

## INTRODUCTION

# Where to for GI? The Who Factor

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“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” (Formosa, 2017, p35). The drive to introduce Spatial Information integration across the Maltese Islands was an ideal, one that brought in technology, methodologies and results. However, as in the classic GIS evolution through the decades pointers on what constitutes a spatial information system were the subject of extensive debate Initially this was driven by the Push – Pull factor where entities using the primitive systems were being pushed by the availability of a mapping system and provision of base maps and hence creating data to fit the system. Initiated in the 1960s through military use, porting the processes to the physical and urban domains in the 1980s and 1990s, further takeup was made in the environmental domains in the 1990s to 2000s and eventually to the social domain in the 2000 to 2010s. Jumping through the decades, the global explosion of GIS and Spatial awareness as well as software, methods and integrative constructs morphed GIS into an availability that made it all possible, particularly through online and web-enabled GIS. This Pull – Push factor caused entities and private organisations to finally break through by creating their own data and then going for the mapping systems that fit their needs, systems that have evolved beyond recognition, both in the proprietary and open-source/open-access arenas.

Just a trip down memory lane to Grimshaw’s 1994 definition of GIS causes one to think:

“A geographical information system is a group of procedures that provide data input, storage and retrieval, mapping and spatial and attribute data to support the decision-making of the organisation” (Grimshaw, 1994)

A missing piece in the spatial puzzle was highly evident: that which caused entities to postpone, stop or even suppress the introduction of spatial information in entities thirsty for the opportunity to create, integrate and jump across domains aiming at societal

change. That missing piece pertained to the WHO (people) factor: if the management, corporate ownership and the relative policy-makers and decision takers were not on board, GI suffered and in turn society.

The people factor is now the most important factor in the spatial field with users practically taking over locational information in every moment either through searching for needs, robotics, environmental studies, analytical functionality and multi-domain spatial analytics.

Hence the need to SpatialTrain, which whilst at an abstract level focuses on the delivery of courses at the diverse qualification strata from certificates to diplomas, degrees and post-graduate degrees, has a more fundamental aspect to it: empowering people at the operational and decision-making levels to partake to an even-playing field in Spatial Information across the public sector and public service. The difficulties identified by Grimshaw (1994) in decades past are still around and SpatialTrain was not unique in experiencing the people factor issues, but its *opus operandi* was to strive for training delivery, which it delivered: an outcome that deserves note. This posits a scenario that the cycle can continue to become an upward spiral as the taught become the tutors for the next generation: a major achievement (Formosa, 2003).

Elaine Sciberras in the prologue stresses that the importance of spatial data within the public administration is growing with the realisation of the applications of spatial data to address EU and national monitoring and reporting requirements. Furthermore, the digital technology in the field of geomatics is growing rapidly necessitating public entities to become more knowledgeable as to how such technology can aid in various fields. Over the past years, EU-funded projects have enabled the public administration to acquire geomatic high-end technology, collate a variety of spatial data and draw up national strategies on the use of spatial data. Training of human resources within the public administration was the next step to ensure the efficient use of such geomatic technology. The SpatialTrain Scholarships Scheme was an ESF-funded project which aimed to provide specialised tertiary education in the field of geomatics to Malta's public administration. Scholarships were provided at Certificate, Diploma, Bachelor and Masters levels. Certificate and Diploma courses were offered through local training, whereas at Bachelor and Masters levels, participants could select a course from an accredited University. Scholarship uptake was multi-disciplinary in the topics selected. Employees participated from a broad range of public entity stakeholders with staff from both at technical and professional levels. The project enabled the knowledge acquired by the scholarship awardees to be disseminated within the different government entities for the respective subject areas. Future dedicated

training initiatives in the geomatics sector will continue to be required at the various qualification levels along with national spatial initiatives for research, geospatial standards and policies.

This publication brings together the results emanating from these studies at MQF Level 4 and 5 (Certificate and Diploma levels). It is with satisfaction that the editorial team presents these papers spread across diverse themes, papers wrought by experts and authors hailing from the technical and professional fields, a literal aggregation of authors spanning the entire qualification levels brought together in their strive to create data, change it to information and hence knowledge across the entities onwards to actions by decision takers. GIS in the Maltese Islands has matured such that integration across the entities is now possible as well as the capacity issues suffered by a small state is now rendered better placed as each expert's knowledge depicted through these papers can be accessed across government.

The publication contains three dedicated editorial papers and thirty six chapters authored by the SpatialTrain contributors: a veritable plethora of new knowledge categorised in seven domains: Air, Land, Water and Marine, Ecosystems, Cultural heritage, Social Wellbeing, Infrastructure and Safety Domains. These chapters can be recategorised by method, delivery, analytics and other facets. However the integrative aspects is pivotal to all as each chapter posits a drive towards spatial functionality that is the Maltese State.

### **The Air Domain**

The first section focuses on the structural concepts and activities that impinge on the air domain, mainly air quality through a unique paper.

