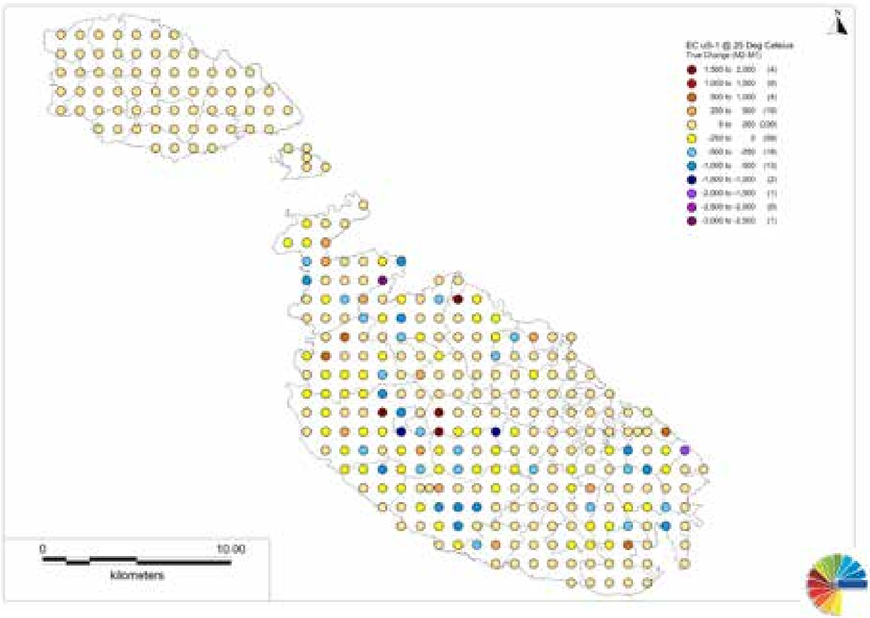


Figure 2b: Change in electrical conductivity between 2003 and 2013 (M2-M1)



The average electrical conductivity of all the sites assessed in 2003 is 518uS-1. The average electrical conductivity for the sites assessed in both 2003 and 2013 (141 sites in total) was of 512uS-1 for 2003 and 430uS-1 for 2013. In view of the national average electrical conductivity, the decline in electrical conductivity observed in 67% of the studied sites is significant. Electrical conductivity is a measure of salinity and is also influenced by soil nitrate levels (Lewandowski et al., 1999). Maltese aquifers are subject to seawater intrusion that results in high levels of chloride concentrations in aquifers (MRA, 2005). Thirteen of the fifteen aquifers have also been reported as being heavily polluted by nitrates, sourced primarily from the excessive use of natural and artificial fertilisers in arable agricultural practices (WCMP for the Maltese Islands, 2011). In view of the treat to aquifer water quality, various programmes were established with the aim of achieving good water quality status. Key amongst these programmes is the Nitrates Action Programme (2011), which proposes various measures that seek to govern the period during which fertilisers are applied and reduce the quantity of fertilisers used in the agricultural sector. Such initiatives may, in part, be an explanation for lower soil electrical conductivity recorded in 2013.

Organic carbon (%)

The organic carbon (%) for the 271 assessed Maltese soils in 2003 (MALSIS 1) fell within the following ranges; ≤1% (very low), 13%; >1 to 1.5 (low), 25%; >1.5 to 2%, 24%; >2 to 5.5% (moderate), 37%; >5.5%, 1%. The average organic carbon for the 70 assessed Maltese soils in 2013 (MALSIS 2) fell within the following ranges; ≤1% (very low), 4%; >1 to 1.5 (low), 17%; >1.5 to 2%, 30%; >2 to 5.5% (moderate), 45%; >5.5%, 4% (Figure 3a).

Change in organic carbon was also assessed for sites where measures in organic carbon were carried out in 2003 (MALSIS 1) and 2013 (MALSIS 2). MALSIS 2 values were subtracted from MALSIS 1, such that a positive change demonstrates an increase in organic carbon and a negative change suggests a decrease in organic carbon. Change in organic carbon has been calculated in 70 sites and exists within the following ranges; ≥2.19%, 3%; <2.19 to 1.20%, 6%, <1.2 to 0.6%, 19%; <0.6 to 0.01%, 31%; 0%, 0%; -0.01 to >-0.6%, 27%; -0.06 to >-1.2%, 9%; -1.2 to >-2.2%, 4%; ≤-2.2%, 1% (Figure 3b). Results suggest that 59% of the locations assessed in 2013 had higher organic carbon content than the same locations in 2003. The average organic carbon of all the sites assessed in 2003 is 1.98%. The average for soil organic carbon content for the sites assessed in both 2003 and 2013 (70 sites in total) was of 2.11% for 2003 and 2.30% for 2013.

Figure 3a: Average organic carbon values for M1 (2003) as the smaller circles and M2 (2013) values as the larger circles surrounding the smaller (M1) circles

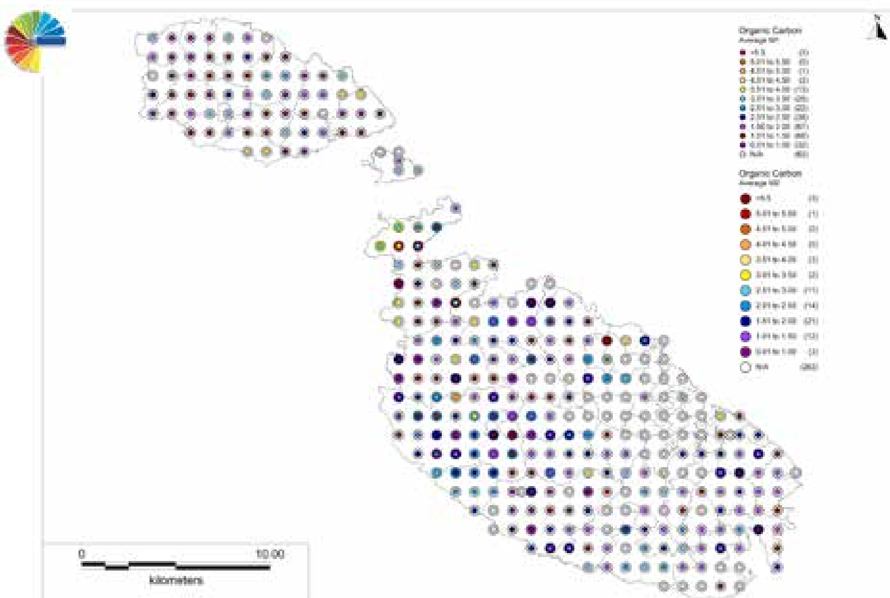
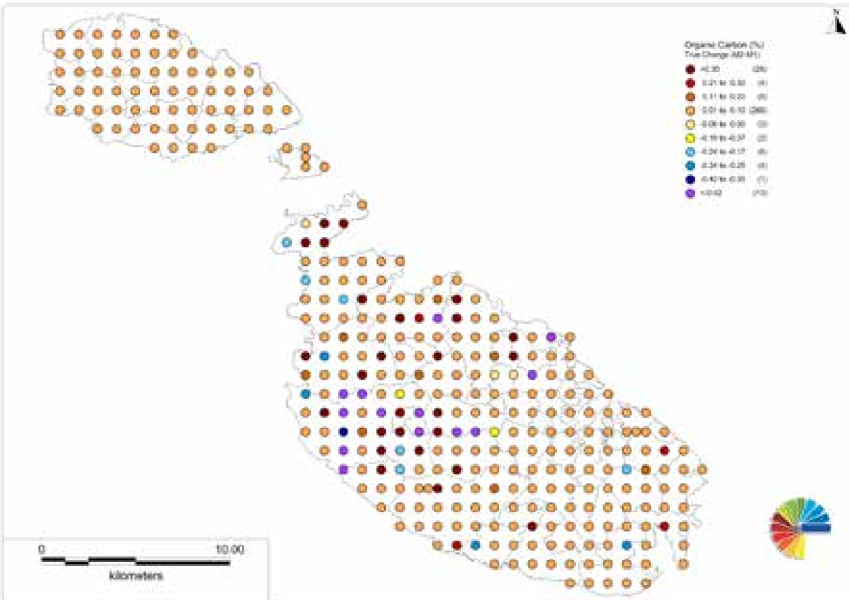


Figure 3b: Change in organic carbon between 2003 and 2013 (M2-M1)

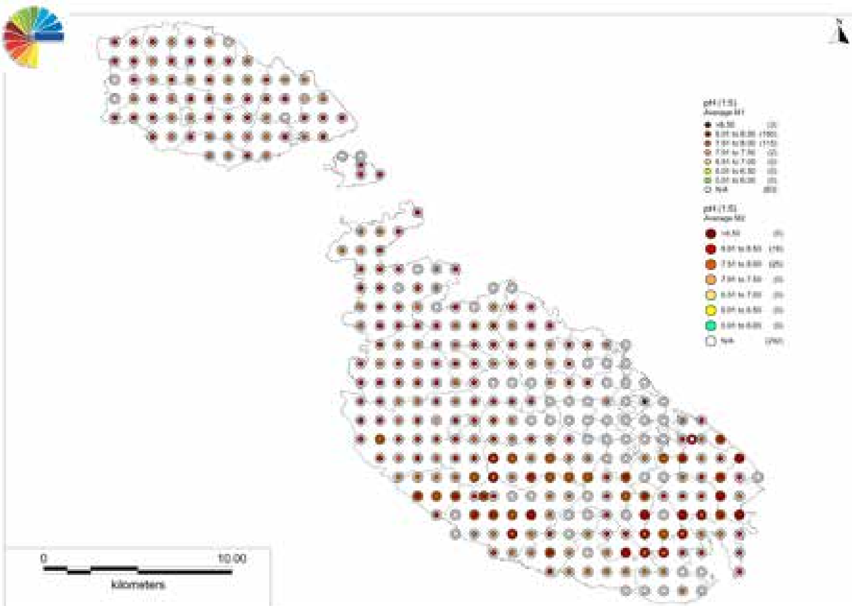


The increase in soil organic carbon strongly and positively influences most of the functions associated with soil quality (Weil et al., 2003). The Rural Development Programme for Malta proposes a number of measures that aim to combat soil degradation, especially in terms of the decline of organic matter and to reduce the level of input of chemical fertiliser. The observed increase in soil organic matter may in part be the result of such initiatives. An additional benefit of an increase in soil organic carbon is that, through carbon sequestration, soil represents a significant sink for atmospheric carbon dioxide (CO2). Climate change mitigation may be enhanced by storing carbon in plant biomass and soils and by reducing emissions from agriculture (Jenkinson & Johnston, 1977; Schlesinger, 1990).

pH (1:5)

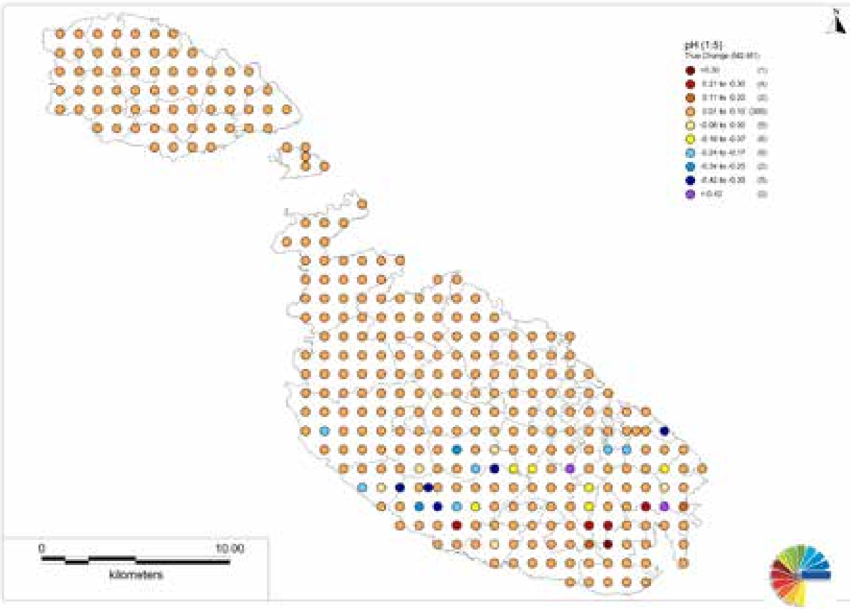
Soil pH (1:5) for the 270 assessed Maltese soils in 2003 (MALSIS 1) fell within the following ranges; >8.5 (alkaline), 1%; 8.5 to >8 (slightly alkaline), 56%; 8 to >7.5, 43%; <7.5, 1%. The average organic carbon for the 41 assessed Maltese soils in 2013 (MALSIS 2) fell within the following ranges; >8.5 (alkaline), 0%; 8.5 to >8 (slightly alkaline), 39%; 8 to >7.5, 61%; <7.5, 0% (Figure 4a).

Figure 4: Average pH values for M1 (2003) as the smaller circles and M2 (2013) values as the larger circles surrounding the smaller (M1) circles



Change in pH was also assessed for sites where measures in pH were carried out in 2003 (MALSIS 1) and 2013 (MALSIS 2). MALSIS 2 values were subtracted from MALSIS 1, such that a positive change demonstrates an increase in pH (becoming alkaline) and a negative change suggests a decrease in pH (becoming acidic). Change in pH has been calculated in 40 sites and exists within the following ranges; ≥0.3%, 3%; <0.3 to 0.2, 8%, <0.2 to 0.12, 5%; <0.12 to 0.01, 20%; 0 to -0.06, 13%, <0.06 to -15, 10%; <-0.15 to -0.24, 18%; <-0.24 to -0.33, 8%; <-0.33, 18%. Results suggest that 65% of the locations assessed in 2013 were more acidic than the same locations in 2003. The average pH (1.5) of all the sites assessed in 2003 is 8.02. The pH (1:5) for the sites assessed in both 2003 and 2013 (40 sites in total) was of 8.01 for 2003 and 7.92 for 2013 (Figure 4b).

Figure 4b: Change in pH between 2003 and 2013 (M2-M1)



Moisture content (%)

Soil moisture for the 270 assessed Maltese soils in 2003 (MALSIS 1) fell within the following ranges; 0 to 2%, 9%; >2 to 4%, 52%; >4 to 6%, 30%; >6 to 10%, 9%; >10%, 0% (Figure 5a). The average organic carbon for the 41 assessed Maltese soils in 2013 (MALSIS 2) fell within the following ranges; 0 to 2%, 1%; >2 to 4%, 42%; >4 to 6%, 39%; >6 to 10%, 15%; >10%, 3% (Figure 5a).

Change in moisture content was also assessed for sites where measures in moisture content were carried out in 2003 (MALSIS 1) and 2013 (MALSIS 2). MALSIS 2 values were subtracted from MALSIS 1, such that a positive change demonstrates an increase in moisture and a negative change suggests a decrease in moisture. Change in moisture content has been calculated in 148 sites and exists within the following ranges; ≥9.2%, 1%; <9.2 to 8%, 1%, <8 to 4, 5%; <4 to 2%, 14%; <2 to 0%, 40%, <-0.01 to -2%, 29%; <-2 to -4%, 9%; <4%, 1% (Figure 5b). Results suggest that 61% of the locations assessed in 2013 had higher soil moisture content than the same locations in 2003. The average soil moisture of all the sites assessed in 2003 is 3.77%. The soil moisture for the sites assessed in both 2003 and 2013 (148 sites in total) was of 3.97% for 2003 and 4.50% for 2013.

Figure 5a: Average moisture content values for M1 (2003) as the smaller circles and M2 (2013) values as the larger circles surrounding the smaller (M1) circles

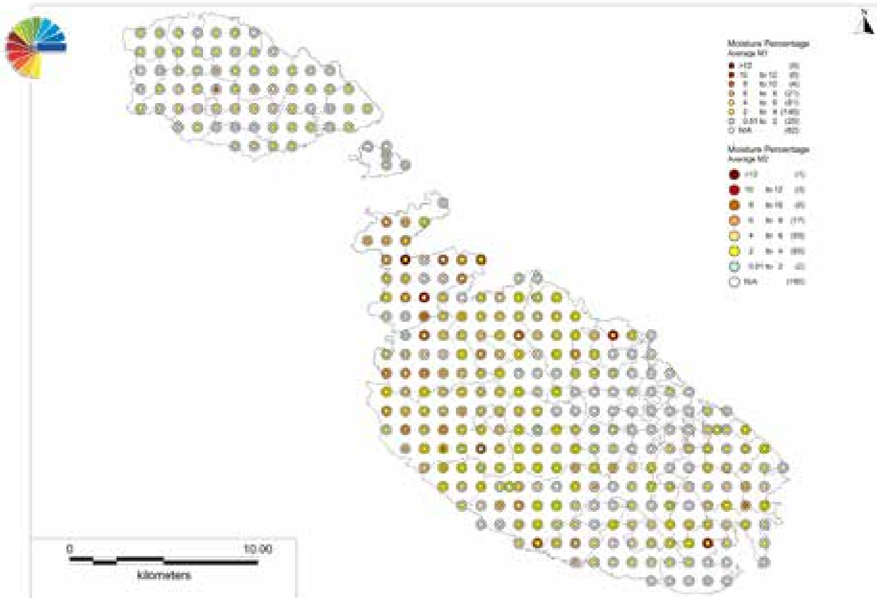
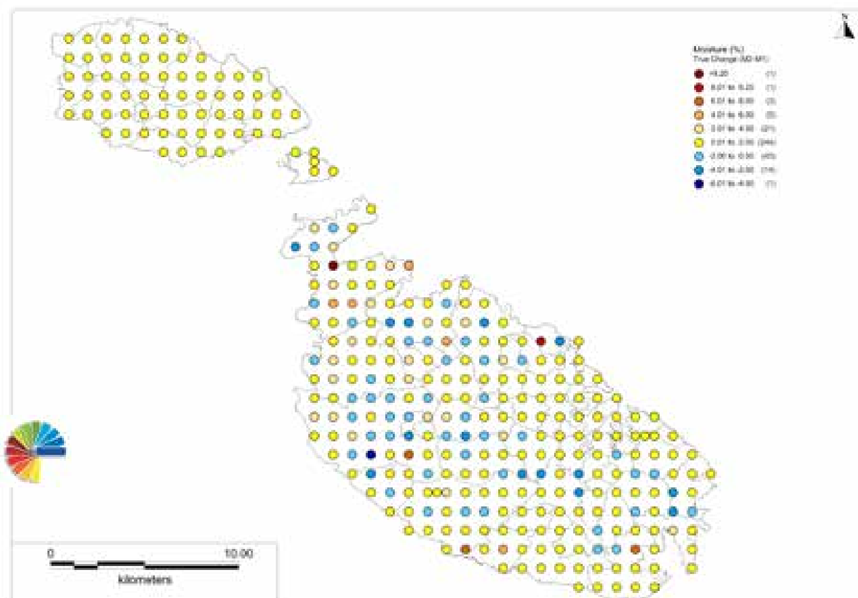


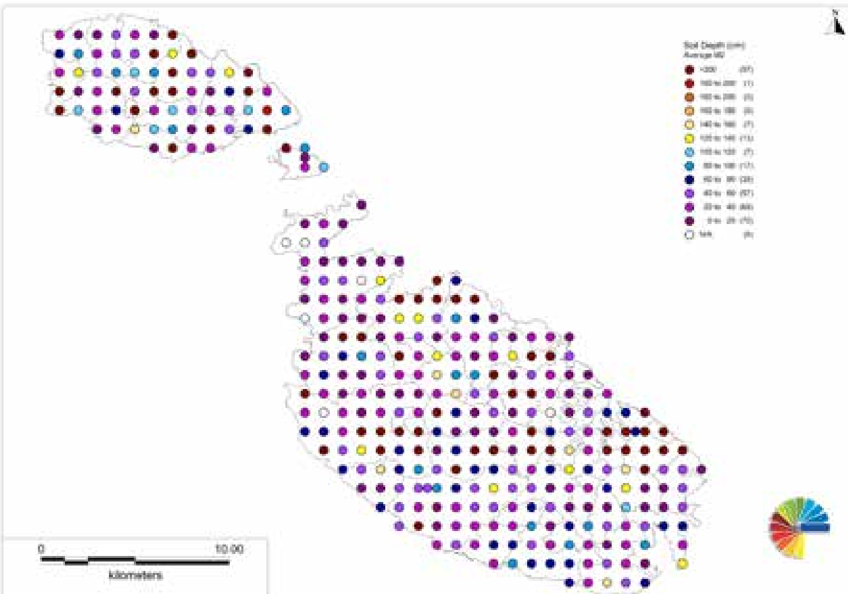
Figure 5b: Change in moisture content between 2003 and 2013 (M2-M1)



Soil depth

Soil depth was not measured in Maltese 2003 (MALSIS 1). In view of the significant lack of systematic quantitative National soil depth data, soil depth was assessed in 343 sites in 2013 (MALSIS 2). The recoded average values fell within the following ranges; 0cm, 2%; >0 to 10cm, 9%; >10 to 20cm, 12%, >20 to 40cm, 20%; >40 to 60cm, 17%; >60 to 100cm, 17%; >100 to <200cm, 7%; >200cm, 17% (Figure 6).

Figure 6: Top figure displays average soil depth values established in M2 (soil depth not calculated in M1)



The average National soil depth in areas where soil was recoded and did not exceed 200cm, was of 47.76cm. Shallow soils, less than 10cm in depth, are often associated with plateaus and surfaces subject to soil erosion (e.g. inclined valley sides). Deeper soils, ranging from 10 to 100cm depth, are typically associated with agricultural areas on relatively flat and moderately include surfaces. Agricultural areas containing soil within the aforementioned depth range, located in included valley sides, often retain soil through the construction and maintenance of soil retaining rubble walls. These structures are paramount to maintain soil in place and where absent or not restored, rapid soil erosion ensues (Sultana, 2015). As suggested by Lang (1960), in this study soils deeper than 100cm were only observed in areas associated with valley beds where material eroded in with the catchment is deposited.

Statistical significance (paired t-test)

The paired t-test calculates the difference within each before-and-after pair of measurements, determines the mean of these changes and reports whether this mean of the differences is statistically significant. A paired t-test is used to compare two population means where you have two samples in which observations in one sample can be paired with observations in the other sample. In this study the paired t-test is applied to assess statistical significance of before (M1, 2003) and-after (M2, 2013) observations for each assessed soil indicator. The difference in soil bulk density results is statistically significant, for electrical conductivity is is not quite statistically significant, for organic carbon it is not statistically significant, and for moisture content it is very statistically significant. Results are displayed in Table 1.

Table 1: Statistical significance with the paired-t test

Soil quality indicator	Bulk density	Electrical conductivity	Organic carbon	pH	Moisture content
Paired t-test result	0.0319	0.0711	0.1968	0.0100	0.0041
Statistical significance, conventional criteria (95% confidence interval)	Statistically significant	Not quite statistically significant	Not statistically significant	Statistically significant	Very statistically significant

Conclusions

The sampling locations identified for this study are the same as those studied in MALSIS (2003) and are based on a 1km spaced grid distribution across Malta and Gozo. All grid points located within soil containing natural and agricultural areas were sampled in this study. The study present involved the survey of 280 sites across Malta and Gozo (Figures 1 to 6).

Bulk density change has been calculated in 97sites. Results suggest that 59% of the locations assessed in 2013 had a greater average bulk soil density than the same locations in 2003 i.e. soil compaction is prevalent. The average soil bulk density for the sites assessed in both 2003 and 2013 (97 sites in total) was of 1.12g cm3 for 2003 and 1.17g cm3 for 2013.

Change in electrical conductivity has been calculated in 141 sites. Results suggest that 67% of the locations assessed in 2013 had a lower electrical conductivity than the same locations in 2003. The average electrical conductivity for the sites assessed in both 2003 and 2013 (141 sites in total) was of 512uS-1 for 2003 and 430uS-1 for 2013.

Electrical conductivity is a measure of salinity and is also influenced by soil nitrate levels (Lewandowski et al., 1999). A number of national initiatives, key amongst which may be the Nitrates Action Programme (2011), may, in part, be an explanation for lower soil electrical conductivity recorded in 2013.

Change in organic carbon has been calculated in 70 sites. Results suggest that 59% of the locations assessed in 2013 had higher organic carbon content than the same locations in 2003. The average for soil organic carbon content for the sites assessed in both 2003 and 2013 (70 sites in total) was of 2.11% for 2003 and 2.30% for 2013. The increase in soil organic carbon strongly and positively influences most of the functions associated with soil quality (Weil et al., 2003). An additional benefit of an increase in soil organic carbon is that, through carbon sequestration, soil represents a significant sink for atmospheric carbon dioxide (CO2).

Change in pH has been calculated in 40 sites. Results suggest that 65% of the locations assessed in 2013 were more acidic than the same locations in 2003. The average pH (1.5) of all the sites assessed in 2003 is 8.02.

Change in moisture content has been calculated in 148 sites. Results suggest that 61% of the locations assessed in 2013 had higher soil moisture content than the same locations in 2003. The soil moisture for the sites assessed in both 2003 and 2013 (148 sites in total) was of 3.97% for 2003 and 4.50% for 2013.

Average National soil depth in areas where soil was recoded and did not exceed 200cm, was of 47.76cm. Shallow soils, less than 10cm in depth, are often associated with plateaus and surfaces subject to soil erosion (e.g. inclined valley sides). Deeper soils, ranging from 10 to 100cm depth, are typically associated with agricultural areas on relatively flat and moderately include surfaces. Agricultural areas containing soil within the aforementioned depth range, located in included valley sides, often retain soil through the construction and maintenance of soil retaining rubble walls.

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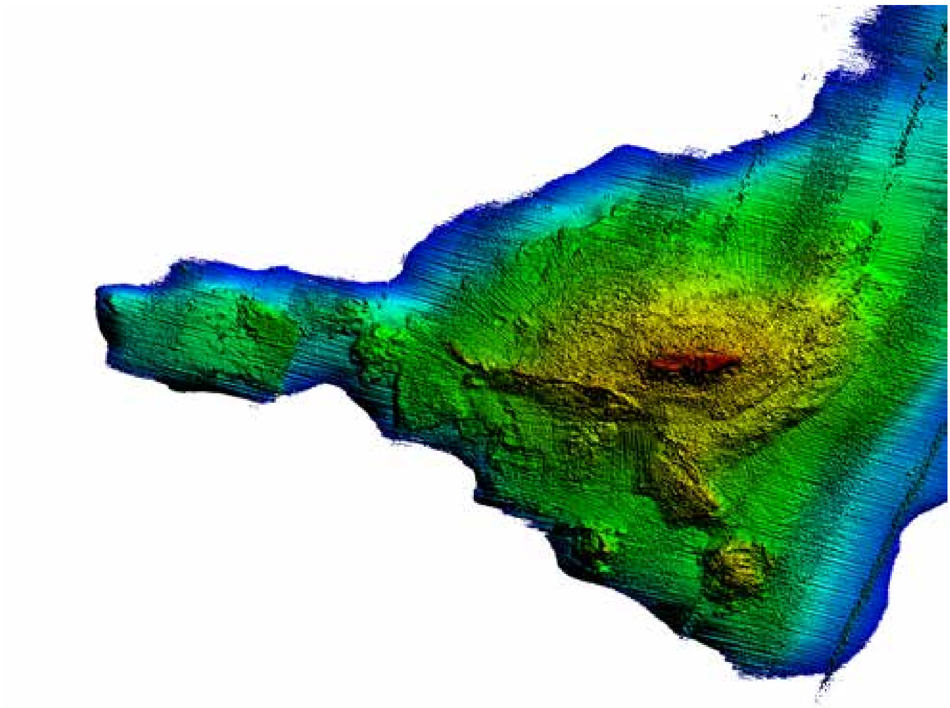
Pivot III

Physicality and Realisms



Filfla

Coast at -75m ERDF156 in 2012

GEO (WGS84) (14.4043388539, 35.7996659720) - -117.55 m,
35° 47’ 58.7975” N, 14° 24’ 15.6199” E

CHAPTER 14

Time and Team Efficiency in Construction Project Management

Francesca Azzopardi

Introduction

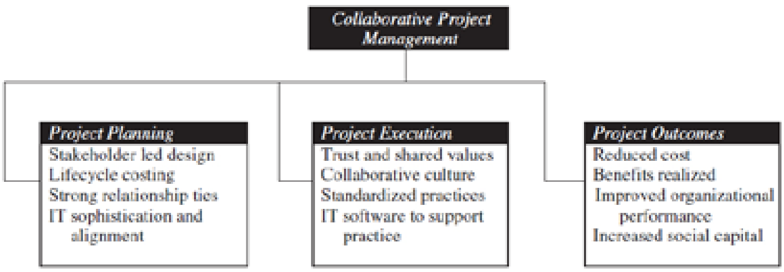
"It is possible to leverage project cost, construction speed and plant operability through effective people management" (Scott-Young & Samson, 2008). Project teamwork affects time management, irrespective of project size, type and scope; the more efficient the team is, the greater the level of project success in the least possible time with the least number of overheads. The client and contractor as well as project stakeholders stand to gain from time and team efficiency with respect to increased profitability and good exposure for works caried out. Societal benefits are also reaped since projects completed in a timely manner reduce nuisance on a macro and micro level, and begin serving the community in an immediate and effective manner.

Theoretical Issues

Collaboration between and within construction companies is being envisaged as a means of improving productivity within the industry by a number of researchers. Amongst these, a study by AMA Research demonstrated that collaboration within the project management team can improve profits for all supply chain partners by as much as 3% (Attaran and Attaran, 2007). Authors Bresnen and Marshall identified several advantages of collaboration, including increased productivity with reduced costs, reduction in project times owing to early supplier involvement and team integration, improved quality, improved client satisfaction and enhanced responsiveness to changing conditions, and greater stability to help companies deploy their resources more effectively. Societal benefits have also been identified where proper communication channels established through such collaboration facilitate understanding between local communities and project stakeholders.

Fulford and Standing (2014) examined the factors impacting on collaboration in the project networks of three large companies through questionnaires and conducted expert reviews on these. Their findings (Figure 1) led them to present a model embracing the concepts of collaborative project management at the planning and execution phases of a project, with project outcomes including reduced cost, improved organisational performance and increased social capital.

Figure 1: A model presented by Fulford and Standing showing the advantages of collaborative project management in the construction industry

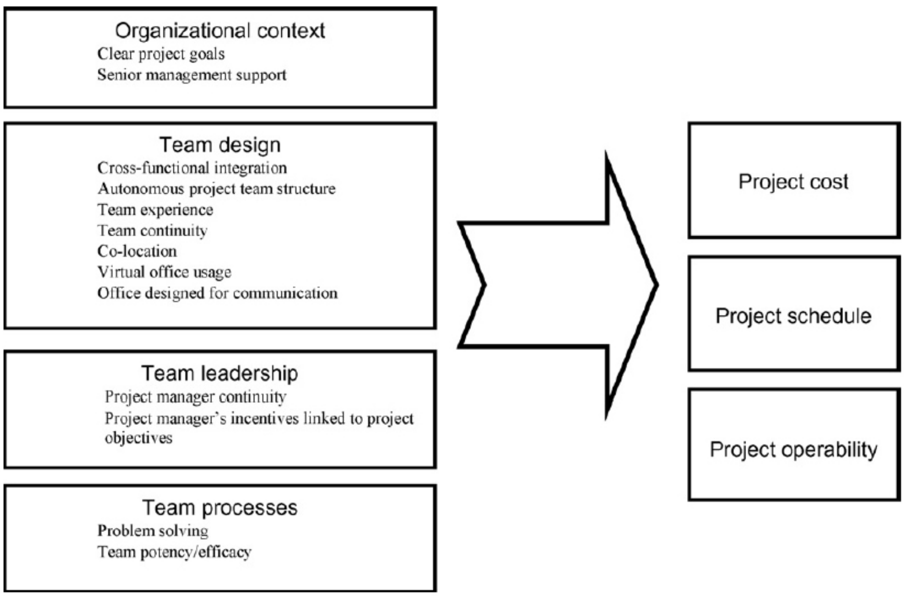


Source: Fulford & Standing (2014)

Scott-Young and Samson (2008) investigated how cost, schedule and operability are driven by project team factors. The researchers created a theoretically-based project team management model with five phases: organisational context, project team design, project team leadership, project team processes and project outcome factors, in order to analyse project management team factors among construction project management teams. Their results showed that having a cross-functional project team early in the project life cycle ensures a broad area of expertise which is needed especially in the initial phases of a project. Ensuring project manager continuity was also a favourable point among the companies taking part in the research. The researchers also found that it is considered vital for a project team to be supported by virtual technology in their office to facilitate effective communication. Virtual technology is in itself a great benefit to society which stands to gain from national and EU projects since it not only encourages project management efficiency but also contributes to helping society in general understand the purpose and gains of such projects in order to utilise these to their maximum potential.

Many empirical studies have been carried out regarding the use and popularity of project management methodologies; the general trend has reported an increase in the use of methodologies and tools within project management (PM) professionals over the years (Fortune, White, Jugdev, & Walker, 2011; Raymond & Bergeron, 2008). Such methodologies and techniques are all developed to help project managers and administrators manage a project as successfully and efficiently as possible, in the shortest possible time with the best yielded results if used correctly. Fortune et al conducted surveys among project managers throughout Australia, Canada and the United Kingdom to determine the extent to which those involved in project management actually make use of the methods and techniques available and how effective these were felt to be in terms of project success and time management.

Figure 2: Model of team-realted factors impacting operability, cost and schedule.



Source: Scott-Young and Samson (2008).

Their research showed that with respect to PM methodologies, "Project in Controlled Environments 2" (PRINCE2) and "Project Management Body of Knowledge" (PMBOK) were deemed the most popular methods. In terms of PM software, "Microsoft Project" proved to be the most popular among the three countries, followed by "Primavera". Use of PM tools was mostly limited to 'GANTT' bar charts, Work Breakdown Structure, SWOT Analysis (Strengths, Weaknesses, Opportunities and Threats) and Programme Evaluation and Review Technique (PERT), listed in order of popularity. "Probability Analysis" and "Life-Cycle Cost Analysis" (LCC) were mostly used as risk assessment tools, whereas the most popular ICT technology support tools included Integrated Groupware (email, collaborative tools, shared access to web portals) and video conferencing.

Experiences Gained Through Project Management and Implementation: Societal Benefits Gained From National, EU and International Projects

"Teams are essential in projects for tackling complex work requiring a variety of knowledge and skills, stimulating creativity and innovation, empowering workers" (Loo, 2002). From experiences gained through construction project management and implementation so far whilst managing a variety of largescale national and EU-funded projects, the author of this chapter identified that successful teams are likely to work on a team-think basis, defined by Erdem (2003) as a constructive and creative approach to teamwork and team building skills. Her research found that "inquiry, critical questioning, challenging behaviours are all positive if they take place in a generally trusting and supporting environment" (Erdem, 2003). The use of virtual technology facilitates time and team efficniecy for the benefit of societal gains.

The author's research effort also identified that the more varied the competencies of the project management team the more likely it is that team members complement each other to contribute to a successful project. Business-orientation coupled with organisational and computer skills, logistical thought and assertiveness are all important traits which need to be nurtured for a project management team to ultimately gain societal benefits from national and EU-funded projects. Locally, the author experienced many contractor groups who were competent in their work, owever, their individual site management was sometimes lacking in proper health and safety enforcement.

Such trends are extremely detrimental to surrounding communities since they not only discourage society from understanding project gains but may also pose a health hazard to neighbourhoods nearby. As an assistant project leader the author sometimes also found it challenging to submit required documentation for recording purposes, as the contractors seemed disorganised when reporting and handing over information.

Some projects suffered delays due to lack of communication between the client, the contractor and the subcontractors. Since one single point of reference was not properly established in the project contract with reference to on-site management, the client and his technical team found it challenging to monitor different trades simultaneously. Measurement of works was also a laborious process and led to delay in payment during some instances because of this flaw. As a result such delay caused unnecessary nuisance to the local community within the project surroundings until the projects were complete.

In turn inadequate selection of contract terms and ambiguous project clauses will also lead to poor productivity. Hence contractual management is an important factor influencing project delivery as it will lead to delay and cost overrun if not followed up correctly, and is important to consider for an effective organised team structure based on proper time management.

Risk Management to Aide Efficiency

Design-Build contract types are becoming increasingly popular among largescale national and EU-funded projects. The 'single-point' responsibility of the contractor in Design and Build contracts is very attractive to clients, particularly those who may not be interested in trying to distinguish the difference between a design fault and a workmanship fault (Murdoch & Hughes, 1998). By removing these blocks to effective communication, experience has shown that programmes and budgets are more likely to be adhered to, and construction time may be shortened as a result (Pain and Bennett, 1998). Design-Build contracts may also be desired in order to encourage contractors to research innovative forms of building whilst simultaneously studying the practicality of their solutions. Malta has no natural resources and we must import material that may take time to procure. One of the biggest disadvantages of design and build is that the employer's requirements must be made very clear from the start and they should not be subject to change during the project. In my opinion this basic fundamental issue may not be adhered to in largescale projects, to the detriment of society standing to gain from such projects.

Design variations by the client prove to be the greatest risk affecting project success, and it may be usual for projects to be criticised for lack of design submitted at tender stage. Although such variations may not impede the pace of construction, it may take a substantial amount of time to be sorted, resulting in the delay of completion of certain project phases. Delays in procurement and purchasing of specific material are also considered risks to project completion. This could be attributed to the high performance and quality expectations of the client and design team. This risk can be identified and assessed better at feasibility stage with respect to project schedule.

Lack of coordination between project participants is a risk which needs to be given quite some weight during feasibility stage. The PM team should be successful in bringing together the design and contracting teams with the client for stipulated meetings. Although there may be delays on certain decisions, the teams' perception of cooperation and communication should as a project progresses, which would to be a positive outcome of the project. Addressing project risks at the earliest stage possible in the project lifecycle could minimise consequences brought about by these risks. The client and designers may work more cooperatively together during feasibility stage to address potential risks in time as a result. Zou, Zhang, & Wang, (2006) suggest that "contractors and subcontractors with robust construction and management knowledge must be employed early to make sound preparation for carrying out safe, efficient and quality construction activities". Limiting the period for employment of contractors could also be considered to mitigate issues arising from potential risks associated with health and safety hazards.

Methodology: The Rise of Virtual Information Management in Time and Team Efficiency

Virtual information management contributes to achieving efficient time management within any project management team. In the construction industry it can be described as diverse and sometimes disorganised throughout many organisations, as many project managers are knowledgeable of IT but are inefficient in collating and using data in spreadsheets for preparation of bids, specifications, etc.

According to Fulford and Standing (2014), "many of the issues created by tiered project delivery could be alleviated through the standardisation of information and alignment of IT across organisations". Such standardisation might include the alignment of types and sizes of cost fields for material supplies or fields required to transfer work breakdown information from project managers to site management teams. Another option may incorporate the creation of a centralised data bank where information is stored and retrieved. Data can be organised on a project-by-project basis and can be accessed from any internet source with the appropriate passwords, in the form of a cloud system.

This system can be updated in real time with respect to the creation and issuing of reports, transactions of purchase, etc. In addition, "statistics, trends and forecasts can be made...readily available, which is invaluable to stakeholders" (Munier, 2013) and managers alike to track project and team progress accordingly. This system will definitely help to overcome the challenge of increasing productivity of the PM team as time is saved in finding and sorting data, albeit some start-up costs if the system is not already in place. Bankvall, Bygballe, Dubois, Jahre, (2010) found that the dissemination of IT is critical for productivity improvements, especially within supply chain management and emphasized the requirement for this to be supported by the use of data standards.

Matos and Lopes (2013) researched the concepts and ease of implementation of PRINCE 2 and PMBOK to support an entire project lifecycle, and argue that "methodologies area an indispensable tool used in project management which allow measure of progress and task control" (Matos & Lopes, 2013). Methodology is useful to assist in time management by analysing each step in the project life cycle and helps formulate measures and targets to deliver on time and with the best quality and resources provided.

PMBOK was created by the Project Management Institute and is a detailed framework of nine knowledge areas broken down into activities along five progress groups. These include initiation (involves gathering of commitments required to get the project started), plan (maintaining a schedule of tasks and resources required to fulfil a business need), execution (focuses on methods of co-ordinating people and resources to execute the project), control (aids project managers to ensure that targets are met by monitoring progress) and closing (formalising acknowledgement that project is complete). PRINCE 2 was created in 1989 by the CCTA (Central Computer and Telecommunications Agency). This has now been incorporated within the UK Government Digital Service. It aims to detail how the techniques of project management should be structures and implemented to develop a successful project (Matos & Lopes, 2013).

The main features of this methodology are based on business focus; "an organisation structure directed to the project management team" (Matos & Lopes, 2013). PRINCE 2 is the standard of project management methodology used by the English Government and is widely recognised and used in the private sector throughout the United Kingdom. PRINCE 2 emphasizes the division of a project into the following phases: starting up, directing, initiating, planning, controlling a stage, managing product delivery, directing and closing. They are intricately linked and can be graphically presented as shown in the image below.

Time monitoring and control is an important process associated with execution and overseeing of the project, and refers to checking of work advances in accordance with the schedule established during planning stage. Critical Path Method (CPM) or PERT methods can be used to time limits for a project plan. The CPMis commonly used to establish relationships between tasks and determine the critical path of the project by establishing durations for each task, taking into consideration tolerance (float). Float is important to consider to study delays due to extensions and to schedule tasks in order to level resources. Monitoring is then done by comparing actual advance of work with planned advance at a certain date, considering scheduled plan of work as a baseline. On the other hand the main goal of the Programme Evaluation and Review Technique (PERT) analysis is to create the distribution of project duration. In a PERT network, activity durations are defined by variables that are assumed to be independent of each other (Hajdu & Bokor, 2014). The distribution of the activity durations follows a so-called PERT-beta distribution. According to PERT theory, the project duration follows a normal distribution, with the mean being the result of time analysis based on activity mean durations.

