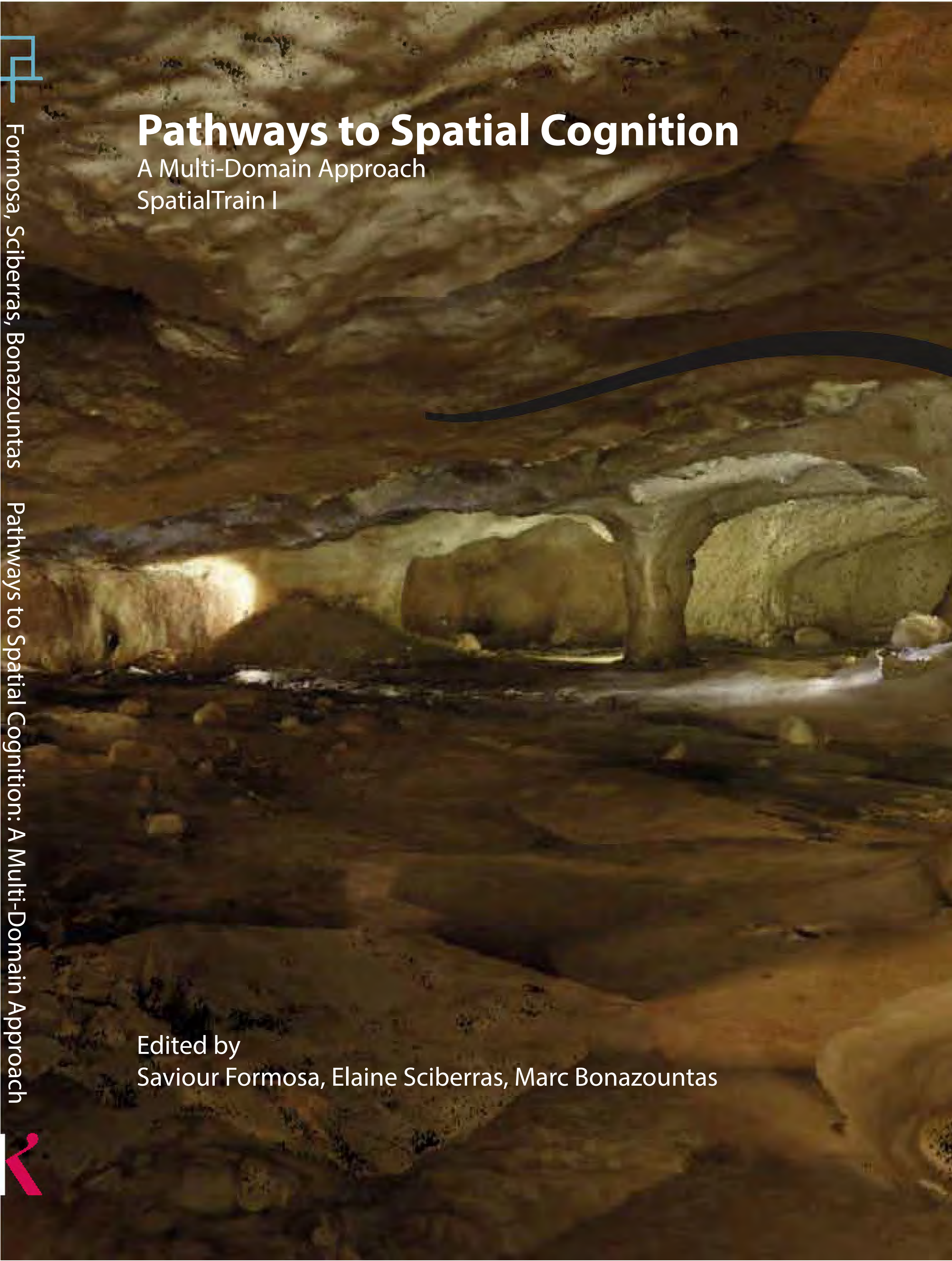

Pathways to Spatial Cognition

A Multi-Domain Approach

SpatialTrain I

Edited by
Saviour Formosa, Elaine Sciberras, Marc Bonazountas

Formosa, Sciberras, Bonazountas Pathways to Spatial Cognition: A Multi-Domain Approach

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PLANNING AUTHORITY

EU funds for Malta 2014-2020

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SpatialTrain I

This publication is funded by the ESF.04.071 SpatialTrain Scholarship Scheme. This project is part-financed by the European Union – European Social Fund (ESF) under Operational Programme II – Cohesion Policy 2014-2020, "Investing in human capital to create more opportunities and promote the well-being of society".