Chapter 1 by Ariana Schembri posits that Green Infrastructure (GI) is known to be beneficial both to the environment and to people's well-being, and while such infrastructure can be implemented in a wide range of areas, this study identified the ideal residential buildings where green infrastructure is considered the most favourable in terms of exposure to traffic-induced pollution as well as densely populated areas. The self-developed GIS-based model 'Suitability Analysis for Green Infrastructure in Malta (SAGIM)' was created and used to determine such locations. The study recognised 1,736 priority buildings considered as ideal areas where GI should be incorporated in infrastructure. In addition, an analysis on nitrogen dioxide concentrations was carried out for the years 2017 to 2020 to identify changes in ambient air quality as a result of restrictive measures introduced in 2020 due to the COVID-19 pandemic.

### **The Land Domain**

The second section of the publication depicts a chapter on vegetation spaces within Valletta as part of a built-up area analysis.

Leanne Dalli and Jean Claude Zahra in Chapter 2 sought to evaluate and analyse the built-up area with respect to the vegetation spaces within Valletta, Malta. Geo-processed orthophotos provided by the Planning Authority were used and served as the base data for this project. Furthermore, plotting of the whole capital city was taken up to designate the areas with their respective land cover classification, according to the CLC categories. The area of each polygon and the total area of each layer were found by using the field calculator and a valid expression was inserted. This was assumed to be able to find the left areas such as side roads, main roads, and fortifications. A pie chart was created to evaluate the statistical differences between each layer and to provide a percentage classification of Valletta for preset land cover classes.

### **The Water and Marine Domains**

The third section, comprised of four papers focuses on the use of GIS to map current and ancient coastlines as well as operational activities inclusive of boating activities and vessel detection and monitoring.

Godwin Borg in Chapter 3 takes readers back some 5.33 million years as the study aimed to map the coastline of the land bridge existing between the two continents Europe and Africa before the sea level rose in the Central Mediterranean Sea due to the Zanclean flood leading to the opening of the Gibraltar Straits. This study identifies depths of sea level rise from a seabed anomaly of a particular area through bathymetry, image analysis and interpolations in the central Mediterranean basin and around the Maltese Islands. The study focused on the implementation of the GIS/QGIS™ open-source software and the integration of other software used at Transport Malta, Ports, Hydrographic Office, as Hypack™ and the D-Kart™. This project is beneficial to the history of formation of the Maltese Islands and can be a guide for oil explorations. Understanding the past will help predict the future from similar phenomena of sea depth change and coastal depletion which may arise.

Chapter 4's author Mark Wright brings readers back to the current period in his study on the use of photogrammetry for coastal zone mapping. Through the arrival of good quality consumer end drones, aerial imagery acquisition has become more affordable to both surveyors as well as customers. As UAV's become more readily available, good photogrammetry results are easier to attain. The process of stitching aerial imagery is left

to the myriad of photogrammetry software that is widely available. However, each case scenario brings about different challenges. Such challenges need to be dealt with using proper aerial photogrammetry and image processing knowledge. Failure to adhere to a proper workflow will only bring about poor results. A comparative exercise was carried out, outlining the pros and cons of applying different methodologies.

Sarah Camilleri in Chapter 5 acknowledges the pressures that recreational boating posits as a growing activity in the Maltese Archipelago throughout the summer season. Such activities are sources of pressure on sensitive benthic habitats, for which their management is seen as a priority. Taking the case of Mellieħa Bay, Malta, this project explored available datasets, of which geospatial analysis could contribute to the understanding of such activities. Google Earth™ imagery capturing mooring and anchoring vessels in peak season were analysed in QGIS™ and resulting heatmaps informed on vessel distribution and densities. Furthermore, the overlay of these heatmaps over mapped bathymetry and *Posidonia oceanica* meadows, showed how such activities concentrated in shallower waters and confirmed the presence of such activities over the sensitive habitat. Operational recommendations included organised mooring, no-anchoring zones, and the use of ecological mooring/anchoring infrastructure. Field surveys to corroborate the heatmap results and higher resolution habitat maps could further contribute to the implementation of recommendations.

Chapter 6 takes a focused approach to the use of spatial constructs in the maritime domain. Stephen Grixti states that that Automatic Identification System (AIS) and Synthetic Aperture Radar (SAR) are key technologies in maritime vessel monitoring. When both technologies are fused in synergy, they add significant value in enhancing spatial maritime awareness. This is of particular relevance in occurrences where vessels are uncooperative, where AIS information is intermittent, misleading, or not available. Subsequently, the fusion of AIS and SAR information may be crucial in various operational scenarios, namely: customs and law enforcement, border control, search and rescue, fisheries control, maritime safety, and more. This research is a proof of concept contributing to the development of a platform that analyses and correlates AIS and SAR data over an area. Publicly available datasets are used throughout the research namely: openly available AIS datasets and Copernicus Sentinel-1 SAR imagery. The concept involves the development of a QGIS model that identifies uncorrelated vessels, categorises them, and displays the output on a map in a user-friendly manner.