Scope changes during project execution and slow close-out once a project is practically complete are two major instances which can contribute to lack of productivity and result in poor time management. Scope changes are the results of uncertainties at planning stage and with each scope change, project resources are diverted to activities which were not identified in the original project scope, leading to pressure on project schedule and budget (Ambituuni, 2011). To achieve proper control of scope change, Ambituuni (2011) suggests integrating a proper change management plan by seeking approval for change from stakeholders and communicating them effectively among all parties involved to avoid disputes. A slow close-out may occur whereby various handing over activities take too long to complete due to unresolved issues with the client, delays in issue of final change orders and disorganisation in issuing and handing over commissioning documentation. These all prolong handing over and demobilisation from site. Reducing idleness from team members to reduce possibility of any extra costs for overheads, ensuring stakeholder satisfaction with the final product and keeping all documentation up-to-date throughout the project lifecycle are all positive factors contributing to efficient time management to avoid conflict and doubt for final issue of certifications and payments.

Conclusion

Project managers and other professionals within the construction industry are becoming more dependent on virtual management with respect to use of tools that assist in the efficient use of time as well as collection and alignment of data. These ensure productivity and standardisation throughout a project to successfully complete it within the least possible time and to budget. Project team management, contractual management and managing scope changes and design errors are all important to consider in the enhancement of an organisation's productivity, and collaboration between different organisations can be sought to produce a more efficient management structure in terms of tendering and execution of a project upon award. The use of virtual information management should thus facilitate the understanding of societal needs in order for the nation to reap the benefits of vital construction projects which aim to improve citizens' lives through increased economy, improvement in accessibility and ease of mobility.

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CHAPTER 15

Challenges and Approaches for Smart Innovative Transport System Replication

Valerian Croitorescu and Alexiei Dingli

Introduction

The environment changes are highly met worldwide, especially inside very crowded urban cities and metropolitan zones. Urban cities with high levels of visitors are subject for the environmental changes in addition to the committed resources to fulfill all the potential activities. The environmental changes apply to several societal levels, depending on the involvement of each in the wellbeing definition. While more citizens will come to urban areas, the environmental changes will change accordingly with their life styles. Urban cities all around the globe have to be prepared for massive changes in terms of sustainable development.

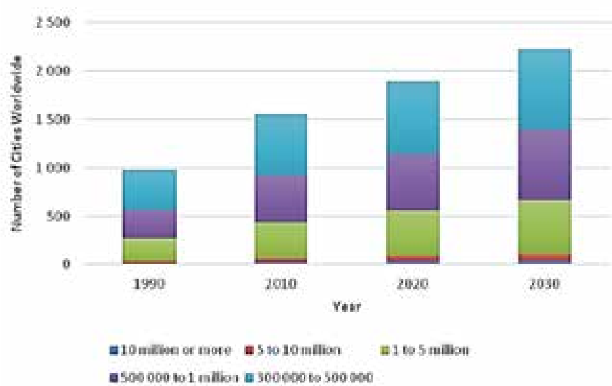
Improving technological level will bring cities to new eras in terms of involving citizens in daily activities. By implementing new innovative life styles, the cities will have different growth and development. The already powerful links created between environment, social and economy are bringing together the bearable, viable and equitable solutions for a better living by introducing new innovative technologies. Several development directions are being followed by many urban cities, having at least one main common objective: to transform the current urban city to an eco-urban-city. The latter refers to a sustainable city designed and implemented as an environmental friendly solution to the inhabitants of urban cities who face several problems regarding emissions, noise and no green areas, with high energy consumption, low level on recycling, low level to regenerate energy, wasting water and natural resources, amongst other scenarios.

Making everybody understand the eco-green city requirement and its importance and the ways to achieve it represents one major objective for the new urban cities. The cities have to be prepared for the future, have to be optimised and configured to achieve the improved livability and social inclusion. More than 66% of the world population will be living in urban areas by 2020 (Croitorescu and Ruichek, 2015) while by 2050, it is expected that nearly 70% of the world's population will live in urban areas (UN-HABITAT, 2012).

More cities are expected to appear and to the number of cities may be of 1/3 higher comparing 2010 when 1551 cities (UN, 2014) were declared worldwide to 2030 when more than 2000 cities are expected to be declared (Moir, Moonen & Clark, 2014). Figure 1 (Moir et al, 2014) presents the perspective of the number of cities from 1990 to 2030, for different population sizes.

Projections show that urbanization combined with the overall growth of the world's population could add another 2.5 billion people to urban populations by 2050, with close to 90 percent of the increase concentrated in Asia and Africa, according to a new United Nations (UN) report (UN, 2014). Currently, the urban population live in cities with less than 500,000 inhabitants, confirming that the people will continue to live in smaller cities rather than in bigger ones. The United Nations said that urbanization is now "unstoppable". In 2010, Anna Tibaijuka, outgoing director of UN-Habitat at that time, said: "Just over half the world now lives in cities but by 2050, over 70% of the world will be urban dwellers. By then, only 14% of people in rich countries will live outside cities, and 33% in poor countries." (UN, 2010). In the same year, Eduardo Lopez Moreno, co-author of the UN 2014 report, said: "Most of the wealth in rural areas already comes from people in urban areas sending money back", referring to the migration to cities, while making economic sense that is affecting the rural economy too (The Guardian, 2010).

Figure 1. Global number of cities 2030 horizon



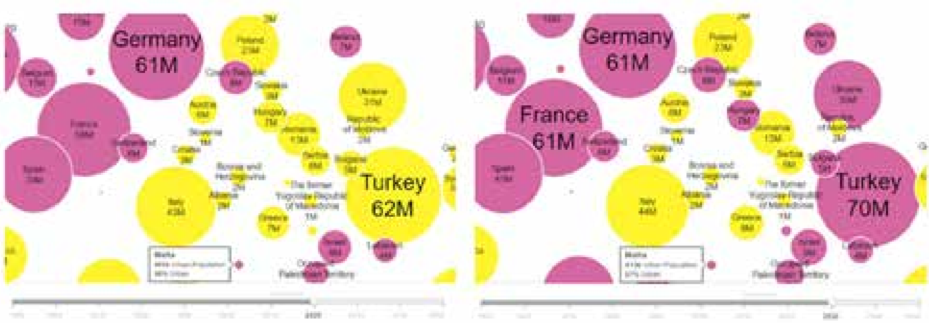
Source: (Moir et al, 2014)

Cities are pushing beyond their limits and are merging into new massive conurbations known as `mega-regions`, which are linked both physically and economically. Their expansion drives economic growth but also leads to urban sprawl, rising inequalities and urban unrest (The Guardian, 2010).

According to Global Health Observatory (GHO) data, the urban population in 2014 accounted for 54% of the total global population, up from 34% in 1960, and continues to grow. The urban population growth, in absolute numbers, is concentrated in the less developed regions of the world. It is estimated that by 2017, even in less developed countries, a majority of people will be living in urban areas (WHO, 2016). According to World Health Organization, the global urban population is expected to grow approximately 1.84% per year between 2015 and 2020, 1.63% per year between 2020 and 2025, and 1.44% per year between 2025 and 2030 (WHO, 2016).

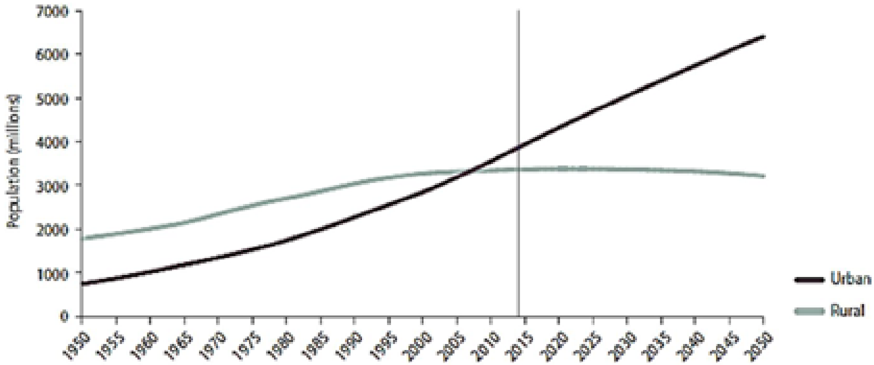
UNICEF (United Nations Children's Fund works for children's rights, survival, development and protection) presented the urban maps as annual graphics from 1960 to 2050 that depicts countries and territories with 2050 urban populations exceeding 100 000 (UNICEF 1, 2012). Circles are scaled in proportion to urban population size. For each country different percentage of people living in cities and towns are presented in addition to the size of their urban population (in millions). Visible growth are seen for most of the countries regarding the expectations for 2020 and 2030 and more (figure 2). Globally, rural populations expected to decrease as urban populations continue to grow (UN, 2015), because more people live in urban areas than in rural areas. The reverse of the global rural-urban population distribution was presented in (UN, 2015), while the data confirms that in 2007, for the first time in history, the global urban population exceeded the global rural population, and the world population has remained predominantly urban thereafter (Figure 3).

Figure 2. The UNICEF perspectives regarding urban population growth, 2020 and 2030 expectations



Source: (UNICEF 1, 2012)

Figure 3. Urban and rural population evolution in the world, 1950-2050



Source: (UN, 2015)

Together with the continuous evolutions, including cities from the low and middle-income countries, the urban cities need new urban design, planning and management for all the activities inside (including transport). The planning for climate change is mandatory, in terms of strategic decision-making processes that incorporates urban objectives to help determine the priorities and allocate the needed resources.

Mobility is fundamental to all societies, being the supporting part for economy, travelling, industry and agriculture. The urban cities have to reduce greenhouse gasses used in energy systems (energy used for transportation) by implementing leading challenges (means of transport that not depend on fossil fuels).

The world greenhouse gas emissions include the 15% emission corresponding to the transport sector, being part of the 76% CO2 emissions (second half of 2010), as results of burning fossil fuels. Natural indicators are able to be used to determine the clear, quantifiable measure for an objective as the volume of greenhouse gasses generated by transport sector are.

The transport sector is typically responsible for about a quarter of the energy-related greenhouse gas production (Figure 4) and private cars account for a significant proportion of this activity (Ingram et al, 2014). Several EU targets have been set to reduce the environmental impacts of transport in Europe, including its greenhouse gas emissions. The transport sector's targets are part of the EU's overall goal to reduce greenhouse gas emission by 80-95% by 2050.

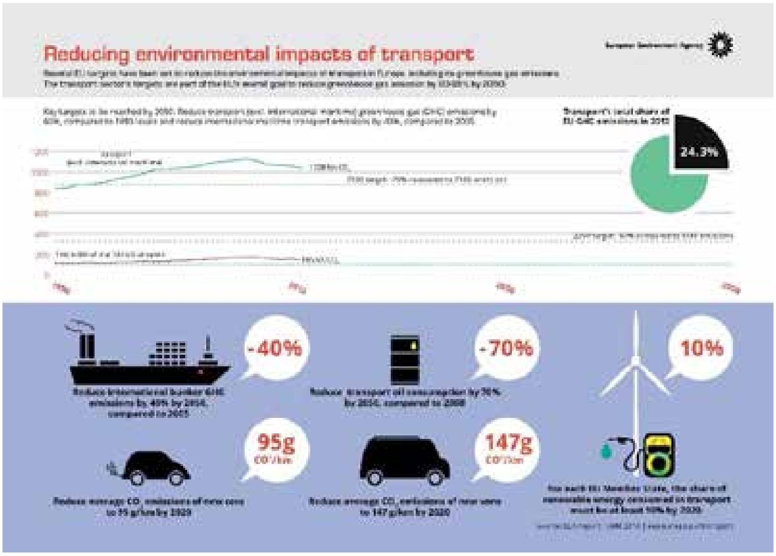
According to the Impact Assessment SEC(2011) 358 of the European Commission, without efficient steps towards sustainable mobility the CO2 emissions from transport would remain one third higher than their 1990 level by 2050. According to the "White Paper on Transport", one of the requirements is to achieve a reduction of the greenhouse gas emission with at least 60 % by 2050 in the transport sector of the European Union (EU) with respect to 1990.

Private cars have a significant role for this percentage as well as light freight road vehicles. As car ownership rates climb in developing countries and urban development continues to spread, further separating the distances between the places people live, work and shop, the greenhouse gas emissions associated with this travel will continue to rise (Ingram et al, 2014). Developing countries met stringent problems by private cars usage even for very short distances in urban environment, being in charge with high quantities of harmful emissions and noise when unnecessary, in addition to traffic congestion and areas vulnerable to climate changes. Planners can help mitigate greenhouse gas emissions by working to reduce vehicle miles travelled and urban congestion through strategies such as compact, high density, mixed-use development (Ingram et al, 2014).

Strategically planned development can also direct development to areas less vulnerable to climate change impacts. The renewable energy in transport represent a well set target unavailable to be met by the last years. Although, the sustainability criteria is representative for reducing environmental impacts from transport. The urban transport has an important role in urban development on several levels. By improving the transport network, the urban traffic congestion will decrease, while implementing new greener modes of transport (public transport, bus transport, cycling, walking etc.) represent the ways in reducing greenhouse gas emissions (Figure 5).

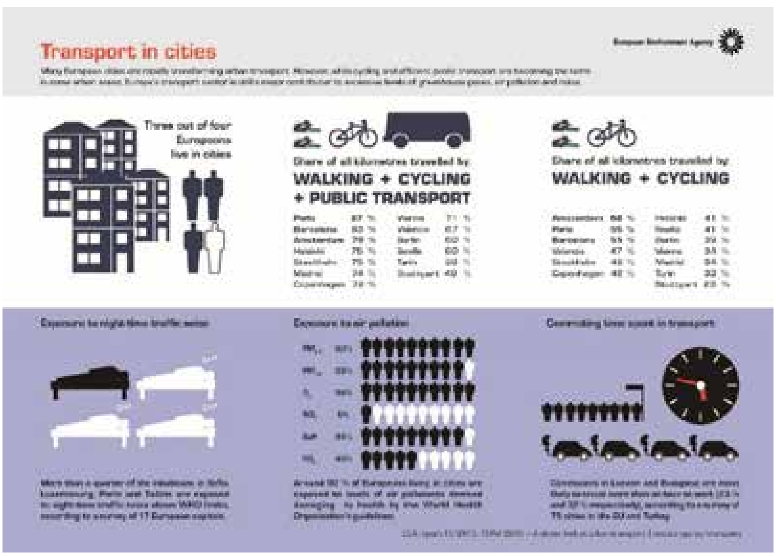
Changing the means of transport in urban cities is a needed reality for increasing the quality of life for the three quarters of Europeans living in cities. As road transport is known as the major pollution source in cities, both by the emissions and by the noise people are exposed also during night, and the private cars are still very often used, many urban cities are trying to encourage people to use public transport, especially the non-motorised modes of transport, while simultaneously restricting the usage of private cars in different areas. Urban city cars should be environmental-friendly and to make the transport more pleasant, with less time spending in traffic. Not only do the infrastructure and the means of transport need improvement but also the people perception need to be adapted to the new era, an innovative new life and with great contribution to wellbeing. The air pollution coming from road transport in urban cities expose many citizens to emissions with high impact on human health.

Figure 4. Reducing environmental impacts of transport



Source: (EEA, 2016a)

Figure 5. A closer look at urban transport



Source: (EEA, 2016b)

Urban cities employ different means of transport, depending on their available infrastructure (water transport, road private cars transport, bus and tram and metro transport, cycling, walking and transport independent lifestyle etc.) and their transport defined zones. Significant effort should be done for organising transport in restricted and protected areas, as well as inside inaccessible areas for everybody. These efforts will bring undoubtedly improvements to the life quality. In addition to the transport infrastructure improvements, the new innovative solutions for the means of transport have their important roles. New green vehicles have to be introduced, being able to regenerate part of the energy while operating, with high energy efficiency, high level of recyclability and low-carbon used materials and low-carbon emissions. Sustainable electric mobility needs to be tackled on all major urban areas, supporting also the cities both for becoming smart and innovative and citizens friendly. Safety is a prior task for all the transport solutions, therefore futuristic tasks are taken into account, one of them being the autonomous driving that comes to fulfill this requirement.

During recent years, the road vehicles became more efficient and met all the exposed targets regarding the emissions and the energy efficiency. Well debated subjects for road transport emissions come from the different driving cycles, because there are some differences between real-world driving emissions and the emissions recorded in the test cycle. The future approaches to determine the real emissions are being introduced to legislation and testing procedures, so international standard tests may be available soon.

Sustainable Mobility

Sustainable mobility in Europe is defined by the European Commission by taking action on urban transport through various policies and funding of projects including CIVITAS. The 2009 Action Plan on Urban Mobility was a major step for European action in this area and its implementation is helping to create cleaner and better urban transport systems. The European Commission's guiding document on transport from 2011, the White Paper on Transport, highlights the importance of the urban dimension. Among other actions is the target to phase out the use of conventionally-fueled vehicles in cities by 2050. In addition after the 2011 Transport White Paper, the European Commission came up in 2013 with an Urban Mobility Package that addresses different initiatives (Civitas, 2013).

Urban mobility seems to be reported to the number of inhabitants and the facing problems caused by transport and traffic. The noise and the harmful emissions reduction, together with the fair prices for transport and to the transport minimum impact on ecosystems represent solutions to be achieved. Daily, several obstacles are met while trying to adopt solutions in order to reduce traffic. In addition, the green vehicle solutions are also facing difficulties in being used because of the charging infrastructure availability. A major challenge is to enhance mobility in the same time while reducing emissions, reducing congestion and increasing safety and security.

The sustainable transport have to allow the basic access and development to the needs of individuals and to design a safer infrastructure, while affordable, efficient and less polluting transportation systems. The sustainable transport have to address social, environmental and climate issues and to assure their impact by using solutions for the vehicles, for the infrastructure and for the source of energy used for transport. The transportation system effectiveness represents the way on how to measure sustainable transport. Based on it, the needed solutions for improvement take into account the short-term activities by controlling vehicles' emissions and reducing fuel consumption and the long-term activities by replacing the conventional vehicles' powertrains with alternative powertrains (hybrid and/or electric and/or using less polluting fuels).

Transport systems are the major emitters of greenhouse gases inside cities. From an automotive perception, by introducing green vehicles, the intention is to have less environmental impact than using conventional vehicles, while assuring safe, secure and pleasure to use. The green vehicles include hybrid vehicles, having at least two different energy storage devices, the electric vehicles that are using only electricity for propulsion and as a back-up may use small internal combustion engines as range extenders, and the vehicles that are using only cleaner fuels as for example the compressed natural gas (CNG) (methane stored at high pressure), bio-ethanol, bio-diesel or hydrogen.

A sustainable mobility city have to be shaped by its transport systems and how it is marketed to the citizens by convincing them to adopt the public transport systems than the public cars and, where possible, to adopt cycling, walking and car-sharing. The policies have a great impact at cities level. The geographic region is defining the available solutions and linking possibilities to the climate protection legislation. Transport plans differs from one city to another, but in addition to improving the roads and the parking lots, the main tasks have to identify and improve the transport networks for a better climate protection and to prioritize the transportation connections for vulnerable groups.

The European Commission adopted the Green Paper "Towards a new culture for urban mobility" on 25 September 2007 (ECGP, 2007). With the Green Paper, the Commission set a new European agenda for urban mobility, while respecting the responsibilities of local, regional and national authorities in this field. The Commission intended to facilitate the search for solutions by, for example, sharing best practice. One referred task is the congestion problem and how to mitigate its reduction. The private cars alternatives have to be attractive and easier to apply by rapidly changing the modes and the means of transport for the best routes. A derivative disputed subject from the congestion problem is the parking places availability inside urban city centers, solutions to be applied for it being the parking places outside the city centers, carpooling and car-sharing, in addition to the efficient public transport and freight transport using green vehicles.

Recent trends to introduce greener vehicles are well demonstrated by oil price changes and the already available technological innovations. Sustainable mobility must also support a good economy. The urban cities already used different mobility solutions that need to be updated and improved, in order to increase their competitiveness. The proposed solutions for better urban cities are based on the two innovative areas of vehicle development: electrification and autonomous driving. The urban cities have to test a set of applications that are based on these two technological fields and to evaluate their efficiency with respect to the aspects of sustainable mobility that were mentioned.

Challenging Technologies for Innovative Mobility Solutions

Vehicles Electrification Mobility Influences

The electrification of vehicles and autonomous driving are two key elements that will revolutionize the mobility of the future whilst providing various options to address and implement the main aspects of sustainability. Cities all around Europe must be well-prepared for the changes that will be initiated by these two fast developing technological fields in order to gain a maximum benefit towards sustainable mobility.

Electrification and autonomous driving are part of the measures to be adjusted to the rapidly developing technologies. Electric vehicles development plays an important role for all global car-manufacturers since this is a key-technology to reach the goals of CO2 reduction. Both hybrid and electric vehicles are already available for commercial use. However, research and new developments in these fields are necessary to make electric vehicles more efficient and affordable, in addition to the charging infrastructure availability, and to the continuous upgrade of the intelligent communication networks between vehicles and between vehicles and infrastructure.

The ultra-low carbon emissions vehicles are mandatory for achieving the climate goals. The market and the infrastructures must be prepared for the changes and the currently battery electric vehicles, the hybrid electric vehicles and the fuel cell vehicles keep to be the main qualified solutions. E-mobility in terms of electric or hydrogen vehicles can deliver sustainable solutions to stimulate the users.

There are several potential benefits of e-mobility while contributing to the sustainable mobility. The public grid charging designed for the electric vehicles and for the plug-in hybrid vehicles represent a cost balance together with the responsible car sharing and the light-weight, down-sized efficient powertrain and the efficient driving techniques. There are also several risks to be taken into account, the time to market and the time to user, in addition to the discouragement to use different fuels, to share the own vehicle with others and to use newly powertrain solutions represent boundaries in implementing e-mobility. E-mobility can affect the sustainable mobility in the way how policies are focused on the new trends.

Green vehicles are part of the e-mobility solutions. The green vehicles, presented as the electric vehicles and hybrid electric vehicles can be defined as many different categories, including: battery electric vehicles, plug-in hybrid vehicles and fuel-cell vehicles. Currently, the hybrid electric vehicles are the only available solution that do not need special improvements or changes to the infrastructure. The hybrid electric vehicles are using at least two energy storage systems, one for the fossil fuel and one for the electricity. Depending on the hybrid powertrain solution, the environmental performances are not increasing considerably, but some changes are able to be seen.

The battery electric vehicles are using only electricity as the main power source, supplied to an on-board battery that delivers electricity to one or more electric machines. The battery electric vehicles have zero emissions while being used, but the used energy may be produced in fossil fuel power plants (that pollute) or in photovoltaic power plants (that are eco-friendly solutions). The battery electric vehicles' range is one of the main obstacles in large scale implementation in addition to the charging infrastructure development. Some battery electric vehicles have a range extender that consists in a small size internal combustion engine that operates only when its operation is strictly necessary and the available battery state of charge is not enough for the drivers' demands. The range extender is able to produce electricity and to increase the standard available range, not being able to drive the wheels by itself.

The plug-in hybrid vehicles are mainly powered by electricity usually on short distances, their range depending of their batteries technologies, having also additional systems to provide electricity when needed, while for operating above defined speeds the internal combustion engine is providing the vehicle's propulsion. For the plug-in hybrid powertrain, the charging to the grid solution is used in parallel to other charging solutions. The internal combustion engine is able to charge the battery using a generator, in addition to the recovery energy system that recovers the braking energy and store it in the batteries.

These vehicles are producing harmful emissions while the internal combustion engines are operating, but generally at low level due to the innovative technologies that allow the engine to operate near the economic pole most of the time.

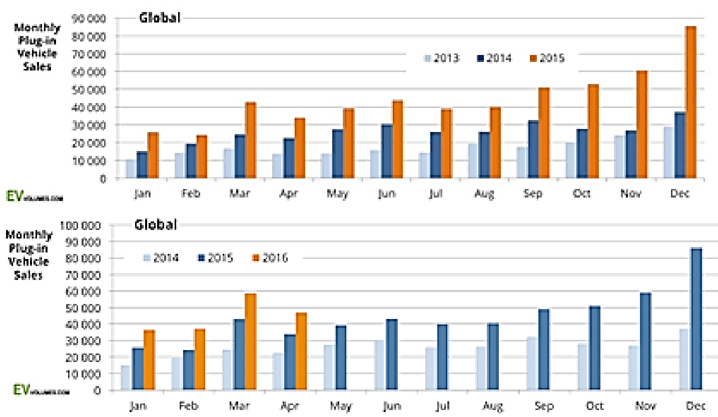
The fuel cell vehicles are using at least one electric machine for propulsion, the electricity being produced inside the vehicle, using dedicated equipment. The highest grade difficulties for the fuel-cell vehicles were solved, but the available infrastructure to charge the hydrogen tanks is limited. Even if the fuel cell vehicles are not so popular due to their high costs, the future will bring them as the main means of transport at least inside the crowded urban cities.

Electric and Hybrid Electric Vehicles Evolution and Charging Availabilities

During the last years, the electric and hybrid electric vehicles sales had considerable growth (Figure 6). Globally, more than half a million plug-in electric vehicles (including battery electric vehicles and hybrid electric vehicles with plug-in systems) were delivered to buyers in 2015 (Ayre, 2016), nearly 200 000 plug-ins being sold only in quarter 4 of 2015. The plug-in hybrid vehicles' sales grew faster, with 80%, than battery electric vehicles, that grew only with 64%.

Until April 2016, the plug-in vehicles sales worldwide were about 180,500 units, being higher with 42% than for the same period in 2015 (Figure 6), including beside the battery electric vehicles and the plug-in hybrid vehicles also few light commercial electric vehicle. Comparing with 2014, the sales were higher with 71% in 2015, while quarter 4 from 2015 was notably stronger in sales (Ayre, 2016).

Figure 6. Plug-in vehicles global sales



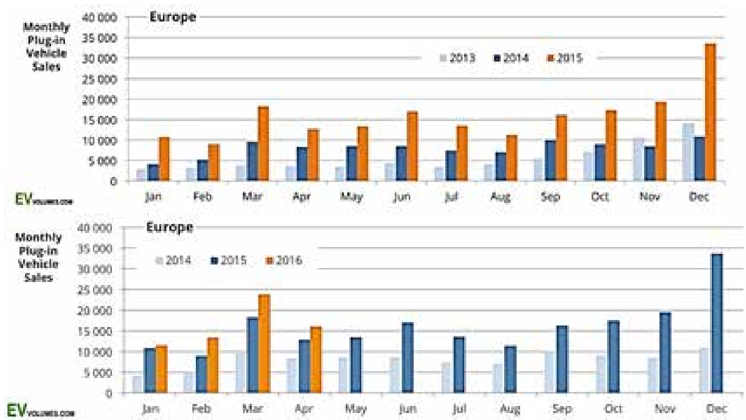
Source: (Ayre, 2016)

In Europe, during 2016, the plug-in vehicles sales were about under 65,000 units including April. Comparing with the sales from 2014 in the same period, the growth was higher with 99%. In 2015, the plug-in vehicles were sold near to 200,000 units, double than in 2014, including passenger electric vehicles and light freight transport electric vehicles.

Many European countries introduced facilities for electric vehicles' buyers, in order to help the growth for this kind of vehicles. But, the total increase is higher than the last year with only maximum 1% in this countries (Figure 7).

Many types of charging types, charging point and charging equipment are available for the charging infrastructure. Electric car charging is different than fuelling a car with gasoline, being more convenient as far as you are at home and you spend a few seconds to plug in and unplug when ready to drive. But the time needed to charge in order to drive 100 kilometres is considerable higher than fuelling with gasoline. But concerning the environment while operating the vehicles, the advantages are evident for harmful emissions and noise.

Figure 7. Plug-in vehicles sales in Europe



Source: (Ayre, 2016)

Home charging is the most used solution, reaching 95% from the available charging options. There are several ways to charge the electric vehicle at home, depending on the available home equipment and the available type of electricity source (having also different voltage of 110V, 220V, 380V), the on-board charger types, that gives the time to charge from the acceptable state of discharge to the ready-to-drive state of charge. A home charging station has different particularities and prices, currently the existing stations including various types of cords and charging capacities, defined in driving range. The available electricity provider may apply special taxes for those who are charging their electric vehicles at home, or using dedicated charging points. Charging point exist near parking places, near restaurants or inside office buildings, where to have access people need to use special applications or login data, some being free, some not. The most important particularities for the charging points are that the electric vehicles may have different plug-in slots and cables, different charging maps allowing how fast to be charged. Several applications and maps are available for finding the closest charging point.

Figure 8. The Europe electric vehicles available charging infrastructure

Source: (www, Plug 1, 2016)

Figure 9. Paris electric vehicles' charging points reported in April 2016

Source: (www, Charge 1, 2016)

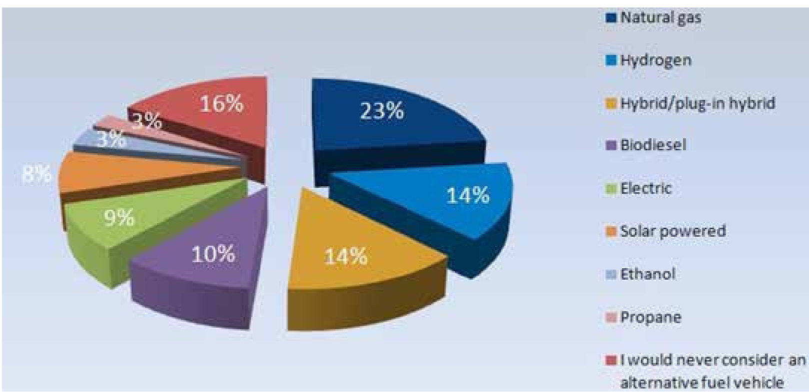
Worldwide, more than 100,000 charging points are available for charging. During the last years the charging point number increased considerably (Figure 8), being more frequently built than conventional fuel stations. Paris has the most number of charging points from Europe, but 84 charging stations (Shahan, 2016) are considered minimal for a city of that size (Figure 9) (www, Charge 1, 2016)

Alternative Fuels

It is considered that alternative fuels are just around the corner and the possibility to be used is supported by environmental friendly manufacturers (KBB, 2012). But, as expected, many fossil fuels producers maintain that alternative fuels are not viable solution, currently only 7% of the total energy consumption being reported to the alternative fuels consumption. People are looking more and more to use alternative fuels because of their lower prices than the fossil fuels and their less polluting advantages.

The available cheapest alternative fuels include the natural gas and the bio-fuels from vegetables. The most likely to be consider alternative fuels are the natural gas (23%) and hydrogen (14%) (Figure 10).

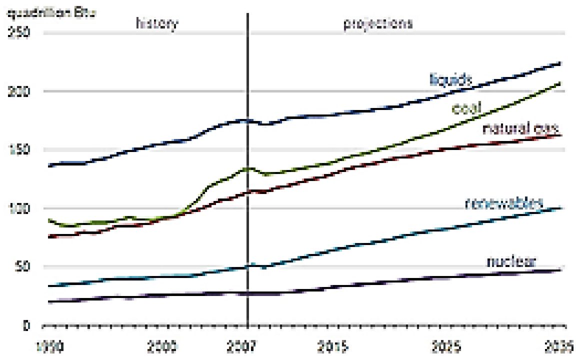
Figure 10. The most likely to be consider alternative fuels for use



Source: (www, KBB, 2012) (Smith, 2013)

According to International Environment Outlook 2016 (IEO, 2016) the usage of alternative liquid fuels increased, with a considerable CO2 emissions reduction of 40% in 1990 and only 36% in 2012. CO2 emissions coming from the natural gas usage represented 19% in 1990, while in 2012 was around 20% of the total greenhouse gasses, with expectations to increase until 2040 to 26%. The natural gas use will rise from 23% in 2012 to 26% in 2040, while the conventional liquid fuels use will decrease from 33% in 2012 to 30% to 2040 (figure 11, figure 12).

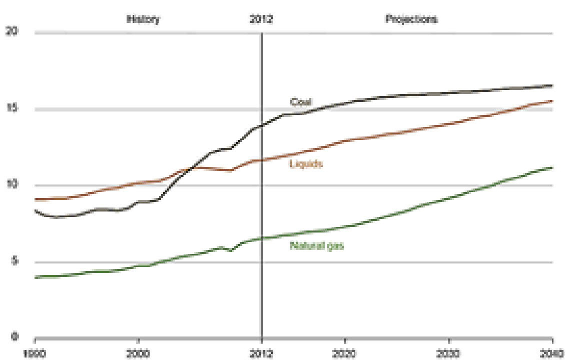
Figure 11. World energy use by fuel type



Source: (USEIA, 2016)

Other liquid fuels – including biofuels, CTL (Coal to Liquid Fuels), GTL (Gas to liquids), kerogen (oil shale), and refinery gain – currently supply a relatively small portion of total world petroleum and other liquid fuels, accounting for about 16% of the total in 2012. Other liquid fuels are projected to grow modestly in importance in the International Environment Outlook 2016 Reference case, as the other liquids share of the world's total liquids supply increases to 18% in 2040.

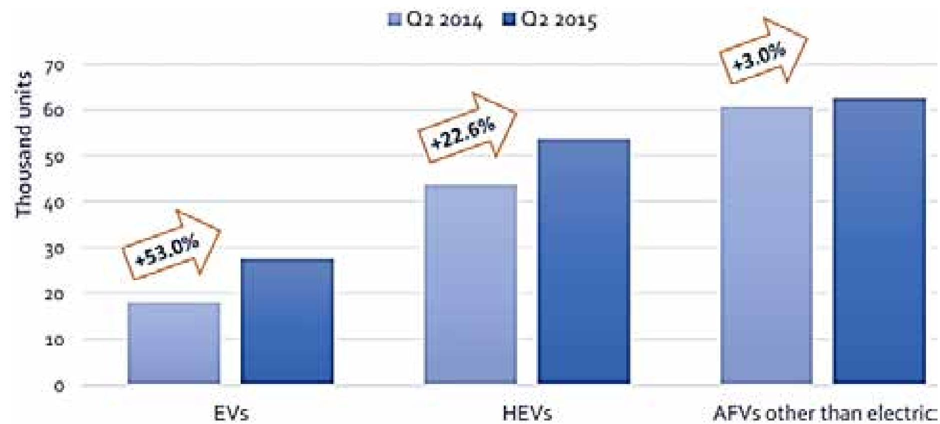
Figure 12. World energy related CO2 emissions by fuel type



Source: (USEIA, 2016)

In the second quarter of 2015, total alternative fuel vehicle registrations in the EU increased (+17.4%), totaling 143,595. Of these, electric vehicle (EV) registrations significantly grew (+53.0%), rising from 18,024 units in Q2 2014 to 27,575 units in Q2 2015 (figure 13). Demand for new hybrid vehicles (HEV) also increased (+22.6%), totaling 53,443 units. 62,577 new passenger cars in the second quarter (+3.0%) were powered by propane and natural gas (www, ACEA 1, 2015).

Figure 13. New alternative fuel vehicle (AFV) registrations in the EU by engine type



Source: (www, ACEA 1, 2015)

Hydrogen is used as an alternative fuel, being a renewable alternative to petroleum fuels. It has been successfully demonstrated to be used for road vehicles, but the production cost, the on-board storage and the safety methods to prevent hazards during operation represent analysis activities to be taken into account. There are two types of road vehicles engines that burn hydrogen. One is an internal combustion engine, the other is a fuel cell. Hydrogen is a clean-burning fuel that can be produced from coal, natural gas, petroleum, solar, or wind energy. A vehicle operating on a fuel cell, which generates electricity by harnessing the reaction of hydrogen and oxygen to make water, produces no CO or VOC (Volatile Organic Compound) emissions and extremely low NOx emissions.

People are expecting higher performances from the hydrogen fuelled vehicles, less costs and better comfort, but currently the already on the market fuel-cell vehicles are very expensive compared with conventional and even hybrid and electric vehicles.

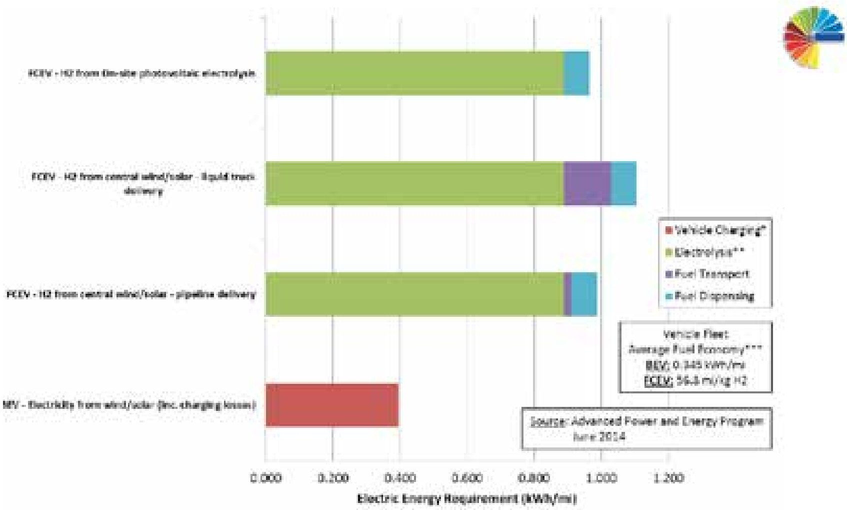
The scientific approach is definitely impressive when the fuel cell vehicles are subject to debate. Like battery electric vehicles, fuel-cell vehicles are using electricity for propulsion but the primary electricity is made by using a fuel cell powered by hydrogen, rather than drawing electricity from a battery. The fuel cell vehicle power is set by the fuel cell and the hydrogen tank sizes. The most common types of fuel cell for vehicle applications are using polymer electrolyte membrane (PEM). Inside the PEM fuel cell the electrolyte membrane is sandwiched between a positive electrode (the cathode) and a negative electrode (the anode). The hydrogen is introduced to the anode and the oxygen (from air) to the cathode. The hydrogen molecule break apart into protons and electrons because of an electrochemical reaction in the fuel cell catalyst. Protons travel through the membrane to the cathode (www, FCEV 1, 2016).

But, the reality on buying and using the fuel cell vehicle daily is not close because the fuel cell vehicles are the most difficult and expensive alternative fuel vehicles even if, as an advantage, they are the most environmental protective vehicles. Several researchers notified that the fuel-cell vehicles are not as environmental friendly as the battery electric vehicles (and some plug-in hybrids) are. Dr Joe Romm (who used to oversee and promote hydrogen funding in the US Department of Energy) mentioned: "Put in more basic terms, the plug-in or EV 'should be able to travel three to four times farther on a kilowatt-hour of renewable electricity than a hydrogen fuel-cell vehicle could'!" (Shahan, 2015). Dr. Joe Romm also mentioned: "The two best cases for FCEVs in the chart (figure 14) – a hydrogen pipeline system from central station renewable generation and onsite renewable generation and electrolysis — are wildly implausible for many decades to come, if ever." (Shahan, 2015)

In 2017, the World's First Plug-in Fuel-Cell Car goes into series production. The vehicle will be a Mercedes-Benz that will start selling a plug-in fuel-cell version of its GLC compact crossover from 2017. The model's fuel-cell stack was developed in Vancouver with a Ford joint venture. The automakers managed to shrink the size of its fuel-cell stack by about 30 percent so that fits within "conventional engine compartments." More importantly, the stack uses 90 percent less platinum. The vehicle will have a combined range of about 500 kilometers, including an all-electric range of about 50 kilometers (King, 2016).

On July 2016, this year, the standard regarding the fuel-cell and the hydrogen distribution, is awaited, under the Technical Specification ISO/TS 19880-1 (ISO-TS 1), Gaseous hydrogen — fuelling stations — Part 1: General requirements, which is a key document for the building of hydrogen fuelling stations worldwide. The Technical Specification are prepared by ISO/TC 197 WG 24, led by co-conveners Jesse Schneider (from BMW) and Guy Dang-Nhu (from Air Liquide), along with Nick Hart (from ITM Power) as secretary. The publication is important also in view of the relevant fuel-cell standards that the EU Alternative Fuels Infrastructure Directive will refer to in the future. The scope of the Technical Specifications` covers the processes from hydrogen production and delivery to compression, storage and fuelling of a hydrogen vehicle. A safety and performance guideline for hydrogen stations is essentially, including the interface to fuel vehicles. The level of safety specified in the technical specification is similar to the level of safety of stations fuelling with conventional fuels (ISO-TS 1, 2016).

Figure 14. Electric energy requirements for electricity-based fuelling pathways



Source: (www, WTW 1, 2014)

Autonomous Vehicles

The autonomous vehicles types are defined based on the level of autonomy the vehicle is able to support. Following the standard J3016, "Taxonomy and Definitions for Terms Related to On-Road Motor Vehicle Automated Driving Systems", a harmonised classification system and supporting definitions are set. Six different levels of driving automation from "no automation" to "full automation" are defined (Figure 15), including the base definitions and levels on functional aspects of technology for eliminating the confusion and covering numerous disciplines, from engineering, to legislation and public disputes. The clear definition for the automation driving levels is able to educate wider communities by clarifying the driver's role for each level, while the automated driving system is engaged (SAE International, 2014).

Each level of automated driving has several particular performances to be achieved. Other definitions are used, like "the dynamic driving tasks" which refers to the operational and tactical aspect, like steering, acceleration, deceleration, monitoring the vehicle and the roadway and responding to the events, determining when to change the lanes, to brake, to use signals etc. The "driving mode" refers to the driving scenario type. The "request to intervene" sent to the driver by the driving assistance systems refers to every notification that the systems expect to be received by the driver and the driver have to promptly begin or resume performance of the dynamic driving tasks.

