CHAPTER 17

Sustainable Underground Development

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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

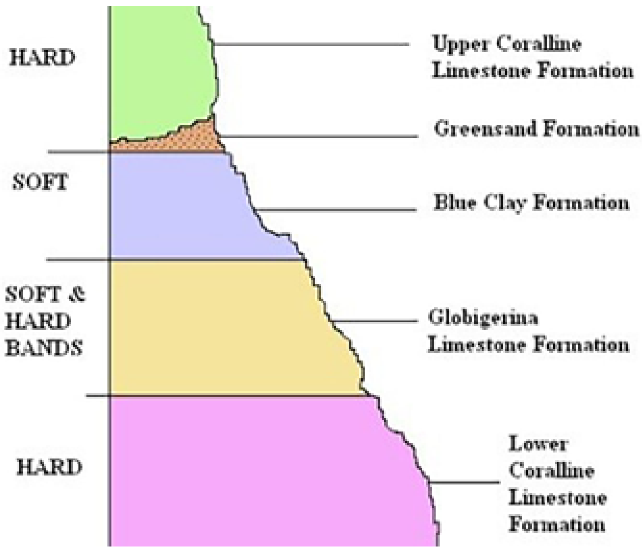
Source: (Politecnica, 2015)

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

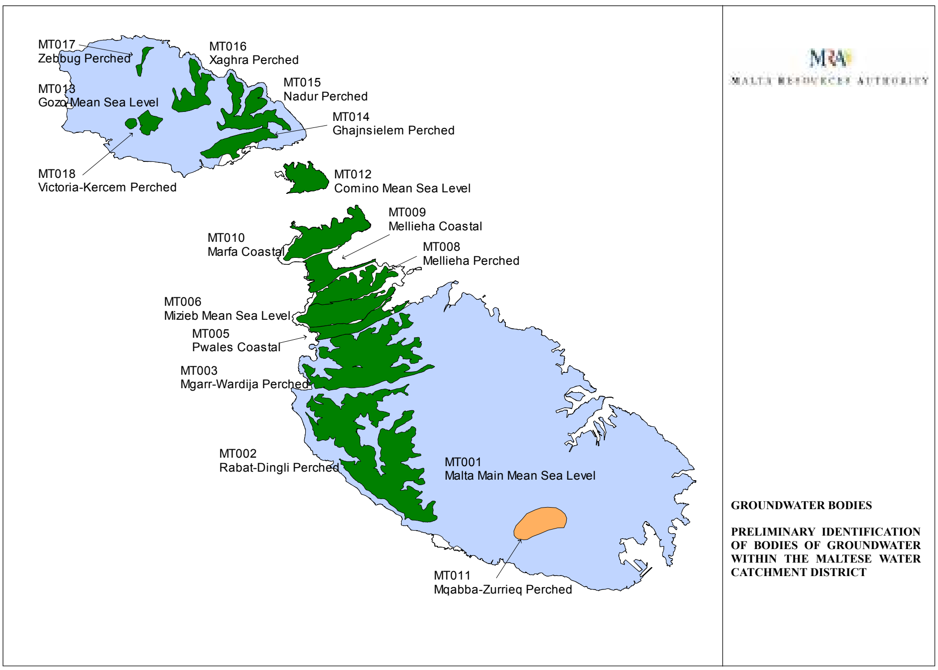
	Recycled	*Recovered*	*Landfilled*	*Disposed at Sea*	*Others*	*Total*
2004	19,916		2,580,454	210,404		2,810,774
2005	15,332		1,970,883	357,942		2,344,157
2006	101,756		2,061,340	329,426		2,492,522
2007	243,818		2,110,641	146,205		2,500,664
2008	173,982		1,522,000	300,360		1,996,342
2009	63,463		462,584	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.

References

Armstrong, W. (1991). *Marsaxlokk Bay Development Area Local Plan,* Malta Underground Space Planning. Malta: Planning Services Division, Ministry for Development of Infrastructure.

Bobylev, N. (2009). *Mainstreaming urban underground space into a city's Master plan.* Land Use Policy, 26(4), 1128-1137. doi:10.1016/j.landusepol.2009.02.003

GoM. (1854, June 10). *Code of Police Laws (Cap 10).* Retrieved August 31, 2015, from www.justiceservices.gov.mt: http://www.justiceservices.gov.mt/DownloadDocument.aspx?app=lom&itemid=8575

GoM. (1874, January 22). *Civil Code (Cap 16).* Retrieved August 28, 2015d, from www.justiceservices.gov.mt: http://www.justiceservices.gov.mt/DownloadDocument.aspx?app=lom&itemid=8580&l=1