### **The Ecosystems Domain**

The fourth section, comprised of three papers focuses on the use of GIS to study protected areas, land take in Natura 2000 sites and species distribution.

Chapter 7's Marita Galea covers a project was to survey anthropogenic pressures within a protected site using a consumer-grade drone and to make preliminary observations of their impacts on the ecology and overall integrity of the site. A DJI Phantom-4 was utilised to capture aerial footage of the area of study - Ramla l-Hamra bay. The drone imagery was processed using the photogrammetric software Pix4D cloud, to generate 2D and 3D maps. Vegetation structure and land fragmentation were also evaluated to further process the resultant orthophoto into QGIS software. The use of such effective tools provided further insight on the state of the protected area. When compared to human survey approaches, this study demonstrates that the use of drones for the acquisition and processing of large areas is a more efficient method that saves time, money and human resources while enhancing result accuracy. Drone data, when paired with Copernicus satellite imagery can also offer substantial benefits, since it delivers higher resolution data, as well as fast and flexible acquisition capabilities.

In Chapter 8, Marko Filipovic focuses on the European Regulation 1143/2014 came into force in 2015 to control invasive alien species (IAS). One of the species included on the IAS list of concern is Crimson Fountain Grass (*Pennisetum setaceum*), a species widely spread in Malta. This study used the Crimson fountain grass spatial distribution data collected by the group of environmentally aware citizens, and raw data collected through surveillance carried out by the ERA officers during 2019-2021 as part of the implementation of the surveillance system required under Article 14 of the Regulation 1143/2014. Focus was on plotting populations located in the Mellieħa area using GIS and analysing density and the proximity of such populations to the closest Natura 2000 sites, using NNJoin plugin. Analysis pointed out locations hosting specimens deemed as of priority for control. Two locations are within Natura 2000 sites, and an additional five are in the direct vicinity.

The final paper in this section, Chapter 9 by Stephanie Farrugia, acknowledges that Natura 2000 (N2K) sites in Malta are facing pressures from land take processes. This study analysed the current land take percentage in N2K sites through spatial analysis of buildings and planning data, using QGIS™. The relationship between the development applications approval rate in N2K sites to their proximity to Urban Areas/Rural Settlements for the period 2016 - 2020 was examined. The results show that the protective designation does not seem conducive to lesser land-take and the location of N2K sites adjacent to urban areas or overlapping with Urban Areas and/or Rural Settlements affects land take with most of the smallest sites having a high percentage of land take. A proximity effect seems to play a part in the land take and also in the development applications approval rate. A positive correlation between building density in the land between the Urban Areas and N2K and the development applications approval rate was also observed.

### **The Cultural Heritage Domains**

The fifth section, overwhelmingly a favourite domain amongst SpatialTrain students comprised of twelve chapters. This section covers the datacycles pertaining to cultural heritage, analytical papers on methodological approaches and theme-specific studies.

A site-specific case study is presented by Alexandra Camilleri in Chapter 10 focuses on the locality of Birżebbuġa, in the South of the Island of Malta. The author seeks to understand that Sea Level Rise (SLR) above Mean Sea Level (MSL) may pose a threat to several coastal towns. The Maltese Islands, an archipelago at the centre of the Mediterranean Sea, has a combined coastline of 196 km, with an intensification of urban sprawl located at coastal zones. This project investigates the possible relationship between global warming, coastal erosion and the rise in sea level. With a rich sea faring and military history, the coastline is dotted with remnants of sites of cultural, archaeological, and historical importance. Sea Level Rise may pose a threat to these sites, as the projected SLR may impact and destroy these sites of importance. Birżebbuġa, a southern-westerly town located at the mouth of Birżebbuġa Bay, is used as a case study for this project. The town has sixty scheduled sites of archaeological, historical, and cultural importance. Their proximity to the coastline varies, with some located either at the shoreline or further inland. Nevertheless, as the model created for this project testifies, certain buildings, areas and zones will be more prone to flooding and erosion than others, twenty-three scheduled sites are estimated to be either underwater or at risk when a projected sea level rise of 6m is expected.

Chapter 11's author, Ann Marie Schembri focuses on a event dated April 21, 1615 when Grand Master Alof de Wignacourt inaugurated the first freshwater supply system from Rabat to Valletta, this being the aqueduct which bears his name. The part of the aqueduct which is above ground (from Attard to Floriana), is mostly scheduled by the Planning Authority at Grade 1 (GN.790.94). Nevertheless, most of the underground tracts, particularly from Attard up to Rabat, are not commonly known or scheduled, and therefore, are often threatened by ongoing development. The aim of this project was to identify and plot the parts marked on the 1968 Survey Sheets as well the GIS maps compiled by Natural Heritage Malta . Furthermore, the exercise created buffer zones with varying grades of importance depending on several criteria, such as analysing whether the part is above ground or below ground, extant or destroyed. The exercise confirmed that the unscheduled tract is almost entirely underground, with some exceptions in the vicinity of Wied Qlejja Area in Rabat.