The definition of the "0" level, named "no automation", refers to that the human-driver is taking care for all the dynamic driving tasks, even when enhanced by warning or intervention system, being in charge for steering, accelerating and decelerating, braking, monitoring all the driving environment, the next level is defined. No automation road vehicles are already equipped with different systems that help drivers to keep to their lane (the lane change assist and the lane departure warning) and to monitor the vehicle surrounding areas, like the blind spot detection system, that warn the driver to avoid unwanted situations. Other systems included already in the no automation vehicles are the park distance control, the front collision warning systems that only announce the driver of an imminent danger.

The level "1", named "driver assistance", corresponds to some driving modes automated achieved, when several activities are made by the driving assistance systems, without human driver intervention, like steering, acceleration, deceleration using the information from the driving environment and with the expectation that the human driver will be able to react and to perform for the other all remaining aspects of the dynamic driving tasks, based on human driver monitoring of the driving environment. The already existing systems that act on level "1" automated vehicles are the adaptive cruise control and the adaptive cruise control stop-and-go that use radar sensors to detect the distance to the vehicle in front and reduce the vehicle's speed in case of emergency and for keeping a safe distance and accelerating to the vehicle in front by automatically applying brakes, the park assist system that steers the car and make the parking possible without human driver intervention for steering, the human driver being in charge only for accelerating and decelerating, the lane keeping assist system that becomes active from specific speed, normally from 50 km/h, takes corrective actions or warns the driver.

The level "2", named "partial automation", corresponds to the driving mode when the driving assistance systems are in charge for complete steering, acceleration, deceleration using information about the driving environment, while expecting that the human driver will perform all the remaining driving tasks. The park assistance system is part of this level of automation and consists in achieving the parking feature into public and/or private parking areas without human intervention from inside the vehicle, the human driver being able to initiate the parking via a smartphone for example, and the vehicle will accomplish the manoeuvre by itself, under the human driver monitoring. The traffic jam assist is another system corresponding to the level “2” of automation, being in charge with following the traffic flow in low speeds, in urban areas or on highways.

The level “3”, named “conditional automation”, corresponds to the driving mode when the driving assistance systems are in charge to steer, accelerate, decelerate, monitor the driving environment, with the expectation that the human driver will intervene only by request. The traffic jam chauffeur and highway chauffeur are level “3” automated driving systems that detects the slow driving of the vehicle in front on highways and similar roads and handle the vehicle both on longitudinal and lateral, while the human driver has to activate the system and any time can switch it off and to take the command, or under the system request if automation gets its own limits to take over the specific driving task.

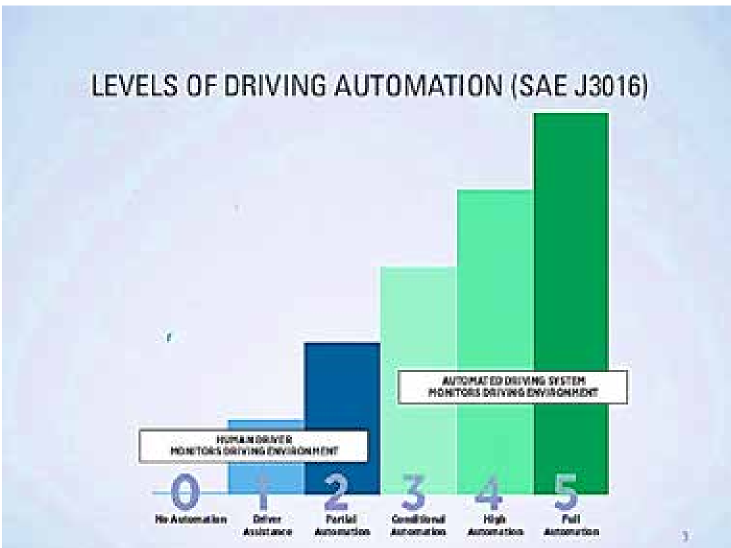
The level “4”, named “high automation”, corresponds to the driving mode when the steering, the acceleration, deceleration, monitoring the driving environment as well as the all aspect of the dynamic driving tasks, even the human driver does not respond appropriately to a request to intervene. The parking garage pilot is the system that includes manoeuvring to and from the parking place as a driverless valet parking without any monitoring from the human driver. The highway pilot is suitable for driving on highways or similar road types, where the speed is up to 130 km/h and is having the possibility to change the lane, to overtake other vehicles, but the system will not issue any requests to the human driver and the human driver can switch it off.

The level “5’, named “full automation, corresponds to the driving mode when the vehicle’s performance is completely made automatic, under all roadway and environmental conditions that can be managed by the human driver. The fully automated vehicles are able to handle all driving between two destinations, without any intervention from the human driver and the human driver presence inside the vehicle is optional.

Starting from the “high automation” level, the responsibility is to keep the vehicles and the traffic safe even in abnormal conditions. Indeed, the costs for such systems are increasing when new additional systems are introduced in order to check for failures and to verify the behavioural responses during the development phases.

Since 2005, several entities initiated project, some of them public funded, to support the development of automated vehicles. Public authorities are defining the action plans for facilitating the development and the introduction of automated vehicles. While in the United States all five levels of automation are able to be met on roads, in Canada the testing automated vehicle on public roads is already started. In Japan and in South Korea the development of automated vehicles reached a high level of knowledge and testing, some dedicated competitions promoting the relevance of automated driving. In China, the government sees the automated driving as the 2020 reality, because they already tested and used automated vehicles. In Australia the automated trucks are taking the lead and their strategic plans include more than 200 self-driving trucks on the current public roads. In Europe, many countries has automated driving projects already implemented or under implementation, that confirms the validity state for the unmanned vehicles for the next years.

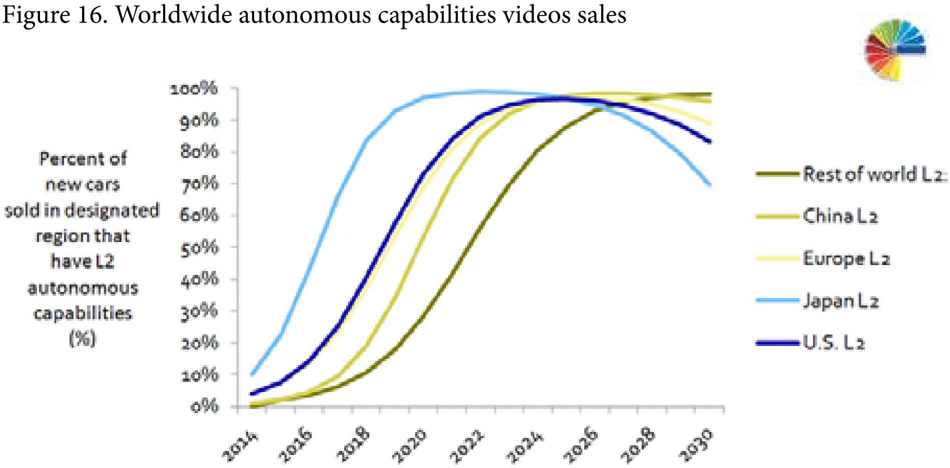
Figure 15. Levels for road vehicles' automation driving systems according to SAE J3016 standard



Source: (SAE International, 2014)

Based on the sales during the last years and the predictions for the next years, the automated driving vehicles having the level "2" autonomous capabilities will continuous grow on international markets, with a fast growth during 2014 and 2024 (Figure 16).

Figure 16. Worldwide autonomous capabilities videos sales



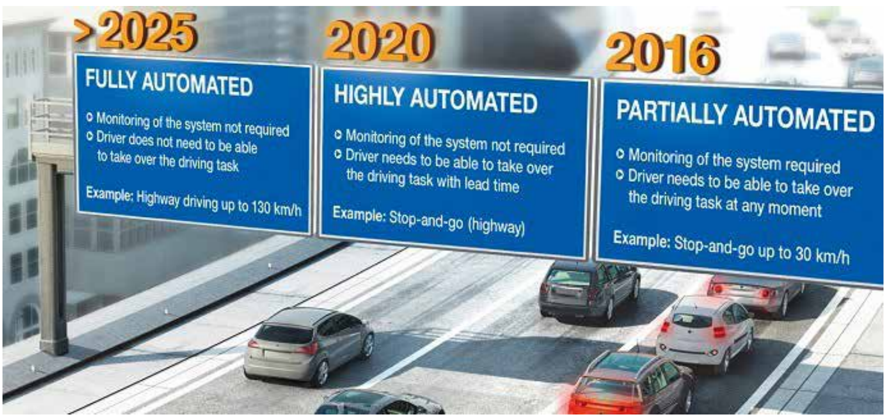
Source: (Laslau et al, 2014) (www, AW 1, 2014)

Google-self-driving-car is famous through its operation in California, for private and public transport, not reaching yet the maturity and is being used to raise awareness of the potential benefits of automated driving among all traffic participants. But Google isn't the only outfit puttering around United States roads with its hands off the wheel. The German automotive supplier Continental received granting for testing and adorning its vehicles in some states in United States, but Continental's autonomous vehicles aren't exactly direct competitors to Google's fare. The company's "highly automated vehicles" are more of an advanced cruise control system than a self-driving vehicle, being capable of navigating stop and go traffic on a freeway, for example, but still requiring the driver to take control as their exit draws near. Continental sees the partially autonomous vehicle as a stepping stone to fully automated cars, and plans to offer the partial solution between 2016 and 2020, switching up to fully automated driving systems by 2025 (Buckley, 2012).

Partially automated driving starting in 2016 (Figure 17) consists in assisting the driver in certain situations, in the first step, which will be technically possible for partially automated systems to support drivers in stop-and-go traffic situations on the freeway traveling at up to 30 km/h. The car takes over steering as well. The driver is relieved of the physical and mental task of driving, but still needs to monitor the driving situation constantly. The highly automated driving from 2020 (Gigure 16) corresponds to the alternative use of the driver's time and refers to the driver who will be able to hand over responsibility for driving on the freeway at varying speeds. For example, in slow-moving traffic, drivers can simply be chauffeured and turn their attention to another activity. They must however be able to resume control again at any time.

The fully automated driving from 2025 (Figure 16) sets the comfort and convenience for the driver, as the third stage, the vehicle being possible to drive whole sections of a trip fully automatically without any human intervention. In other words, the vehicle would be able to be controlled automatically on the freeway at up to 130 km/h. When the vehicle is in fully automated mode, drivers will no longer need to be able to take over, which will increase their freedom enormously and allow them to turn their travel time into leisure time (www, Conti 1, 2016) (Buchholz, 2015).

Figure 17. Automated vehicles prediction



Source: (Buchholz, 2015)

At the European level, high automation driving vehicles are able to be met only when low vehicles' speed and dedicated infrastructure are available. Several funded programs supported the automated driving projects from the early days, the radar technologies being able to gain innovations, the sensors information combined with the communications and positioning services being improved, many automation modes being tested, the platooning between automated driving vehicles being optimised also for daily persons public transport and for light freight transport, intelligent networks for using the communication facilities between vehicles, vehicles and infrastructure, vehicles and everything being implemented, other related driving advanced assistance systems.

Some examples of automated driving vehicles are presented below. The Cybercars are small automated vehicles for individual and collective transport, both for people and goods that can run without human drivers' intervention and can continuously communicate with the traffic control centre. The necessity of using intelligent transport systems in protected environments was achieved and the automated driving vehicles are able to operate on roads where no other vehicles are allowed on low speeds. The High-Tech Buses are operating more like trams, using dedicated infrastructure and always have a human driver who is able to take the control anytime. The Advanced City Cars are integrating zero or ultra-low pollution powertrain and several driving assistance systems which are using the intelligent transport communication systems, including the car-sharing option (ERTRAC, 2015). Overall, the driving safety have to increase whilst the robot vehicle is being introduced.

Approaches, Initiatives and Responses on Autonomous Driving

Intelligent mobility is seen as major opportunity, including the connected vehicles, the vehicle to everything communications, the increasing safety, the decongestion and the access to mobility advantages. All vehicles' manufacturers already produced and tested different automated driving vehicle solutions, being able to have clear plans for the next decades following their experiences. The energy efficiency is one of the targeted objective achieved by using automated driving vehicles equipped with hybrid or electric powertrain. The automated driving systems will choose the proper functional mode for the powertrain in order to have the minimum consumption and emissions.

Action plans regarding the introduction of automated vehicles were presented by public authorities all around the world following the continuous development of the automation technologies and the tendencies to move the driving tasks from the human drivers to the smart systems and machines.

Initiatives and responses

The initiatives and the responses in various countries and regions are following the same goals, to introduce the automated driving vehicles at large scale, at least form level "3" upward. American auto-manufacturers enhanced their plans by implementing the level "2" solutions, while different states allowed higher level driverless vehicles to operate on public roads. In Europe, most of the auto manufacturers and systems developers are launching different programs and are implementing different projects, some of them only demonstration projects, for making people aware of the necessity for the automated vehicles and to emphasize the incisive requests for introducing them. In addition, the traffic infrastructure is under massive changes for allowing the detailed communication with the vehicles and the humans inside them, to present the location, the intended destinations, the road traffic environment and flow, the vehicle control stability in order to high precision usage of digital maps and other issues that may be addressed in the future.

The high automation vehicles are taking into account the already existing driving scenarios, including traffic accidents and the road vehicles' operation. Based on how realistic the vehicles is driven without human intervention, the driving assistance systems are offering the alternative solutions when the human driver is able to take control if necessary. The goal is to deliver and use an extended and personal mobility that is safer, economic, comfortable and less time consuming for humans during driving. Several scenarios are taken into account by both vehicle manufacturers and companies that are proving the intelligent systems for achieving the automated driving and operating on public and private roads, when the human driver no longer monitor the vehicle and is able to have different activities during the trip besides operating the vehicle.

The extended mobility that can be offered is continuously being improved by introducing scenarios for the future vision when the functionality of the automated driving systems no longer accepts the intervention of the human driver even in an emergency situation with defined or unforeseen circumstances. Personal mobility is following revolutionary scenarios for preventing accidents and reduce harmful emissions, without following the driving assistance systems upgrades, but using both traffic and drivers patterns, when the automated driving system is taking completely the control. This approach is possible to be implemented by learning algorithms and artificial intelligence, when the automated driving systems are operating near the limits by mimicking human behaviour, using digital mapping and online services (Beiker, 2016).

Infrastructure

The digital maps that are used for tactical driving and the update using the automated driving vehicles are necessary, taking into account the work zones, the weather any accidents, lane closures, or other dynamic factors. (WP-AD, 2015) The position of the vehicles are reported in real time and the automated driving vehicles are able to use the information regarding the road state immediately.

Communications between the vehicles and infrastructure are needed for the introduction of automated driving vehicles and the intelligent transport systems technologies that are enabling the information and warnings on traffic for combining the keeping the lane assistance system, the adaptive cruise control and other at least level "3' automation systems with the safety technologies in transport sector regarding the infrastructure current state. The automated driving vehicles will contribute to the considerable reduction of traffic fatalities and congestion using the new generation for urban and extra-urban transport. Different types of automated vehicles are able to demonstrate the abilities such vehicles offer on road obstacles avoidance, passenger recognition, strategical escape in case of accident and economical operation by receiving information in a combined manner form the vehicles' sensors, radar, GPS and from the road infrastructure. The continuous growth of automated driving vehicles are defining the decision criteria for the non-human driver tasks. The difficulty appears when understanding the danger is subject to debate also for different human-drivers when defining and combining the driving scenarios with the driving tasks in different situations.

The infrastructure plays an important role in transport efficiency, on bus and freight transport, on private vehicles, helping the vehicles to be informed about the closest charging points, available parking places, reducing the congestion, the traffic volumes and the emissions by critical analysis on the current reported state (FFI, 2015). In addition, the infrastructure is responsible for informing the automated driving special vehicles used on maintenance and services (Croitorescu and Ruichek, 2015) about the current state of the factors under investigation.

Safety, security and liability

Data security represent one stage for ensuring the social acceptance of automated vehicles. This stage consists in different parts, from processing the large amount of data, store the data and make the data accessible for the future scenarios, communication and identification, to the data evaluation and interpretation. One major boundary is the data ownership approach. In addition, the automation systems liability and the applied solutions are problems that must be solved. The data protection is absolutely necessary, being not only a concern for automated driving vehicles, but also to road infrastructures. The data protection and security have to be as transparent as possible to the user, but have to be secured in order not to be modified by anybody. But, the "online data security" is anytime under the possible attacks danger. While automation does not fundamentally bring new cybersecurity vulnerabilities, the level of risk for any malicious attack certainly increases at the higher levels of automation in which the driver role is decreased or non-existent (WP-AD, 2015).

Anyhow, the adequate security measures were taken into account for the beginning and the updating and optimising steps are continuous. The liability and safety are introducing concerns considering the responsibilities in case of accidents starting from level "3" upward. The discussions include the human driver, the vehicle manufacturer and the vehicle's owner. The balance between these three potential responsibilities has to be established. In addition to the three responsible solutions, another person can be consider responsible for the accident if that person is considered guilty and it is outside the automated driving vehicle, as pedestrian or is driving a normal vehicle.

The automated driving vehicles' liability is subject of three major challenges, first, the communication cannot be established between a high-tech automated vehicle and a no modern technologies vehicle, second, the limits of the monitoring surrounding equipment, not all angles and spots are able to be captured and processed, and third, the adaptability to all traffic modes and types, from one country to another.

The automated driving vehicles safe state is ambiguous and depend on the individual perception for each human driver. The acceptable definition for safety refers to a risk level that depends on the vehicles' situation. The automated driving vehicles are taking the decision based on the stationary and dynamic objects, the intention of the dynamic objects, the legal conditions, received mission that consists in the final destination and the current energy performances of the vehicle. The automation systems may be switched off by request, but the human driver will monitor both lateral and longitudinal motion. But, safety may suffer and the safety requirements may be different. While designing the automated driving vehicles' guidance, the environment recognition and the vehicle operations are meant to be fully available as examples. The vehicle's redundant sensors cover the control decision factors indicating the handling, acceleration/deceleration and braking.

The safety features are also integrated in the infrastructure, being able to prevent all the vehicles from a certain route or road and also to track all their behavior (Reschka, 2016). Monitoring the vehicles behavior by the infrastructure considers already defined scenarios, described, tested and implemented in a safety environment. The tracked vehicles are able to be control via the infrastructure information in terms of processing the information and choosing the best decisions according to the situations met. The robotics involved on automated driving vehicles are safety-oriented and their control is following the most efficient, the most economic and the higher comfort driving style according to the legislation and the traffic criteria about avoiding any action with low level of trust. In transferring control situation, the robotics are considered under the command of the human driver, but when no human driver is controlling the vehicles' operations, no humans are inside the vehicles and no remote control operator is available, the vehicle will choose the best solution by applying the functional limits of the system and it will control all the vehicles' motion in the same time with signaling all the other vehicles and informing the infrastructure.

The full automated driving vehicles are using human drivers for extending their capabilities, especially on non-marked roads or on off-road routes, without any existing maps. Military applications were already tested using these constrains and the successful results demonstrated that the possibilities exist and the necessary maneuvers are practically achieved by the vehicle automation systems and guidance without using predefined maps.

The predictions and the automated driving vehicles' actions are bringing together smart systems to achieve the demands in terms of safety, security, functionality, efficiency and robustness and to support the comfort, the fuel efficiency, the decreasing emissions and the prices.

The automated vehicles smart components and systems integration will be on long term and will contribute to social wellbeing, increase social inclusion, bring added value on energy efficiency and reduce road fatalities. The excellent knowledge involved in automated driving vehicles represents a promising application of internet of things in the mobility sector. The controlling functions are allowing the human driver to partially or fully dedicate his attention to something else instead driving, but the human driver reactions for levels from "0" to "3" have less than one second from warning to action. Therefore, only when the human driver is not needed to monitor the driving process, the automated driving vehicles using non-human driver will decide all the safety and security situations (FIA, 2015).

The automated driving vehicles are very complex systems that contain large number of sensors that should communicate also between them and the vehicle's dedicated electronic control unit and to the infrastructure using algorithms, evaluate the driving state and using processed data to deal with the traffic, store and understand the data from the environment and human-drivers own reactions and interventions.

The automation systems are designed to prevent all critical situations by monitoring the drivers' responsiveness in automation levels up to "3" and the human drivers should be periodically warned about vehicle's monitoring state. All the technical measures have to prevent predictable and dangerous misuse of automation systems like sleepiness, or leaving the driver's seat, amongst other actions. The communication between the vehicle and the human driver is done using the human machine interface that is capable to provide the needed information in time to keep the human-driver active all during the route. The automation systems implication has limitation that the drivers should be aware of. The combination of the human drivers' performances and the automation systems represent the achievement for the successful automated driving vehicle design. The safety of traffic is depending on this combination and the human drivers' tasks should be easier.

Human-driver

The possible confusion that may be met currently refers to the definition of the "driver". The human driver is expected to take control whenever necessary, with or without the vehicle's warning, the control resuming being as fast as possible, in sufficient time, to avoid any unwanted situations and to take the operational decision. The human driver's vigilance represent the central aspect, which may decrease immediately after the control is taken by the vehicle, in addition to the distraction that may occur after not more than five minutes of assistance. According to (Box and Wengraf, 2013), distraction, the root cause of 25 to 55% of all accidents, will be growing in a world of automated driving.

The human drivers differs especially on age and gender, due to their decisional operations during different driving scenarios situations. Different education and training about driving performances define the demands for the automation systems, together with the realistic scenarios and the drivers' expectations. Each automation system has its own boundaries and the human driver should understand this. The automation systems are reliable as they are available as equipment on vehicles. Therefore, any failure that may appear will be possible to avoid any accidents by the human drivers' intervention (FIA, 2015).

The human-drivers are aware all the time of the vehicles' automation level and about their responsibility to react and monitor the vehicle. When the human-driver is not able to intervene, only at level "4" for some situations and at level "5', the automation systems are reacting for all the tasks. During the levels "0" to "3" the human-drivers have to permanently monitor the vehicle, not being allowed to take their eyes from the road. The minimum requirements of automated driving vehicles for level "4" and "5" include the possibility to the human drivers to engage different non-driving tasks, without assuming the driving tasks. The human-drivers intervention have to be recorded in order to decide who may be responsible for any incident (FIA, 2015). A possible example can be the level "4" automated valet parking for passenger vehicles that is an interesting application which will be realised in the near term because it is low speed and may operate also off the public road. The idea is that the human driver steps out of the car at the entrance to a parking facility and uses the smartphone to instruct the car to park. The vehicle autonomously drives away empty, without any humans inside, and finds a space, returning to the entrance when called by the driver (WP-AD, 2015).

Definitely, the next revolution in mobility will the automated driving electric vehicles. Therefore, as human errors are still the major reason for road accidents, the automated driving vehicles' equipment is expected to make future transport safer. The potential is huge while its introduction on large scale for daily public use is environmental friendly, efficient and should be accessible (UNECE, 2016). The electric mobility is continuously growing and the support services are adequate for the current use, but for sure will need to grow accordingly in the future.

Legal Overview for Autonomous Driving Mobility Solutions

Both electrification and automation in road vehicles are two spectacular attractions and the predictions to fully electrified automated road vehicles from 2025 are following the intelligent transport systems evolution and the continuously tested automation solutions levels, from partial automation, already met on roads, to fully automation. The automated electrified driving can be applied to different means of transport, from bikes, scooters, light vehicles, light trucks, but the passenger vehicles automation represent the main target. The extension to other vehicle, for example to agricultural machines, to luggage carriers inside airport etc. are concepts to whom the knowledge transfer and replication will be made.

The current existing automated vehicles are worldwide spread but the legislation differs from each continent, country or state to another. Social and legal challenges are taking into account the responsibilities of the human drivers and the automation systems as well as the ability to understand the decisions independently processed and achieved during driving.

The legislative boundaries are challenges that can only bridge the further development of environment monitoring, driver assistance systems implementation and control role.

The current regulations in Europe regarding road vehicles automated driving are following the Vienna Convention of 1968 (VC, 1968), which, according to Article 8 "Every moving vehicle or combination of vehicles shall have a driver" and Article 13 "Every driver of a vehicle shall in all circumstances have his vehicle under control…", referring to the driver's necessity of possessing the physical and mental ability and being physically and mentally fit when driving, and possessing all the knowledge and skills to drive and to control the vehicle at all the time. The Vienna Convention is able to facilitate international road traffic and to increase road safety by establishing standard traffic rules among the contracting parties. The Vienna Convention has been ratified by 70 countries, but those who have not ratified the convention may still be parties to the 1949 Convention on Road Traffic.

The Geneva Convention of 1949 had similar text and approach, probably does not prohibit automated driving, but promoted road safety by establishing uniform rules, including the requirement that each vehicle should have a human driver able to control or to intervene at all times in the automated vehicle's operation. The Geneva Convention on Road Traffic is accepted by 95 states. The 1949 Convention's description of a Driving Permit and International Driving Permit are located in Annexes 9 and 10. Switzerland signed but did not ratify the Convention. There is a European Agreement supplementing the 1949 Convention on road traffic, in addition to the 1949 Protocol on road signs and signals, concluded in Geneva on 16 September 1950.

Comparing both conventions, the Vienna Convention imposes somewhat more extensive obligations on the driver of a vehicle (Csepinszky et al, 2014). In March 2014 an amendment on Article 8 of the Vienna Convention mentioned that the driver still has to be present and also be able to take over the steering wheel at any time, but the car can be driven by itself as long as "the system can be overridden or switched off by the driver" (Dokic et al, 2015). In March 2016 another amendment will be introduced to the Vienna Convention and automated driving technologies transferring driving tasks to the vehicle will be explicitly allowed in traffic, provided that these technologies are in conformity with the United Nations vehicle regulations or can be overridden or switched off by the driver (UNECE, 2016).

Regarding the two conventions, other regulations are sharing the legal progresses, like the ECE Regulation 79, which contains requirements for the steering configuration that is problematic for automated driving vehicles. An "Advanced Driver Assistance Steering System" is only allowed to control the steering as long as the driver remains in primary control of the vehicle at all times, according to paragraph 2.3.4. In addition, such systems "shall be designed such that the driver may, at any time and by deliberate action, override the function" (Lutz, 2016) (paragraph 5.1.6.1 "Whenever the Automatically Commanded Steering function becomes operational, this shall be indicated to the driver and the control action shall be automatically disabled if the vehicle speed exceeds the set limit of 10 km/h by more than 20 per cent or the signals to be evaluated are no longer being received…".) (ACSF, 2015).

Until now ECE Regulation 79 has been the primary regulatory hurdle for the type approval of automated vehicles in Europe, being in charge with setting the operation for the steering systems. The major regulatory aspect is to introduce technical background and provisions for the steering system control, based on corrective measures and safety while driving on highways. The current limitation of automatic steering functions below 10 km/h have to be removed and, since 2014, the experts ran several research activities to evaluate the technical requirements for safer operation, the results being expected to be publish during September 2016 and the adoption in 2017 (UNECE, 2016).

Public Acceptance and Authorities' Involvement for Electric Autonomous Vehicles on Improving Mobility

The electric and the autonomous vehicles are subject to debate by many people. The trust in electric vehicles is limited by the missing charging infrastructures and by the batteries costs. Indeed, the dynamic performances, the less emissions during operation and the energy consumption prices are better than for the conventional vehicles. However, the hybrid electric vehicles are more common, being a viable alternative for both diving range and fuel consumption.

The leak of trust in automated driving vehicles comes from the insufficient information that people received during last years and the failure rates people meet while using different home equipment and machines because not all manufacturers payed the necessary attention during the development phases. More on that, the driving pleasure represent another boundary between the limits the interest for the automated driving vehicles.

Safety of automated vehicles will also impact on the level of social acceptance and uptake. Acceptance will depend on the likely deployment scenarios and feelings towards it may be very different for example towards truck platoons on the motorway or low speed delivery vehicles on separate infrastructure in urban areas. The role of consumer information programmes will also be important to explain and build confidence and drive best practice in safety (ADP, 2016). At this stage, user acceptance poses a challenge indicating that they "would not trust manufacturers and government assurance that driverless cars were safe (FIA, 2015). The technology should also be accessible to all categories of the population. It is not acceptable that only a certain group can acquire such vehicles even if the technology is regulated. New financing models (with the support of the insurance sector) could also be developed.

One topic related to safety that represent an important boundary for the public refers to the vulnerability the road users have in front of the automated driving vehicles. The pedestrian and the cyclist represent dynamic objects to be identified and protected by the automated driving vehicles and the particularity of "non-vehicles" roads may be accepted only for human-driven vehicles while the automated driving vehicles will operate on that kind of roads at low speeds using visual and audible warnings.

Even if the people may continue to act suspicious towards the new technologies, the information campaigns and special education and training classes are expected, including demonstrations at virtual and real-life levels to feel the technologies. On European level, the citizens have to think in terms of behavioral changes. The cities can be maintained as attractive places, with less pollution and wellbeing by introducing innovative mobility solution. The education and training have the major role in raising the citizens' awareness about the environment and about their needs regarding better efficiency in transport and services. The urban mobility offers different options, but the future options include a better lifestyle, more solutions to choose, new knowledge involved and new culture. But, the cities are not able to face all these challenges alone, only at local level.

Harmonised regulations should be taken, and the taken solutions should involve all Europe's resources. Meanwhile, the European Commission is presenting options without any clear solutions and all already launched debates included challenges on environmental friendly transport only applicable on local levels. The local administration are in charge of defining and implementing the urban mobility policies, but the European Commission have to support their actions and encourage the development of the new culture, for urban mobility in Europe, without imposing solutions that are not adapted to local circumstances. European Commissions should encourage the sharing of good practices across Europe and should better promote the cooperation, the interoperability, the financial support, the legislation and the advantages that come with the new innovative solutions in urban mobility.

Conclusions

Still, electric vehicles and e-mobility services have low usage among communities. One of the aims to be reached is to increase the awareness of needed zero-emission vehicles. The new technologies and solutions are meant to increase the users' confidence on e-mobility. The aims include the possibility to show what positive impact will have the integration of light autonomous electric vehicle inside and through communities.

The potential of replication of the transport solution is high: it can be replicated to small cities transport system, community service intelligent vehicles, city centers tours transport or exhibition transport.The risks are also high. The possibility that these vehicles will not be accepted by the potential users is a strong debated subject. Being new concepts, the light autonomous electric vehicles might not be trustworthy, and the population will not want to rely on a vehicle that has autonomous driving capabilities. From this point of view, a new risk appears that the programming dedicated to the autonomous driving system will be hacked by bad intended people and an accident may occur, which will be a major problem for the project.

Several boundaries regarding the available roads for the testing and implementation phases can be taken into account. Technological boundaries can be also met.

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CHAPTER 16

Would Spatial Planners Benefit from Better Familiarity with Integrated ICT Based Technologies?

Frans Mallia

Introduction

In contrast to popular notion, spatial planning does not belong solely within the privileged realm of spatial planners. Spatial planners constitute just one link in a chain of stakeholders who may use the tools provided by the planners with a view to achieve sustainable development objectives (Karlenzig, 2012). The success or otherwise of spatially oriented plans and policies greatly depends on each link within this imaginary chain.

Properly executed spatial planning processes can potentially reap many benefits. Some of the benefits include:

- An overall functional and cost-effective infrastructure;
- Allocation of sufficient space for appropriately sited social and community facilities;
- Resolution of conflicts especially those arising from juxtaposed functions and competition for spatial resources;
- Areasonably good supply of territory available for a spectrum of envisaged uses and activities;
- A healthy provision of open space and the allocation of sufficient space for formal and informal recreation;
- Sufficient designation of areas intended for primary industry (including agricultural areas);
- Statutory protection of areas of cultural and natural value; and
- The creation and maintenance of an enjoyable urban, peri-urban, rural and coastal environment set within an overall attractive landscape

The general publicmay downplay the benefits of spatial planning. There are various reasons that contribute. One reason may be due to the fact that the tangible benefits of are often not readily perceived. Malta's particular situation of limited territorial extent coupled with a high population density does not lend itself to alleviate matters. Moreover there are many reasons why planning results may not necessarily match public and/or individualexpectations. When planning does not leave the desired results, the consequences tend to be widely perceived and generally are of a rather permanent nature. There are many other reasons that may contribute to less desirable planning consequences and these often include socio-economic factors. Examples of contributors could include short term considerations prevailing over longer term ones or the adoption of certain priorities over others at the various decision making or decision taking stages.

Additionally, planning interventions build upon a previous context and any shortcomings in the preceding context are often carried along with the newer interventions. It is often ratherchallenging to satisfactorily address previous adverse situations and indeed sometimes situations which are conducive to exacerbate an existing situation can develop. Furthermore, planning policies are often a combination of technical advice coupled with other socio-economic considerations. Again this could lead to spatial policies which may aggravate rather than remedy a previously existing situation. Other complicating factors include the application and interpretation of planning policies in the development planning permit process. This process may also be adversely affected by policy vacua, inappropriate policies, outdated policies, misinterpretation of policies or consideration of matters which go beyondplanning policies. There is also the enforcement aspect that plays a role in the translation of policies aspect. Therefore what happens on the ground may not necessarily always reflect the policy thrust.

Good policy formulation is dependent on good quality, reliable and up to date information that can be ultimately assimilated into datasets which would ultimately inform the spatial planning formulation process. The evidence based approach to policy formulation should be coupled with the application of sound planning principles. This involves all the processes that lead to the drafting of the plan and the effective communication of the outputs to key stakeholders and the public. A well executed process increases the likelihood of the formulation of a successful spatial plan. ICT based technology can play a very determinant role in the collation, analysis, formulation, communication and execution of the relevant spatial plan (PEARL, 2015).

This paper mainly focuses on the relevance of certain aspects of ICT (Information and Communication Technology) to spatial plan and policy formulation processes and the spatial planners who draft them (Caperna, 2016). The main emphasis is on the spatial planning and policy formulation aspects. It must be pointed out that there are other extremely important spatial planning activities such as planning permitting, enforcement, monitoring and legal aspects (Huang, 2012). However these are only cursorily referred to.

The current legal basis for the development of planning policy

The various development planning related aspects in Malta are mainly regulated through ACT VII of 2016 (GoM, 2016). This Act is also known as the Development Planning Act of 2016 and supersedes Act X of 2010 (GoM, 2010). On the policy formulation front, the Act also stipulates that a number of procedural steps areadhered to when formulating planning policy. The Act also stipulates that a number of statutory public consultation stages are conducted in association with policy formulation processes.

The Development Planning Act of 2016 contemplates a number of planning tools which form the planning framework upon which the rest of the planning functions are based (GoM, 2016). The overarching strategic framework is the Spatial Strategy for Environment and Development, known by its acronym SPED (GoM, 2015). Subsidiary policies are based on this overarching document. Subsidiary plans and policies include Subject Plans, Local Plans, Action/Management plans, Development Briefs and other policies and guidelines.

Planning policy formulation or revocation can be initiated either by government or by the Planning Authority and in all cases except for strategic policy, endorsement lies at a ministerial level. Strategic policies such as the SPED would be require to be approved through a parliamentary resolution.

Public consultation is envisaged in various stages of policy formulation. The rationale for the statutory consultation processes is for the planning process to benefit from the wider knowledge present within the community as well as to include a measure of transparency which is essential in a modern democratic society. It is crucial to encourage meaningful and widespread public participation as the policy formulation process may positively benefit from such interventions (MNCPPC, 2015).

The Development Planning Act - 2016 also provides for the protection of immovable natural and cultural heritage through Scheduling and Conservation Orders as contemplated in Article 57 of the said Act (GoM, 2016).

The role of ICT based Technology in the Policy Formulation process

The Maltese spatial plan and policy formulation process together with Scheduling of property of Cultural and Natural importance and Conservation Orders rely heavily on ICT based inputs (MEPA, 2015). Two very important components of the plan and policy formulation processesinclude the data management function and the information exchange function.

The data management component includes database design and database updating, upgrading and management. Given the spatial nature of the planning function, databases are increasingly coupled with Geographical Information Systems (GIS) attributes in order to facilitate 2D, 3D or 4D representation which greatly enhances the assimilation of complex information sets. Additionally, these spatiotemporal oriented databases are increasingly being updated under near real-time conditions, thus facilitating simultaneous access by the wider community through electronic means. These databases are indispensable in generating the necessary evidence based numerical underpinnings, statistics and graphic representations necessary at all stages of the plan and policy formulation processes.

More recently, GIS referenced real, virtual or processed imagery is increasingly being used to better depict projected outcomes so that decision makers and decision takers are in a better position to undertake their respective roles. Moreover, a participatory wider audience is empowered to better understand possible future implications, assess potential benefits and gauge possible risks. Thus the spatial planning process is rendered more transparent and in turn is rendered more accountable to the wider public (Nunes Silva, 2011). Satellite, aerial (including drone imagery) and processing of considerable amounts of acquired sensor data (IR, Radar, Lidar, Sonar etc.) render 3D imagery much easier to produce and quicker to distribute. Thus superimposed or virtual depictions which may include projections of envisaged interventions may be viewed from any chosen point and these points are not limited to terrain based observation platforms. Moreover, various software packages enable the addition or removal of tagged objects to facilitate a "what if" visualisation of a potential situation.

Irrespective of how well databases are designed, the use of a database would be rather restricted if wider dissemination is precluded. This is especially relevant in a situation of a regulator like the Maltese Planning Authority. Here internal and external consultation as well as statutory requirements relating to freedom of information, dissemination of planning related information and accountability feature very prominently. Thus the design of the databases should also consider the information exchange function. This is to ensure that datasets may be disseminated to nodes which can read to and/or write mutually comprehensible information. Such exchanges need to be subjected to the necessary electronic security safeguards. In such cases it is paramount to ensure that simultaneous data exchanges do not slow down data exchanges to unreasonable speeds and that unauthorised data access, tampering or malicious disruption does not occur. This dissemination may rely on a variety of networks which are either land-line or wireless based. Increased use of wireless network s greatly facilitates access especially to people on the move who would otherwise be required to access data from a fixed point. The positive aspect of modern technology is that data exchanges (especially web based ones) are not spatially limited by borders. In the last few decades it has become possible to almost instantaneously exchange information with any point on earth connected with the right equipment, software and access authorisation (if relevant) to the germane network.

Well designed databases and specialised image manipulation software also assist the planners with presentation to various audiences which can range from internal presentations to colleagues, to decision takers, professional representatives, constituted bodies and the wider community.

Background to ICT based technology use in spatial planning in Malta

When the Maltese Planning Authority (PA) was established in 1992, most of the information available that led to the approval of the Structure Plan for the Maltese Islands - (approved by Parliament in 1992) - was paper based (GoM, 1992). At that time, the web was locally practically unknown and even electronic mail was still in its infancy in Malta. However, even at that time there were endeavours to introduce computerisation to the various planning processes in order to render them less laborious and thus more efficient.

Earlier initiatives included the digitisation of cartographic maps, the slow but steady introduction of electronic mapping, the setting up of a Mapping Unit and an Information Technology (IT) Unit and the equipping of plan and policy formulation teams with training and equipment. This would eventually lead to the production of digital base maps and plans. Although planning permit and enforcement related databases are not directly related to the planning formulation process, they proved to be useful tools in extracting statistics and other information which contributed to eventual plan and policy formulation process. Later on there was a degree of linkage between these predominantly alphanumeric databases with a GIS system (Formosa, 2014a).

Around the turn of the century, the Planning Authority had embarked to undertake the review of the Structure Plan for the Maltese Islands. Various studies had been compiled using IT platforms and these were started to be electronic means available at the time. Naturally the penetration of internet at that time was not as extensive but still the potential was already being perceived. Various studies undertaken by PA staff coupled with input from external consultants. At approximately the same time, a number of geo-referenced data collation exercises were undertaken to build the PA's heritage protection inventory. A number of subject studies developed on the said studies were thus disseminated through the Malta Environment and Planning Authority (MEPA) website, these being intended to be the basis for the replacement Strategic Plan. The MEPA website quickly gained popularity and in 2002 it was awarded the "best overall website" and the "best public sector website" through the Datastream awards (MEPA, 2002).

These innovations eventually also culminated in generation of 7 Local Plans which were approved in August of 2006 and published in DVD-rom format as well as being simultaneously available on the MEPA website (MEPA, 2006). In terms of graphics and textual information, to date (mid-2016) this remains the most extensive compilation of data published by the PA as one collective exercise. This development permitted a much wider reach at a fraction of the cost of printing hundreds of pages of plans and text in full colour (especially the maps which were required to be in A3 format).

Digitisation presented a number of opportunities which included:

- Faster data assembly, superimposition and assimilation;
- Improved querying opportunities and extraction of meaningful data in various formats;
- Better opportunities for presentation;
- Faster and better opportunities for updates and amendments;
- Superior and faster quantification and scaling of the various planning parameters;
- Very cost effective solutions when compared to paper based options;
- Creativity only limited by the software capabilities, the training of the various operators and imagination;
- Near real-time updating of information;
- Faster dissemination of information with potential for simultaneous distribution; and
- Enhanced opportunities for involvement, co-ordination and participation.

Further in the 2010s, there were other innovations such as the introduction of electronic aerial imagery (most notably colour orthophotos), the availability of a web based GIS on the MEPA website (MEPA MAPSERVER), the undertaking of a Lidar survey in 2012 and other similar initiatives (including visualisation tools) through the ERDF156 project, all of which contributed towards the compilation of studies intended for the revision of subsidiary plans (MEPA, 2013). At this point it needs to be mentioned that in order to achieve reliable results, one must avoid the pitfalls of expecting too much from tools which may have limited capabilities. Moreover, the experience with GIS tools suggested that there was scope to improve upon:

- Well planned and integrated databases coupled with a similarly organised GIS database;
- A more organisation-wide structured approach to dataset collation (especially in terms of co-ordination, extraction, lineage recording, error minimisation techniques and so forth);

- More advanced training in GIS being given to a larger staff cross section and upgraded from time to time;
- The availability of more capable and faster GIS software and associated hardware (including processing and display facilities);
- Better database networking between the various sections within the organisation;
- Better exchange compatibility with a direct access to reliable externally based GIS sources of information;
- Greater reliance on GIS oriented sensors for automatic or quasi-automatic dataset generation;
- Better quality control;
- Improved security measures and intervention recording and accountability; and
- Future Resilience.