ISBN 978-9918-23-093-8 (paperback)
ISBN 978-9918-23-094-5 (e-book)

Production: Kite Group
Cover: Saviour Formosa
Printed by: Poultons Ltd.

Figures in Colour

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.

Operational Programme II – European Structural and Investment Funds 2014-2020
"Investing in human capital to create more opportunities and promote the well-being of society"
Project part-financed by the European Social Fund
Co-financing rate: 80% European Union Funds; 20% National Funds

To the ones who strove to achieve, those daring to cross new boundaries, those who managed to break the inter-domain barriers.

To all those who sought to achieve a dream, deliver a project and achieve qualifications during a work-study endeavor.

And to all those who pushed the boundaries whilst waiting for SpatialTrain to morph from an idea into a fruitful and implementable outcome.

To them we dedicate this publication as a springboard for further studies and the furthering of spatial knowledge to the country.

ACKNOWLEDGEMENTS

Thanks goes to all those who made this book happen, the Planning Authority, the University of Malta, the ESF mechanism through the Planning and Priorities Co-ordination Division (PPCD), the different entities who partook to spatial information during the past decades striving to push GIS to its fruition. In conjunction with SIntegraM, a sister ERDF project, SpatialTrain sought to deliver the training and research component in a veritable adventure aimed at bringing together all-spatial data related entities within one single data transfer and sharing core, whilst identifying those knowledge lacunae and morphing it to ensure delivery in governance, operational functionality and academic research within a central GI core.

Thanks also goes to the authors who dedicated the past years towards the study of unique domains, coming together to achieve collaboration across the entire data cycle, with projects ranging from data design, capture, cleaning, analytics, outputs and dissemination. Technologies, methodologies and deliverables are brought to the fore in order to achieve this outcome. It is not trivial to bring together specialists in diverse domains to focus on a common foundational element as is spatial information and achieve a cross-theme speak between the domains and the subsequent informational layers, Such is the nature of spatial information: data and subsequently information can be overlaid and this is what the projects achieve: a sharable, multi-thematic, multi-disciplined cross entity system of systems. Domains included Air, Land, Water and Marine, Ecosystems, Cultural Heritage, Social Wellbeing, Infrastructure and Safety and Security.

On an international academic front, the collaboration between the editors, the course delivery entities and the respective tutors has rendered a just result to each of the students who partook to the project at the L4 and L5 levels.

The authors deserve a veritable round for the endurance they showed in their drive to deliver: Aquilina Kevin, Asciak Gillian, Attard Claudia, Bianco Joe, Bonello Susanna, Bord Kevin, Borg Godwin, Borg Malcolm, Borg Marika, Brightwell Luke, Cachia Marsh Patrick, Camilleri Alexandra, Camilleri Elaine, Camilleri Sarah, Cardona Tania, Caruana Josef, Caruana Massimo, Cassar Mark, Cassar Yasmin, Ciantar Kevin, Dalli Leanne, Ellul Alan, Farrugia Stephanie, Filipovic Marko, Formosa Daniela, Galea Adrian, Galea Marita, Galea Naomi, Grixti Stephen, Gureva-Mihova Anna, Incorvaja Kenneth, Mercieca Spiteri Bernardette, Ronayne Gary Lee, Scerri David, Scerri Delia Clara, Schembri Anne Marie, Schembri Ariana, Scicluna Fabio, Scotto Mark Anthony, Spadaro Paolo, Tartaglia Sergio, Vella Amadeo, Watkinson Gordon, Wright Mark, Zahra Charmaine and Zahra Jean Claude.

Finally, a word of appreciation to those thematic experts who reviewed the authors' works during study and in delivering their topics for this publication.