Authors Kevin Borda, Bernardette Mercieca-Spiteri, Gordon Watkinson from the Superintendence of Cultural heritage, in Chapter 10 describe a spatial analytical study

of the discoveries of archaeological remains in the towns of Mdina and Rabat in Malta. The study seeks to approach the latest changes to the Area of Archaeological Importance (AI) for Mdina and Rabat, and assess the incidence of discoveries through the years, thus addressing whether the 2013 enlargement of the AI in this area was justifiable, and whether it requires changes. This study reveals that changes to the AI may in fact be required with further development in the outskirts of Rabat. The spatial analysis used allows the identification of hotspots within the AI, and to formulate prediction model analysis. The interesting results enhance our knowledge on the historical activity in these areas and show how spatial analysis can be used to assess development applications and explore measures that can protect archaeological remains during development in a practical and informative manner.

Chapter 13, authored by Daniela Formosa studies Malta's rich history and how it has ensured that a rich legacy of cultural heritage sites is passed on to the present generations who must strive to conserve and protect it for future generations. One way this is ensured is through the scheduling of heritage sites, a process which creates a large volume of scheduling data, made up of spatial and tabular information on each scheduled site. This project uses QGIS to enable spatial analysis of such scheduled datasets with the aim of generating meaningful information from such data. Networking tools were used to create three different public trail maps for the purpose of sharing them with cultural heritage stakeholders, such as the public, tourists, educational institutions, and entities. These public trail maps not only identified sites with heritage value and connected them together according to function, but also serve to raise awareness and educate different stakeholders about these heritage sites. The benefits and potential of using spatial analysis on heritage data was demonstrated and encouraged as this can greatly aid in conservation.

With cultural heritage being constantly subject to interventions and threats from other industries, Fabio Scicluna in Chapter 14 states that there is both a need and an opportunity for new technologies such as BIM (Building Information Modeling) and GIS in supporting the management and protection of heritage. Malta is witnessing a rising interest in heritage, with many resorting to the media to express their discontent every time heritage is under threat. Besides its influence on the decision-making process, the public has been helpful on several occasions in identifying cultural assets. This project sought to study PPGIS (Public Participation Geographic Information System) to further engage the public in processes relating to heritage identification and promote a fairer distribution of cultural assets, through both a desk-top and a field app data gathering approaches. This study resulted in a functioning prototype, designed, and tested by potential users as a proposal for a democratic approach towards identifying assets of social significance.

Gillian Ascik in Chapter 15 delivers a strong case for viewshed analysis in order to safeguard a unique city. The city of Valletta is a UNESCO World Heritage Site, and its skyline and views are essential to its designation as a site of outstanding universal value. Several recent development projects consisting of additions on buildings within Valletta have unfortunately not been accompanied by the proper visual impact assessments. These assessments are carried out in order to understand the effect developments may have on the historic context and landscape of Valletta. Through the use of selected case studies, this project explored the viewshed analysis tool of QGIS to test its usefulness to predict the impact of a development on its surroundings. The outcome indicated that viewshed analysis results, when compared with real life situations of developments already completed, appeared to be mostly reliable. While factors such as land cover, street width and surrounding developments should be taken into consideration, the overall results indicated the efficacy of the viewshed analysis tool when applied in this situation.

Chapter 16 focuses on improving interconnectivity and visitor experience in Heritage Malta sites. The author Josef Caruana partakes to the statement that part of Heritage Malta's mission statement is to make the sites entrusted to the agency accessible to the public. In accordance with this part of the mission statement, the aim of the project was the design of heritage trails using published data and a Geographic Information System (GIS). These heritage trails were designed and categorised according to location, theme or attribute. GIS was also used to determine the best location for the placement of banners within the UNESCO World Heritage Site of Valletta, by which means visitors to Heritage Malta sites can be directed from one of the sites under the agency's guardianship to another in this city. It is recommended that similar heritage trails are advertised to visitors to the Maltese islands for them to maximise the limited time available during their stay.

Chapter 17 enhances upon the previous chapter and depicts a method to build a spatial layer, one that can be employed across all domains particularly as that depicted in Chapter 15. Kenneth Incorvaja sought to input the data of all the buildings in Valletta, which the Restoration Directorate has restored. This will enable all the data to be stored in one place, thereby facilitating research. The approach used QGIS™ 3.6.3 and Grass™ 7.6.1 software. The Open Street Map™ was used as a base map. For data input, various vector models (points, lines, and polygons) were used to locate all the restored buildings in Valletta in a shapefile. This project aimed to make Valletta with its restored landmarks more accessible to tourists by designing footpaths that lead to historical buildings.

The information gathered on all the restored buildings in Valletta was used to create various tables in the G.I.S. This process enabled us to develop multiple Heritage trails

according to preferred criteria such as the date of building, the type of building (example: church, Auberge, Palazzo) and the location. Furthermore, these footpaths can be used to create Heritage Trails for visitors.