These requirements led to plans to procure more advanced technologies coupled with training initiatives. In the meantime the MEPA demerger process was concluded in 2016 through the creation of two separate authorities namely the Planning Authority (PA) and the Environment Resources Authority (ERA). This necessitated further data restructuring as well as updated of existing ICT and GIS related technologies in order to meet current and foreseeable requirements and to better meet the new organisations' statutory obligations.

The legislative changes in ACT VII of 2016 stipulate a greater degree of consultation and participation. Modern society has greater expectations from modern regulators to be informed, updated and presented with user friendly evidence based information in an efficient and equitable manner. Transparency also thus features heavily.

The Implementation aspect of Spatial Plans and Policies

Spatially oriented plan and policy formulation processes were guided for a considerable period through the strategic direction provided by the Structure Plan for the Maltese Islands (MDI, 1990). Other subsidiary policies had supplemented this guidance until the approval of all the Local Plans in 2006. Experience has suggested that a section of the Maltese public and development related professions preferred a deterministic situation,where the plans have sufficient spatial resolution and the associated policies clear-cut. Thus the development attributes of a property could be determined without recurring to a considerable degree of ad hoc interpretation. Conversely, there were many instances where other sectors within society and the same development related professions advocated the requirement for a higher degree of flexibility so that development proposals could satisfactorily address the prevailing and envisaged dynamic socio-economic challenges. These conflicting "requirements" have led to plans and policies sometimes leaning to the more deterministic approach, and some time later leaning to the more flexible approach (Flexibility.co.uk, 2016).

Both the deterministic and the flexible approaches have their advantages and shortcomings. The deterministic approach introduces a greater degree of security and stability and thus may foster a greater peace of mind. However it may introduce unnecessary constraints which may stifle innovation or changes to development patterns which ensue in a dynamic economy. Conversely, the flexible approach introduces possibilities for novel interventions which are better suited for changing market needs but may introduce a considerable degree of uncertainty and a degree of suspicion in the operation of the various planning processes.

Is it possible to integrate the two approaches? The answer is possibly in the affirmative but much depends on the substantiating data (clear, unambiguous and scientifically based data) which underpins the plans and policies, the development of options on which planning scenarios are based and a clear and transparent justification for the selection of the favoured scenarios. Moreover, the plans and policies have to be designed in such a manner as to limit flexibility on overriding considerations but extend it where this is not critical. Of course such is easier said than done but this is believed to be possible. Additionally, there must be a clear and transparent linkage between the actual policies and their interpretation through the consideration of development planning applications. In the past such deviations have not always been satisfactorily justified and even when possibly justified, the justifications were rarely sufficiently evidence based to initiate policy amendment to address an unsatisfactorily operating plan or policy. Critical to be addressed is the time required to amend a policy as too much time to undertake the exercise is often detrimental to the rational for changing the plan or policy.

On the participation front, it can be readily inferred that spatial plans and policies which included site specific graphics tended to generate more reaction than proposals which had the absence of such graphics. To a lesser extent, plans and policies which were thematic in nature tended to attract more public reaction than policies which were general in scope.

One of the main Achilles' heels of plans and policies was a significant discounting of a number of socio-economic realities. Past experience suggests that in some cases,less than satisfactory policy performance was predicted by some long before the actual policy was approved. Existing and envisaged socio-economic realities should feature very prominently in policy formulation. The planner should keep in mind that one of the main aims of the plans and policies is to improve the overall socio-economic milieu of the country.

Trials on Graphic Depiction through integration of existing databases with GIS software

The PA has a number of datasets which are GIS coupled. Most of these are made available to the public free of charge through the Mapserver of the PA website. During preparatory processes required for a number of subsidiary planning exercises, possibilities that went beyond what was available in 2014-2015 were explored. The rationale was to radically revise database classification, organisation and setup and proper lineage recording was in place in order to facilitate future analyses, presentation, extraction of meaningful data and monitoring.

A number of tests were conducted to probe the capabilities of available data sets coupled with freely available software. This set the stage to explore other hardware and software possibilities so that future coupling of GIS oriented data sets with spatial planning requirements would be more readily understood. During the same period, additional work was undertaken to examine technologies that couple intelligent sensors intended to regularly and quasi-automatically update existing and future databases (Formosa, 2014).

Most of the tests depicted in this paper are based on Lidar data which was generated through a EU funded project entitled Developing National Environmental Monitoring Infrastructure and Capacity, awarded to MEPA in 2009 (MEPA, 2013). The main aim of the tests was to evaluate depiction capabilities of the various GIS tools - i.e. the presentation aspect. Some tests were undertaken to explore the analytic potential of existing datasets which coupled to a GIS framework. Examples of these trials are indicated in Figures 1 to . These results are encouraging in the sense that they clearly show that when properly depicted, GIS data can convey much more information than graphic data presented as a distribution of symbols or polygons on a map. The psychology of visual perception needs to feature prominently in the generation of these representations. Modern technology also facilitates the use of graphic depiction to better understand either the evolution of a situation over time or the three dimensional aspects of a stretch of territory and interventions thereon. This requires software which depicts dynamic imagery (eg. videos of flythroughs, virtual time lapses and so forth).

The spatial planner is one of the key persons that needs to have a good grasp of the evolving complex interactions between a number of agents and actions over time. ICT based tools can assist with the assimilation of this understanding, the development of sound proposals and to better prospects for more successful conveyance of the said proposals to the rest of the stakeholders.

Figure 1: Test converting LIDAR data into relative surface altimetry to directly estimate building number of floors. Ground verification indicated very good degree of correspondence between the relative altimetric height and the envisaged number of floors. Grey depictions either low structures or trees - test could not distinguish between the two. Construction tower cranes feature as short straight lines. Location - Sliema peninsula. Based on MEPA Lidar data 2012

Figure 2: Test depicting topographical feature extraction from LIDAR data. Steep cliffs, rubble walls, cultural features and other built structures are easily identifyable. Map very useful to understand topography, feature inter-relationships and interaction between topography and history. White cut-outs are built structures. Location - Xrobb l-Ghagin Penisula and il-Hofriet. Based on MEPA Lidar data 2012

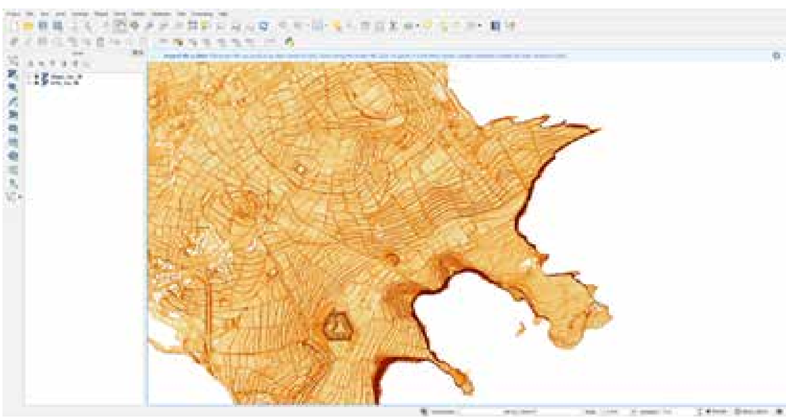


Figure 3 : Test using aspect to extract the 3D-nature of the terrain without using photographic imagery. Natural and mad-made features are often easily distinguishable. White cutouts are built structures. Location - Gharb / Ghasri / San Lawrenz area with L-Gholja tal-Ghammar at the centre of the image. Based on MEPA Lidar data 2012

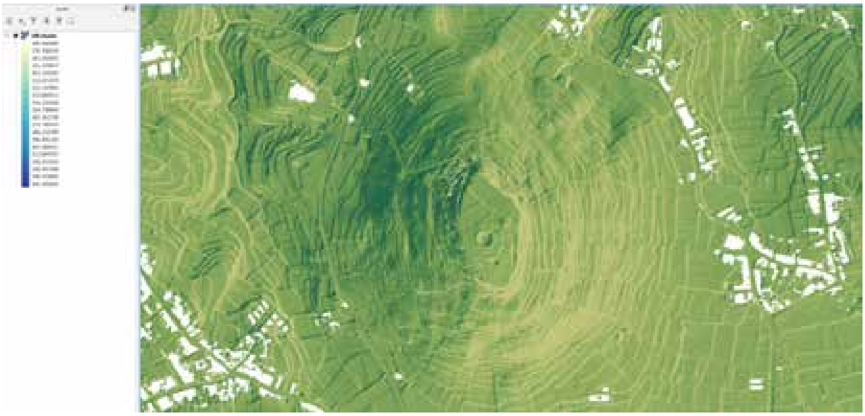


Figure 4 : Test depicting higher resolution altimetric map showing significant sloping terrain. V-shaped valleys and the cliff dominated coastline can also be readily inferred from this image. White cut-outs depict buildings, built structures and the larger trees. Location - Wied Babu area - Zurrieq. Based on MEPA Lidar data 2012

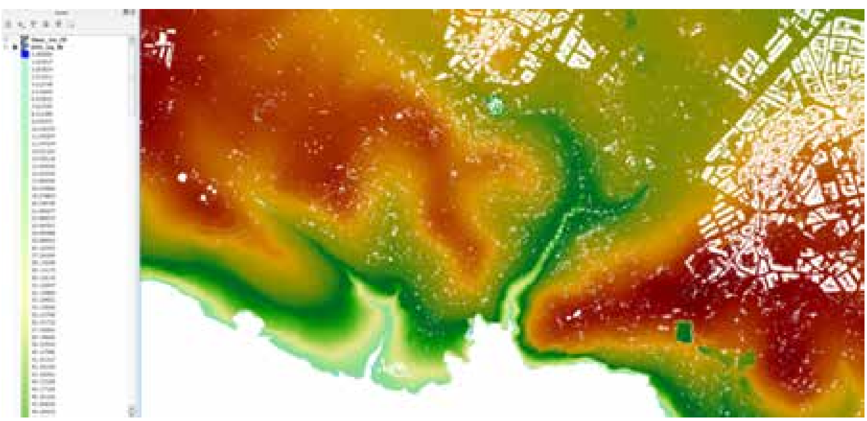


Figure 5 :Test showing a higher resolution altimetric map clearly suggesting the rationale for a number of man-made features (including roads and fortifications). Such maps may also assist in the identification of areas subject to wave action and localized pluvial flooding. White cut-outs include higher stuctures such as buildings and higher trees. Location - Valletta and surrounding areas. Based on MEPA Lidar data 2012

Figure 6: Test depicting the Hill shade function used to highlight the intervention of man-made terraces on the natural landscape. Location - Wied Migra l-Ferha area due SW of Mtahleb. Based on MEPA Lidar data 2012

Figure 7: Test indicating how careful choice of slope parameters and corresponding chromatic depiction can greatly facilitate identification of structures such as the more imposing fortifications. Location - Valletta and surrounding areas. Based on MEPA Lidar data 2012

Figure 8: Test showing slope mapping applied on a monochromatic basis. White features are the built up areas or significant structures, grey areas represent relatively flat terrain whilst black areas represent steep slopes. Excavations, steep sided mounds and V-shaped valleys thus feature prominently in this map. Location - Area around the Malta International Airport. Based on MEPA Lidar data 2012

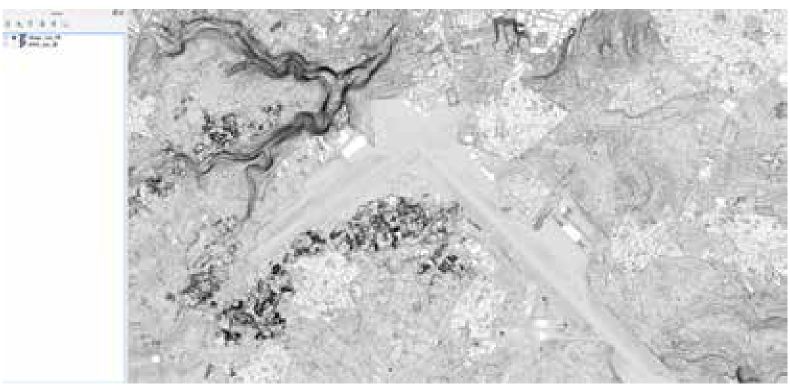
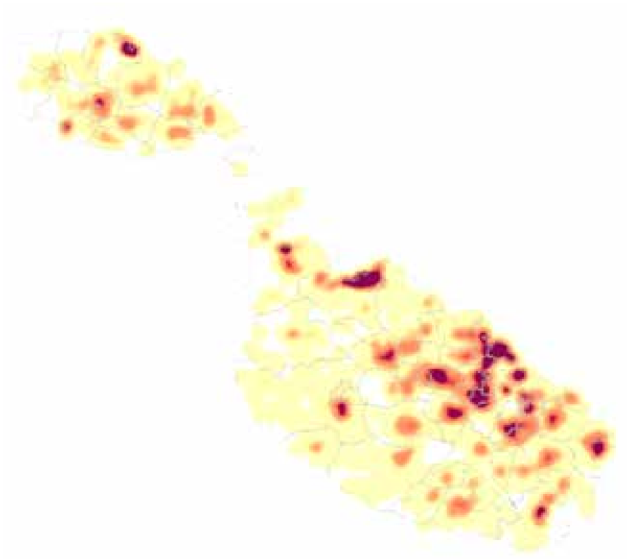


Figure 9: Test showing heat map depicting distribution of vacant dwellings in 2011. The darker colours indicate higher concentrations of vacant dwellings. The heat map suggests a greater percentage of vacant dwellings in the area around the inner Harbour area and Tourism oriented areas. The level of resolution is however too low to permit a deeper analysis. Based on aggregated data of water and electricity meterage registering zero consumption



Relevance of newer ICT based technology to future Spatial Planning

There is always scope to support spatial plans and policies with better evidence based information which is as user friendly as possible. Although there is much greater potential in modern technology, it is often complex to use and requires considerable technical skill to operate. Equipment and software are expensive and need specialised personnel to maintain, troubleshoot and periodically upgrade. Moreover, if not diligently employed,ICT based technology may complicate rather than facilitate the understanding of spatial planning situations. Additionally, the participatory nature of modern planning implies that the planners need to have better administrative, managerial, leadership, communications and presentation skills in order to fully convey the underpinnings of their proposals. Technology based on ICT/GIS related platforms, if well understood and judiciously employed, can assistwith the better conduct of the above functions.

So in which areas can new ICT based technology be relevant? Given that spatial planning has a spatio-temporal aspect, it is important that the hardware and software used to assimilate, analyze, model and depict data is versatile enough to process informationin quasi real-time.Moreover the information has to be as up to date as possible and organisedin formats that are amenable to be used by the planners and associated expertise. The same information should also be easily converted into electronic formats which are readily accessible in formats that are familiar to other key stakeholders and the general public.

Therefore the following are considered to be the main areas for improvement deemed possible through new ICT based (especially GIS) technologies and the associated expertise:

- More organised and better networked data collection processes;
- Improved data validation tools and quality control;
- Superior cross-platform and interagency collation, organisation, assimilation and analysis of data;
- Enhanced data exchange and handshaking through faster networks (fixed and wireless);
- Improved generation of evidence based statistical and other quantified data;
- Better depiction and presentation of significantly larger quantities of data;
- Greater use of image manipulation and dynamic imaging software (e.g. fly throughs) to enhance depiction flexibility (in space and in time);
- Better opportunities to develop scenarios based on available and projected information;
- Opportunities to upgrade and update data at much more frequent intervals to update,maintain and upgrade relevant datasets. This would greatly enhance the planning related monitoring processes and the prospects of updating plans on the basis of the most recent data. There is ample scope for automation on some datasets;
- Permit the increased direct input of various intelligent sensors which are coupled to automatically generate meaningful data in lieu of time consuming and less reliable manual data collation. More advanced real time data acquisition and monitoring delivered through a range of smart networked sensors would thus be achieved;
- Marked improvements in security and error protection facilities in software to keep track of and tabs on all interventions in the various planning processes with the required access and updating security protocols in place;
- Enhanced integration and exchange of information between public and private agencies; and

- Improved prospects of having dynamic plans whereby certain policies would be future resilient by being designed to operate according to predesigned triggers which are subsequently acquired from monitoring data (i.e. changing policy provisions according to monitoring outputs - i.e. if this happens, then an appropriate policy provision would be applicable).

In order to achieve better communication with ICT/GIS specialists, other stakeholders in the planning process, the key decision takers and the public at large, it is important that at least some spatial planners are equipped with ICT/GIS skills to facilitate dialogue and networking with the specialists in these fields. This would essentially translate into better multi-disciplinary handshaking and easier translation of planning ideas into outputs that can subsequently not only inform the planners but the rest of the players involved in the processes leading to the adoption of the respective spatial plans and policies. It is therefore deemed beneficial that the average planner has at least a basic understanding of modern GIS based and related data management and analysis software.

Familiarity with visual simulation, data (including GIS) querying, media presentation and image manipulation software would also be useful assets. Although spatial planners may not always be required to generate plans which include maps, associated imagery and graphics which can be comprehended by the widest possible spectrum within society often help with the participatory and consultation processes.

Conclusion

It is clear that ICT based technology can go a long way to render the various spatial planning processes more efficient, available to a wider audience and more comprehensible. Like every other tool, ICT based technologies are only as good as the intentions, knowhow and diligence in application of their use. Moreover, these technologies require considerable investment to secure the hardware and software which can efficiently process, exchange and effectively display huge amounts of data. Staff using the technology would require to be well versed in the capabilities and limitation of the said technologies and thus training is a must in order to promote the best possible use of the relevant tools.

To date, most spatial planners tended to have limited technical competence in the use of the various ICT based technologies. This paper is proposing that greater familiarity with these tools may open opportunities in terms of better exploitation of the as yet untapped potential and better communication with other experts in the field leading to superior deliverables and better externalisation of the processes and results.

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CHAPTER 17

Sustainable Underground Development

Adriana Zammit

Introduction

Current trends in society which affect urban development

Migration of poor people from developing countries in consumerist cities is increasing worldwide. Many of these end up living in sub-standard environments (Rogers, 1997). In 1950, 30% of the world's population was deemed urban; currently it is at 54% and by 2050, 66% of the world's population is expected to be living in cities (United Nations, 2014). Demographic intensification in cities is challenging the supply of land and this is leading to social instability and deterioration on the environment.

"Cities are consuming three quarters of the world's energy and causing at least three quarters of global pollution" (Rogers, 1997, p. 27). Pollution, exhaustion of raw materials, waste and congestion are some of the major environmental concerns caused mainly by cities (United Nations, 2014). Further urban sprawl to accommodate the increasing population density is leading to a decrease in agricultural and green land. Growing urbanisation requires more energy services for lighting, heating, cooling, appliances, electronics and mobility and this consequently increases the CO2 emissions (Kamal-Chaoui & Roberts, 2009).

The result of this continuous pressure on the environment is leading to climate change, which is notably leading to global warming, sea level rise and degradation of drinking water supplies. Extreme weather systems and flooding on a massive scale are threatening the fabric of society and cause massive economic disruptions (Kamal-Chaoui & Roberts, 2009).

Cities need to be more resilient and city governments need to prepare themselves to cope with new phenomena through the formulation of adaptive measures. These measures include the better utilisation of spaces and proper management of public infrastructure. This would ensure sufficient living space per inhabitant and improved standard of living of the citizens. The main aspiration is to identify methods of how humans can progress without deteriorating the environment.

The contribution of underground space to sustainable development

Sterling (1996) submits that the use of underground space for infrastructural development has substantial potential to attain a high level of sustainability and generally offers the most environmentally friendly solutions. This said, Sterling (1996) sustains that the underground is not a universal alternative to the surface, that is the underground is not a panacea to current environmental problems.

The interest in underground construction and development is increasing because the technology available to 'underground' engineers enables them to deal with a wide range of problems. Indeed, this branch of engineering is creating openings for the further expansion of related sectors such as construction, transportation, public service, energy and mineral resource extraction (Huanqing, 2013, p. 24). Thus, underground development is not only a means to improve the quality of life of society; it also has the potential to contribute to economic growth and to create less pressure on the environment.

In the transportation sector, for example, underground networks contribute to the control of congestion in surface networks and therefore results in a reduction of air pollution (Sterling, Admiraal, Bobylev, Parker, Godard, Vahaaho, Rogers, Shi and Hanamura, 2012). Underground developments tend to use less energy than their surface counterparts because they are shielded from external climatic conditions. A well-planned underground development strategy can contribute to the mitigation of climate change problems. Planning the underground requires the consideration of its four dimensions (space, geo-materials, groundwater and energy) in a holistic and sustainable manner.

The downside of underground structures

Engineers are aware that underground structures may have adverse impacts on the subterranean environment. Such impacts would include groundwater and noise pollution and ground movements which may affect buildings. Also, the construction of facilities consumes energy, and natural and financial resources. For sustainability purposes, such costs have to be balanced with long term resource savings and environmental benefits. Life cycle costs need also to be considered. Subterranean construction may not deteriorate through environmental exposure but may still suffer deterioration, especially due to humidity or water leakages which may be more difficult to repair without shutting down the facility. Thus, resilient structures are to be constructed (Sterling, et al., 2012).

The development of underground space is an irreversible action and once it has been developed it cannot ever be returned to its original state. The underground contains natural resources that can be altered by human activities (Sterling, et al., 2012). Sterling (1996) states that it is essentially impossible for a modern city to exist or be sustainable without underground transmission and sewerage tunnels and pipes. However, the adequate use of the underground is often considerably hindered by the first come first served nature of former underground uses. This is the main reason behind the importance of planning and co-ordinating the subterranean development to achieve sustainability. Thus, urban planning needs to coordinate the space above and beneath the ground on a large scale in order to define its future development.

Planning of underground spaces, when combined with appropriate design, construction, operation, maintenance and regulation, will equip society to take informed decisions on how to best utilise the underground space from a social, economic and political perspective (National Research Council, 2013). Bobylev (2009) considers the importance of understanding the existing situation of urban underground space, through geological modelling and surveys of existing structures. These include the preparation of a 3D map of the city that includes the underground space, the prospective planning of the underground with a perspective of time, and the identification of the prospective services. Also, space for different scenarios should be reserved, and decision-making should understand the component of sustainability.

Sustainable underground development in Malta

Similarly, in Malta, the high population density, combined with poorly planned urban growth and a growing economy, has led to scarcity of space. The extensive urban sprawl in Malta has been a major source of concern for many since the 1980s (MEPA, 2010). Society is now facing a situation of insufficient space to accommodate land uses necessary for economic and social development. Underground development can be part of the solution to meet the challenges of the future without destroying our heritage or worsening the surface environment.

Although, on a national level, the machinery to develop subterranean spaces exists, the underground is still not being developed in a sustainable manner. Projects tend to be done in a piecemeal manner, with most of them being implemented ad hoc with no real long-term subterranean planning. The underground is an important resource that must be developed efficiently by considering the long-term economic, social, and environmental benefits. Failing to do so, most of the benefits that would have been obtained from developing this space would otherwise be lost and sustainable development of urban areas would be limited (ITA-AITES, 2010).

Research Overview

This study delves into the availability of space, geo-materials and groundwater to enable a holistic vision of the subterranean. Using the underground for energy purposes is still under study from a national perspective and is not considered in this research. Reference is also made to current laws, policies, planning documents that are related with the development of underground space.

Following, this assessment, this study focuses on the identification of those obstacles that could hinder the potential of underground space as an element of our built environment. This is done to assess as to what extent the underground space can be planned locally. Thus, establishing how the better utilisation of underground space could lead towards more sustainable development in Malta.

It is hence the aim of this study to contribute towards providing an answer to the following questions:

- What are those issues that hamper the achievement of using the greatest value of the underground space in Malta?
- What are the opportunities that can enhance our abilities to develop and use underground space in a sustainable manner?
- Will an Underground Planning Strategy aid in achieving the greatest value of underground space?

National Dimensions of the Subterranean

Segment 1: Space

Throughout different historic periods, the subterranean in Malta was developed for various reasons. Uses included catacombs, crypts, military infrastructure, shelters, large scale sewage networks and disused railway tunnels. Nowadays, the advancement in technology coupled with changing demands of society has totally morphed how underground spaces are developed. The underground serves as a space for many urban services such as parking facilities, transport tunnels, retail centres and cinemas and so on. One of the most recent major developments Malta, known as the Tigné Point complex (MIDI plc, 2015) is a case in point. Other major underground projects in Malta which were built in the last decades include energy and water tunnels, landfills, and the flood relief project depicted in Figure 1(GoM, 2013).

Figure 1: The National Flood Relief Project

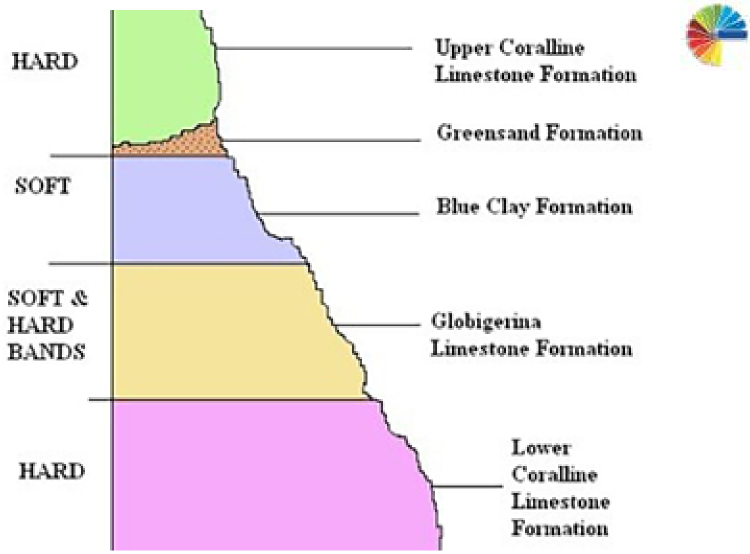
Source: (Politecnica, 2015)

Segment 2: Geo-materials

The principle rock type of Malta is limestone which is soft and relatively easily excavated and supported, thus enabling the construction of large stable underground chambers and tunnels (Armstrong, 1991). In relative simple terms, local rock falls into five horizontal layers (Figure 2), starting from the bottommost and oldest layer being Lower Coralline limestone, followed by Globigerina Limestone, Blue Clay, Greensands and Upper Coralline Limestone. The latter resides at the topmost layer.

The excavation of underground spaces involves the management of considerable quantities of bedrock. With the construction industry being a high contributor to the local economy, Construction and demolition (C&D) waste forms the largest waste stream that is generated in the Maltese Islands (MSDEC, 2014). The amounts produced fluctuate in proportion to the economics of this industry. Table 1 indicates a reduction in the generated C&D waste over the period 2008 to 2011 due to the economic crisis. Moreover, major developments increase the amount of C&D waste generated (MSDEC, 2014).

Figure 2: Section of Malta's rock formation



Source: (Seismic Monitoring & Research Unit, 2012)

Table 1: C&D waste management over the period 2004 to 2011

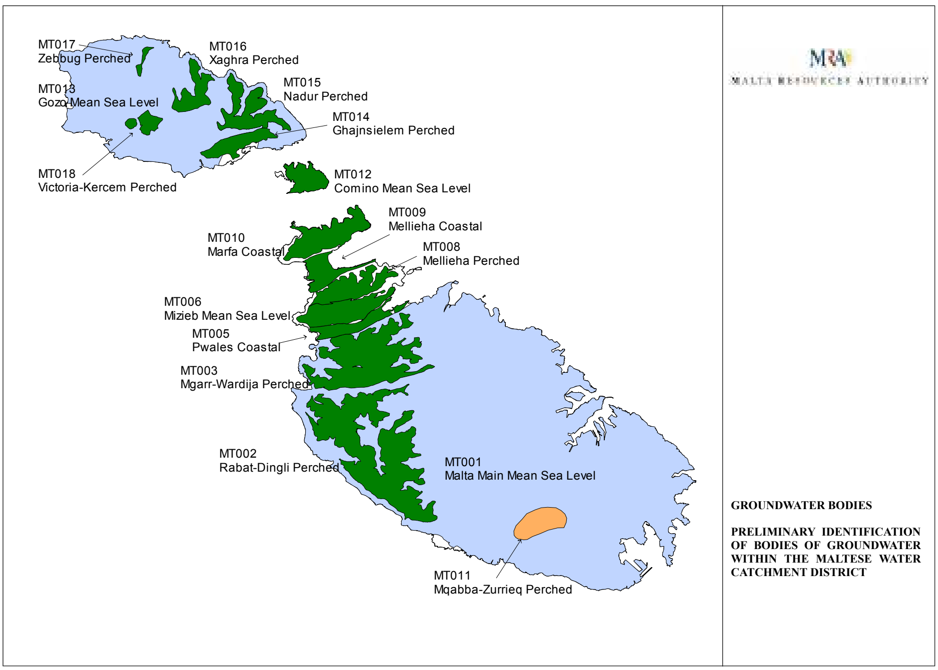
	Recycled	*Recovered*	*Landfilled*	*Disposed at Sea*	*Others*	*Total*
2004	19,916		2,580,454	210,404		2,810,774
2005	15,332		1,970,883	357,942		2,344,157
2006	101,756		2,061,340	329,426		2,492,522
2007	243,818		2,110,641	146,205		2,500,664
2008	173,982		1,522,000	300,360		1,996,342
2009	63,463		462,584	74,370		600,417
2010	114,149		688,061	290,120		1,092,330
2011	139,144	3,611	422,057	149,120	2,125	716,057

Source: (MSDEC, 2014, p. 75)

Segment 3: Hydrogeology of the Maltese archipelago

Malta has no surface water and freshwater resources are scarce. This is mainly attributed to the local geological and climatic conditions (Spiteri, Scerri, & Valdramidis, 2015). In fact, the groundwater resources in Malta are restricted to a number of aquifers. The largest underground water storage is provided by the sea level aquifer and this serves for eighty percent of the groundwater extraction. This body of freshwater has the form of a lens that floats on denser saltwater. There are also a number of perched aquifers that sit on impervious strata above sea level. These are shown in the Figure 3. These aquifers are replenished when rainwater is absorbed into the ground and slowly percolates into them, making them a finite resource (Spiteri, Scerri, & Valdramidis, 2015). A number of illegal boreholes have been dug to extract such resource without any regard to sustainability and thus leading to the deterioration of the underground freshwater (MRA, 2004). There is also the issue of contamination from the infiltration of pollutants (MRA, 2004).

Figure 3: Groundwater Bodies



Source: MRA, 2004

National Laws and Regulations related to the Subterranean

Ownership

The law affecting the possession of underground development includes Article 323 in Civil Code (Cap 16) (GoM, 1874). This law dates back to centuries and regulates property ownership in Malta. It states that land owners have rights of the airspace above and the soil below, meaning that the owner of the surface owns 'from heavens above to the centre of the earth below' (GoM, 1874). On the basis of this ground law, an interview was carried out with an official of the Lands Department, to understand better how the issue of land ownership is managed when it comes to public utilities.

Reference was made to Chapter 88 of the Laws of Malta: Land Acquisition (Public Purposes) Ordinance (GoM, 1935). In particular article 29 of the said law that states:"(2) When for any public purpose any land is declared to be subject to subsoil rights, no owner shall make any new or extend any existing underground work or excavation without the prior permission, in writing, of the Board" (GoM, 1935). Sub-soil refers to just below street level. Depth is not quoted in the Law (Official of the Lands Department, personal communication, July 16, 2015).

Groundwater regulations

Regarding the laws related to excavations within the saturated zone, there is regulation 4 of Legal Notice 254 of 2008, "Borehole Drilling and Excavation works within the Saturated Zone Regulations which seeks to protect the groundwater table and states that "the drilling of a borehole or any form of excavation works carried out partly or totally within the saturated zone is prohibited, unless a permit to this effect is issued by the Authority [Malta Resources Authority]" (GoM, 2008).

Development Planning Act, 2016

The recently enacted Development Planning Act (Cap 552) is the piece of legislation that regularises the Planning System processes. It provides for:

- the Strategic Plan for the Environment and Development (SPED), 2015. This plan was approved in Parliament in July 2015 (GoM, 2015a);
- subsidiary plans and policies including subject plans, local plans, action plan or other plans; and
- development orders (GoM, 2016).

The SPED considers a strategic vision to regulate the sustainable management of land and sea resources. It aims at providing a framework for an integrated planning system. The reference to underground development in the SPED is Thematic Objective 4 that specifies that "existing strategic infrastructure is safeguarded and that provision is made for infrastructure (water, electricity, sewers, fuel storage and telecommunications) to sustain socio-economic development needs whilst encouraging the Best Available Technology and protecting the environment" (GoM, 2015a, p. 20).

The Local Plans consist of seven map-based plans for the entire Maltese Islands and cover approximately 33km2. They have been published in 2006, except for the Marsaxlokk Bay and the Grand Harbour Local Plan which were published earlier (GoM, 2015b). The Local Plans designate the land use, building heights, conservation areas and development boundaries. They provide guidance as to where development can take place and set the criteria against which development proposals are decided by the Planning Authority. The Grand Harbour Local Plan, 2002, Map 4 makes the only reference to the underground, and indicates an underground rapid transit route as part of a long term transport strategy. To date, this long term strategy has not been implemented. The other local plans make no specific reference to the development of the underground. Hence, the zoning of the underground is usually dictated by the surface use. In addition, the maximum depth for underground development is not yet regularised by any plan.

Methodology

The approach adopted for the study was purely a qualitative one. The principal reason underlying this decision was that the purpose of the study was to explore new perceptions of how the underground in Malta can be developed in a more sustainable and systematic manner. Moreover, the author wanted to gather deep thoughts from the participants involved in the research and therefore took advantage of qualitative tools to gather the insightful information required. The approach adopted to select the participants involved snowball sampling. This method consists of initially identifying and interviewing a number of participants that have the requisite expertise. These participants are used as informants to identify other themes or other possible participants who can be included in the sample. A semi-structured, one by one interviews were used as the primary investigation tool to gather data from respondents who are experienced in the field and who were willing to participate in the study.

Variables for analysis

A set of eight themes were prepared beforehand and these were used to guide the conversation which included:

- the financial and economic aspect;
- technical opportunities and hurdles;
- the use of the underground and its function;
- the social perspective;
- environmental benefits and constraints;
- institutional difficulties;
- room for improvement; and
- planning the underground.

The interviewees were given the opportunity to discuss in detail their thoughts and views about the opportunities they envisage, and the hurdles they may have encountered in the development of the underground.

Sample selection in this study

The interviewees were selected according to their involvement in underground development and their level of experience in the field. It was imperative to choose experienced participants in the sector to obtain the desired in depth responses. Persons who have been recommended during the research process were also interviewed. This was only possible because of the flexible approach adopted. The interviewees were divided into three main sections: those directly involved in construction; regulating authorities; and stakeholders that are experts in the field of underground resources. These included:

- a major contractor involved in various national underground developments;
- a project leader and a structural engineer engaged in the flood relief project;
- officials on behalf of the Water Services Corporation and Enemalta Corporation (Enemalta plc is a corporation responsible for electricity generation and distribution in Malta);
- an official of Enemed Ltd., responsible for the fuel storage facility;
- a Transport Malta engineer;
- an official of the Lands Department;
- two representatives from the Planning Authority (referred to as Planner A and Planner B);
- an environmental management specialist;
- a Geo-technical engineer;

- an expert in historical infrastructure;
- a Geographical Information Systems professional; and
- a member of parliament.

The sample size is not an exhaustive one but is deemed to cover all the major themes and involved a minimum of one professional from each relevant field.

Results

Data Analysis

Interviews were conducted with a total of 15 participants. In view that the participants were selected from different sectors, they generally focused their contributions from the point of view of their particular sector. This led to certain themes being discussed in more detail than others and new unanticipated issues emerged throughout the discussions. The approach adopted in the data analysis, included a review of the transcripts and the identification of the categories that emerged throughout the interviews. The data was organised using a tabular format according to each category as depicted in Table 2.

Table 2: Framework of data organisation

	Benefits	*Constraints*	*Solutions*
Theme 1			
Theme 2			
...			

The participants' feedback from varying sectors highlights a number of common themes with a variety of hurdles and opportunities as discussed in the themes below.

Financial Cost

The financial cost of going underground was considered a major burden by most participants. Although the bedrock of the Maltese Islands is relatively soft when compared to other countries, difficulties are encountered in the estimation of the actual costs and timeframes to conduct subterranean projects. This is attributed to the varying bedrock properties. In addition, placing of infrastructure without proper records and/or thought on future implications is posing financial restrictions on the further development of the underground.

Whilst it is noted that initial cost is the main reason behind most projects being overlooked, a national underground planning strategy can reduce this financial burden by considering a holistic vision of the required underground projects and trying to integrate the required uses together in a planned number of projects.

Integrating Uses

The Developer remarked that if the electricity distribution tunnels were large enough they could have been combined with transportation. "Rather than going straight, alter a bit the route and increase a little bit the length of the project" (Developer). However, given that such tunnelling projects are constructed and financed by one entity, coordination between different entities is not that simple and depends greatly on priorities. In addition, integrating certain uses within one tunnel is not always technically possible.

The difficulty in integrating all services in one network should however not hinder the development of a planning strategy. A planning strategy would permit the combination of complementary land uses and operations in one underground infrastructure (Planner A).

Interesting to note that uses considered suitable at underground level by the participants include:

- an LPG network;
- the adaptation of quarries for industrial or recreational uses;
- water storage;
- casinos;
- supermarkets;
- pools;
- parking;
- gymnasia;
- warehousing;
- relocation of overhead wiring;
- sewage treatment plants;
- waste collection networks; and
- transport.

Archaeology

Another drawback of underground development is Malta's extensive underground cultural heritage close to the surface. This combined with the lack of data and surveys of existing historical spaces does not help at all in their integration of archaeological spaces in new projects. Other challenges in readapting archaeological spaces include the provision of adequate ventilation and sanitary requirements. However, there are ways and means of how archaeological spaces can be used and integrated with major developments, as highlighted by a representative of the Planning Authority and the Historian. A case in point is a subterranean telecommunications centre built during the British period which was discovered during construction. This was integrated in the overlying project by being utilised on a commercial level. The developers retained the original telecommunication installations as a showcase of history.

Existing Infrastructure

Similar to archaeology, existing infrastructure poses hurdles to future underground development. The WSC engineer argued that the underground infrastructure is taking a lot of space and services are crossing each other. Drainage and water leakages are also a huge problem. The Transport engineer also referred to the underground utilities as an underground congestion without any planning. "Everyone passed a service through the underground without much thought" (Transport engineer).

Data Co-ordination

Planning the underground to achieve sustainable development requires more information and data on the existing underground status. The lack of coordination between different entities and also within the same government departments is creating barriers. Electrical conduits and water networks are not plotted accurately and this is resulting in damages to the infrastructure while other projects are being carried out. There is no comprehensive database. Similarly, the national inventory on archaeological heritage at underground level is not up to date and this is impeding the visualisation of the underground. The Planning Authority has base maps but not of the underground.

2D and 3D mapping is required to work around congestion of basements and services that lie below surface. "This (underground mapping) is very important to avoid new proposed developments intersecting the path of catacombs, shelters or water galleries" (Historian). 3D underground scanning and Ground Penetrating Radar are important to gather knowledge of what actually exists below the surface. Such technology can help to safeguard archaeology or important geological features.

Whilst most participants considered that deficiency in data co-ordination is a result of lack of political will, the Member of Parliament considered that such issue is a question of power because data is perceived to offer power and in turn is hoarded. However, the government is exploring the idea of a consolidated effort and appointed the Planning Authority as a national mapping agency to hold spatial data. Through a proposed national ERDF project led by the Planning Authority, here are prospects that all entities will eventually put the information on an integrated platform. It is envisaged that all entities can potentially upload all the information (underground and over ground) on the project's platform (Planner B). This platform is being co-funded by the EU. The Authority is exploring the availability of technology to scan the roads and establish the existing situation. However, the uncertainty about the accuracy of data requires skilled labour to interpret it.

This initial step is considered a positive approach towards sustainable planning. The knowledge on the location of the existing spaces and the areas of available land for new development is required to enable proper planning. This project, despite being at its initial stages (refer to Chapter 2) is considered by the author as a very positive prospect, particularly due to the technological advancement involved.

Conclusion

From a national perspective, an underground planning strategy should aim towards enhancing the socio-economic and environmental aspects of the country and should:

- govern the use of a valuable resource and urban land;
- support three-dimensional planning, co-ordination of different departments and data management as a means to envisage a holistic picture of space;
- promote awareness and knowledge on international technological advancements;
- identify the current and prospective users of urban underground space and the services that are to be located at subterranean levels;
- prioritise projects and reserve spaces accordingly;
- consider the integration of services to reduce numerous and scattered infrastructural projects. This is a means of enhancing project feasibility;
- manage underground spaces to avoid a situation of subterranean chaos;
- consider and connect the subterranean with aboveground development;
- ensure the protection of cultural heritage;
- promote the efficient use of resources including local stone and waste management;
- integrate sustainability issues and deal with long-term development perspective; and
- integrate and analyse sustainability from a holistic perspective and reduce assessment and decisions based on a sectoral approach.

Gathering data, analysis and map it is the initial step towards the creation of a national underground planning strategy. Failing to do so, most of the benefits that would have been obtained from developing this space would otherwise be lost. Sustainable development of urban areas would be limited and this can make Malta less competitive than other countries. On the contrary, such strategy can provide us with better infrastructure solutions which can lead to many positive outcomes such as feasibility, better landscape and less polluted environment, a more resilient country in terms of management of space and services and helps in saving urban underground space for future generations.