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PROLOGUE

The SpatialTrain Scholarships Scheme Project

Elaine Sciberras

Keywords: SpatialTrain, geomatics, GIS training, spatial data, public administration

Introduction

The use of spatial data at a national level is growing steadily due to the realisation of the application of spatial data in various thematic areas. These range from a simple use of navigation using free commercially available maps on one's mobile devices to more focused applications on querying datasets to obtain value-added maps, statistics and information systems. Within Malta's public administration system, at the time of writing, various entities are already using digital maps for various applications. These can range from the use of the Planning Authority's (PA) basemap and aerial imagery for spatial planning, added value maps for infrastructure and transport planning, environmental spatial data for both environmental monitoring and reporting, to highly specialised spatial data acquisitions using Unmanned Automated Vehicles (UAVs) and lidar scanners for detailed smaller scale analysis.

In recent years, the importance of the use of spatial data within the public administration has taken greater precedence given the investment in high-end technology for data capture. The concept of digital transformation and the contribution towards EU's digital strategy (European Commission, 2022a) are key elements for pushing the digital drive in the field of Geomatics. Indeed, spatial digital technologies are instrumental in providing knowledge and driving policies related to issues such as the EU's Green Deal (European Commission, 2022b), the European Commission's Space Strategy for Europe (European Commission, 2016), the European Environmental Agency's (EEA) reliance on spatial data for land monitoring (Jensen, 2014), the European Spatial Planning Observation Network's (ESPON) formulation of territorial development policies (ESPON, 2022) and monitoring the UN's Sustainable Development Goals (SDGs) (UN, 2022).

Recent technological developments, particularly in the fields of digital mapping, remote sensing and imagery and mobile phone apps, were a game changer for spatial data. As the technology continues to develop, the availability and the quality of spatial data will increase (Jensen, 2014).

A significant portion of such high-end technology has been acquired through EU-funded projects, such as the PA's *ERDF.02.030 SIntegraM - Developing Spatial Data Integration for the Maltese Islands* (Planning Authority, 2017) and its predecessor, the *ERDF 156 - Developing a national environmental monitoring infrastructure and capacity: shifting the state of access* (Hili, 2014). The latter project resulted in the design and establishment of national monitoring programmes and baseline surveys in the areas of air, water, radiation, noise, soil and marine and monitoring equipment for air, noise and radiation monitoring. The SIntegraM project deliverables included geospatial technology such as aerial, terrestrial and marine scanners, an updated national basemap, an online spatial information systems and the development of a National Spatial Digital Initiative (NSDI). The digital drive is one that should be accompanied by an equal investment in spatial information systems for the dissemination and updating of data, data harmonisation across public entities and the creation of spatial data strategies. The acquisition of spatial datasets also allows a plethora of data analysis to be carried out. It is such data analysis which enriches the value of the data being acquired. Spatial outputs can provide valuable information and answers to the researcher, policy maker and the decision maker. This can range from understanding the current processes in land use planning with respect to environmental requirements, simulation for events such as flooding, and 3D visualisations of specific scenarios (Formosa, 2017)

Once the investment in spatial technologies is initiated, the efficient and intelligent use of the acquired spatial data follows. This involves activities such as the data analysis, data harmonisation and sharing, simulation and 3D modelling. Such a plethora of data usages are key to ensure an efficient use of spatial data acquired to be made available within public entities. Hence, training of public administration staff is vital to maximise the use of spatial data within their respective entities. Specialised training in the field of geomatics within the public administration was the drive behind the SpatialTrain Scholarships Scheme project.

Project Scope

The ESF.04.071 SpatialTrain Scholarships Scheme project was part-financed by the European Union – European Social Fund (ESF) under Operational Programme II – Cohesion Policy 2014-2020, "Investing in human capital to create more opportunities and promote the well-being of society".

The SpatialTrain Scholarships Scheme aimed to provide quality tertiary education in the field of geospatial technology (geomatics) to the public administration within government entities. It provided the human capacity and expertise to upgrade the knowledge base in the use of geospatial technology as part of the development of the national spatial infrastructure within the public sector.