Another study drafted in Chapter 18 by Luke Brightwell focuses on heritage constructs, this time the underground World War II shelters and the risk they experience construction. As a result, archaeological remains are at risk of being potentially damaged or worse destroyed. Therefore, it is necessary to investigate the threat that modern day construction imposes onto archaeological remains, particularly Malta's very own World War II shelters. The objectives of this project were to implement the relevant GIS tools to a known archaeological record and analyse the threat that modern day construction imposes onto these archaeological remains, in this case WWII shelters. Using a study area in Naxxar, in the north of the Island of Malta, QGIS was used to plot all WWII shelters located there, following by generation of a heatmap showing all shelter locations; and analysis of the number of shelters located under the streets, public spaces and private houses, and finally, identification of shelters deemed to be under greater or lesser threat to modern day construction.

Mark Cassar in Chapter 19 takes readers overground once again in his study on fortifications. Throughout many centuries, the fortification walls that surround Malta helped to shape the island's architectural legacy. In the last few years, incentives have been taken to restore such walls to retain their historic value. However, due to the constant reoccurring forms of deterioration, further observations with regards to the source of their damage were needed. Therefore, the overall approach has been to use Geographic Information Systems software to help record and analyse data related to several fortification walls and identify the common forms of deterioration present. For this, a series of restoration projects based on fortification walls were selected around Valletta and Mdina. The results have proven that whilst natural forms of deterioration have occurred, there were other underlying issues that made certain walls weaker than others. In Valletta, poor construction and constant restoration projects every 100 years, led one wall to be deemed inferior to others. On the other hand, in Mdina, the geological implications that surround the fortification walls have effectively contributed to the structural damage that was occurring.

Paola Spadaro in chapter 20 takes readers even higher through the use of unmanned aerial vehicles and their use in studying cultural heritage. Spadaro's study posits that photogrammetry and archaeology have been interacting in the last decades as part of the science of Geographic Information Systems that developed and offered newer fields in the

implementation of both disciplines. Archaeological science had always been forced to deal with the science of measuring surfaces, as well as with the issue of a visual restitution of the cultural heritage. The project was focused on the relationship as fruitfully established between an archaeologist and the methodology of photogrammetry. The application of a photogrammetry-based software, by using previously acquired imagery of an archaeological site, resulted in the creation of a reliable orthoimage. By using the imagery outputs and the dedicated software, the photogrammetry output provided a useful tool for understanding and reconstruction of the archaeological site.

The final Cultural Heritage section paper published as Chapter 21 by Yasmin Cassar focuses on environmental and the composition of a particular heritage that was the Maltese Railway. Competing urban construction puts features such as railway routes and ancillary structures at great risk. Geographic Information Systems (GIS) offer efficient support in the investigation, assessment, and management of railway heritage. This analysis reviewed the status of the application of GIS on linear railway heritages studies using the case study of the Maltese Railway, alongside a geodatabase design which facilitated the identification of existing and destroyed features in relation to the original route. The study provided an identification of notable characteristics in relation to the historic route, namely the large spatial extent of territory, the dynamic contextual environment, and the complex composition of heritage elements.

### **The Social Wellbeing Domain**

The sixth section, comprised of four papers focuses on the use of GIS to map the betterment of social wellbeing, with two papers analysing accessibility through pavements whilst another two look into obesity and testing and vaccination centres during the Covid-19 pandemic.

Elaine Camilleri in Chapter 22 analysis the accessibility of pavements for people with visual impairment the town of Naxxar, specifically the parish church area vicinity. Everyone uses pavements hence safety needs to be prioritised with precautions. People with visual impairment require adaptable safety measures of pavements to be used independently and safely. Data was gathered through site visits, observations, capturing photos and statistical data. Results and spatial analytical tools helped to identify the environmental safety measures required to improve pavement accessibility. This study highlights how the Maltese pavements are not adequately accessible. The spatially structured maps enable identification of the various accessibility obstacles that visually impaired people encounter. Recommendations were identified to improve the quality of pavements to be safely and accessible, together with mobility and orientation training and educational awareness.

The next study, Chapter 23 by Gary Lee Roynane, developed an accessibility map of the local centre of the town of Paola. This map aimed to include several Places of interest and most importantly this map included information of where accessible sidewalks and non-accessible sidewalks can be found. The Area of Interest was identified following the identification of the places of interest, so that no place which could be of need and service to the community, was left out. QGIS software was used for data analysis while onsite data was captured using a mobile device and an application called QField. This project found two major flaws with respect to the pavement accessibility and obstructions. A map was derived which aimed to help the community of this town with pavement accessibility. This was intended both for persons with movement disabilities such as wheelchair users, as well as parents with strollers, persons with visual problems or lifting heavy objects.