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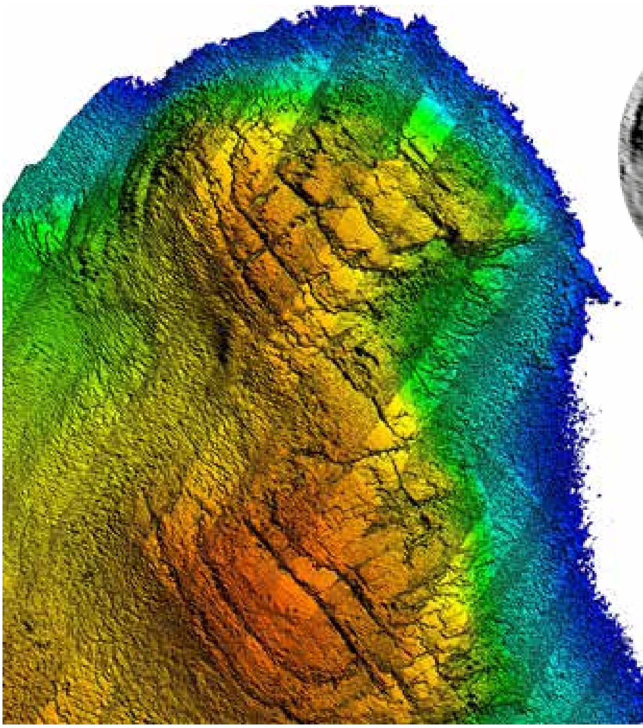
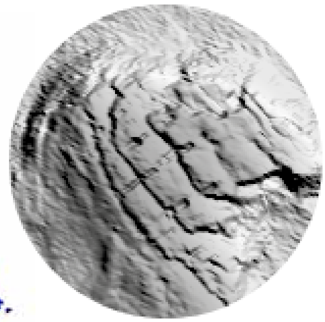
Pivot IV
Social Wellbeing





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35° 53’ 11.8980” N, 14° 34’ 19.3497” E

CHAPTER 18

Risk Assessment: Supporting Public Policy in an Uncertain World

John Agius, Marc Bonazountas, George Karagiannis, Elena Krikigianni and

Chrysovalantis Tsiakos

Introduction

As the emergency management paradigm shifted from response to prevention in the 1980s (Auf Der Heide, 1989), risk assessment progressively turned into a key requirement for civil protection authorities (Schwab, Eschelbach, and Brower, 2007). The European Commission Directorate-General launched the Risk Assessment and Mapping Guidelines for Disaster Management in 2010, whilst the European Parliament and Council Decision 1313/2013/EU on a Union Civil Protection Mechanism requires Member-States to develop risk assessments at national or appropriate sub-national level by 2015 (FIAU, 2013). In parallel, the development of national risk assessments (NRA) became an ex ante conditionality (Baubion, 2013) of the EU Cohesion Policy 2014-2020.

The process of the Disaster Risk Assessment (DRA) development is therefore more vital than the outcome. Prevention is better that cure when it comes to natural and man-made disasters. However, the hazards and threats facing a community may not be known and, even if they are, funding is rarely if ever sufficient to address all of them at the same time. In addition, policy-makers are increasingly required to prioritize the use of scarce resources in an uncertain planning environment. Pressures from the electorate may cause public policy to increase community vulnerability by supporting development in unsafe areas, adopting unsafe building practices and diverging funds from emergency management.

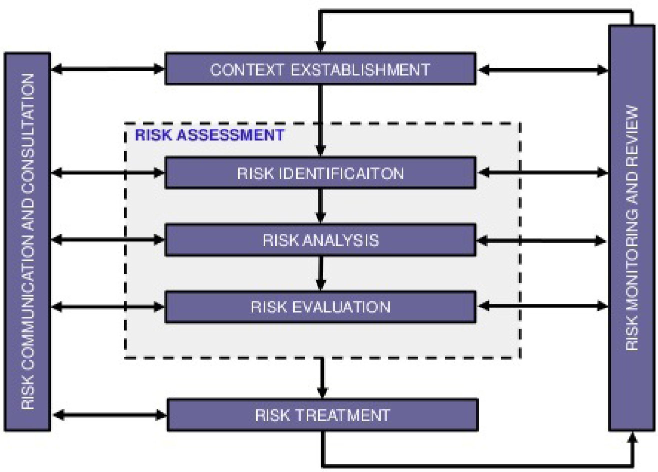
The purpose of a risk assessment is to support decision-making in an uncertain environment, by identifying the hazards and threats that a community is facing and comparing their expected consequences. The process of developing a risk assessment is fundamentally an educational endeavor that can foster a shared understanding of the challenges that a community needs to address.

This study provides an innovative comprehensive approach to the development of disaster risk assessments as strategic planning tools for communities and countries. It outlines the procedure and main steps, to identify and manage the risks and describes the methodology for developing a disaster risk assessment in a defined territory. Finally, this methodology is applied to the Maltese islands with a view of evaluating the risk from known threats and hazards that have potential to significant impact to the Malta's security.

Methodology

The European Commission Risk Assessment and Mapping Guidelines (EC, 2010) adopt the risk assessment process established in ISO 31000:2009 (ISO, 2009). This process (figure 1) is used as a baseline for the National Disaster Risk assessment methodology.

Figure 1: Risk assessment and management process



Source: (ISO, 2009)

The developed methodology employs a 7-step process with several sub-steps (Table 1). Risks are identified, analysed, evaluated and mapped based on the procedure defined for each step and sub-steps. The analysis is based on historical records, statistical data, and information on consequences for each hazard, questionnaires, vulnerability assessments, expert judgment and testing scenarios.

Table 1: Risk Assessment methodology steps and sub-steps

Steps	Sub-Steps
1. Context analysis	1.1 Establish the analysis context at national level
	1.2 Establish risk criteria and indicators
2. Risk identification	2.1 Identify risk sources
	2.2 Identify risk sequence and plausible single & multi-risk scenarios
3. Risk analysis	3.1 Hazard analysis
	3.2 Vulnerability analysis
	3.3 Loss estimation
4. Critical infrastructure assessment	4.1 Define asset and system parameters
	4.2 Collect and gather information
	4.3 Screen infrastructure assets
	4.4 Assess consequences
	4.5 Assess hazards & threats
5. Risk evaluation	5.1 Risk matrix
	5.2 Determine the acceptable level of risk
6. Risk mapping	6.1 Hazard maps
	6.2 Elements at risk and critical infrastructures maps
	6.3 Risk maps
7. Develop Risk Reduction and Management Strategies	7.1 Capability assessment
	7.2 Strategy development

Risk scenarios are necessary to address the uncertainty inherent in risk assessment. A scenario is a plausible description of how the future may develop. Scenario building is mainly based on experiences from the past, but also events and impacts which have so far not occurred should be considered. Scenarios should be based on a coherent and internally consistent set of assumptions about key relationships and driving forces (EC, 2010).The following paragraphs summarize each step of the national disaster risk assessment methodology.

1. Context analysis

Context analysis is the initial step of the methodological approach (Kendon, 1990). It articulates the objectives, defines external and internal parameters to be taken into account and sets the scope and risk criteria for the remaining process. It involves two main sub-steps:

1.1 Establish the analysis context at national level

This includes establishing the external context (i.e. national and international legal and regulatory requirements, stakeholder perceptions, technological and economic context), the internal context (Civil Protection Department culture and tasks, measures, policies and strategies in place, information systems, information flows and decision-making process, standards and guidelines adopted by the managing authority, contractual relationships) and the context of the risk management process (goals, scope and objectives, responsibilities and accountabilities, organisational structure, products and services to be delivered). The scope is to define general objectives and decision-making criteria as a first approximation, to be refined at a later stage.

1.2 Establish risk criteria and indicators

The established criteria and risk indicators that will be used in steps 3 (risk analysis) and 5 (risk evaluation), will reflect the values, objectives and resources:

- They are directly related to risk acceptability and inherently have a social and political dimension (Slovic, 2000);
- They will be derived from national and European legal and regulatory requirements, using an iterative process that requires feedback from steps 2 and 3.
- The nature and type of causes and consequences and their respective metric, definitions and timeframe(s) for likelihood and/or consequences and the different levels of risk will be analysed. Exposure indicators (e.g. duration, intensity, extent and likelihood), threat and vulnerability indicators (e.g. contextual site factors, vulnerable elements, aggravating factors) and consequence indicators (e.g. costs for repair, deaths) related to each national case will also be defined. Data relevance and availability on the appropriate scale should be verified at this step.

2. Risk identification

Risk identification is the process aimed at identifying sources of risk (hazards in the context of physical harm), areas of impact, their causes and potential consequences. It is a screening exercise and it serves as a preliminary step for the subsequent risk analysis stage. Potential sources of information for the risk identification could include official government reports, papers, publications, newspaper or media articles, or even anecdotal information from long-time residents. Although information collection will be hazard- and threat-specific, structured interviews with experts and analysis of existing documentation will be the primary information collection approaches (EC, 2010).

The goal of the risk identification is to screen risk sources and select those risks that pose a significant threat. The result is a selection of risk scenarios to be further analyzed at the risk analysis stage (stage 3). It includes an overview of the various risks and a description of the single- and multi-risk scenarios to be further analysed during the risk analysis stage.

The risk identification involves the following two sub-steps:

- Identify risk sources: The objective is to generate a list of potential hazards and elements that alone or in combination are likely to generate detrimental consequences; it basically involves the identification of hazards that could threaten the territory of the Maltese Islands;
- Identify risk sequence and plausible single and multi-risk scenarios. The objective is to acquire a good understanding of the risk process, from the event source to the related consequences and identify plausible scenarios for single and combined hazards.

3 Risk analysis

Risk analysis involves an understanding of the risks in depth. It provides input to risk evaluation and serves as a decision basis for determining whether risks need to be considered. For every risk and risk scenario identified in the previous identification stage, the risk analysis process carries out a detailed estimation of the probability of its occurrence and the severity of the potential impacts. Quantitative data are sought, were available. Where quantitative data are unavailable, scenario analysis is based on qualitative information. The EC Risk Assessment and Mapping Guidelines require that national risk analysis incorporates at least hazard and vulnerability analysis. Therefore, risk analysis involves three sub-steps: hazard analysis, vulnerability assessment and loss estimation.

3.1 Hazard analysis

Once the hazard, threat and risk identification is completed, a hazard profile will be built by addressing the following information for each hazard (Godschalk et al., 1997; Brower & Bohl, 2000):

- Delineate the location and boundaries of hazardous areas;
- Delineate the magnitude of potential hazards. Magnitude is measured in a different way for each hazard;

- Delineate the likelihood of occurrence of hazardous events. The probability of occurrence of hazard is generally difficult to determine; at minimum, a repetitive probability scale will be used (Karagiannis et al., 2013); and
- Describe and analyze the separate characteristics of potential hazards and threats.

3.2 Vulnerability analysis

The objective is to identify the characteristics and circumstances of the community that make it susceptible to the damaging effects of a hazard (UNISDR, 2009). Vulnerability is analysed against a hazard; therefore, once a hazard has been profiled, vulnerability can be analysed by looking into the following questions (Godschalk et al., 1997; Brower & Bohl, 2000):

- Assess the number of people exposed to hazards and threats, including special populations (e.g., elderly, hospitalised);
- Assess the value of property exposed to hazards;
- Assess critical infrastructure (e.g. hospitals, bridges, water and sewage treatment plants, schools, power plants, and police and fire stations) exposed to hazardous forces, using the criteria established in the European Critical Infrastructures (ECI) Directive;
- Assess the danger from secondary hazards (e.g. dam breaking);
- Assess the danger from hazardous facilities (e.g. chemical plant) in hazard areas;
- Assess the danger from exposure to hazardous materials in wake of natural disaster; and
- Assess environmental impacts of a disaster.

Various techniques can be used to inventory the people and assets (property, critical facilities, hazardous facilities etc.) that could be exposed to hazards. Data from urban planning data, national cadaster data, population census data, fiscal data, industrial data and other sources can be used as required and appropriate. The overall objective at this point is to determine as accurately as possible which parts of the community can be exposed to the hazards that have been previously identified and analysed.

3.3 Loss estimation

The purpose is to estimate the consequences of disastrous events (hazards) to people, buildings, and other important assets identified above. Consequences are estimated in terms of potential losses using a deterministic approach that can directly yield the risk severity (Karagiannis, 2012). The potential losses from the occurrence of a hazard are actually a function of the intensity of the hazard and the community's vulnerability to that hazard.

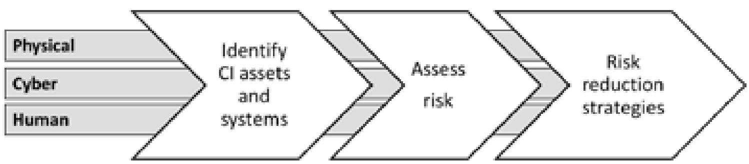
Therefore, one needs to analyze the information gathered during risk identification, hazard analysis and vulnerability analysis. Loss estimation is a two-step process:

- The first step is to calculate the extent of damage from any given hazard. Damages from a hazard are calculated in terms of losses to structures; losses to contents of buildings; losses of structure use and function; and human losses; and
- Then, the total losses due to a specific hazard event can be estimated by adding the losses to structures, to building contents, to structure use and function, and human losses for all assets identified within a community (FEMA, 2001).

4 Critical infrastructure assessment

The loss or disruption of critical infrastructures, such as power, water, transportation and communications, is particularly important in the framework of multi-risk scenarios addressing natural disasters, e.g. earthquakes and tsunamis, and terrorist events (ENISA, 2013), including cyber-threats. However, the new and emerging threats faced by critical infrastructure assets and systems, in conjunction with the interdependencies among them at national and European level, makes it virtually impossible to keep addressing critical infrastructure safety in the traditional, hazard-based way. A systems approach has therefore been used for the assessment of critical infrastructure assets and systems (Figure 2) .

Figure 2: Critical infrastructure assessment core methodology



Source: (adapted from Department of Homeland Security (DHS), 2013)

It is important to note that the assessment of critical infrastructures was not conducted as a separate exercise from the remainder of the risk assessment. Rather, the identification of hazards and threats, and the analysis and evaluation of the risks thereof, have been conducted simultaneously with the assessment of critical infrastructure assets and systems. This combination of the contingency and systems approaches has proven highly useful and has been a major improvement to the overall outcome compared with traditional risk assessment approaches.

The identification of critical infrastructure is based on the guidelines established in Annex III of EU Directive 2008/114/EC on the identification and designation of European Critical Infrastructures (ECIs) and assessment of the need to improve their protection. Specific criteria will be determined in consultation with the Critical Infrastructure Protection (CIP) Directorate. Therefore, the list of criteria is likely to include:

- the necessity of the infrastructure for the maintenance of vital societal functions, health, safety, security, economic or social well-being of people;
- severity of impact;
- the availability of alternatives;
- the duration of disruption/recovery; and
- the potential impact of the disruption to other EU Member-States (ECI).

Critical infrastructure can include, but not be limited to, the following:

- Energy (electricity, oil, gas, renewable energy)
- Transportation (road, rail, air, water – inland and ocean)
- Communications and information technology
- Emergency services
- Healthcare and public health
- Water, wastewater services and dams
- Food and agriculture
- Commercial, critical manufacturing and chemical facilities
- Financial services
- Government facilities
- Defense facilities

5 Risk evaluation

Risk evaluation involves comparing the level of risk found during the analysis process with the risk criteria established when the context was considered. It involves two main sub-steps: the risk matrix and the level of acceptable risk.

5.1 Risk matrix

The Contract, and the EU Risk Assessment and Mapping Guidelines and the Standard on Risk Management (ISO 31000:2009) require that each risk must be assessed on the basis of its likelihood and its consequences, using a risk matrix that is appropriate to the country level of risk. From the matrix, there emerges a measure of the severity of the risk, and a recommendation on how to proceed. A system for assessing the severity of a risk requires three components:

- A multi-level scale for rating the likelihood (or the probability of occurrence) of a risk;
- A multi-level scale for rating the consequences (or the severity of impacts) of a risk; and
- A matrix for scoring each possible combination of likelihood (probability) and consequences (impacts).

The ISO standard requires that the three components be realistic within the context of the analysis and reflect the perception of risk within the specific country.

Risk matrices are commonly used in risk assessments, as they help illustrate the relative prioritisation of each hazard according to the combination of their probability of occurrence and severity of impact. A 5×5 risk matrix (Table 2) can be used in risk assessments (EC, 2010). Each risk is represented by a point on a risk matrix. This point corresponds to a defined degree of probability of occurrence and severity of impact (Cox, 2008).

Table 2: A 5×5 risk matrix

		Probability of occurrence				
		Highly Likely	Likely	Unlikely	Highly Unlikely	Extremely Unlikely but yet possible
Severity	Catastrophi c					
	Significant					
	Moderate					
	Minor					
	Limited					

Source: (EC, 2010)

Determining the probability of occurrence of a hazard is a key step in a risk assessment. The probability of occurrence for a known hazard will normally have been determined during the risk analysis phase. A qualitative or quantitative (depending on available data) scale should be used. The qualitative and quantitative scales illustrated on Table 3 will be used to provide a relative likelihood of the occurrence of a hazard.

Table 3: 5-class probability scale

Probability class	Quantitative	Qualitative
A	More than 10^{-2}/year	Highly likely
B	10^{-2}-10^{-3}/year	Likely
C	10^{-3}-10^{-4}/year	Unlikely
D	10^{-4}-10^{-5}/year	Highly unlikely
E	Less than 10^{-5}/year	Extremely unlikely but yet possible

A hazard's severity of impact on a given community also needs to be determined if the risk from the hazard to that community is to be estimated. The severity of the impact of a hazard is actually a function of the intensity of the hazard and the community's vulnerability to that hazard. It is therefore determined by analyzing the hazard's own characteristics (e.g. location, boundaries, magnitude, intensity etc.), which have been determined during the risk identification and analysis phases. The result of the combined analysis of hazards and vulnerabilities is the estimation of potential losses. A deterministic approach is used to estimate losses from the occurrence of a hazard.

The estimated losses can be directly used as an indication of the hazard's severity of impact in a risk assessment. Severity ratings need to be consistent for all hazards; otherwise the purpose of performing a risk assessment is defeated. Table 4 illustrates the scale of severity ratings that will be used.

5.2 Determine the acceptable level of risk

In this step the acceptability of risks is determined based on the risk criteria adopted, risk standards and regulations, tipping points (e.g. technical, financial, spatial or societal/cultural acceptable limits) and uncertainty considered based on the precautionary principle. The choice of probability and severity scales reflects the level of acceptable risk in the nation. Research has shown that risk acceptability depends on psychological factors and has a strong social and political dimension (Slovic, 2000).

Table 4: 5-class severity scale

Severity	Characteristics
Catastrophic	• Multiple deaths • Complete shutdown of critical facilities for 30 days or more • More than 50 percent of property severely damaged
Significant	• Injuries and/or illnesses result in permanent disability • Complete shutdown of critical facilities for at least 2 weeks • More than 25 percent of property is severely damaged
Moderate	• Injuries and/or illnesses do not result in permanent disability • Complete shutdown of critical facilities for more than 1 week • More than 10 percent of property is severely damaged
Minor	• Injuries and/or illness treatable with first aid • Shutdown of critical facilities and services for 24 hours or less • Less than 10 percent of property severely damaged
Limited	• Less than "Minor" effects

Source: (adapted from FEMA, 2007)

Once the probability of occurrence and the severity of impact of a hazard are determined, a risk level can be defined. Generally, the higher the risk level, the higher priority must be given to the prevention measures aimed at that risk. In addition, risks with high probability of occurrence or high severity of impact should be given particular attention.

6 Risk mapping

Maps are useful tools that can be used to support risk assessment. They show information about hazards, vulnerabilities and risks in a particular area and thereby support the risk assessment process and overall risk management strategy. They can help set priorities for risk reduction strategies (EC, 2010). Maps are especially useful for hazards that can be spatially defined.

Risk mapping is being increasingly used with the advent of information technology and aerial photography for civilian purposes, both of which enable the development of Digital Terrain Models (DTMs) and Geographical Information Systems (GIS). A GIS is in essence a digital map (based on a digital terrain model), upon which additional layers are overlaid to describe specific types of information, such as demographic factors, the built environment, networks, topography, geophysical phenomena etc. (Alexander, 2002). In addition, maps can help assess the reliability, validity, spatial specificity, and relevance of the existing hazard data.

A base map will include the following descriptive categories of shapefiles or coverages:

- Built-up areas (by population size/census data)
- Roads and Bridges
- Transportation Grids
- Telecommunication Grid
- Sources of Energy
- Energy Facilities/Utilities and Power Grids
- Environmentally Regulated Facilities
- Forests/Vegetation
- Fire Service locations
- Special Areas of Conservation (SACs) NATURA 2000
- Special Protected Areas (SPAs)
- Watersheds/Dams/Water Utilities
- Land cover/use
- Town Planning Zones
- National Cadastral maps
- Soils
- Digital Elevation Models (DEMs)
- Topography

Based on this base map, three types of maps are developed:

6.1 Hazard maps are used to represent critical characteristics of each hazard;

6.2 Vulnerability maps illustrate the spatial distribution of elements at risk, including but not limited to people (population density maps), property, critical infrastructure or the environment; and

6.3 Risk maps are a combination of the information included in hazard maps and vulnerability maps. They provide an estimation of the level of risk based on the combination of likelihood and impact of a certain event as well as for aggregated hazards (Alexander, 2002)

7 Develop Risk Reduction and Management Strategies

Risk Reduction and Management Strategies are developed based on the knowledge gained throughout the risk identification, analysis and evaluation processes:

- It is perhaps the most important part of the entire risk assessment endeavor.;
- It clarifies the objectives of the policy by determining precise and measurable statements of the intended results to be achieved at different levels; and
- It defines the course of action to be followed to achieve the results, as well as the indicators by which to measure those results.

The development of Risk Reduction and Management Strategies includes the following two steps:

7.1 Capability assessment

The capability assessment and the risk assessment form the "fact basis" of the Risk Reduction and Management Strategies. The capability analysis should outline the strengths and weaknesses of the institutional mechanism to deal with risk mitigation. The capability assessment will review existing prevention policies, as well as any problems associated with current policies; opportunities for and obstacles to new prevention initiatives; the level of present effort devoted to prevention; and intergovernmental coordination of programs (Brower & Bohl, 2000). Capability assessment is a two-step process: Exploring the existing policies, laws and actions that may affect vulnerability and investigating the capability of government departments and agencies.

7.2 Develop strategies

Risk Reduction and Management Strategies should not merely refer to the purposes of the risk assessment as a document (e.g. to fulfill EU requirements). Strategies should instead refer to the ultimate ends of risk reduction that the nation is trying to achieve. Risk Reduction and Management Strategies should be broad in scope and far-reaching in application, and they should be structured as positive statements that are attainable rather than negative observations about the community. Strategies should be cross-cutting in areas of public interest in addition to disaster prevention. For instance, strategies can support such principles as improving water quality, preserving natural areas, and creating open space (Schwab et al., 2007).

The first step in a risk reduction and management strategy is to define its goals, i.e. the intended effect of the policy. A goal is defined as the long-term results that a policy seeks to achieve, which may be contributed to by factors outside the policy itself. Once defined, goals are broken down in objectives, which define the primary results that the policy seeks to achieve in order to accomplish a goal (IFRC, 2010). A goal may include one or more objectives. Although there is no limitation as to the number of objectives per goal, three or four are usually adequate, otherwise the project could become rather complex.

The difference between goals and objectives can be quite subtle. The goals explain the long-term reasons why the community chooses to undertake a prevention policy (e.g. "to ensure public safety"). The objectives, on the other hand, are more specific, measurable, and intermediate ends which are achievable and mark progress toward the goals (e.g. "reduce population in at-risk areas by fifty percent"). The goals and objectives should be articulated clearly at the start of the disaster prevention planning process to inform the selection of the proposed strategy which makes up the heart of the plan. Individual objectives will vary widely depending on a number of factors, such as the nature of the hazard threat, the level of local and regional resources, and the time frame for implementation of the plan (Brower & Bohl, 2000).

Finally, each objective may be broken down into disaster prevention measures or activities. Activities are the collection of tasks that produce the tangible products, goods and services and other immediate results that lead to the achievement of objectives (IFRC, 2010). One objective may have two or more measures/activities. Although there is no limitation as to the number of activities per objective, more than 7 activities per objective could make the policy too complex to realize in the field.

Malta Test Application

The aforementioned methodology, has been selected to be applied in the country of Maltese Island. The geographical coverage of the NRA includes Malta's territory, territorial waters and air space. However, the analysis was extended outside Maltese territory in some cases, as appropriate. For example, oil spill and marine pollution risk analysis required information about Malta's continental shelf, while the analysis of aviation accident risks will naturally extend throughout Malta's Flight Information Region (Camillieri, 2003 & 2006, Chetcuti, Buhagiar, Schembri and Ventura,, 1992) .

Malta's National Risk Assessment focuses on three types of risks:

- Contingency events with defined beginning and endpoints, such as floods, hurricanes, earthquakes, terrorist attacks;
- Chronic societal concerns, such as illegal immigration, and others not generally related to national disaster preparedness, including traffic accidents and money laundering;
- Loss or disruption of critical infrastructure.

The output of the risk identification phase is the identification of hazards and threats. A total of 33 hazards and threats (with 42 scenarios), and 3 horizontal issues have been identified in the Maltese National Risk Assessment.

Risk analysis involves an understanding of the risks in depth. For each of the 10 risks selected at the hazard and threat identification stage, the risk analysis process carried out a detailed estimation of the probability of its occurrence and the severity of the potential impacts. The end result of the risk analysis is the severity and probability of occurrence of the selected hazard and threat scenarios, which serve as input to the risk evaluation stage. The output of this phase was a detailed risk analysis and evaluation of Malta's top hazards and threats.

The goal of the assessment and mapping of critical infrastructures is to identify critical assets and systems that are essential for the maintenance of vital societal functions, health, safety, security, economic or social well-being of people, and the disruption or loss thereof would have a significant impact in Malta as a result of the failure to maintain those functions.

In addition, throughout the NRA exercise, more than 500 critical and other relevant infrastructure assets and systems have been identified. Based on the results of the assessment and mapping of critical infrastructure, two additional National Planning Scenarios were identified. At the same time a series of GIS-based systems and a GIS application have been developed to support the NRA exercise. Also, a separate Risk Reduction and Management Strategies Report has been prepared. It defines the course of action to be followed to achieve the results, as well as the indicators by which to measure those results. The following table (Table 5) briefly present these strategies that stem from the National Risk Assessment exercise:

Table 5: Risk Reduction and Management Strategies

Title of Strategy
Improve Knowledge and awareness about hazards, threats and risks
Mitigate hazards and threats
Protect Critical Infrastructure and Key Resources
Improve response and recovery capacity

Conclusion

Natural hazards can cause serious disruption to societies and their infrastructure networks. The impact of extreme hazard events is largely dependent on the resilience of societies and their networks. The Disaster Risk assessment methodology which is described above, performs a critical decision support role in maintenance decision making. Malta's test application was conducted as a comprehensive exercise aimed at identifying sources of risk and understanding of the risks and their consequences in depth.

Acknowledgments

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CHAPTER 19

A Contextual Analysis on the Socio-Spatial Relationships of Unauthorised Graffiti and Street Art

Steve Fenech

Introduction

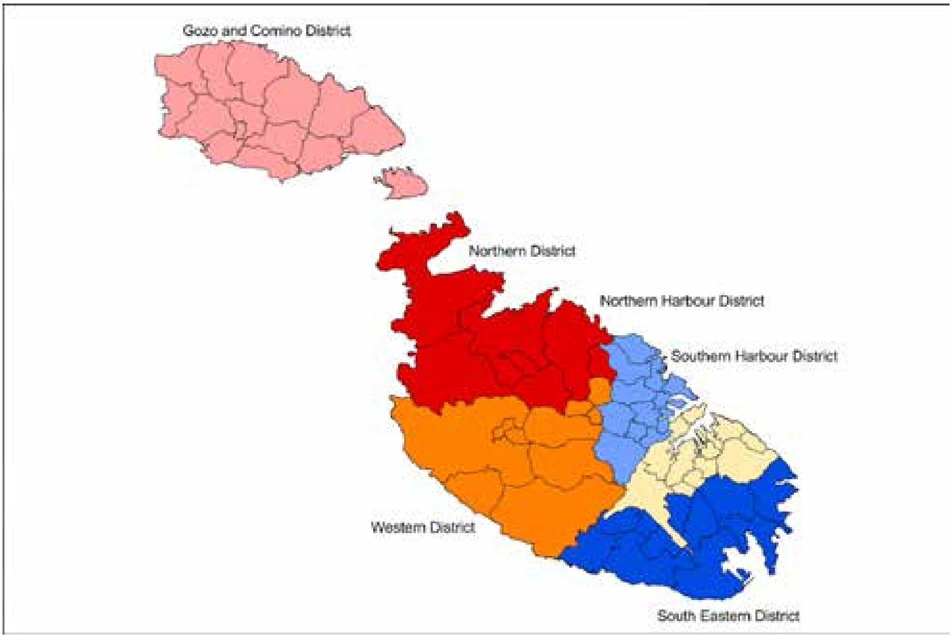
In today's day and age, it has become quite common to encounter some form of wall-writing that categorises itself as either graffiti or street art, becoming for many "an object of their travelling gaze" (Pennycook, 2010: p. 137). The phenomenon of graffiti and street art has throughout the years attracted a multitude of academics, stemming from different backgrounds, to systematically scrutinise its nature and the existing relationships it holds with other domains. Different perspectives exist on the topic, however one may notice that the phenomena are often renowned for their illicit nature. Halsey & Young (2006) posed the fact that the phenomena have been mentioned in many writings for their subculture, delinquent nature, and historically, as a regulatory problem.

The following research investigates the phenomena that was carried out illicitly in certain localities within the Northern Harbour District, in Malta (Figure 1). Due to the phenomena's inexhaustible nature, the study focused on forms of art carried out using only two particular mediums which were spray-aerosol paints and inks, on immobile platforms. The aim of this article, and the study behind it, is threefold. Firstly, the study served as a window of opportunity to create the first data set that unravelled the incidence of unauthorised graffiti and street art on a local context. Secondly it helped unravel the social, spatial and other relationships related to the phenomena. Finally, it aimed to better scrutinise the topic, understand its intricate nature, and point out the criminological aspects that are relevant to the subject matter.

The Phenomena

Although graffiti and street art are not the same, authors such as Hughes (2009) pointed out that these phenomena share a lot in common, and as concepts they have many overlapping properties such as the medium used or the fact that they are mostly associated with public forms of art. Furthermore, many seem to debate on the nature of the phenomena as either being art or vandalism. The derivation for such conclusion has been questioned and under discussion by many (Abel & Buckley, 1977; Bandaranaike, 2003; Ferrell, 1993; 1995; Hagen et al., 1999; Raymond, 1989), however, it should be made clear that an object, or an act, can bear coexisting properties, being both artistic and criminal. This statement has been supported in previous literature by authors such as Barbaro, Chayes & D'Orsonga (2013), Bou, (2005), Halsey & Young (2006), Marter (2011) and Thompson et al. (2012) who acknowledged the phenomena's criminal nature and artistic properties.

Figure 1: The six districts on a NUTS 4 level



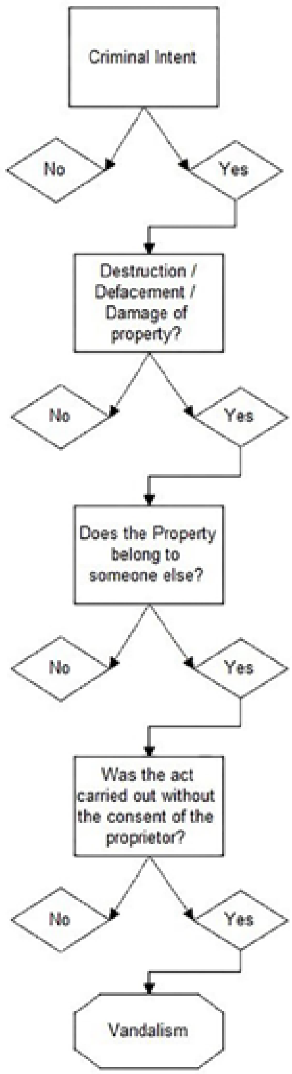
Source: (MEPA)

The author identifies that although art is subjective, according to the views pertaining to the individual, the criminal factor that coexists is objective, and thus is always present when the act goes against the rule of law. For this particular reason, the subjective concepts of graffiti and street art were defined, as well as the more objective concept of vandalism, to understand more the relevant themes prior to further discussion. Starting with the most objective concept of the three, based on different laws stemming from different countries, vandalism can be defined as:

The intentional and wilful destruction, defacement or damage, to any private or public property without the proprietor's consent to carry out such an act.

Cohen (1972) also added that vandalism can be put in different categories based on the cause of why the act was committed. However, no matter the reason behind the act, based on the author's definition which was formulated on existing laws, all types of vandalism comprise of four properties as shown in Figure 2.

Figure 2: The four elements that make a vandal act



Graffiti is not just an Italian import, but is also a derivate of Latin and Greek (Clarkson, 2014; Marter, 2011; Miller, 2005; Pereira, 2005). It has been documented to exist for thousands of years (Bates, 2014; Bingham, 2010) being a phenomenon that had many purposes and evolved throughout the years from simple scribbles to more distinctive themes (Rogers, 2009). Graffiti, although usually associated with hip-hop graffiti, is a concept that holds many different sub-categories and ranges from simple wall etchings to elaborate murals. Needless to say, as a concept, it has always been subject to interpretation and different authors such as Alonso (1998), Marter (2011), and Weisel (2004) have categorised the phenomena differently making it hard to establish an objective understanding within the scientific community.

Waclawek (2011) mentioned how graffiti is unique in three particular ways. Primarily the graffiti subculture is sustained by the young and predominantly by males (Macdonald, 2001; Waclawek, 2011) who practice this illicit pictorial tradition that kept developing through the years (Waclawek, 2011). Secondly, the graffiti art movement has flourished in other artistic movements such as post-graffiti art practices. Lastly, graffiti and street art "… take their place within the matrix of visual culture" (Waclawek, 2011: p. 12).

Therefore, based on the work of previous authors such as Bingham (2010) and Marter (2011), graffiti can be defined as:

The name given to the wall writings and designs on walls and surfaces (whether they are scribbled, scratched or sprayed), on public and private property which are most of the time done without consent.

Much like graffiti, street art "takes much of its meaning from its location in public space, on private property" (Young, 2014: p. 3) and most of it tends to be delinquent (Bou, 2005). Although it seems like a subset of graffiti as many of its properties are derived from this form of art, street art has elements that are not present in graffiti making it a concept of its own (Bates, 2014). Street art's application is wider than graffiti and can adopt techniques of all sorts ranging from the traditional use of paint to more modern techniques such as the use of digital graphic designs, departing the artist from the transient and illegal aspect of graffiti (Bou, 2010). Street art can be both legal and illegal, yet it seems that within the street art culture, more credit is given to the art which is done without permission, and the artists who do take this path are considered to be more authentic (Young, 2014).

Based on works of authors such as Waclawek (2011) and Bou (2005), street art was defined as:

An art movement which is a derivative of graffiti with a broader spectrum of motives incorporating "all artistic incursions into the urban landscape" (Bou, 2005: p. 6).

Existing Research

As already mentioned, the phenomena have already been scrutinised elsewhere in order to unravel the relationship it shares with other variables. Starting off with the overall area, McDonough (1992: p. 325) stated that there is some form of statistical consistency with the "inverse relationships of disorder with neighbourhood solidarity, satisfaction with and attachment to the residential area, and the positive association between disorder and crime". However, it was added that the overall geographical size does not really infer the overall number of crimes or vandalism, thus the two variables do not share a relationship. This statement was contradicted to a certain extent by Voncannon (2000) who noticed that the bigger the area, the more one would expect for a population to increase resulting in more crimes. Voncannon's claims on populations were seconded by Teng et al. (2012) who found out that in Utah, District 2 of Florida, and Arizona the amount of expenditure on graffiti control was increasing.

This was proportionate to the increase in population both States were experiencing. Anderson (2014) also agreed with the affects population has on vandalism rates, but contrary to what previous authors have said, Anderson stated that the existing relationship is inverse, meaning that with an increase in population there would be a lower incidence of vandalism. With regards to age, ample research supports the claim that acts of vandalism are associated with the younger aged cohorts. As already mentioned, these forms of art are sustained by the young (Macdonald, 2001; Waclawek, 2011). Snyder (2009) said that as one gets older, people tend to moderate their behaviour. A recent study by Megler et al. (2014) showed that graffiti is created in areas with a high density of young males and the phenomenon correlates with areas where young males live or hang out in. Halpern (2014) also posited the fact that the incidence of vandalism is closely related to child densities.

On a different front, McVie (n.d.) presented her statistics showing how in Scotland property vandalism takes place mostly in remote rural areas, whilst also showing that the percentage of crimes reported to the police, with regards to property vandalism, happen more often in rural zones than in urban areas. This was further supported by Anderson (2014) who claimed that vandalism occurs in areas which are sparsely populated. However, according to Ceccato et al. (2002) most acts of vandalism and violence occur in public entertainment areas; a claim similar to Megler et al.'s (2014) who stated that commercial zones have a higher rate of graffiti reports and are considered as a migratory push factor from the inner cities in the UK (Bowen & Pallister, 2006). Also, statistics from Higgins et al. (2010) have shown the total opposite of what McVie (n.d.) stated, reporting that in England and Wales, 7.2% of urban areas were victimised by vandalism whilst 4.7% were targeted in rural areas.

The last themes that are going to be mentioned in relation to the phenomena are poverty and crime rates. Adisusanto et al. (2009) mentioned the existence of a correlation between graffiti incidents and unemployment rates, as well as income levels. However, not all authors seem to agree. Megler et al. (2014) said that there is no relationship between income and graffiti, but also added that high income areas are more likely to have a lower density of graffiti and also a low tolerance towards it. The States of Guernsey Scrutiny Committee (2009) said that poverty and vandalism may not have a direct link, but poverty is surely a factor of social exclusion which can provoke vandalism. As with regards to crime, Snyder (2009: p. 52) stated that the "relationship between vandalism and violent crime is not nearly as casual as we are made to believe", whilst Wilson & Healy (1987) and Thompson et al. (2012) discussed that there is no existing relationship, based on statistics, that shows a link between violent crimes and graffiti. This being said, there still exist claims stating that graffiti bring forth the degradation of the social status, diminishes property value and triggers other forms of crime in the community (Teng et al., 2012).

For most of the variables listed above, little can be said about their relationship with graffiti and street art, as data which focuses on such specific queries may not be readily accessible. Therefore, during particular instances, surrogate themes were used. For example, the data provided by Formosa (2007) pertaining to the mapping of all reported crime categories did include graffiti under damages, however due to the police information reporting system (P.I.R.S) data structure, the graffiti-related reports couldn't be extracted for direct comparisons.

Methodology

The Methodology carried out was of a quantitative nature, aiming to visualise the incidence of the phenomena and to seek for any social, spatial and other relationships that currently exist. Prior to any field work, the study zone was outlined. It constituted of 7 localities within the Northern Harbour Region on a NUTS 4 level (Figure 3). According to Formosa (2007), NUTS 4 refers to the apportionment across the Maltese islands into six districts. He also added that "no real administrative powers exist at this level" (Formosa, 2007: p. 146). The localities were; Pembroke, St. Julians, Msida, San Ġwann, Ta' Xbiex, Pieta and Gżira.

The process required for data to be gathered manually throughout the rural and urban areas of each locality using a handheld GIS device, to spatially map down the target points on a digital base map. Once the data was captured, the points were transferred as a whole unified layer. The points gathered from the field were presented as a vector data set which is the translation of physical elements using basic units of spatial information in point, line or polygon features; to display, manipulate and analyse the data at hand (Santos, 2013). Using only points, the data was presented on a planar (WGS84 and UTM ED 50) projection. In order to find any underlying relationships, the gathered data layer was analysed. A cross thematic analysis was carried out with other data sets provided by Formosa (2007; 2015) which included layers representing:

- Enumeration areas (EAS)
- Population within EAS
- Age group cohorts within EAS
- Crime and damage related data within the EAS
- EAS Land Use cover
- NNH1 Poverty Layer

Figure 3: The Northern Harbour Region

The process of visualising the data points consisted of the following steps:

- The Shape file (shp) was converted to MapInfo tab format to run queries on 'Mind Mapper' and 'Map info' after data points where extracted using 'Arc ESRI Map 10.1'. Data was exported and saved as a database file from the input layer points attribute table to be accessible on Microsoft Excel.
- The file was uploaded into MapInfo. Input points had different data attributed to them including object ID, surveyor, locality, different categories, date, and medium used.
- A base layer was added to the input points to give context to the gathered data.
- The layers were edited showing the study zone in different formats as shown in Figure 4, and the study zone was divided in its seven localities visualising each area using the input data layer on top of a polygon base map.
- SQL was used to transfer different data sets from GIS software to Microsoft Excel. The cross comparative analysis between the chosen variables and the data points gathered was worked out to find out the:

    1. Input points per total area
    2. Input points per capita
    3. Input points per age group cohort within an area
    4. Land use query (Input points in urban and rural environments)
    5. EAS offence query (Input points per offence and input points per damage related offence)
    6. Nearest Neighbour Hierarchical (NNH) Poverty Clustering Query

vi) The tables presented later on in the findings will amongst others contain three particular fields entitled estimated zone rate, observed rate and rate. Estimated zone rate consists of the total count of the phenomena divided by the total count of the variable being scrutinised, such as the total area of all locations or the total population. The observed rate includes the count of the phenomena divided by the total sum of the variable within a particular locality or belonging to a particular age group cohort. Finally, the rate is the result of the observed rate divided by the estimated zone rate.