GoM. (1935, October 8). *Chapter 88 Land Acquisition (Public Purposes) Ordinance.* Retrieved August 28, 2015, from www.justiceservices.gov.mt: http://www.justiceservices.gov.mt/DownloadDocument.aspx?app=lom&itemid=8632

GoM. (2008, October 7). *Subsidiary Legislation 423.32, Borehole Drilling and Excavation Works within the Saturated Zone Regulations.* Retrieved August 28, 2015, from www.justiceservices.gov.mt: http://www.justiceservices.gov.mt/DownloadDocument.aspx?app=lom&itemid=11782&l=1

GoM. (2013). *Rainwater Flood Relief Project.* Retrieved August 23, 2015, from Government of Malta: https://mti.gov.mt/en/Pages/WASD/PROJECTS/Rainwater-Flood-Relief-Project.aspx

GoM. (2015a). *SPED.* Floriana: Malta Environment and Planning Authority.

GoM. (2015b). *Legislation, Policy and Guidance - In Force.* Retrieved August 28, 2015, from Malta and Environment and Planning Authority (MEPA): https://www.mepa.org.mt/ghlp?doctypeid=1&groupid=74&plan=Grand%20Harbour

GoM. (2016, January 26). *Legislation, Policy and Guidance Document Details.* Retrieved July 2, 2016, from www.pa.org.mt: http://www.pa.org.mt/LpDocumentDetails?syskey=1782

Huanqing, L. (2013). *An Integrated Strategy for Sustainable Underground Urbanization.* Lausanne: École Polytechnique Fédérale de Lausanne. doi:10.5075/epfl-thesis-5869

ITA-AITES. (2010). *Planning the use of underground space.*

Kamal-Chaoui, L., & Roberts, A. (2009). *Competitive Cities and Climate Change.* Paris:

OECD Regional Development Working Papers. doi:10.1787/218830433146

MEPA. (2010). *The Environment Report 2008*. Malta: Malta Environment and Planning Authority. Retrieved August 10, 2015, from http://www.mepa.org.mt/ter

MIDI plc. (2015, May 11). *Tigné Point*. Retrieved August 23, 2015, from http://www.midimalta.com/: http://www.midimalta.com/news.aspx?nid=1041

MRA. (2004). *A Water Policy for the Future*. Retrieved August 28, 2015, from Malta Resources Authority (www.mra.org.mt): http://mra.org.mt/wp-content/uploads/2012/08/17.1.consultation-document-water-policy.pdf

MRA. (2012). *WFD – Identification of Groundwater Bodies*. Retrieved August 30, 2015, from Malta Resources Authority (www.mra.org.mt): http://mra.org.mt/wp-content/uploads/2012/08/wfd-Groundwater-Bodies.pdf

MSDEC. (2014, January). *Waste Management Plan for the Maltese Islands*. Retrieved August 28, 2015, from Ministry for Sustainable Development the Environment and Climate Change: http://environment.gov.mt/en/document%20repository/waste%20management%20plan%202014%20-%202020%20-%20final%20document.pdf

National Research Council. (2013). *Underground Engineering for Sustainable Urban Development*. Retrieved July 15, 2015, from The National Academies Press: http://www.nap.edu/catalog/14670/underground-engineering-for-sustainable-urban-development

Politecnica. (2015). *Politecnica Ingeneria e architettura*. Retrieved August 28, 2015, from Flood Relief Project: http://politecnica.it/en/commessa/flood-relief-project/

Rogers, R. (1997). *Cities for a Small Planet*. (P.Gumuchdjian, Ed.) London: Faber and Faber.

Seismic Monitoring & Research Unit. (2012, October 1). *The Geology of the Maltese Islands*. Retrieved August 30, 2015, from University of Malta (www.um.edu.mt): https://www.um.edu.mt/science/physics/smru/generalinformation/geologyofmalta

Spiteri, D., Scerri, C., & Valdramidis, V. (2015, May). The Current Situation for the Water Sources in the Maltese Islands. *Malta Journal of Health Sciences,* 2(1), 22-25. doi:http://dx.medra.org/10.14614/WATERMALTA.2.1.22

Sterling, R. L. (1996, July). *Going Under to Stay on Top, Revisited. (R. L. Sterling, Ed.) Tunelling and Underground Space Technology,* 11(3), 263-270. Retrieved August 30, 2015, from http://www.sciencedirect.com/science/article/pii/0886779896000211

Sterling, R. L., Admiraal, H., Bobylev, N., Parker, H., J.Godard, I.Vahaaho, Rogers, C.D.F., Shi, X., and Hanamura, T. (2012). Sustainability issues for underground space in urban areas. Proceedings of the ICE - *Urban Design and Planning*, 165(4), 241-254. doi:10.1680/udap.10.00020

United Nations. (2014). *World Urbanization Prospects*. New York: United Nations.