Chapter 24 by Marika Borg acknowledges that obesity prevalence has increased in Malta. Obesity is a multifactorial and complex problem and there is no easy solution to address it. GIS techniques were used to understand health data better and guide resource allocation. The aim of this study was to carry out a spatio-temporal analysis of obesity prevalence amongst adults living in Malta & Gozo. Non-spatial data was obtained from the European Health Information Survey of 2002 and 2014. Tabular data was integrated in the locality polygons for Malta in QGIS. Spatial analysis was done using QGIS, creating choropleth maps, heatmaps and performing spatial autocorrelation analysis using LISA and Moran's I functions. The overall average prevalence of obesity in Malta increased by 2% between 2002 and 2014 (23.2% to 25.2%). In 2014 while the obesity prevalence varied by 6.2% at the region (LAU1) level, it varied by 49% at the locality (LAU2) level. Gozo region had the highest obesity prevalence. The spatial distribution of obesity in Malta varied significantly.

Another health-related spatial study, that by Tania Cardona, offers readers an interesting read on how GIS can be used to during potential and through the Covid-19 actual experiences. The COVID-19 pandemic brought the world to a halt, with disruption of normal life all over the world. COVID-19 testing and vaccination remain the cornerstone of fighting the pandemic, and therefore, removal of geographical barriers to accessing these services can help hasten the return to normality. This project aimed to map Malta's public resources for COVID-19 testing and vaccination and analyse their distribution to assess for equitable access. This was carried out using captured data of the centre locations and routinely available datasets. The results showed that most testing and vaccination centres are clustered in the Central and Harbour areas, matching the population distribution. A shareable map that can be used by the public was created to help improve access to these sites. The major recommendations are to plan future testing

and vaccination sites by taking into consideration the population distribution, and to regularly update the shareable map.

### **The Infrastructure and Safety Domains**

The seventh and final section, comprised of thirteen chapters focuses on the use of GIS to map the multi-faceted domain that are infrastructure and safety. From four dedicated chapters on communications and broadcasting, the sections depict chapters ranging from resource renewal, through green infrastructure, utilities, obstruction modelling, transport and climate change. This section delivers an eclectic coverage of what fruits emanating from GIS and spatial information knowledge trees can be plucked.

Chapter 26 by Adrian Galea and Amadeo Vella, states that broadcasting is an effective means to disseminate information which may be received directly by the general public and includes sound or television transmissions. It is an effective and reliable means for point-to-multipoint information delivery. Sound broadcasting is of relevance to citizens and according to the Broadcasting Authority, 64% of the Maltese residents listen to radio programmes (Broadcasting Authority, 2020). FM (Frequency Modulation) sound broadcasting is one of the most popular technologies for the reception of sound programmes in Malta. FM sound broadcasting transmissions can be categorised in either national or community (localised) and their reception area is dependent on various factors, including the antenna height and effective radiated power. Malta has an uneven terrain and the building clutter is very dense especially in urban areas. This offers challenges for prospective operators when searching for the best site to host their transmission infrastructure. This paper explored the use of Quantum GIS (QGIS) to identify appropriate transmission locations within a predefined locality using a high-resolution Digital Elevation Model (DEM) dataset. A viewshed analysis was carried out to establish a line-of-sight coverage map of the locations visible from selected candidate sites. The validity of the outcome was then assessed by means of a path-specific propagation prediction model using a radio spectrum planning tool, namely ATDI HTZ communications. Although, in terms of radio coverage, the accuracy of the viewshed analysis was limited, it was concluded that QGIS provides an effective tool in determining appropriate transmission locations.

Chapter 27's author Clara Scerri Delia moves the topic to the analysis of how Mobile communications have revolutionised our way of connecting with one another. They have become the *de facto* means of communication. They are portable, always at hand, relatively fast and allow for both voice and data communication. To facilitate mobile communications, service providers need to install radiocommunications equipment (Radio Base Stations) in the areas where service is required. In the case of Malta, equipment

is installed nationwide. Radio Base Stations expose their surroundings (including people) to electromagnetic waves. In most cases, radiation limits are within safety margins as predefined in international standards. Notwithstanding this, people are still concerned. This study maps the location of the mobile radio base stations in Malta. Concurrently, it maps the location of the complaints received by the Malta Communications Authority (MCA) in relation to mobile communications. In turn, it establishes the correlation that may exist between the two sets of data and evaluates the results.

In Chapter 28, David Scerri further delves on the radio-transmission related electromagnetic fields exposure in children's recreational areas. The usage of wireless networks and mobile communication is on the increase. This requires hundreds of radio base stations to be deployed. The electromagnetic environment is therefore ever present and increasing in both urban and non-urban areas. Consequently, exposure to ElectroMagnetic Frequencies (EMF) is inevitable. All around the world, Malta being no exception, these antenna installations have induced a public concern about exposure to electromagnetic fields. This study aimed to reassure the public that the children's public recreational areas were safe from EMF exposure, through nationwide real-lifetime measurements. Geographic Information Systems and spatial extrapolation techniques provided the right framework for setting up EMF intensity maps which depicted an estimate of the EMF exposure levels. Results obtained showed that the exposure levels at street level to EMF around all the Maltese islands were well within the safe reference levels.