These queries were carried out using the EAS data set, which in this case consisted of the study zone divided into 132 EAS each representing 130 dwellings as shown in Figure 5.

Figure 4: Different representations of the study zone

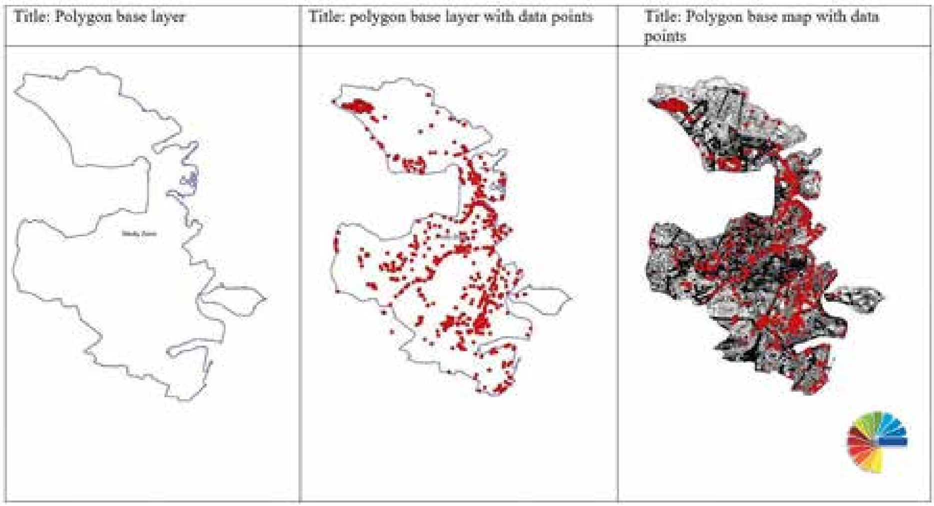


Figure 5: 132 EAS each holding 130 dwellings

Source: Formosa, 2007

Discussing the Research Findings

Incidence of crime and spatial hotspots

The following will overview the results on a local context, visualise the outcome and compare research findings to existing data. Queries were carried out using GIS related software, Microsoft Excel and Structured Query Language (SQL) which is "the language for generating, manipulating and retrieving data from a relational database" (Beaulieu, 2005: p. ix). The crème de la crème of all queries was the generation of the hotspots within the study zone. This particular research generated density maps of input points within 10m, 50m and 100m proximity of each other. All outputs yielded the same results. Using Figure 6, which is a 3D illustration of points with 100m proximity, it can be argued that the only existent hotspots within the study zone where in Pembroke and Msida. Pembroke peaked much higher due to the high number of dilapidated buildings within its rural zone, away from the urban areas.

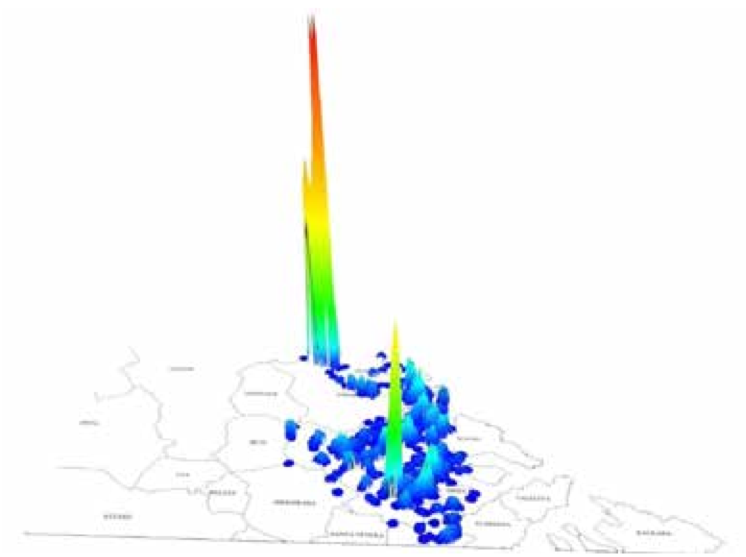
This reinforces the broken window theory that views crime with relation to the surrounding environment. The premise of this theory states that social or physical disorders lead to a reduction in social control which in turn adds the probability for crime to flourish (Greene, 2007; Eck, 2010). To even further hit the nail on its head, Eck (2010) mentioned how 'vandalism or graffiti' attribute as physical disorders leading to this chain reaction. Greene (2007) stated that this metaphor implies that if one window goes unrepaired, then it is taken as an invitation for the breaking of more windows. The same thing happens with community standards; as soon as they start to break, the community becomes ever more vulnerable to crime. Furthermore, Formosa (2007) mentioned a study conducted by Sherman et al. (1989) where the 'places cause crime' statement was posited as a possible explanation towards the origination of crime itself.

The second hotspot was found in Msida's skatepark. This area contains legal murals which were consented by the authorities, however the author took into account all the scribbles, tags and others forms of illicit art that were conducted without authorisation. For this occurrence, as well as for the previous hotspot, one can adopt the crime pattern theory. Although crime's geographical placing seems to be disorderly, there is some rationality behind its occurrence in both space and time (Rossmo, 1999). According to Rossmo (1999), this theory states that whilst the victim may be chosen randomly, the place in where the criminal act is about to be committed is not, and thus the process is spatially structured. Rengert & Wasilchick (1985 as cited in Greene, 2007) and Brantingham & Brantingham (1981) also posited the fact that the place evinces certain cues which trigger specific responses from offenders.

The offender's choice of a target depends on the particular travel path and awareness/ activity spaces in which the cues are located (Greene, 2007). Brantingham & Brantingham (1991 as cited in Greene, 2007) and Chainey & Ratcliffe (2005) mentioned that between travels from home to work to recreational areas (nodes of activity), offenders tend to develop their awareness space which is the area they are most likely to target their victims. Brantingham & Brantingham (1993: p. 259) remarked that "each criminal event is an opportune cross product of law, offender motivation, and target characteristics arrayed on an environmental backcloth at a particular point in space-time". Therefore, by applying Santos' (2013) shortened explanation, one might say that criminal activities are likely to occur if there is an overlap between the activity space of potential offenders and the activity space of potential victims (in this case being the areas that are about to be vandalised). It is also worth mentioning that this theory incorporated elements of the routine activity theory (RAT). In a nutshell, the theory implies that crimes occur when certain elements are accessible in both space and time (Chainey & Ratcliffe, 2005; Lersch & Hart, 2011; Santos, 2013). The elements applied within the context of this study include:

- motivated offenders (the artists and writers);
- suitable targets (the platform the offender chooses to work on); and
- the lack of capable guardians (lack of police patrols, no surveillance cameras in the vicinity or even the lack of a neighbourhood watch).

Figure 6: Hotspot 3D representation (100m proximity)



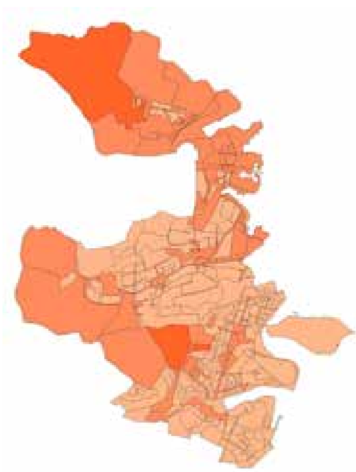
Input points per area

The findings show that there is a relationship between the area and the phenomena. Out of seven localities only San Ġwann did not follow suit, having the largest surface area but placed fourth when comparing input counts. Only Pembroke and St. Julians were above zone rate, meaning they were above the average count per km sq. (Table 1). Figure 7 shows the degree of points per surface area across the EAS (the bright orange indicates a high number of points in relation to the theme it is being compared to). This might affirm Voncannon's (2000) views when he stated that criminal opportunity is more present when the area gets bigger and might suggest that area and criminal opportunity may share a relationship. However, this query only proved that within the context of the study zone, the relationship between the phenomena and the surface area, of a locality, exists.

Table 1. Input points per km sq. - Rate Comparison Query (Zone Rate = 1.0)

Locality	*Estimated Zone Rate*	*Observed*	*Rate*	*Zone rate*
Pembroke	142	250.44	1.8	Above
St. Julians	142	168.37	1.2	Above
Msida	142	138.77	1.0	Zone rate
Gżira	142	115.14	0.8	Below
Pieta	142	86.30	0.6	Below
San Ġwann	142	65.68	0.5	Below
Ta' Xbiex	142	30.81	0.2	Below

Figure 7: Input points per area (EAS)



Input points per capita

This query had to be carried out twice after finding out that Pembroke was an outlier when scoring much higher than the zone rate. Having discarded Pembroke and worked out the rate again using only the remaining six localities, the findings revealed that with an increase in population there would also be an increase in unauthorised graffiti and street art; however, for the second time San Ġwann placed fourth out of six localities even if it had the largest population count. Only St. Julians and Msida were above the zone rate (Figure 8 - Table 2). This finding not only strengthens Voncannon's (2000) views but also complies with the study carried out by Teng et al. (2012), where they noticed the proportionate relationship shared between an increase in graffiti and population. Therefore, the findings show the existence of a relationship between population and the studied phenomena.

Figure 8: EAS population (Left), EAS input points per capita (Right)

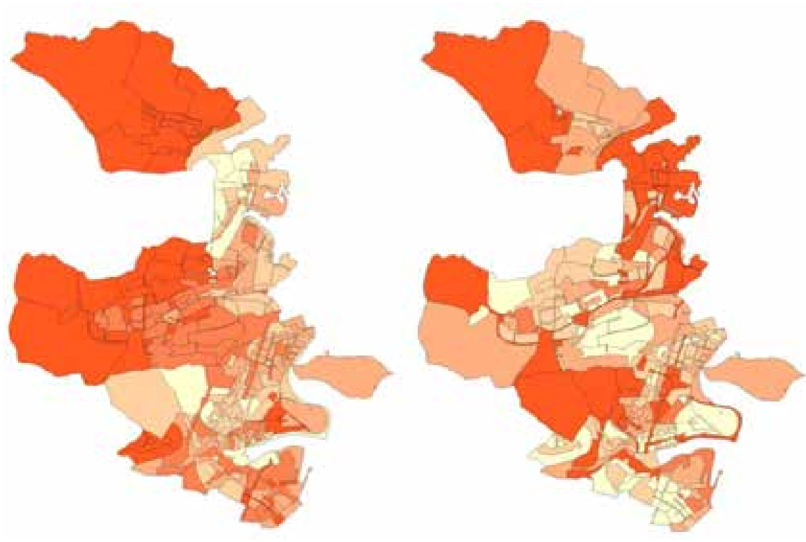


Table 2. Input points per capita excluding Pembroke

Locality	*Estimated Zone Rate*	*Observed*	*Rate*	*Zone rate*
St. Julians	0.02	0.03	1.46	Above
Msida	0.02	0.03	1.46	Above
Gżira	0.02	0.02	0.97	Below
San Ġwann	0.02	0.01	0.49	Below
Pieta	0.02	0.01	0.49	Below
Ta' Xbiex	0.02	0.01	0.49	Below

Input points per age group cohort

When working out the mean percentage of input points of different age group cohorts, there seemed to be a pattern between the age group cohort variable and the studied phenomena, showing an increase in the mean input count as the group cohort aged. This result suggests that such figures may be shadowed by the fact that the country is facing an ageing population (Agius Decelis, 2013; Dalli, 2014; Formosa; 2014a; 2014b). Despite it all, when working out the rate of input points per capita of different age group cohorts residing in these areas, the query established that there is a pattern (Table 3). The highest rate belonged to the 15-25 age group cohort followed by the 0-14 age group cohort, thus proving that graffiti can be related to young age. This shed light on the literature found and the studies carried out by certain researchers, suggesting that these forms of art are predominantly sustained by the young (Macdonald, 2001; Waclawek, 2011).

On a final note, this result does indeed comply with what Megler et al. (2014) stated when they found that graffiti correlates with areas in which the young live or hang out in. It also supports Halpern's (2014) findings, who added that the incidence of vandalism is closely related to child densities. Therefore, young age and the studied phenomena were shown to bear a relationship in this study.

Table 3. Input points per age group cohort - Rate Comparison Query (Cohort Rate = 1.0)

Age Groups	*Estimated Zone Rate*	*Observed*	*Rate*	*Cohort rate*
15-24	0.03	0.04	1.24	Above
0-14	0.03	0.03	1.05	Above
46-64	0.03	0.03	1.04	Above
25-44	0.03	0.03	0.95	Below
65+	0.02	0.02	0.77	Below

Land use query

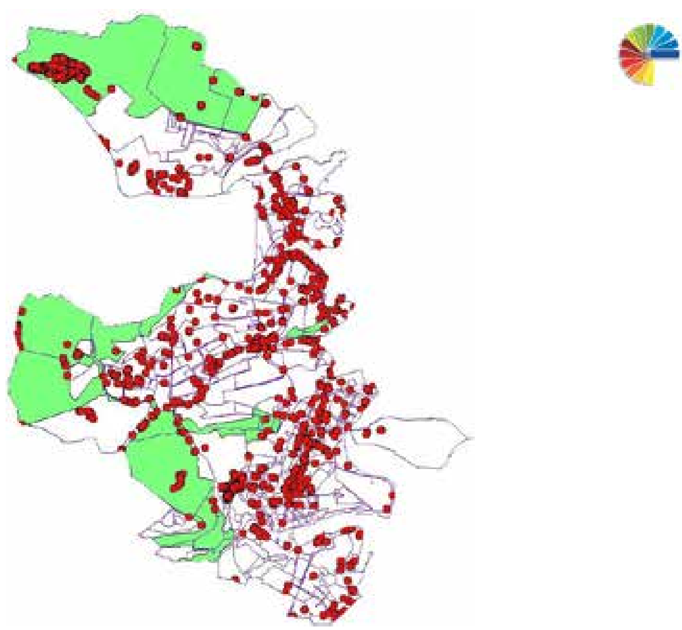
The following map (Figure 9) shows the land use characteristics of the EAS and the spatial whereabouts of the input points to give a visual idea of their occurrences. The EAS with a green shade signify a rural land cover, whilst EAS with a white shade signify an urban land cover. Findings have evidently shown that there is no relationship between land use cover and unauthorised street art and graffiti within the study zone as indicated in Table 4. When working out the rate of input points per km sq. in rural and urban environments, the results were almost identical.

These findings do not harmonise with what McVie (n.d.) stated, saying that vandalism in general is higher in remote rural areas rather than in urban zones and in areas which are sparsely populated (Anderson, 2014). These findings also do not concur with the English and Welsh context, where urban areas were found out to be more vandalised than rural areas (Higgins et al., 2010). This shows that there is no relationship between the input points and land use cover. However, it would be ideal for future research to be carried out and see whether this lack of relationship persists throughout the years, especially when one takes into consideration the amount of work and investment currently being made in Pembroke's rural area.

Table 4: Table showing the percentage of the input points within the land use coverage and the total percentage of the areas (both rural and urban zones)

Land Use	*Counts*	*Percentage %*	*Area*	*Percentage %*
Rural	411	29	2.976	30
Urban	1007	71	6.962	70
Total	1418	100	9.938	100

Figure 9: EAS input points in urban and rural zones



Nearest Neighbour Hierarchical (NNH) Poverty Clustering Query

NNH is an aggregation method where points that are close to each other are analysed for their relationship in terms of the space they occur in, thus rendering a hotspot where high concentrations of incidents are present (Formosa, 2007). The NNH clustering technique involves the aggregation of incidents into groups by a series of merging steps on the basis of their geographical proximity. This would imply that the first order clusters would contain the individual input points within its ellipsoids, whilst second order clusters would include within its ellipsoids the first order clusters which would then be treated as individual input points. This follows the same pattern up the hierarchal clustering order (Clarke et al., 2009; Formosa, 2007; Hirschfield, 2011; Hizir, 2003).

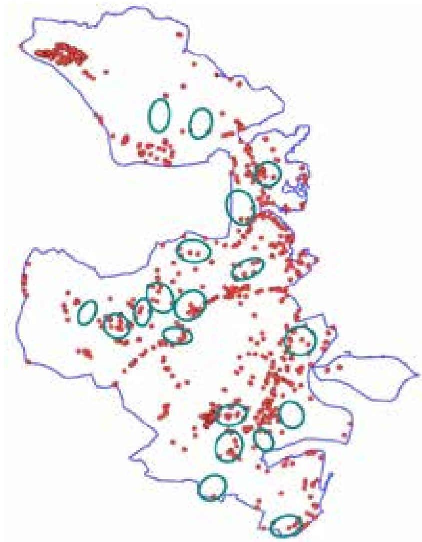
Figures show that San Ġwann has the highest input count within its NNH1 poverty clusters followed by Msida and St. Julians, however the percentages in Table 5 indicate that there is no relationship between poverty areas and the studied phenomena. This query did not find any relationship between the total counts within the NNH1 poverty ellipsoids, taken from Formosa (2007), and the total count of graffiti in each locality. The highest percentage of NNH1 counts against total count was in San Ġwann scoring 32.18%. However, the other localities scored low not exceeding 15.25 %.

The findings do necessarily posit the fact that such a relationship is lacking in certain areas on the Maltese islands or around the world, but objectively shows the absence of a relationship between the variable of poverty and the phenomena within the context of the study zone. McDonough (1992) said that there is an association between poverty and disorder which did comply with Adisusanto et al.'s (2009) statement, who found a correlation between graffiti incidents and the rate of unemployment. Yet again, the findings are more in favour with Megler's et al.'s (2014) assertion that there is no relationship between graffiti and income levels.

Table 5. Percentage of NNH1 counts against total counts

Locality	*Counts*	*Counts within (NNH1) poverty ellipsoids*	*% of NNH1 counts against total counts*
Pembroke	577	1	0.17
San Ġwann	174	56	32.18
Msida	236	36	15.25
St. Julians	277	39	14.08
Gżira	112	14	12.50
Pieta	39	4	10.26
Ta' Xbiex	9	0	0.00

Figure 10: EAS input points in urban and rural zones



EAS offence query

Queries were carried out to find any relationships within the study zone between input points and offences in general and input points and damage related offences. In both queries, Pembroke was accounted as an outlier thus it had to be withheld from such queries. The reason behind it was that Pembroke had the lowest total offence count and the second lowest damage related offence count, while having the highest count of input points. When the queries were carried out, no relationships were found between the rate of input points per offence and input points per damage related offence as shown in Table 6 and 7 respectively. For instance, St. Julians had the highest number of total offence counts, damage related offences and input counts of the phenomena, however it was below the zone rate and ranked low when compared to other localities.

If there was a relationship in input points per offence and input points per damage related offence, the following order would have been expected: [1] St. Julians, [2] Msida, [3] Gżira, [4] San Ġwann, [5] Pieta' and [6] Ta' Xbiex. Although some localities followed the pattern, it was not enough to establish a relationship between the phenomena and the variables. Also this research conducted interviews with some artists, who practice graffiti and street art, and uncovered that the act is usually carried out for aesthetic, political, cultural and other various reasons that are not related to the direct commission or presence of crime. This result affirms Snyder's (2009: p. 52) statement that the "relationship between vandalism and violent crime is not nearly as casual as we are made to believe". Wilson & Healy (1987) also mentioned that the relationship between violent crime and graffiti isn't statistically significant. The idea that graffiti triggers crime, as mentioned by Teng et al.

(2012), was not the case in this scenario using the quantitative findings from this research as scientific proof. Pembroke's high rate could have been the result of the dark figure of crime and the crime report paradox. Fenech (2015) posited the possibility of the crime report paradox, a theoretical notion that underlies the subjective nature of reporting. He implied the possibility of having a scenario where a single report may cover one act or a multitude of acts.

This type of subjective reporting may cause inefficiencies in the data gathered by the police force when analysing a particular type of crime. There is also the existence of the dark figure of crime, a renowned theory that explains how certain crimes may go unreported or unrecorded as stated by certain authors such as Formosa (2007), Rosenfield (2006) and Wilson (2009). Reports on damage related offences, and therefore on total offences, could have also been shadowed by the fact that reports can be inaccurate due to "differential acceptability of graffiti by location" (Megler et al., 2014). In brief, the findings substantiate what Wilson & Healy (1987) stated; the artists and writers are not after the person, but they are after property for self-expression.

Table 6. Input points per offence excluding Pembroke - Rate Comparison Query (Zone Rate = 1.0)

Locality	*Estimated Zone Rate*	*Observed*	*Rate*	*Zone rate*
San Ġwann	0.01	0.03	2.71	Above
Msida	0.01	0.03	2.04	Above
Gżira	0.01	0.02	1.21	Above
Pieta	0.01	0.01	0.65	Below
St. Julians	0.01	0.01	0.57	Below
Ta' Xbiex	0.01	0.00	0.39	Below

Table 7. Input points per damage related offence excluding Pembroke - Rate Comparison Query (Zone Rate = 1.0)

Locality	*Estimated Zone Rate*	*Observed*	*Rate*	*Zone Rate*
San Ġwann	0.09	0.16	1.82	Above
Msida	0.09	0.13	1.53	Above
Gżira	0.09	0.09	1.05	Above
St. Julians	0.09	0.06	0.70	Below
Pieta	0.09	0.05	0.60	Below

Conclusion

The study was subject to many limitations such as human error during the process of data gathering, and lack of resources. Also, the direct links to the phenomena studied can never be objectively scrutinised beyond reasonable doubt if data sets are shadowed and incomplete due to the dark figure of crime and subjective crime reporting. The fact that the phenomena is subject to opportunity, over space and time, also makes it very hard to study and control at the same time. However, this should not hinder research and therefore assumptions should be taken in order to grasp the spatial aspect of graffiti and street art in order to better understand its incidence and find out any relationships which might trigger its existence. This research serves as window of opportunity for many stakeholders, such as policy makers, who can provide more legal opportunities for the artists to express themselves. It may also instigate further research on other aspects of the phenomena, and may as well assist other disciplines or authors who wish to understand the subject, especially within the local context.

On a final note, it may also provide a window of opportunity to those who wish to establish a universal definition or create an ontology that shows the relationship that exist between the sub-concepts of graffiti and street art.

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CHAPTER 20

Urban Ecology and the effects of Migration in Marsa

Clayton Xuereb

Introduction

The topic of migration has always generated opposing views. Discussions on online social networks are characterised by hatred, xenophobic and labelling observations while others promote cultural diversity and integration. In the last ten years, Malta had to deal with the influx of several migrants. This is possibly the result of a considerable amount of people living in African countries experiencing uncertainty, high crime, poverty and unemployment rates and who are seeking a better future (LeMay, 2007). Studies have shown that migration is partly responsible for poverty and other economic and social deficiencies, although this hypothesis has not always been confirmed (Tienda & Liang, 1994). Several countries are re-assessing their social and economic policies to combat economic pressure, crime and other problems which are possibly being exacerbated by such a phenomenon (Parsons & Smeeding, 2006).

This continuous debate about the effects of migration inspired the researcher to identify related issues requiring further research. The idea behind this study emerged from a combination of the researcher's competencies and background. Having read for a Bachelor degree in Criminology, together with over three years of experience in the migration sector motivated the researcher to study a topic that embraced both subjects. The researcher has been residing in the southern part of Malta for all of his life. Marsa lies on the main route that connects the southern to the northern part of Malta and during frequent stops on the way to work, due to the daily traffic congestion the researcher observed the dynamic activities in Marsa to be different to those of other towns.

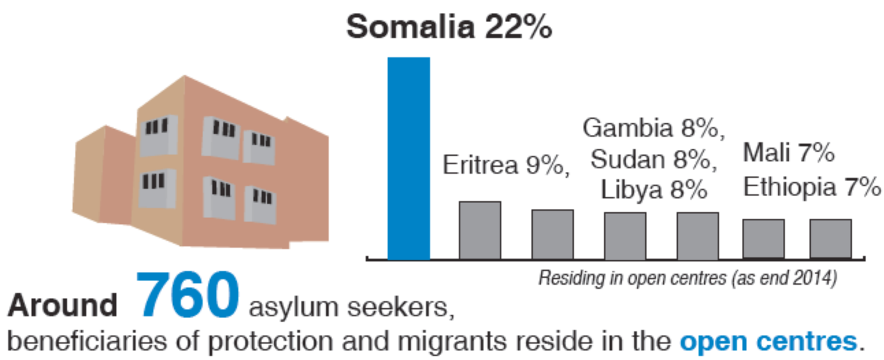
Space was observed to be utilised by locals as well as migrants, a possibly new scenario for this town. This led the researcher to review literature about both the domiciliation of migrants in Malta and the situation in Marsa.

Domiciliation of migrants in Malta

Malta applies the detention policy to migrants who enter the country without the permission of the migration authorities and who are apprehended before they lodge their application for asylum (Jesuit Refugee Services, 2010). Once they leave detention, migrants are given the opportunity of residing within a Refugee Camp (Agier, 2002), locally known as an Open Centre since their lack of resources makes it difficult for them to settle in alternative housing.

These centres were initially created to provide humanitarian protection and to supply basic needs to people escaping from civil war, inhuman or degrading treatment, or persecution (Cameron, 2010). These are administered by the Agency for the Welfare and Integration of Asylum Seekers (AWAS) and include the Hal Far tent village, the Hal Far Open Centre, Dar il-Liedna, Dar is-Sliem and Marsa Open Centre (Cassar, 2013). As can be seen in figure 1, more than 700 asylum seekers, mainly from Sub-Saharan African countries were residing in these centres by the end of 2014.

Figure 1: Open centres in Malta. Reprinted from UNHCR launches Malta Fact Sheet – Asylum Trends 2014



Source: (UNHCR Malta, 2015, Retrieved May 27, 2015, from http://www.unhcr.org.mt/component/content/article/35-slideshow-news/790-unhcr-launches-malta-fact-sheet-asylum-trends-2014-)

Moreover, the sites chosen induce suspicion of premeditated isolation as they were established to provide refuge during times of national emergency however, when this situation was over, no other solution was provided (Agier, 2002). Even though Census data did not specify and include the various nationalities of migrants who live in private houses, as can be seen in Figure 2, Cassar (2013) noted that after that they leave the Open Centres, migrants in Malta have opted to live in four different localities; Bugibba, Gzira, Msida and Marsa.

Figure 2: Malta: Popular settlement locations for migrants. Reprinted from Researching Migration and Asylum in Malta

Source: (A Guide (p. 44), by C. M. Cassar, 2013, Malta: PCFMalta)

Theorical issues

Marsa

The name Marsa means port. In fact, other towns in Malta such as Marsaxlokk, Marsamxett, Marsascala and Marsalforn in Gozo are all ports or part of one (Guillaumier, 2002). Marsa is an industrial area that is also a harbour to different types of boats (Azzopardi, Formosa, Scicluna & Willis, 2013) even though many areas are inhabited. This town can be found on the eastern side of Malta (Marsa Local Council, n.d.) as shown in Figure 3.1. The coal energy power station in Marsa used to contribute to the highly polluted air. In Marsa, there is also a primary school. The residents live in a typical Maltese village context, including houses, various maisonettes and apartments (Azzopardi, Formosa, Scicluna & Willis, 2013). Marsa also provides recreation for many Maltese through its sports facilities including the golf course, horse racing and the diverse athletic amenities located in this area.

Situation in Marsa

According to the NSO (2014), Census data for 2011 showed that the population in Marsa was that of 4,788 residents. Compared to Census data collected in the previous years, there is a clear picture showing that the population in Marsa is decreasing. The level of education in Marsa is low, and most residents are from a low working class background (Azzopardi, Formosa, Scicluna & Willis, 2013). Caruana (2007) argued that even though the level of education in Marsa had improved, many young people chose not to further their studies. She also noted that many inhabitants did not have jobs that required higher education. According to the 2011 Census data (NSO, 2014), Marsa also had the highest rate of illiteracy in the Maltese Islands with more than 700 people, constituting 16.3 per cent of all residents aged 10 years and over.

The family structures in Marsa are not always traditional since there are various single parents and dysfunctional families contributing to economic hardship. The unconventional family structure might create social disorder in Marsa (Azzopardi, Formosa, Scicluna & Willis, 2013). Caruana (2007) argued that this town was an "unattractive place and a secluded one" (p. 82) and sometimes it is even avoided by certain migrants who "preferred to avoid living in the Marsa region" (p. 82) as they want to steer away from the boat people (Zammit, 2012, p. 63). Caruana's (2007) aforementioned unflattering descriptive words relate to Marsa's "location, chaotic environment" (p. 82) and "mentality of people towards this town and its inhabitants" (p. 82).

Recently, Marsa has also suffered a major setback as the governments reduced its budget by 20,000 Euro and the council members by two due to the decrease in voting residents. According to the mayor, the government was not taking into consideration the residents of the Open Centre. The government's decision was based upon statistics that showed that the number of residents in Marsa was decreasing ("Mayor's anger over," 2015). He had earlier complained about this evolving situation in Marsa. He noted that migrants were often engaging in rowdy and unorthodox behaviour that included public urination (Pisani, 2009). International newspapers also reported that the recent influx in this town induced fear in the residents who are reluctant to allow their children to use public spaces (Colin & Squires, 2013).

The mayor attributed this as a consequence of the activities in the proximity of the Open Centre, which he indicated as being particularly susceptible to crime and was negatively affecting the residents (Pisani, 2009). Furthermore, the media's portrayal of migrants' behaviour has also fuelled gossip about Marsa's security situation, inducing the emerging concept of Social Disorganisation.

The residents also attributed urban decay in Marsa to the presence of migrants who they blame for the reduction in their properties' value and an increase in pollution (Colin & Squires, 2013). Mr. Debono also noted that certain zones in Marsa are desolate lacking police presence and that crime related areas ought to be secured through the installation of cameras (Pisani, 2009).

Marsa is now primarily associated with migration and it has been described by state officials as a no-go area and a Ghetto. The mayor spoke about the "invasion" of migrants who introduced "cultures and practices that are very different to our own" (Colin & Squires, 2013, para. 23). Mr. Debono also suggested that this was leading to segregation as he deemed that after the inception of the Open Centre, the Maltese were reluctant to visit this town (Pisani, 2009).

Social disorganization

Shaw and Mckay (1942) assumed human ecological concepts to study the relationship between juvenile delinquency and their urban surroundings, through which they developed the Social Disorganisation theory. This theory stands on three main pillars: Physical, Economical and Population statuses. Sampson and Raudenbush's (1999) definition of this term is that of "behaviour usually involving strangers and considered threatening, such as verbal harassment on the street, open solicitation for prostitution, public intoxication, and rowdy groups of young males in public" (pp. 603-604). Shaw and Mckay (1942) mapped the addresses of delinquents in Chicago and analysed them with census and spatial data. Through their research, they found that notwithstanding population turnover, high rates of crime were persistent in certain areas, independent from the resident ethnic group. Burgess' concentric zone model was then employed and they found that crime figures were higher in the transitional zone and gradually fading when moving outwards from the inner city centre to the suburbs.

This idea led them to retract the notion that crime could be explained through individual traits and they focused on spatial data in combination with the characteristics of social disorganisation and weak social control as "delinquency has its roots in the dynamic life of the community" (p. 435).

Urban decay

Burgess (1925) proposed that the suburbs were mainly inhabited by the affluent. This was confirmed later in the 1950's and 1960's, when cities in the United States changed their formats as a new process of "suburbanization" had started (Giddens & Sutton, 2009, p. 217). The growth rate of the suburban areas was five times as much as that of the inner city areas (Giddens & Sutton, 2009, p. 217) and it "involved the migration of populations" (Karp, Stone, & Yoels, 1991, p. 231). Most of the "whites" left since they did not want their children to integrate with other races, especially in school (Giddens & Sutton, 2009, p. 217). Boger and Wegner (1996) blamed the post-war policy makers, arguing that their decisions influenced the shifting of "housing, transportation, defense" (p. 85) to the outer layers of the city. Blackman (1995) added that inner cities can be "unfriendly" (p. 228) due to pollution that can either be noise or environmental and this affects "urban life" (p. 228) negatively. The most prominent centres for shopping and dining used to be located in the city centre, but these were relocated to the suburbs (Karp, Stone, & Yoels, 1991) and "green field sites" (Blackman, 1995, p. 228).

This shift led to "inner-city decay" (Kneese & Schultze, 1975, p. 7) also referred to as physical disorder through "deterioration of urban landscapes, for example, graffiti on buildings, abandoned cars, broken windows, and garbage in the streets" (Sampson & Raudenbush, 1999, pp. 603-604). Inner cities were inhabited by "an increased concentration of the most disadvantaged segments of the urban black population" (Sampson & Wilson, 1995, p. 42). Suburbs in the US were still predominantly inhabited by white people however, their numbers were decreasing since many people coming from ethnic minorities moved in (Giddens & Sutton, 2009, p. 217). In fact, Waldinger (1989, p. 225) confirmed that new migrants do not always opt to reside in "traditional, immigrant neighbourhoods" (p. 225). There were cases when they decided to settle in areas that were predominantly inhabited by "white, middle-class population" (p. 225).

Segregation

Massey (1990) explained that there is a correlation between racial segregation and high poverty levels. Massey performed various simulations using data obtained from various US cities. The results showed that a minor increase in poverty rates in racially segregated cities resulted in a "rise in the concentration of poverty" (p. 329). These increases in poverty are also related to other social problems such as urban deterioration, poor education and dependency on social benefits that, in turn, lead to higher crime rates.

Segregation through housing practises is called Racial Steering and this prevents racial diversity within neighbourhoods (Polikoff, 1986, p. 44). According to Hanson, Hawley and Taylor (2011), landlords are more likely to let their properties to white people than to African Americans. They use subtle discrimination by means of more positive language; they answer quickly and their emails are longer when answering queries by white people than those by blacks. This has also been confirmed at a local level through a qualitative research by Fsadni and Pisani (2012). Property owners in Malta have called migrants names and refused to rent out their properties when their clients were of African or Arabic origin. Others who managed to rent properties argued that they were forced to pay high deposits and utility bills without being shown the actual invoices.

Massey (1990) argued that during the 1970's, in the US, black poverty became more consistent and geographically concentrated in American cities. Some proposed that this was a consequence of the welfare system, industry, new family structures and the exit of the middle class from inner-city neighbourhoods. The researcher did not exclude these factors however, he contended that the key aspect for the creation of the underclass and the concentration of poverty in the 1970's was racial segregation.

Methodology

Aim of research

The aim of this research is to study the effects of migration on the urban ecology in Marsa. This was conducted by investigating the migrants' spatio-temporal dynamic activities. The study seeks to shed light on the real situation in Marsa as the media's depiction is not based upon any research, and it is purely judgemental and characterised by racist and stigmatising comments. The researcher, both through literature and firsthand knowledge acquired from residing close to this context, noted that there was a gap in the literature pertaining to the socio-spatial aspect of Marsa. Local literature on the Geo-spatial composition of migrant activity is non-existent. All the data collected was analysed and structured into urban, social and criminological perspectives. Three objectives are derived from this aim, and these are listed in the following part.

Objectives

- The first objective was to investigate the urban situation in Marsa through an environmental criminological and social approach. This was conducted to shed light on the effects of migrant activity and urban decay through the collection of GI data and elite interviews.
- The second objective was to study the level of disorganisation in Marsa. The aim was to understand whether migrants contribute to crime and disorder in this town by analysing the results of some key interviews, geo-referencing and by direct observation of migrant activities and interaction.
- The third objective was to verify whether migrants were being segregated. This step was considered essential to the study to verify whether the residents and official policy coerce migrants to occupy a certain space, through geo-referencing, observations and exclusive interviews.

Research Questions

The research questions were designed to investigate the effects of the migrants' dynamic activities upon the urban and social component of this town from social, spatial and temporal points of views. Criminological, sociological and urban concepts pertaining to the Chicago School were used to formulate these questions mainly based on the Broken Windows Theory, Social Disorganisation Theory, Opportunity Theory and other concepts related to racism, prejudice and segregation. Literature shows that these concepts may be intertwined, however, the following three separate research questions were formulated in an attempt to cover the whole socio-spatial temporal effects of migration in Marsa;

- Are there areas in Marsa characterised by urban decay?
- Are there areas in Marsa which are socially disorganised?
- Is there migrant segregation in Marsa?

Research design

In this study, time and space are central components so an approach that included both aspects pertaining to the dynamic daily activities of migrants in Marsa and their impact on its urban ecology was sought. The research questions in this study were countered through the adoption of a time geographic approach utilising multiple data collection methods; Geo-spatial data collection , Interviews and Observations that allowed data triangulation to minimise gaps produced by single methodological tools. "In practice, triangulation as a strategy provides a rich and complex picture of some social phenomenon being studied" (Mathison, 1988, as cited in Ely, Anzul, Friedman, Garner, & Steinmetz, 1991, p. 98).

Analysis and presentation of results

The multi-approach adopted within this study generated a considerable amount of information and data triangulation was possible. Data triangulation "gives a more detailed and balanced picture of the situation" (Altrichter, 2008, p. 147) and improves credibility and minimises "distortion in findings" (Viney & Nagy, 2012, p. 58). Two different techniques were used to analyse the elicited findings: Thematic and Spatial analysis. The elicited findings were presented in different forms, mainly by highlighting the hotspots and through choropleth maps based on the Chicago urban ecologist Burgess' (1925) concentric ring model.

Variables For Analysis

When conducting research in social science the researcher's goal is to find data in line with the laws of research in general. The results of such studies have to support or refute past theories (Questia, n.d.). The link between an independent and a dependent variable is referred to as the hypothesis. Forming a hypothesis is considered to be one of the most dynamic aspects of social science research. Typical hypotheses are created through the researcher's intuition who identifies a possible relationship between a dependent and an independent variable (Cross & Belli, 2004). The hypothesis and the methods used for the research are thus based on past theories.

- Hypothesis 1: Migration has affected the urban ecology in Marsa.
- Null Hypothesis: Migration did not affect the urban ecology in Marsa.

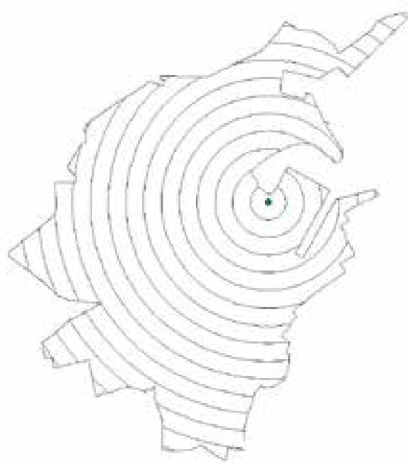
The results obtained from research can support or refute a hypothesis, but they will not prove it since hypotheses and theories are different in both their features and their purposes (Keeley, 2010).

Results

General Overview

In Marsa, the urban densities vary and concentrate around a limited number of streets. The Open Centre was the most important factor for the inception of migration in Marsa and it was situated in the loop of Burgess' (1925) concentric ring model as can be seen in Figure 3.

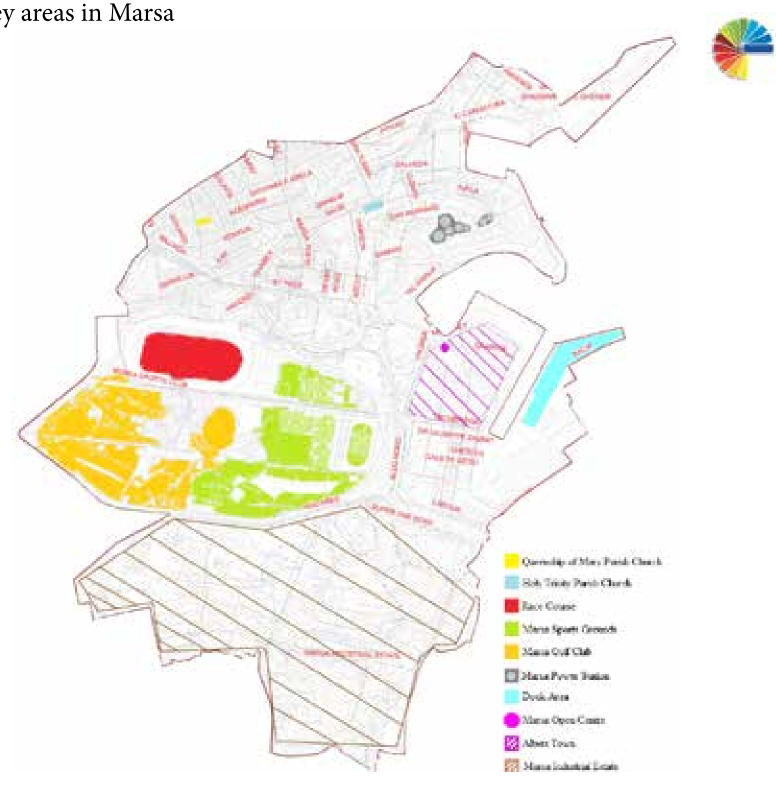
Figure 3: Open centre 100 metre buffers



Source: (Adapted from Crime Maps, In Crime Malta, 2015, Retrieved April 10, 2015, from http://crimemalta.com/map.htm. Copyright 2015 by Formosa. Adapted with permission).

Figure 4 depicts the key areas in Marsa pertaining to the study. In this chapter, frequent reference to these landmarks will be made in conjunction with the surrounding areas. The areas depicted as Albert town, the Dock area and the Industrial estate have unofficial boundaries and their setting was based on the researcher's observations. Moreover, in this chapter, street names are referred to in Maltese as this was the only available data.