The project's key objectives to strengthen the public administration were:

1. to enhance the administrative skills pertaining to spatial information systems, spatial data creation and management and their dissemination for internal and public use;
2. to upscale existing skills of public officers to reach better outcomes on evidence-based policy making based on the analysis and interpretation of their spatial data; and
3. to improve the implementation of decisions based on informed results emanating from management and executive information systems utilising spatial information (Planning Authority, 2018).

Training was offered to public administration employees in spatial data technologies and Geographic Information Systems (GIS) that were not in place in the Maltese islands in a dedicated and coherent manner. This aimed to increase the technical skills of public officials with respect to the use of spatial data and to improve the utilisation of public resources in the field of geomatics. The knowledge gained developed human resources for a more efficient processing of the spatial data cycle: design, creation, input, analysis, presentation, and dissemination, as based on the DIKA (Data-Information-Knowledge-Action) process (Formosa et al., 2012). Moreover, this component trained people in different thematic areas that had not been tapped to date in terms of data analysis, such as ecosystem spatial dynamics, bathymetric modelling, disease dispersion, utilities identification, cultural heritage risk management, infrastructure management and other themes. This will provide a more comprehensive base towards the creation of policies and legislation requiring spatial data analysis and improve the performance of public administration in this respect.

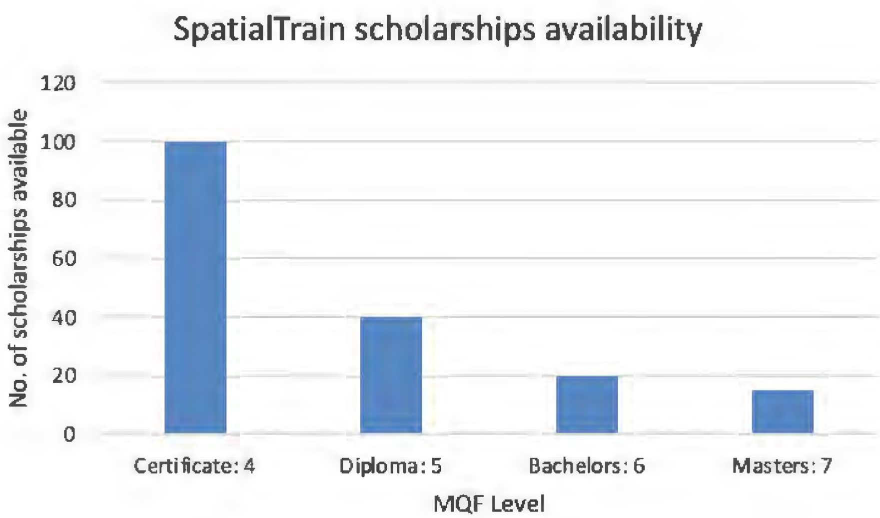
Overall, the training scheme aimed to enable the public administration to carry out more informed processes using spatial data as the basis of such decisions and thereby increase the overall performance on the public administration.

Training provided

Four MQF levels (levels 4-7) of training in the field of Geomatics (spatial data) were offered in the SpatialTrain's scholarship scheme. Level 4 (Certificate) and Level 5 (Diploma) training was provided as dedicated courses provided by a local contractor. On the other hand, Level 6 (Bachelors) and Level 7 (Masters) scholarships were offered to participants who could choose their own specialisation geomatics course. In such cases, their research focused on thematic aspects relevant to their line of work within their respective public entity.

Two calls for scholarships were issued at all MQF levels - Call 1 in 2019 and Call 2 in 2020 with the project closing off in December 2022. Figure 1 depicts the number of scholarships offered with respect to MQF Levels with a total of 175 scholarships being offered.

Figure 1: Distribution of scholarships made available during the SpatialTrain project.



Scholarship Topics

This project offered scholarships in a range of topics related to geomatics. Topics aimed to provide the tuition on the principles of Geomatics, the use of GIS, as well as its applications to the various fields which would complement the roles of various government entities. Therefore, the target was to offer training opportunities to staff with basic knowledge or use of geomatics up to staff who already deal with spatial data but would need to specialise in more detailed analysis and data modelling. The topics for which scholarships were made available is provided in Figure 2.