Chapter 29 by Kevin Aquilina also focuses on EMF exposure from Over-The-Horizon transmitting towers, where the concept of mobility plays an essential role in the development and use of new technologies. This leads to an increase in the number of wireless connected devices which are intended for both personal and commercial/industrial use. Such use of wireless equipment has led to an increase in the number of radio communication transmitters, and this led to an increase in concerns among the public about ill health effects that may be caused by electromagnetic fields generated by such radio transmitters. The electromagnetic fields generated by the radio transmitters are directly proportional to the power of the radio waves being emitted from the respective antenna. Around the Island of Malta, there exists a number of high power Over the Horizon Transmitting Towers. One of these towers is in Triq Fidiel Żarb in Gharghur. This site is used to transmit all the local FM Radio Stations across the entire geographic footprint of the Maltese islands.

Anna Gureva-Mihova takes readers on a journey in Chapter 30 that states that Protected Areas (PAs) connectivity is crucial for safeguarding nature and biodiversity.

This project provided GIS analytical evaluation of clustering of terrestrial PAs, as a sign for connectivity, which is essential for the progress towards achieving Malta's national biodiversity targets. This study examined spatial clustering of urban areas by using the Nearest Neighbour Analysis Module in QGIS. GIS geoprocessing functions were applied to identify potential locations for green infrastructure (GI) projects in urban areas and along major roads. With this aim, buffers of 300m, 500m and 1000m around PAs were created and intersected with urban areas polygons and the European Transport Network dataset. Potential locations were derived which bordered existing PAs to promote spatial multifunctionality. The analysis and the literature suggested that PAs and urban areas in Malta are clustered. In addition, GI features were proposed as a way for enhancing connectivity, mitigating land fragmentation, strengthening urban resilience and promoting community wellbeing.

The use of photovoltaic systems to generate power is ideal for Malta due to the solar abundance the Islands receive, a topic covered in Chapter 31 authored by Charmaine Zahra. The project aimed to locate the optimal site for solar panels and to calculate the solar potential on building envelopes using non-commercial Geographic information systems (GIS) tools, specifically the Urban Multi-Scale Environmental Predictor (UMEP) plugin (Lindberg et al., 2018). High quality Digital Surface Models (DSMs) obtained from Light Detection and Ranging (LiDAR) data; and meteorological data for the Maltese Islands, were used to compute the height and aspect raster of building envelopes and the annual solar power (irradiance) of building roofs at the pixel level was obtained as the final output. This is a relatively new application for Malta and is an easily replicable method. It can be used to build an irradiance map and help professionals and citizens alike to decide whether to invest in and install solar energy systems on buildings.

Chapter 32 by Claudia Attard and Sergio Tartaglia state that GI has a major say in the use of enabling GIS for Waste Management data management. The consultation document for a Long-Term Waste Management Plan 2021-2030 for the Maltese Islands considers waste data management to be the key to success for sustainable waste management. This paper combined two research projects which have analysed the novel concept of designing and developing an integrated system as a first step towards propagating sustainable waste management practices. It proposed a framework which aims to serve as an integrated and innovative model that supports spatial decision-making justified by a data-centric system using real-time context-aware solutions to address waste management. This paper illustrates the potential use of mobile GIS web applications as 'enablers', proposing ArcGIS Online© as an online cloud-based mapping tool to develop a prototype of a Waste Data Management System, focusing on the collection and visualisation of real-time data vis-a-

vis the collection of recyclables in Malta and Gozo from bring-in sites and the door-to-door initiative. It explained how GIS solutions have the potential to redefine waste data management as situational, collaborative, and lifelong.

Chapter 33 by Joseph Bianco and Susanna Bonello depict a case scenario focusing on the impacts of sea-level variations on low-lying areas along the coast. The study was driven by a situation where Triq ix-Xatt Sliema in the area known as Sliema Ferries within Marsamxett Harbour, tends to suffer from flooding under certain weather conditions, such as under the effect of seiches. The aim was to model long-term potential impacts whilst providing information on how this could affect decisions related to road infrastructure upgrading and improvements required in the future in view of potentially impacted land-uses. The knowledge and data available at the Hydrographic Office and the Traffic Management and Road Safety Unit within Transport Malta, were aggregated fused to combine tide data and geographic data of the coastal road zone, to visualise the spatial relationship and produce a representation of the inundation events at various sea water levels. Key results showed that when the water level reaches between 0.60m and 0.90m, parts of the road, bus lane and parking area are inundated. Engineers would need to take these results into consideration with the aim to mitigate the impacts at the potentially affected uses.

Kevin Ciantar in Chapter 34 takes the readers on a drone and LiDAR experience, specifically that pertaining to the Enforcement Directorate of the Malta Planning Authority (PA), which is responsible to monitor land use, investigation of its illegal development, and intensification of areas already subject to enforcement actions. Dangerous locations, inaccessible sites, and quantifications of large quantities of material, make the investigation process challenging, with traditional methods. To overcome this barrier, this project used drone -captured imagery to detect intensification of illegal activity from excavation and deposition of granular material. Data was processed with PhotoScan™ to produce a dense point cloud and a digital surface model (DSM), that was exported to QGIS™ where it was compared to 2018 DSM data of the Planning Authority. Differences in elevation were computed through Raster Calculator™ with volumes also calculated outputted.