Figure 4: Key areas in Marsa

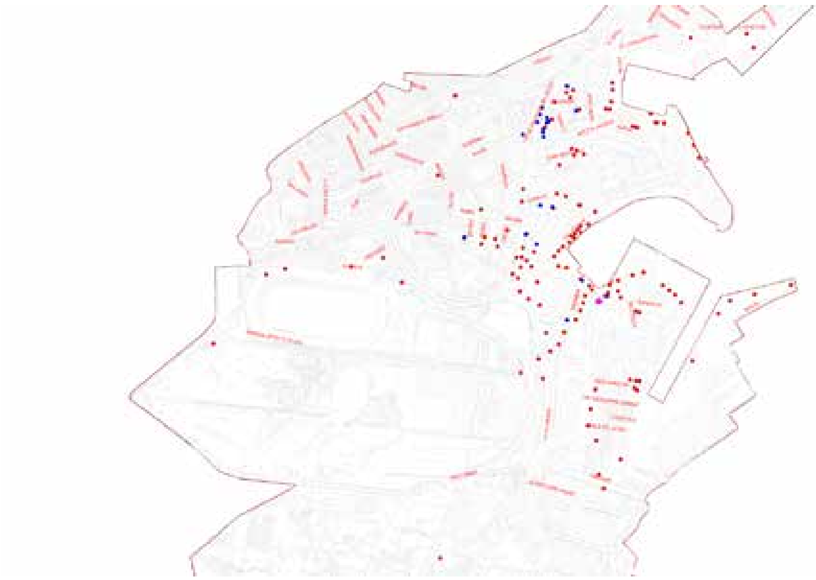


Source: (Adapted from Crime Maps, In Crime Malta, 2015, Retrieved April 10, 2015, from http://crimemalta.com/map.htm. Copyright 2015 by Formosa. Adapted with permission).

The two mapped vector layers collected in the morning and night sessions can be seen in Figure 5. The points amassed during the mornings are depicted in red while those collected at night are in blue. From the initial maps it is immediately evident that there is a concentration of points in certain areas of Marsa, mainly next to the Open Centre and in Triq is-Salib tal-Marsa (Marsa Cross Street), situated opposite to the Holy Trinity Church. This suggests that the spatio-temporal activities of migrants were found to take place within the first 700 metres from the Open Centre, mainly in the third concentric ring.

This space is characterised by various dilapidated and old buildings, uncontrolled rubbish and some graffiti. Crime related to vandalism was prevalent in the suburbs of this town even though statistics in the third concentric ring suggest that this might also be a hotspot.

Figure 5: The two vector layers; morning (red points) and night (blue points). Compiled using MapInfo (2012)



Social disorganization

During the observations and GI data collection period, it was noted that in Marsa there are various old buildings and no new development areas. The main types of residences are townhouses and old apartments that are mainly two stories high. In the Queenship of Mary's area, there is also a government housing estate that appears rundown. Most of the shops in Marsa are old and many require refurbishment and could use a coating of fresh paint. Another emerging fact was that such concentrations of deterioration do not exist in the suburban areas of the town. This is visible in Figure 5.13 in which a choropleth map with 100 metre concentric rings shows that the most deteriorated zones are found between 200 and 400 metres and from 500 to 700 metres from the Open Centre. It is also noted that even though they vary in density, all concentric rings up to 700 metres describe areas of deterioration. Figure 6 also shows that after the seventh concentric ring there is an urban improvement as the suburbs are depicted in lighter colours.

Figure 6: Deterioration point count by ring buffer. Compiled using MapInfo (2012)

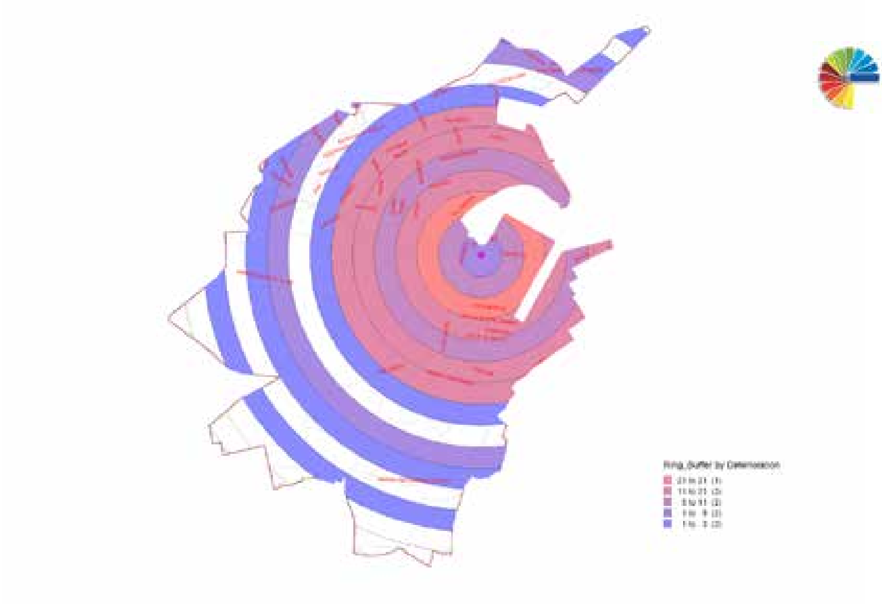
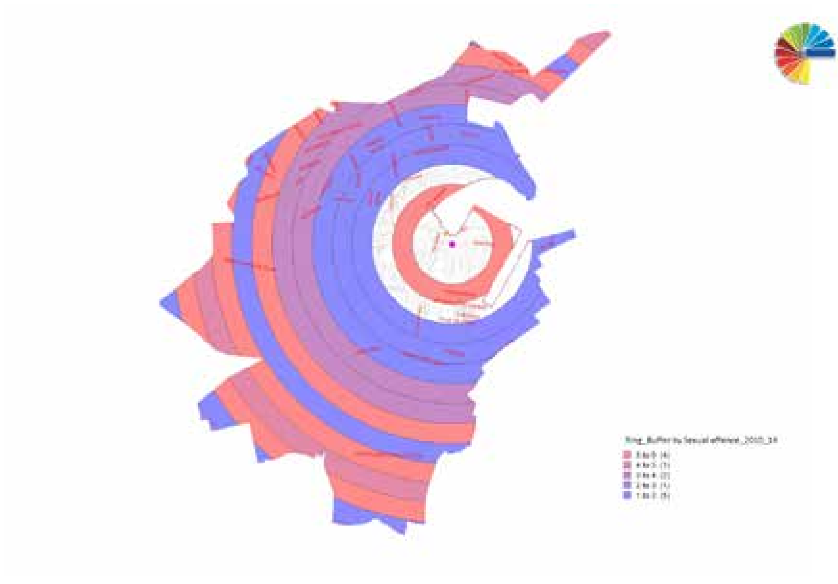


Figure 7: Sexual offences in Marsa from 2010 to 2014 by ring buffer.



Source: (Adapted from Crime Maps, In Crime Malta, 2015, Retrieved April 10, 2015, from http://crimemalta.com/map.htm. Copyright 2015 by Formosa. Adapted with permission).

Charted crime statistics pertaining to sexual offences (Crime Malta, 2015) were studied since prostitution falls under this sub-category. Figure 7 shows that in the past five years, the area covering 200 to 300 metres away from the Open Centre was one of the most frequently affected by sexual offences. This area corresponds to the concentric ring with the highest migrant activity.

Crime data pertaining to drug abuse (Crime Malta, 2015) was studied. As shown in Table 1, statistics revealed that over a five year period, the highest percentage of drug abuse was found to be 700 to 900 metres away from the Open Centre which also constitute the median figure.

Table 1. Drug offence statistics in Marsa

Concentric Ring	Drugs 2010-2014	Mean percentage	Median	Drugs 2014	Mean percentage	Median
1	1	0.4	0.4	0	0.0	0.0
2	2	0.8	1.3	1	2.6	2.6
3	14	5.9	7.1	9	23.1	25.6
4	1	0.4	7.5	1	2.6	28.2
5	0	0.0	7.5	0	0.0	28.2
6	3	1.3	8.8	1	2.6	30.8
7	60	25.1	33.9	3	7.7	38.5
8	66	27.6	61.5	7	17.9	56.4
9	4	1.7	63.2	0	0.0	56.4
10	39	16.3	79.5	6	15.4	71.8
11	6	2.5	82.0	1	2.6	74.4
12	9	3.8	85.8	2	5.1	79.5
13	8	3.3	89.1	1	2.6	82.1
14	10	4.2	93.3	5	12.8	94.9
15	7	2.9	96.2	0	0.0	94.9
16	9	3.8	100.0	2	5.1	100.0
Totals	239	100		39	100	

Note. The data was adapted from Crime Malta (2015)

Similar statistics in 2014 describe a comparable median figure, however, a high concentration of drug abuse can be seen in the area covering 200 to 300 metres away from the Open Centre, suggesting an overall shift of drug-related crime to the third concentric ring.

Throughout the research, it was also noted that numerous migrants loiter for jobs next to a particular roundabout near the Open Centre as can be seen in hot spots in Figure 8. The majority of the migrants were West African together with some East Africans, mainly Somali, Eritrean and Ethiopian. Cars or vans were seen stopping and jobs were being offered. The type of vans and cars observed suggested that that the majority of the migrants were taken for construction work, perhaps for gypsum decoration or to building sites. Some migrants appeared to be discussing payment terms while others seemed familiar with the people they were meeting. Many of the migrants were not residents in Marsa as they were seen descending from buses at the stop in the main road and walking to the roundabout next to the Open Centre.

Figure 8. Migrant job waiting hot spots and NNH (red) and 2NNH (green) poverty hot spots. Compiled using MapInfo (2012)

Source: (Formosa, 2007Adapted with permission).

Prostitution or gang brawls, uncontrolled exploitation of migrants through illegal work and poor conditions, possibly unlicensed and uncontrolled bars, together with uncontrolled alcohol consumption in the streets, confirm that the area covering 700 metres from the Open Centre in Marsa is characterised by social disorganisation. Even though crime related to bodily harm, drugs and general crime is more prevalent in the suburbs, statistics pertaining to the third concentric zone show that this is a potential hot spot. This buffer also corresponds to the concentric ring with the highest migrant activity and is also in the proximity to the main liquor serving shops. These are The Tavern and The Tiger Bar which both seem to be run by migrants and cater for people of African descent. The elite interviewees blame these bars as the main reason Marsa is regarded as an "African area" since they do not pay licence and they do not pay taxes and the area in which they are situated is filthy.

Segregation

During the day, the space occupied by the Maltese and the migrants overlap. This changes completely at night, as hardly any Maltese visit the Open Centre area. Similar observations were noted in the zone next to the small park in Triq is-Salib tal-Marsa where there are migrant shops and many migrants meet for recreational purposes. The locals used to frequent this location when the local shops were open. It was observed that as the hours passed by, the locals' presence diminished and it was only after sunrise that they returned to this zone.

The locals also avoid this space which is utilised by the most unsettled and disadvantaged sub-Saharan migrants especially at night. This might be due to the ageing local population and the average lack of education, coupled with possible cultural conflict and racism. The residents are also fearful of migrants and they are leaving this town since they are not willing to open up to them.

The elite interviewees noted that the majority of migrants in Marsa are of Muslim faith and only a few Christians that are mainly from Eritrea, Gambia and West Africa. Migrants in Marsa are detached from the community as they are hindered from developing any ties due to current policy. Moreover, the elite interviewees suggest that the situation in Marsa may degenerate if the stakeholders do not counteract the challenges brought forward by this phenomenon.

Discussion

One could observe that like various other towns and cities, processes of industrialisation and urbanisation have moulded Marsa (Giddens & Sutton, 2009) creating a rust-belt community (Formosa, 2007). The centrality and the multi-purpose role of Marsa cause several flows of people to dynamically interfere with the daily social activities of the locals. On top of that, the Open Centre's residents change from time to time. New jobless migrants coming from several sub-Saharan countries arrive to replace existing migrants who are not allowed to dwell in the centre for more than one year. This turned Marsa into a transitional area (Burgess, 1925). This may also have implications for the community since the migrants who have lived at the Open Centre for some time gain integration tools such as language and ethics while the new ones are still to start the integration process. This population turnover might also impact the community due to the characteristic of an ongoing flow of uneducated people. Poverty, population turnover and ethnic heterogeneity (Shaw & McKay's, 1942) and residential instability (Stowell, 2007) have been associated with Social disorganisation.

The data forthcoming from the research describes that apart from the influx of uneducated migrants, the town is also losing residents, mainly the younger generation. This was also confirmed when the local council was penalized with a budget reduction and the number of local council members reduced from seven to five reflecting the diminishing number of the "attached" residents (Wilson and Kelling, 1982, p. 3) in the locality. A reduction in attached residents has also been linked to urban deterioration that is then intrinsically related to the formation of breeding grounds for prostitution, drug trafficking and drunkards creating slums (Wilson and Kelling, 1982). This research produced similar results, as in Marsa, crime related to drugs and bodily harm is present both in the outskirts and in the third concentric ring. The findings elicited from this study are in line with Wilson and Kelling's (1982) literature as they remarked that the only people who find it difficult to leave their disrupted neighbourhoods are the old, poor and those who suffer from racial discrimination. They added that these zones have a high possibility of becoming slums since they experience social disorder and crime.

Even though ethnic areas are difficult to define (Logan & Zhang, 2004), throughout the years the area in the vicinity of the Open Centre has been described as a Ghetto and no-go area. Perhaps the most suitable social construct related to its' characteristics can be achieved through a combination of literature pertaining to Burgess (1925), Wilson and Kelling (1982) and Shaw and McKay (1942) as a transitional multi-ethnic slum.

The findings of this study suggest that Marsa has developed as a job seeking centre for migrants during the morning. The lack of control concerning the employment of migrants has changed the town into an unofficial Migrants' ETC where they wait for potential employers to offer them dead-end, tiring and unguaranteed jobs. A globalist interpretation to this can also be provided by the Dual Labour Market Theory (Piore, 1979). Its adoption to the local context explains why migrants are pulled to certain areas in Marsa as they are given the possibility to work in jobs that are ignored by the locals. This leads to the development of new social networks between the most disadvantaged of migrants and those who are ready to exploit them.

The socio-spatial usage of the area within 700 metres off the Open Centre is predominantly characterised by the dynamic activities of migrants. The Maltese avoid this space and this suggests dynamic social segregation. Even though from a western perspective, the zone surrounding the Open Centre demonstrates common traits of a transitional multi-ethnic slum, yet this spatio-temporal study suggests that it may provide a very important role. Migrants living in other towns take advantage of its central location to visit this area as it may be considered their unofficial capital city in Malta since it caters to all their needs. This social space has become a job-seeking, recreational and shopping area dedicated to migrants with minimal interference from the locals.

Conclusion

Despite the negative connotations associated with this region, little has been done to alleviate the problem. A joint effort by all the stakeholders, especially those who are directly involved in policy making, is urgently required as the deficiencies in the infrastructure and social networks affecting migrants and the residents are aggravating the polarisation between both communities. An alternative solution to the Open Centre has to be found, despite the fact that order and control within have been achieved, the previous disorganisation found inside has shifted to the surrounding areas and is making it difficult for both the residents and the migrants to achieve a successful integration. Loitering for both prostitution and jobs has to be controlled and street drinking needs to be terminated to restore order and reduce the residents' fear, which could encourage them to stay in their natal town. Capable guardians have to increase as both the environment and the lack of police presence are leading particular areas in Marsa to become zones that provide opportunities for criminal acts.

Education is another key issue that needs to be addressed as the percentage of illiteracy is high and may be linked to the lack of will for integration. The necessity to bring about a general improvement in the urban environment in Marsa was raised and can be achieved through investment by both the public and private sectors as otherwise demand for property in this locality will continue to decrease, giving rise to clusters of the most disadvantaged and poor people. Even though similar research in other towns has not been conducted, and the general feeling is that the situation is slightly better, however, the ailing situation in Marsa could spread to other locations if policies fail to address these deficiencies.

This study identified the migrants' spatio-temporal activities that were analysed in relation to the urban ecology in Marsa. The findings of this study suggest that migrants are utilising Marsa for different purposes and their activities have impacted this town directly and indirectly, both socially and urbanely. Migrants have been segregated from the local community through institutional racism practises while the spaces they frequent are avoided by the locals. The socio-spatial composition of a particular 100-meter tract in the proximity of the Open Centre may be providing opportunities for crime. A literature-based definition of the area surrounding the Open Centre can be that of a transitional multi-ethnic slum, but this could also be their unofficial capital city. This topic needs to be continually revisited as it is a rapidly evolving situation that impacts social and urban systems.

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EPILOGUE

Islands on the Move

Timmy Gambin

Introduction

Malta and Gozo's population have always been influenced by movement. People, goods and ideas that sailed on and across the Mediterranean Sea came into contact with the islands and inhabitants - some purposely, other not; some peacefully, others not. It would be mistaken to believe that such maritime traffic was one way. Since prehistory, inhabitants from the Maltese Islands travelled from the islands to explore and settle overseas. More recently, Maltese people also moved and populated other Mediterranean areas that included Gibraltar, Alexandria and Tunis. Beyond Mare Nostrum, the Maltese wandered as far afield as New York and Sydney - some left for good but others were unable to resist the lure of their homeland.

Whether traversing long distances or otherwise, any journey from one point to another requires one to know three basic facts: 1) where one is; 2) where one is going and 3) how to get there. Although navigation is an inherent skill, over the millennia humans have become consistently more reliable on navigational aids such as the compass and more recently Global Positioning System (GPS). Whatever the instrument used, the basis of all forms of navigation, even modern-day satellite systems, is the map. It is the map that provides essential knowledge which can be used to supply the three basic yet indispensable facts listed above. If we know where we are we can plot where we are on a map - just as we can locate where we would like to go. Information contained in the map will also tell guide us as to the best possible routes to reach our destination. Journeys could be planned with, amongst other matters, speed, safety and profit in mind.

It was therefore essential to keep maps updated and produce new ones with more data included. Countries like England and France excelled in the production of terrestrial maps and marine charts in the 19th and 20th centuries - reflecting the global dominance of these two powers - powers that needed maps to administer territories. So important were these depictions of space that the 19th century witnessed the the production of thematic works such as William Smith's Geological Map of England and Wales and Part of Scotland (1815). Such works permitted landowners to invest in coal mines, canals and other industries. What is important to note here is that Smith's map was not used to move from one place to another but rather to plan ahead.

This brings us to the second function of maps - that of managing and planning. Just as Smith's map helped with the 'planning' of Britain's coal exploitation, maps started to be utilised all forms of knowledge. In 1854, Dr John Snow plotted 13 public water sources alongside the known cholera deaths around a specific part of London, a unique case of early GIS albeit decades before technological spatial aids became availeble. By visualising and 'querying' his data, Snow was able to identify the very pump that was infected and causing the cholera outbreak. Snow's map was not simply something that helps navigate but the plotting of different datasets (water sources and cholera deaths) enabled a basic but very effective methodology that is today referred to as spatial analysis. It is little wonder therefore that Snow's work is often referred to as a proto-Geographic Information System (GIS). Inversely, Elbrige Gerry used a similar exercise to attempt to restructure an electoral map as an aid to get re-elected. The episode, known as the 1811 Map the Political spectrum, when Elbridge Gerry was governor, was facilitated by the Jeffersonians, who desiring to retain their control of the state, rearranged the election districts in their favour in a grotesque salamander-like shape, a political manoeuvre then named by his opponents and since known as a gerrymander (from his name and salamander). Such early GIS examples depict how powerful the spatial information was and with noew analystical technology as combined with hi-end data-catpture devices, has become.

It is clear therefore that maps can be used or at least three different purposes: 1) navigation; 2) locating resources and 3) spatial analysis. All three 'map functions' are not mutually exclusive but rather intertwined. Snow could not have queried his data if he couldn't locate the water sources the occurrence of cholera deaths. Neither could Gerry be re-elected.

Therefore, at the heart of forms of spatial based knowledge is the base map: a time-stamped dataset that subsequent datasets or maps could be compared with in order to analyse change. Maps however, can never be static. In this day and age of rapidly evolving urban landscapes and climate change the need to keep maps updated is more relevant than ever before. Likewise, the intricacies of modern day life, with its complex social fabrics contribute to a dynamic and fluid situation that is in need of mapping so that it may be better understood.

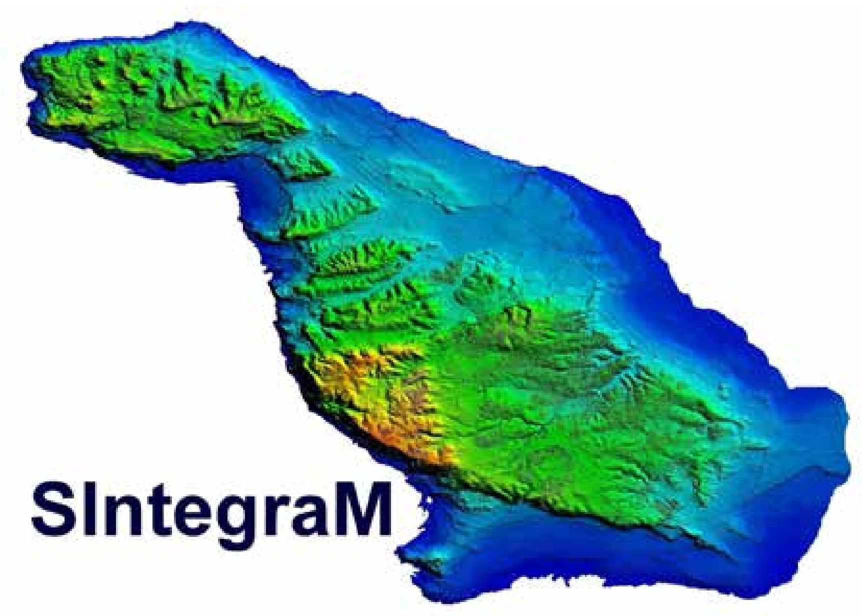
Because of their function maps must, in order to remain relevant, be consistently updated. Base maps that do not reflect the reality on the ground are not simply obsolete but also dangerous. Any decisions based on wrong data will almost certainly lead to undesired results. As young modern European nation it is therefore vital that Malta is equipped with a system that enables the gathering and maintenance of spatial data that are in turn made available to persons working towards the improvement of the islands' efficient management. It was indeed a ground-breaking step in the right direction when the decision was taken to implement the SIntegraM Project. The list of sectors that can benefit from these up to date and state of the art spatial datasets generated by SIntegraM is too large to list here and beyond the scope of this short communication. It is however, essential to point out that the planned data will not only transcend boundaries but will also create synergies between entities, whether public or private, that should in turn facilitate better decision making.

Finally, the decision to invest in equipment and human resources ensures that a future for Maltese surveying and mapping is being secured. As a nation, we will no longer be dependent on overseas service providers for the gathering and production of spatial data.

We will, for the first time in our history, have the capacity to, quite literally, map our own future.

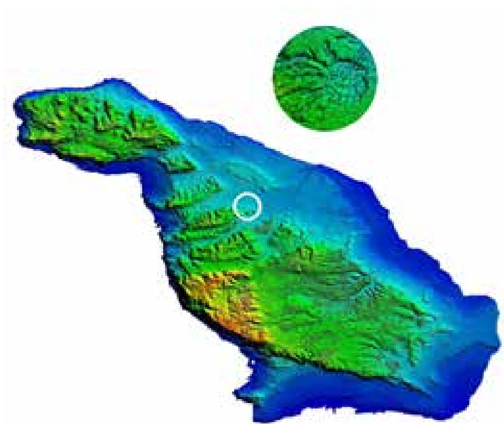
COLOUR IMAGERY

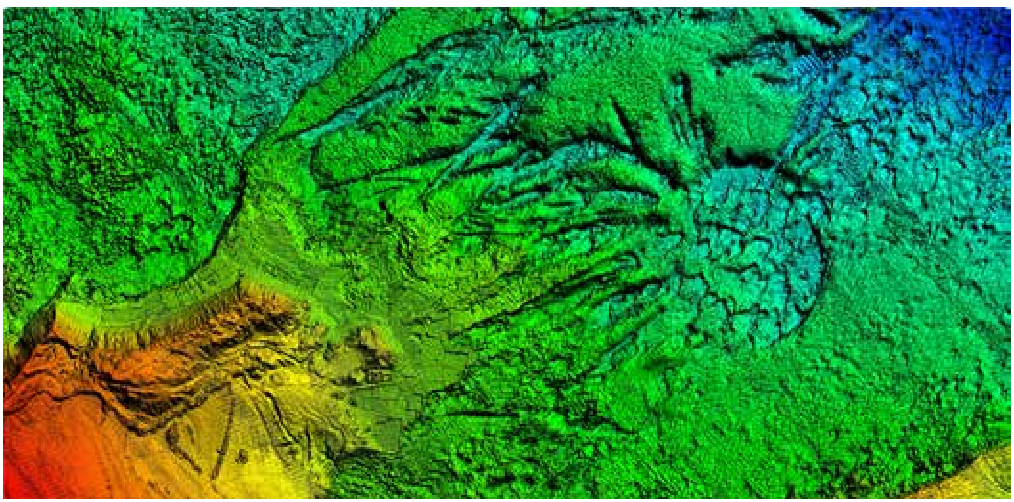
This section depicts colour versions of selected images from the chapters



l-Għariebel

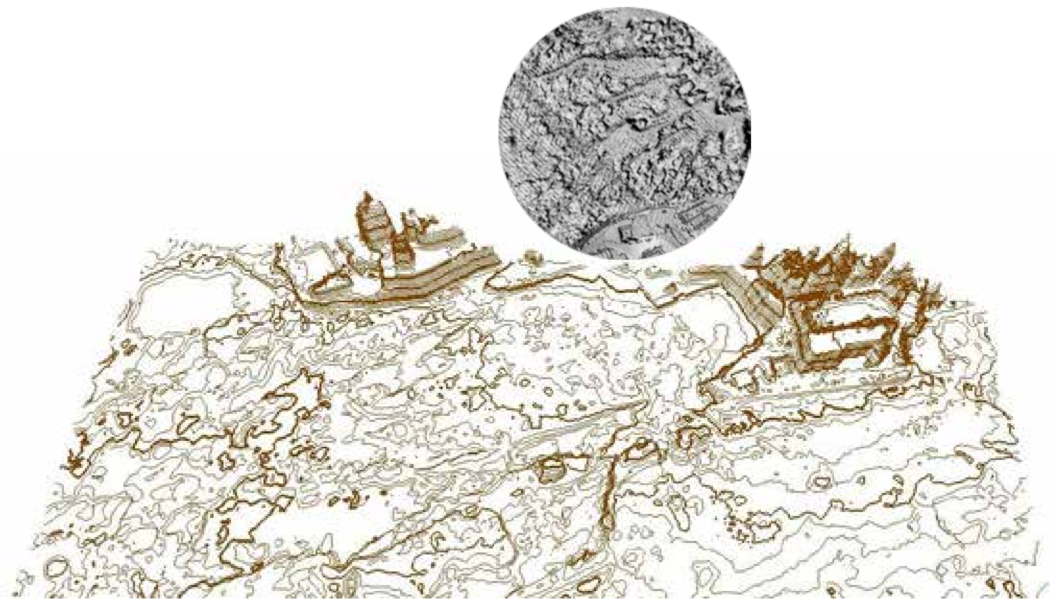
Discovered by Saviour Formosa on
01 May 2014
UTM 33N (ED50) (445925.754, 3980766.794, -12.547m),
35° 58' 09.2645" N, 14° 24' 01.0390" E





Pivot I

Technological Constructs as Foundations for Change

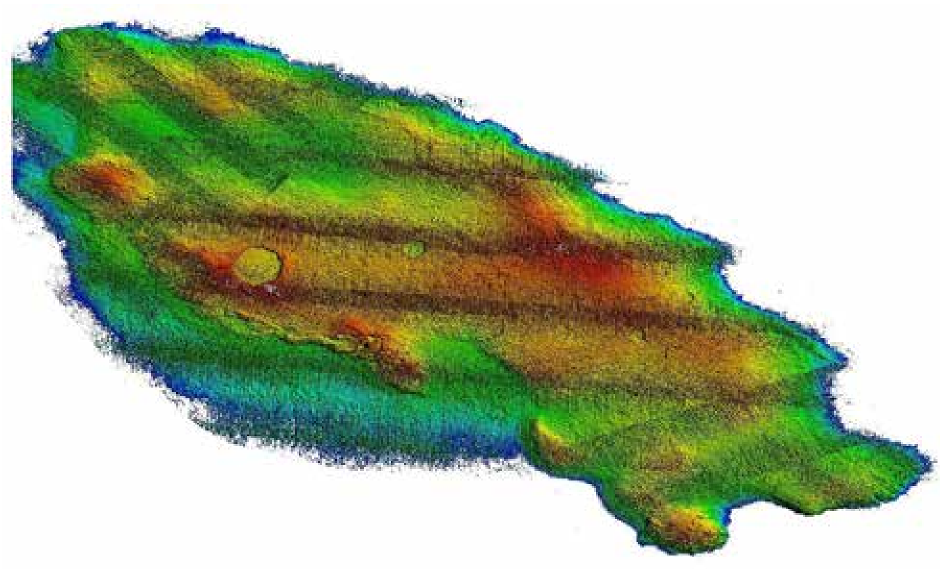


Ta' l-Għazzenin Rock-Cuts

Underwater rock-cut identified by Saviour Formosa on 15 June 2015
UTM 33N (ED50) (446211.297, 3978812.634, -8.006 m),
35° 57' 05.8990" N, 14° 24' 12.9159" E

Pivot II

Constructs for an Environmental Understanding

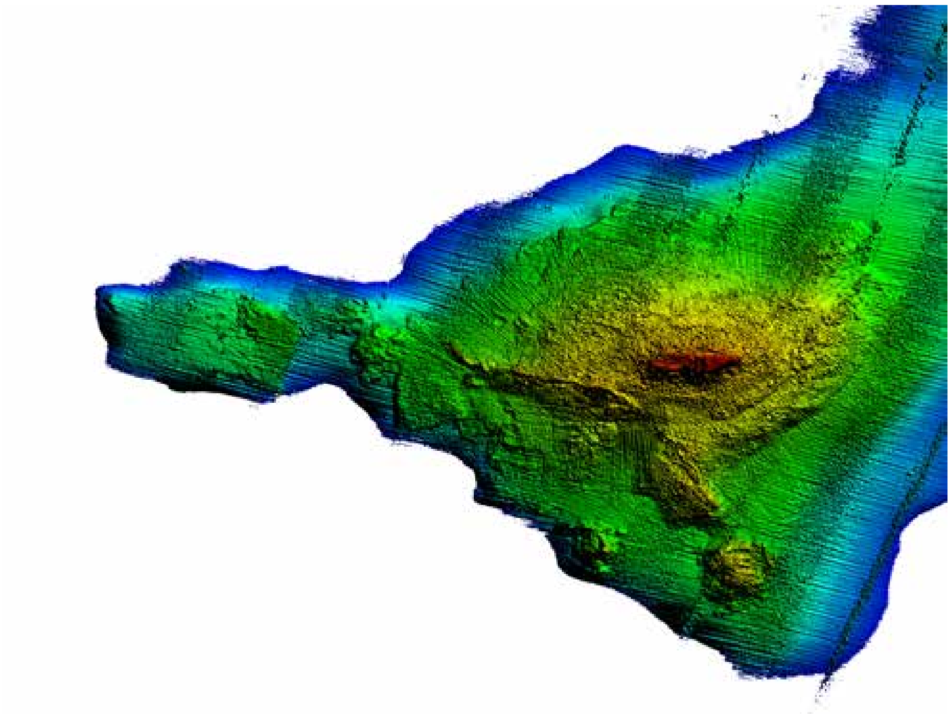


Sikka l-Bajda Dolines

Underwater dolines identified through ERDF156 in 2012

GEO (WGS84) (14.3921986161, 36.0020301927) - -22.3 m,
36° 00' 07.3087" N, 14° 23' 31.9150" E

Pivot III
Physicality and Realisms



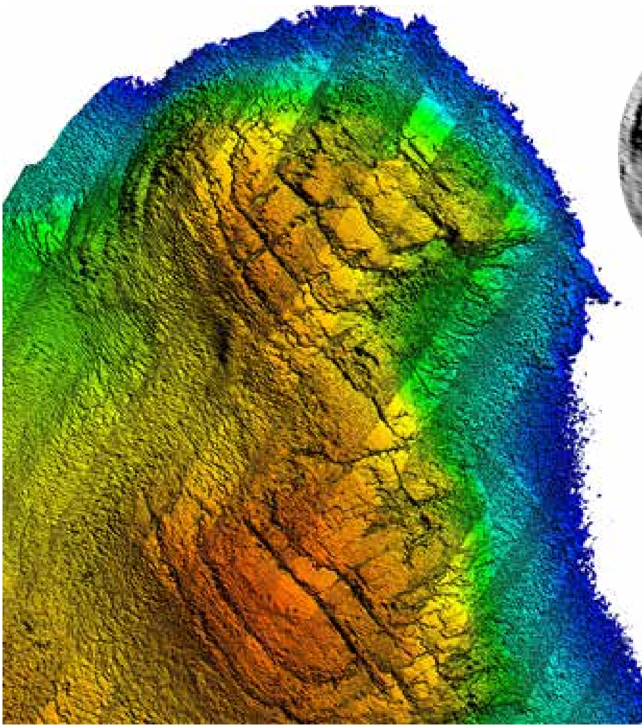
Filfla

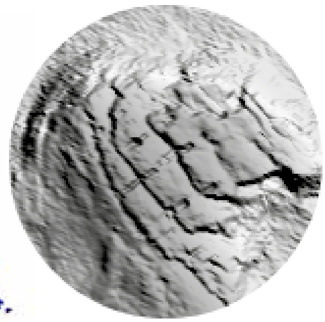
Coast at -75m ERDF156 in 2012

GEO (WGS84) (14.4043388539, 35.7996659720) - -117.55 m,
35° 47' 58.7975" N, 14° 24' 15.6199" E

Pivot IV

Social Wellbeing





Zonqor Paradelia

Stepped Hill identified in 2015

UTM 33N (ED50) (461372.177, 3971523.265, -17.965 m),
35° 53’ 11.8980” N, 14° 34’ 19.3497” E

Chapter 1

Figure 5: Meter reachability spatial analysis

Figure 9: Geo-coding of planned projects in red in conjunction with current distribution network

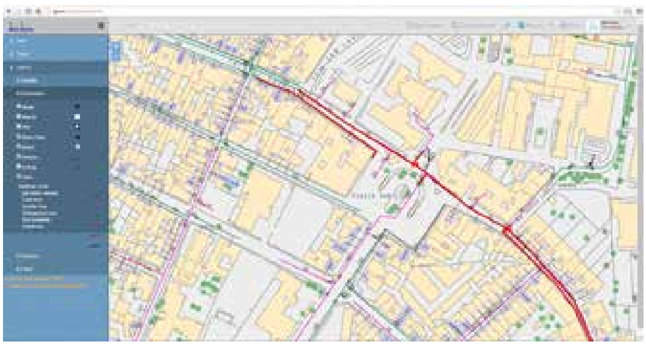
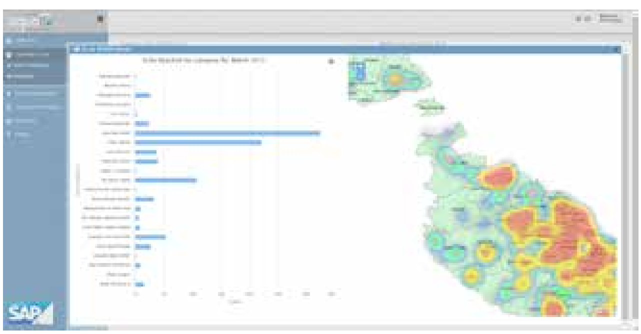
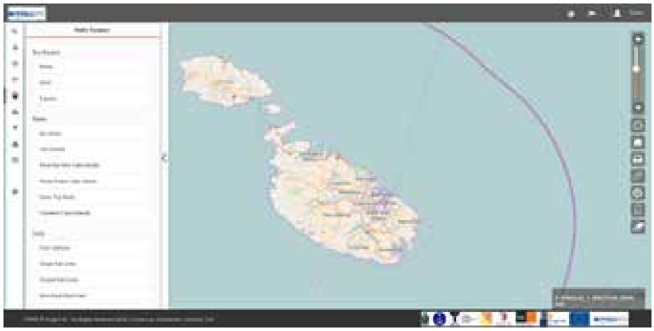


Figure 12: Heat map of notifications



Chapter 2

Figure 1: STREETS interface



Chapter 3

Figure 1: NSO population maps

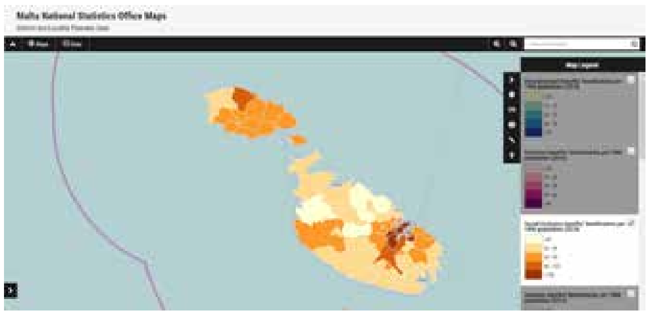


Figure 2: Crime maps

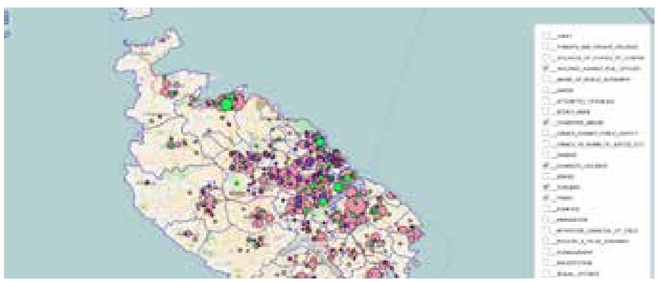
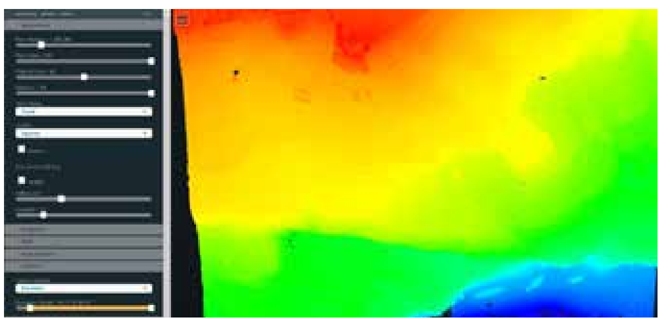


Figure 3: Cloudisle 3D



Chapter 4

Figure 1: Watershed Analysis using RapidEye (5m) Imagery

Figure 4: Example of a CleanSeaNet Alert Report received by the Maltese Authorities

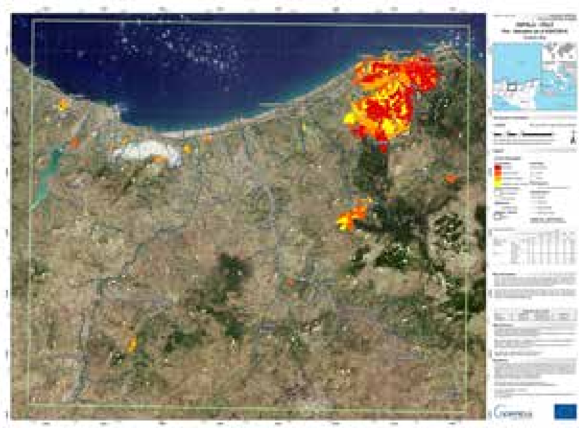


Figure 7: EMS Grading Map covering the June 2016 Forest Fires in Sicily

Chapter 6

Figure 1 - Routes layer of the Maltese Islands

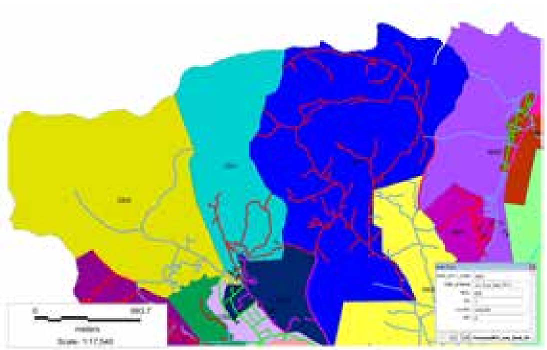


Figure 2 - Inputting the information of the polygon

Figure 4 - Final Census 2011 EA's Map

Chapter 6

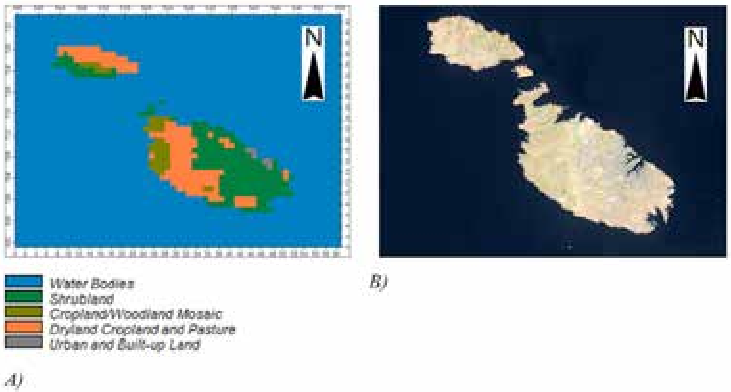


Figure 2: The default WRF USGS 24-category Land Use Categories data

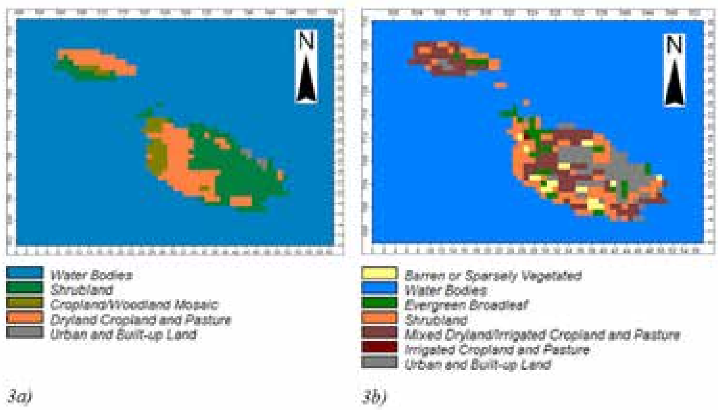


Figure 9: Geo-coding of planned projects in red in conjunction with current distribution network