In Chapter 35, Mark Anthony Scotto posits a paper on safe cycling and e-bikes. The author describes a design of a safe cycling route for use by Mountain Bikes, E-Bikes and similar. Several criteria were taken into consideration which included the avoidance of heavily trafficked roads, in particular, major arterial roads, the avoidance of steep inclines, the avoidance of long inclines and the length of the route. The route had to be achievable within preset hours at typical speeds cycled by beginners. For new riders in hilly Malta

this is around 16 km/h. Beginners cycling speed varies significantly depending on the elevations and inclines that are encountered along the route. The route had to be circular. The chosen location were the Southern Harbour cities and towns in Malta of Paola, Isla, Bormla, Birgu, Kalkara, Xghajra, Marsascala and Żabbar due to their built cultural heritage. The route was not intended as a heritage trail but rather as an interesting route that allows one to Appreciate this heritage while cycling. The project was carried out using QGIS, QGIS plugins and other GIS software.

Chapter 36 by Massimo Caruana presents a 3D digital model of a targeted building obtained by using images taken from a drone. The study area is King Nikola's Palace in Bar, Montenegro. The high-resolution 3D model of King Nikola's Palace allowed the construction of a Digital Elevation Model (DEM) and orthomosaic. This study serves as a proof of concept to demonstrate the potential upgrade in the acquiring of terrain and obstacles data and how elevation can be quantitatively analysed in terms of GIS methods. Furthermore, the technique used in this project represents the importance of a harmonized regulatory framework for the integration of drones into the aviation system. The aviation sector is faced with the difficult task of ensuring public safety with responsibility and consequently this factor is accorded the highest on any other factor. Through the aerial images and Geographic Information System (GIS) software results were achieved which can thus be exploited towards terrain and safety studies and used in the aviation sector.

Chapter 37 by Naomi Galea explores Terrain and obstacle analyse for air traffic safety. The Electronic Terrain & Obstacle Database (eTOD) of an airport contains terrain and obstacle geospatial data, according to specification set by the International Civil Aviation Organisation (ICAO), because objects can impose hazards to air navigation at take-off and landing. This database is updated every 28 days. Geoprocessing of LIDAR data through open-source software such as Cloud Compare, LAStools, Fugroviewer and QGIS, makes it possible to process LAS files. GEOTIFF files DEM model was used for the creation of a contour file, used to determine terrain profiles. The creation of the obstacle database was created through digitization of each building block and creation of polygons. Introducing a centroid in the middle of the polygon, was deemed a suitable reference point for the identification of the obstacle. As a result, centroid coordinate, elevation, and identification reference code, define the obstacle in the eTOD database.

The final sectional Chapter 38 by Patrick Cachia Marsh looks at transport network analysis. Network centrality is a measure of the primacy or importance of certain nodes in a network over others. Centrality analysis is an important procedure within wider network analysis for both physical and intangible networks. Indeed, regarding transport

networks, such analysis can assist transport planners to identify and exploit the primacy of key network nodes to ensure the maximum effectiveness of transport policy and optimum return of investment in transport infrastructure. This project analysed the four prime centrality indices to measure network centrality (degree, closeness, betweenness, eigenvector), discussed their effectiveness and developed a new index based upon these. To demonstrate the utility of this research, the developed index was used to identify optimal locations of transport hubs in a regional transport network. The regional transport network of Sliema-Gżira was used as pilot.

### **A Word in Space**

Saviour Formosa posits some thoughts on the role spatial information, technologies and a drive to affect change wrought to investigate a zone replete with beauty but also mystery and danger. A case study on Għar Lapsi in 2019 highlights the methodological approaches taken to understand the structural aspects of an erosion-prone, the technologies employed and develops a case for further research into the employment of space and time to analyse changes in cliff faces. Employing unmanned aerial vehicles, terrestrial laser scanners and backpack scanners as well as videos and imagery. Formosa depicts a series of processes that covered the data cycle: design, capture, cleaning, integration, analysis, outputs. The paper delivers on a million-euro balcony, a tunnel 'discovery, an eroded cliff and provides tools for analytical studies through WebGL.

Malcom Borg concludes the publication with an overview of how society evolves through its use of information, particularly spatial information. As the domains become more integrated. GI becomes more unobtrusive, eventually becoming part of everyday activities where users would not need to understand the technology but partake to its fruits.

In conclusion, this publication delivered forty-two unique caches of knowledge emanating from spatial informatics, an outcome that posits a firm observation that GI knowledge and expertise can only spread wider. The thematic sectors as covered due justice to the endeavour to embark on the SpatialTrain initiative, an initiative that sought to expand the people factor and enhance knowledge gain. To this end, the chapters offer a sound read for newcomers to the field and experienced masters of their own domain.

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