Chapter 7

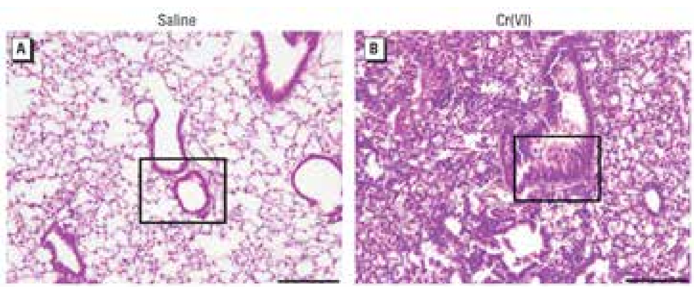


Figure 5: Lung histological sections

Figure 7: Greyish-blue skin discolouration (left) compared to normal (right). The patient suffered from Argyria due to his ingestion of colloidal silver to treat joint aches

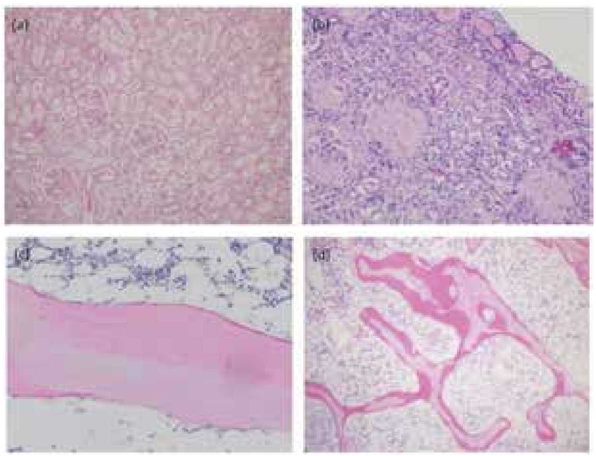


Figure 8: Histological sections of normal renal cortex (a), IID patient renal cortex (b), normal iliac bone (c) and IID patient iliac bone (d). Renal cortex atrophy in (b) and iliac bone osteoid lesions in (d) can be observed following prolonged exposure to Cd

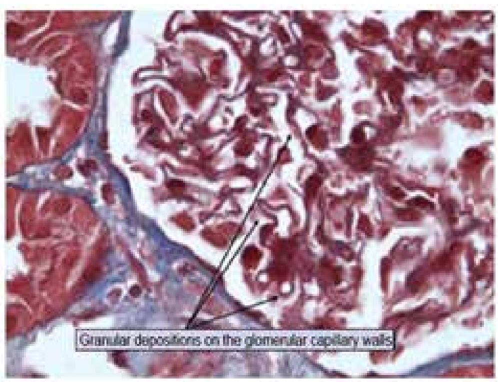


Figure 9: Histological section showing depositions on the capillary walls of glomeruli made up of granules formed by antibody-antigen complexes that did not clear successfully

Chapter 9

Figure 2: SPED strategic proposals on land

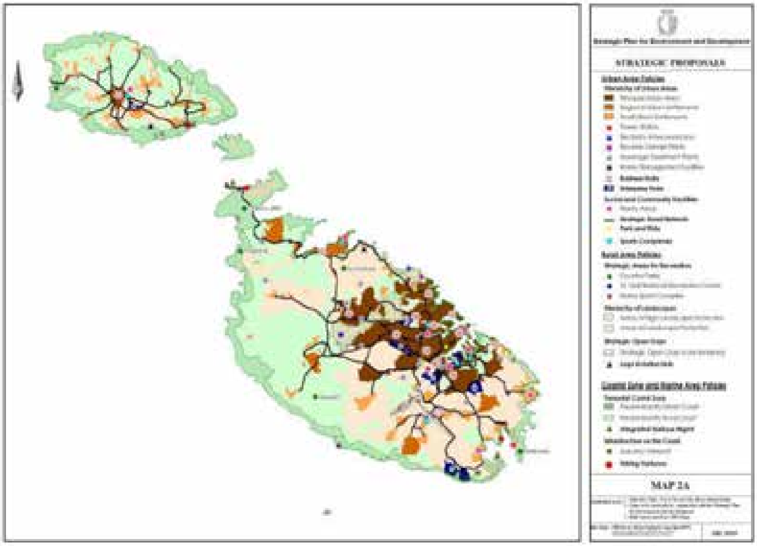
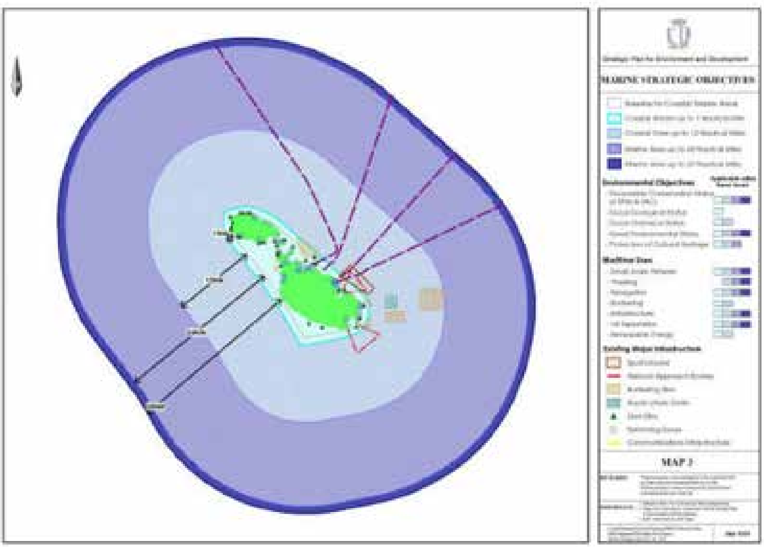


Figure 3: SPED marine strategic objectives



Chapter 10

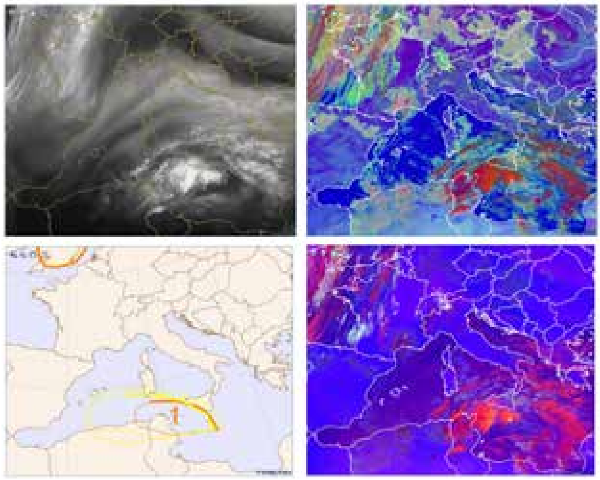


Figure 2a-b. Left (a): Water vapour image showing dense accumulation over the central Mediterranean region; Right (b): Microphysics image showing extensive red patches over the Maltese islands, indicative of convective clouds with severe updrafts and ice particles. Case study: 29 November 2011. Source: EUMEtrain.org

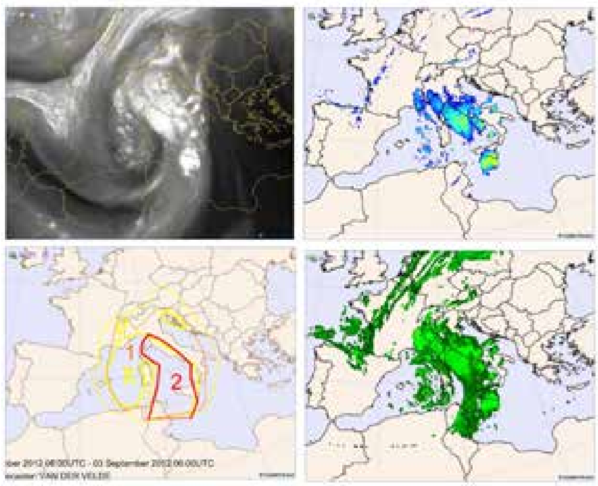


Figure 2c-d. Left (c): Area marked as '1' refers to probability of severe weather within highlighted region; Right (d) Magenta patches over the Maltese islands refer to severe convection with cold cloud tops associated with severe updrafts and fierce weather. Case study: 29 November 2011. Source: EUMEtrain.org

Chapter 11

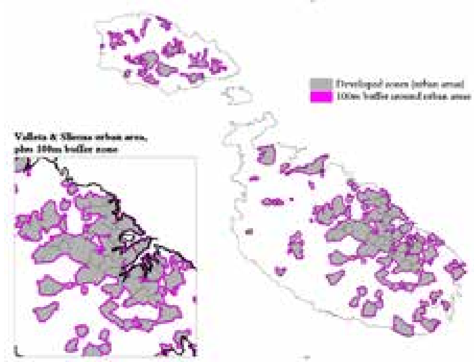
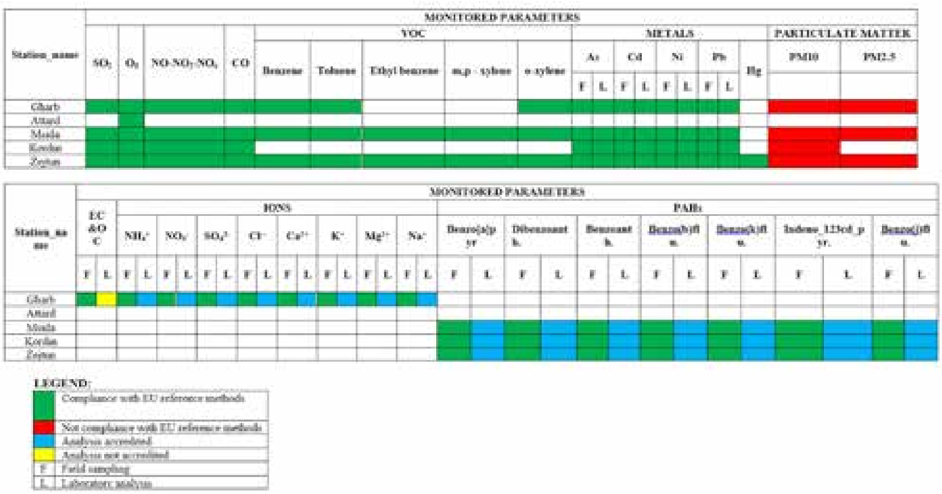


Figure 1: Urban areas with an indication of the 100m buffer zone made by Bush and Stacey for the identification of the main agglomeration

Figure 7: Monitoring Stations

Table 11: Overview of the pollutants monitored by MEPA real-time network.
Source: www.mepa.org.mt. (2013)



Station_name	SO2	O3	NO-NO2-NOx	CO	VOC: Benzene	VOC: Toluene	VOC: Ethyl benzene	VOC: m,p - xylene	VOC: o-xylene	METALS: As F	As L	Cd F	Cd L	Ni F	Ni L	Pb F	Pb L	Hg	PARTICULATE MATTER: PM10	PM2.5
Gharb																				
Attard																				
Msida																				
Kordin																				
Zejtun																				

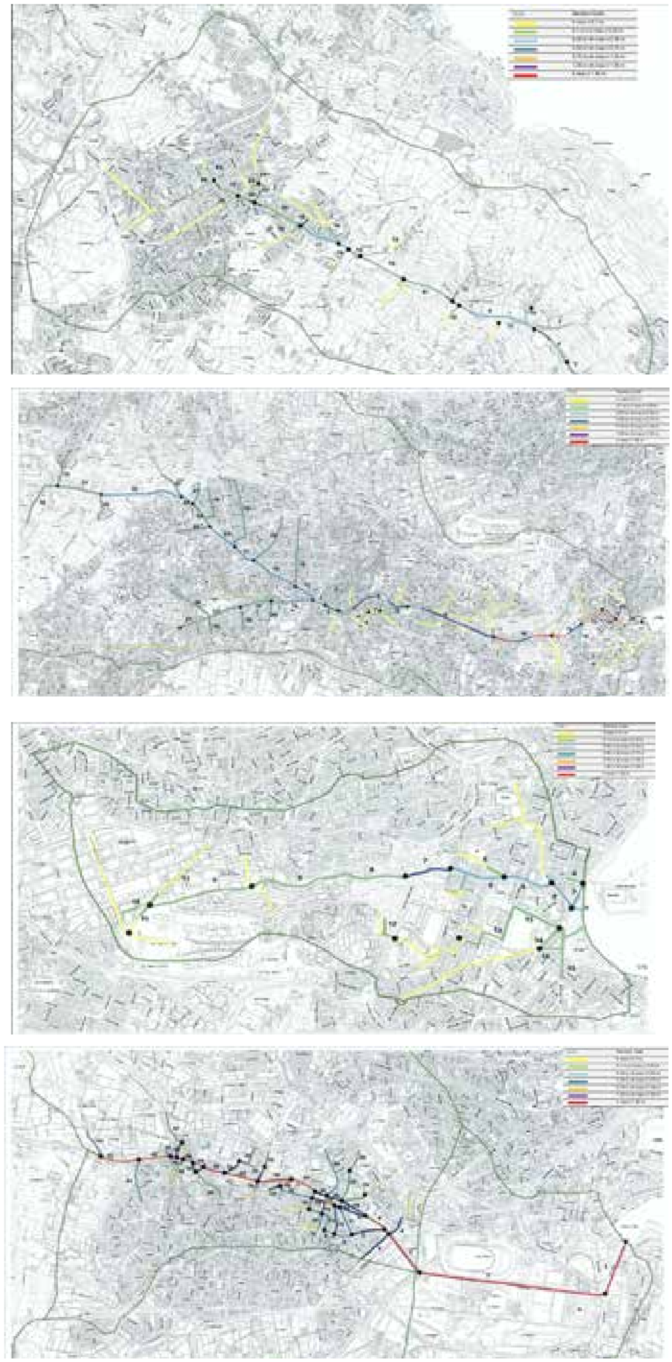
Station_name	EC &OC F	EC &OC L	IONS: NH_4^+ F	NH_4^+ L	NO_3^- F	NO_3^- L	SO_4^{2-} F	SO_4^{2-} L	Cl^- F	Cl^- L	Ca^{2+} F	Ca^{2+} L	K^+ F	K^+ L	Mg^{2+} F	Mg^{2+} L	Na^+ F	Na^+ L	PAHs: Benzo(a)pyr F	Benzo(a)pyr L	Dibenzoanth. F	Dibenzoanth. L	Benzoanth. F	Benzoanth. L	Benzo(b)flu. F	Benzo(b)flu. L	Benzo(k)flu. F	Benzo(k)flu. L	Indeno_123cd_pyr. F	Indeno_123cd_pyr. L	Benzo(j)flu. F	Benzo(j)flu. L
Gharb																																
Attard																																
Msida																																
Kordin																																
Zejtun																																

LEGEND:

	Compliance with EU reference methods
	Not compliance with EU reference methods
	Analysis accredited
	Analysis not accredited
F	Field sampling
L	Laboratory analysis

Chapter 12

Figure 3: Watershed boundaries, flood simulation water depths and survey codes as delineated in the NPRP study for (a) Marsascala (b) Birkirkara-Msida (c) Gzira (d) Marsa catchments



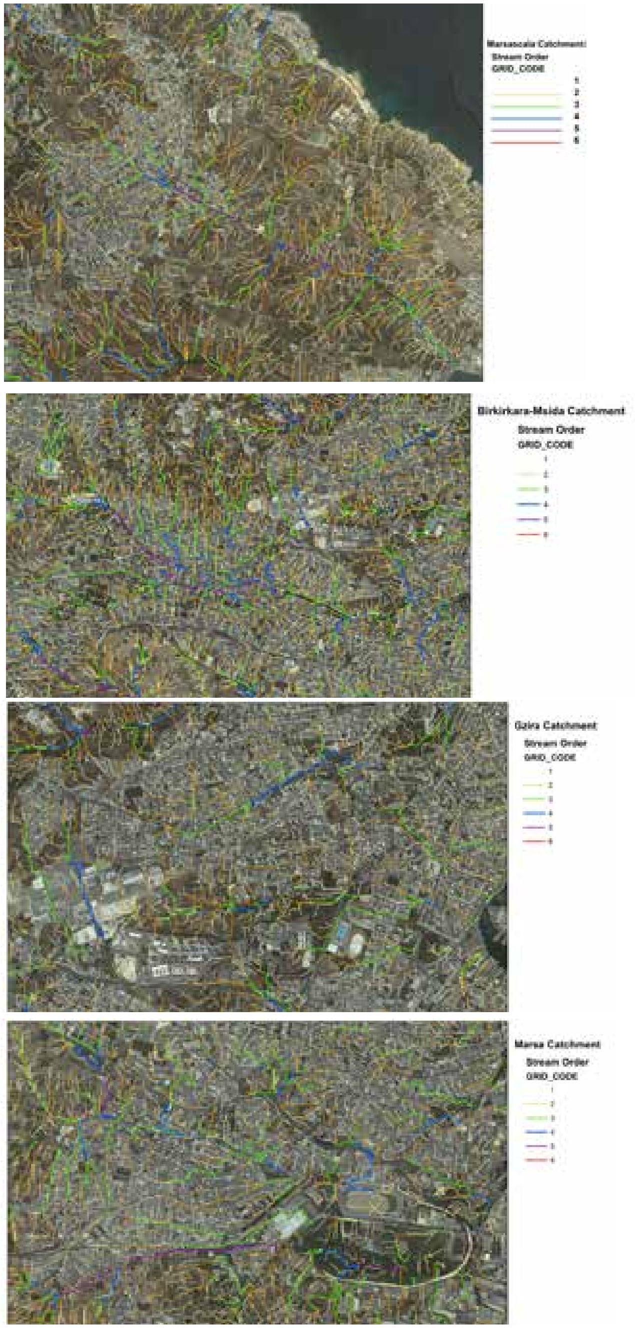
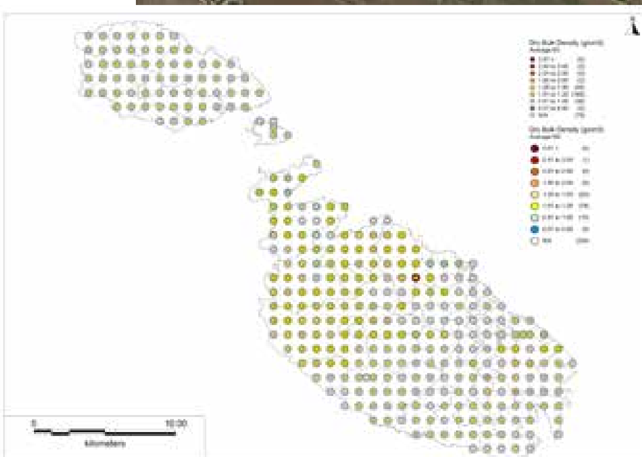


Figure 4: Stream networks derived from the LiDAR data for (a) Marsascala (b) Birkirkara-Msida (c) Gzira (d) Marsa catchments

Figure 7 (a): Diversion of stream network in the Marsascala catchment caused by a false pit (b) result of editing to join stream network along stream order 5 (shown in voilet)

Chapter 12

Figure 1a: Average bulk density values for M1 (2003) as the smaller circles and M2 (2013) values as the larger circles surrounding the smaller (M1) circles



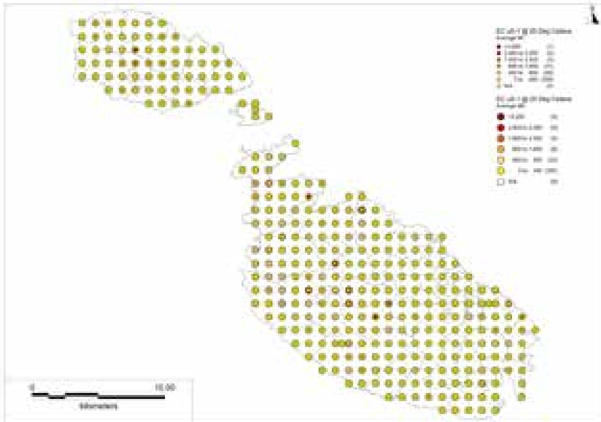


Figure 1b: Change in bulk density between 2003 and 2013 (M2-M1)

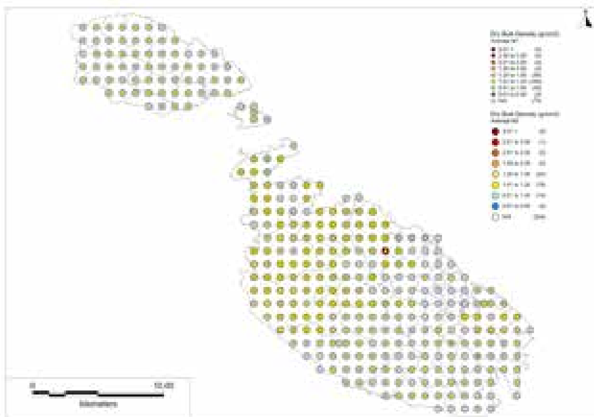


Figure 2a: Average electrical conductivity values for M1 (2003) as the smaller circles and M2 (2013) values as the larger circles surrounding the smaller (M1) circles.

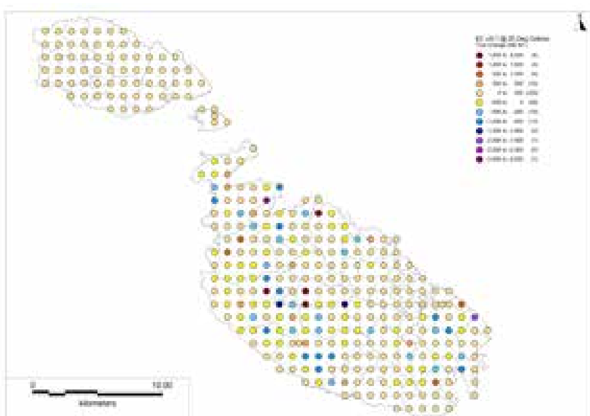


Figure 2b: Change in electrical conductivity between 2003 and 2013 (M2-M1)

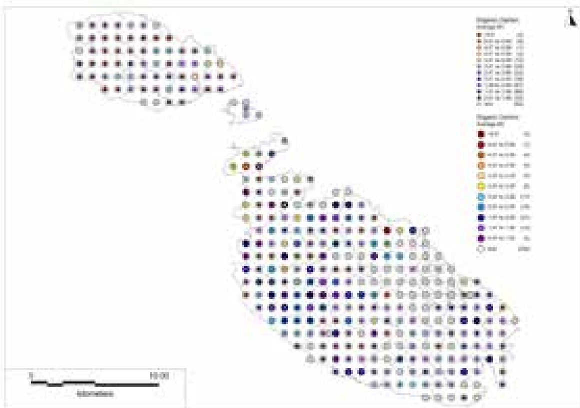


Figure 3a: Average organic carbon values for M1 (2003) as the smaller circles and M2 (2013) values as the larger circles surrounding the smaller (M1) circles

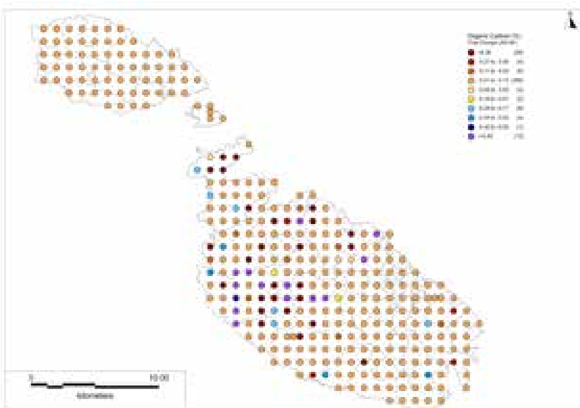


Figure 3b: Change in organic carbon between 2003 and 2013 (M2-M1)

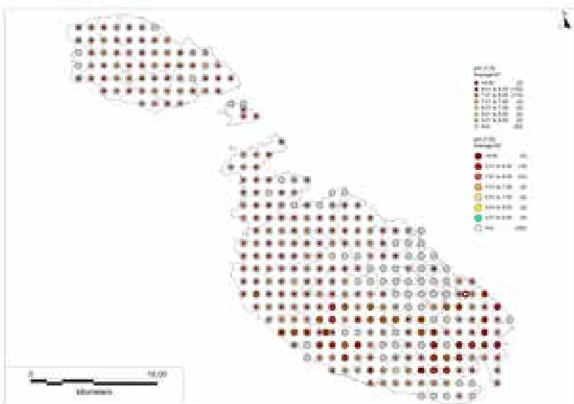


Figure 4: Average pH values for M1 (2003) as the smaller circles and M2 (2013) values as the larger circles surrounding the smaller (M1) circles

Figure 4b: Change in pH between 2003 and 2013 (M2-M1)

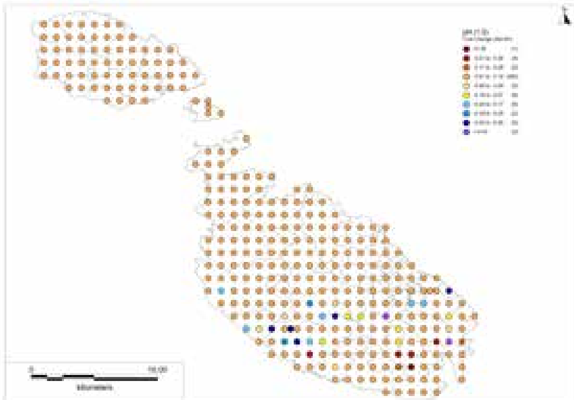


Figure 5a: Average moisture content values for M1 (2003) as the smaller circles and M2 (2013) values as the larger circles surrounding the smaller (M1) circles

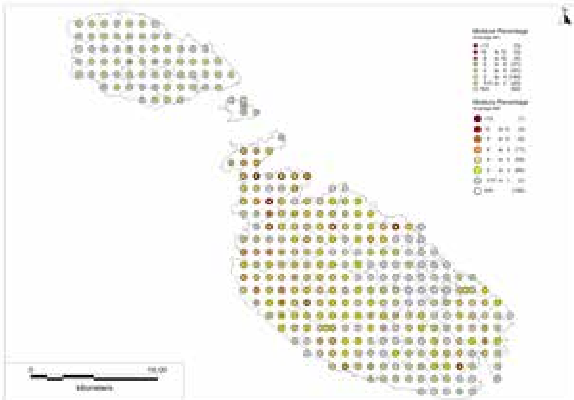


Figure 5b: Change in moisture content between 2003 and 2013 (M2-M1)

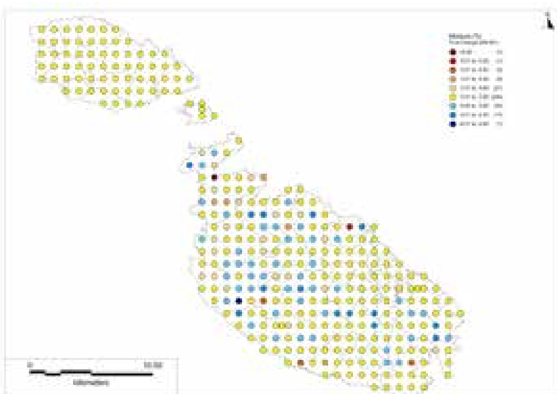


Figure 6: Top figure displays average soil depth values established in M2 (soil depth not calculated in M1)

Chapter 15

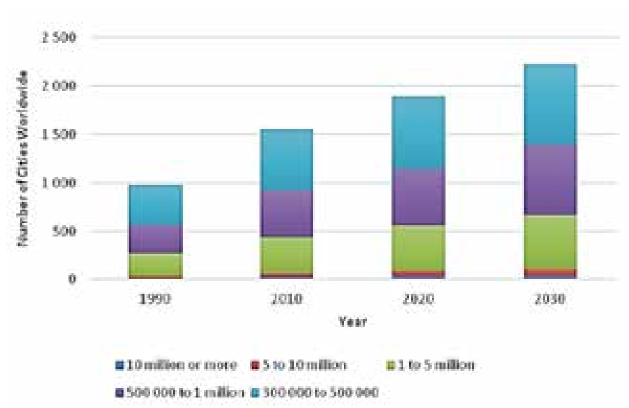


Figure 1. Global number of cities 2030 horizon

Figure 8. The Europe electric vehicles available charging infrastructure

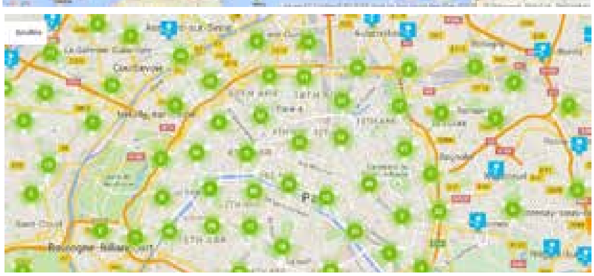


Figure 9. Paris electric vehicles' charging points reported in April 2016

Figure 10. The most likely to be consider alternative fuels for use

Figure 14. Electric energy requirements for electricity-based fuelling pathways

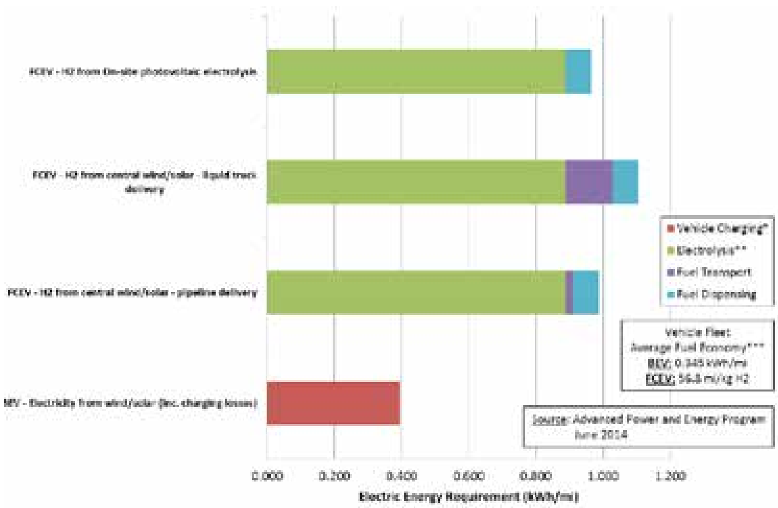
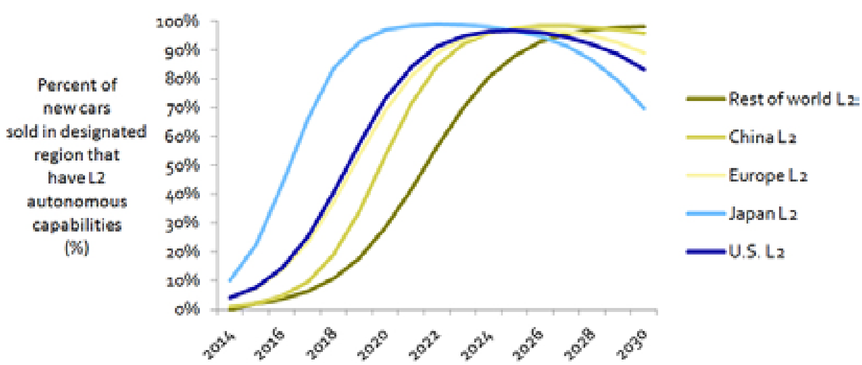


Figure 16. Worldwide autonomous capabilities videos sales



Chapter 16

Figure 1: Test converting LIDAR data into relative surface altimetry to directly estimate building number of floors.

Figure 4: Test depicting higher resolution altimetric map showing significant sloping terrain.

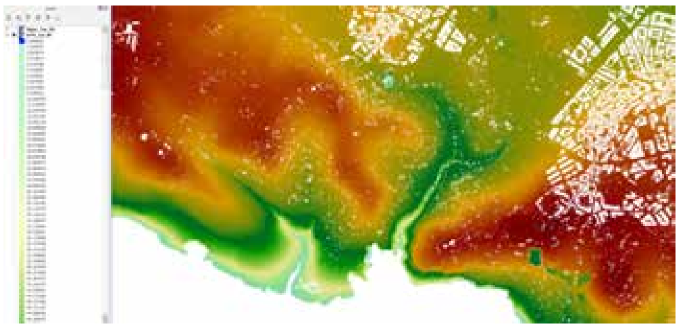
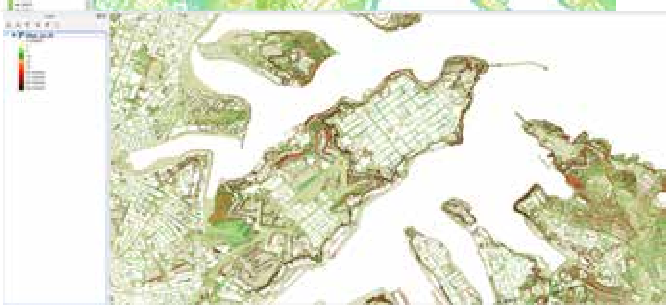


Figure 5: Test showing a higher resolution altimetric map clearly suggesting the rationale for a number of man-made features (including roads and fortifications).

Figure 7: Test indicating how careful choice of slope parameters and corresponding chromatic depiction



Chapter 17

Figure 1: The National Flood Relief Project

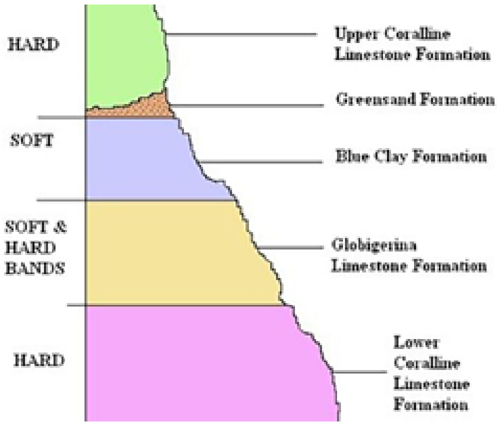


Figure 2: Section of Malta's rock formation

Chapter 18

Table 2: A 5×5 risk matrix

		Probability of occurrence				
		Highly Likely	Likely	Unlikely	Highly Unlikely	Extremely Unlikely but yet possible
Severity	Catastrophic					
	Significant					
	Moderate					
	Minor					
	Limited					

Chapter 19

Figure 4: Different representations of the study zone

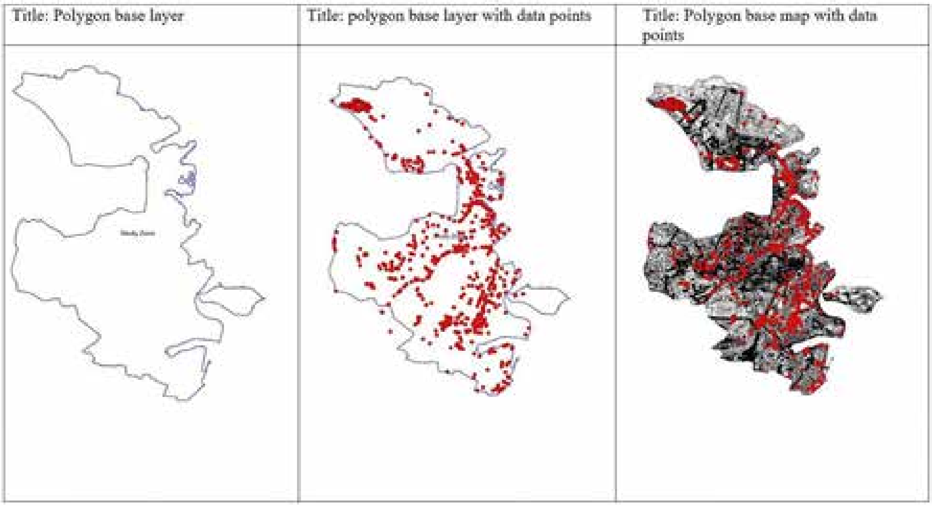


Figure 9: EAS input points in urban and rural zones

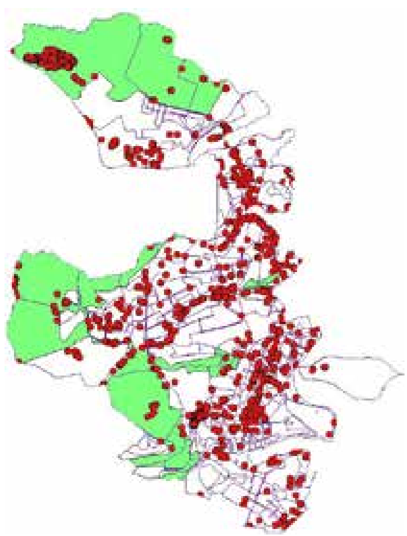
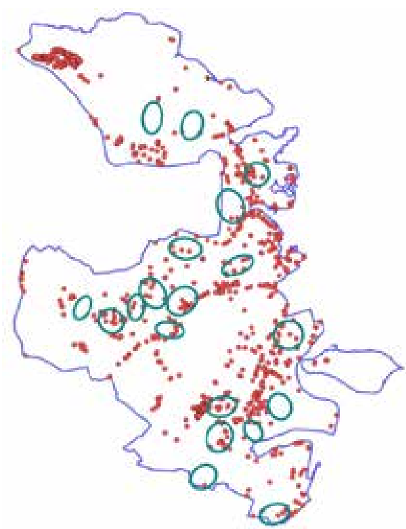


Figure 10: EAS input points in urban and rural zones



Chapter 20

Figure 2: Malta: Popular settlement locations for migrants. Reprinted from Researching Migration and Asylum in Malta

Figure 4: Key areas in Marsa

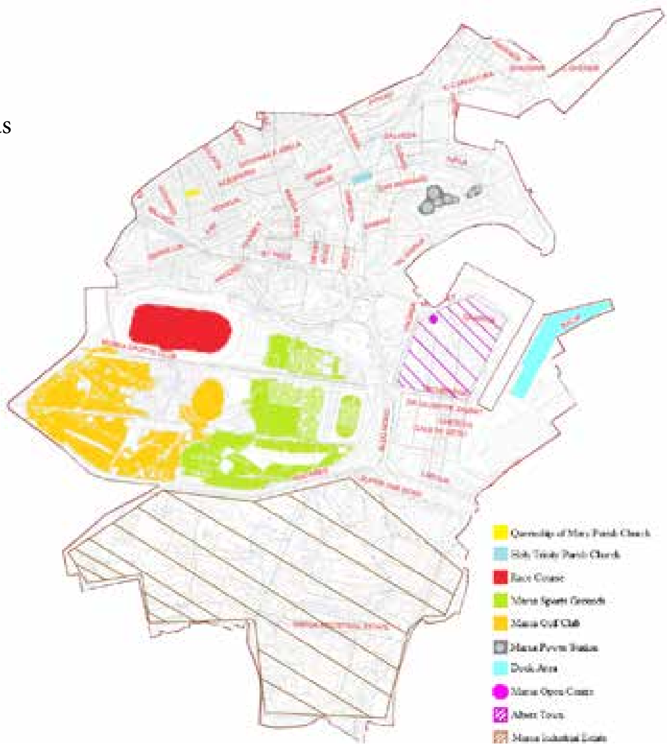


Figure 6: Deterioration point count by ring buffer. Compiled using MapInfo (2012)

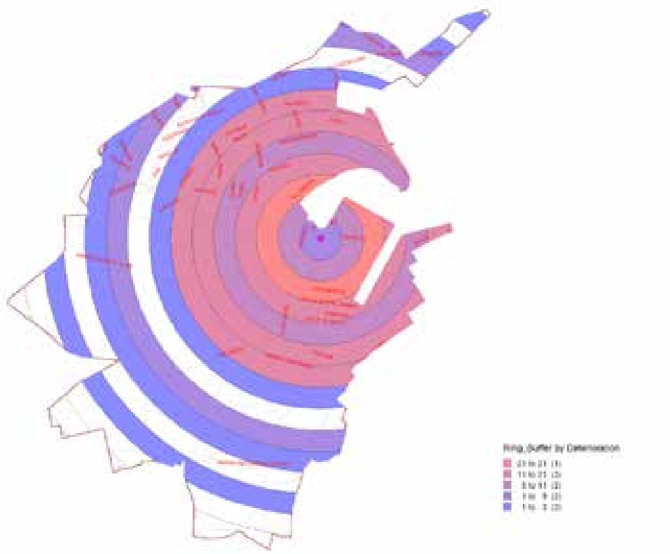


Figure 7: Sexual offences in Marsa from 2010 to 2014 by ring buffer

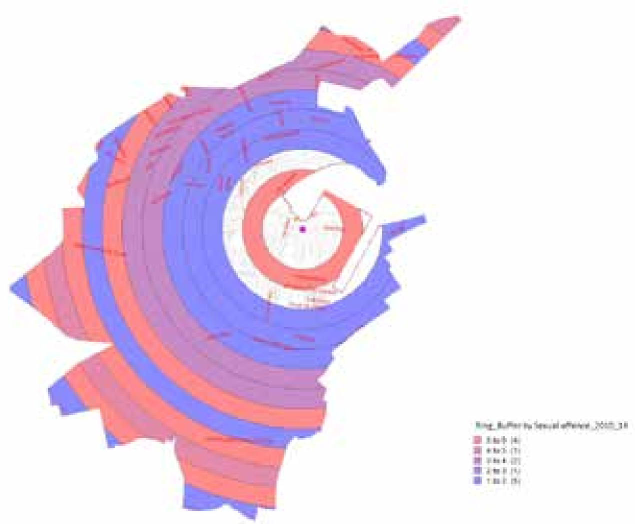


Figure 8. Migrant job waiting hot spots and NNH (red) and 2NNH (green) poverty hot spots. Compiled using MapInfo (2012)

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