Figure 2: Range of study areas for which scholarships were offered through the SpatialTrain project.

Priority Study Areas	Other Study Areas
• Basics of Geomatics • Geographic Information Systems (GIS) • Spatial Analysis for various applications (e.g. environmental, urban planning, • infrastructure or coastal management) • Land surveying • Remote Sensing • Bathymetric analysis • Spatial data capture and spatial data infrastructures • Spatial data management • Spatial simulation and modelling (Smart Cities and urban analytics; 3D modelling; geospatial predictive modelling) • Spatial data harmonization and standardization, including compliance to INSPIRE Directive • Remote devise pilot/controllers	• Spatial econometrics (social and economic perspectives of spatial interventions) • Geographic Information for management staff (basic technical training) • Spatio-political analysis • Other related areas

In the case of L4 and L5 training, a Programme of Studies was created by the local contractor. Courses were organized into four categories (Figure 3).

Figure 3: Categorisation of training aims for L4 and L5 courses.

L4/L5 category	Training Aim
Basic	• Recognise the basics of geomatics and GIS • Relate to spatial databases • Distinguish spatial data capture methods • Relate to Geodetic Reference Systems
Intermediate	• Relate and examine to the principles of the presented disciplines • Investigate each discipline • Apply the concepts and methods acquired in Basic Training in discipline-related problems
Advanced	• In-depth analysis of the examined GIS disciplines • Relate to advanced discipline-related concepts and principles • Extensive investigation and application of basic knowledge into discipline related problems • Hands-on experience on advanced GIS methods and techniques
Applications	• Introduce the trainees into specific GIS problems • Allow the trainees to develop holistic GIS processing chains to address a single problem • Enable the application of the acquired knowledge into a large-scale project

Whilst topics in the basic category (Figure 3) were mandatory at both L4 and L5 levels, participants were able to select topics in the intermediate, advanced and applications categories according to the relevance of the topic to their line of work.

Scholarship eligibility, applicants' selection and progress monitoring

SpatialTrain scholarships were only open to applicants who were employed within the public sector or public service and had obtained official endorsements to participate from their relevant Ministry.

A Project Monitoring Board of Review (PMBR) was set up to review the selection process and the implementation of the training process of the successful applicants throughout the duration of their scholarship period. Submission of the required administrative material by each Call was followed by interviews of the applicants by the PMBR based on the criteria noted in Figure 4.

Figure 4: Criteria used for the selection of applicants for the SpatialTrain Scholarship Scheme. Pass mark set at 50%.

Selection Criteria	**Maximum marks possible (%)**
Academic merit of the Applicant	20
How studies are related to the Applicant's current work within the respective Government entity and the project's remit	30
The level of initiative of the applicant to contribute to innovation in spatial information and improve the overall performance of the public administration	30
Aptitude of the applicant to complete the course	20

A database was also created with information on the applicants, their courses, duration and successful completion of such courses. A monitoring mechanism involving mandatory reporting was also put in place. In the case of MQF Levels 4 & 5 quarterly reports were required to be submitted by the trainee and institution. In the case of MQF Levels 6 & 7, mid-yearly reports were to be submitted by the trainee and the respective academic supervisor.

Scholarship uptake by public entities

Uptake of scholarships ranged from a broad range of public entity sectors. Indeed, various dissemination activities for each Call resulted in a significant amount of interest and requests for information. This supported the fact that the need for the use of geomatics training was significant. Ultimately, participation boiled down to the time commitment by the participant and support from the respective management. Indeed, some limitations to the course uptake and implementation included the occasional lack of management support to some employees to apply for a scholarship or drop-outs of some students due to their work commitments.

Scholarship uptake was multi-disciplinary. In fact, scholarship applications at all four MQF levels were received from diverse public sector entities:

1. Ambjent Malta
2. Department of Public Health Medicine
3. Environment Resources Authority (ERA)
4. Heritage Malta (HM)

5. Malta Air Traffic Services Ltd (MATS)
6. Malta College of Arts, Science and Technology (MCAST)
7. Malta Communications Authority (MCA)
8. Malta Council for Science and Technology (MCST)
9. Malta Police Force (MPF)
10. National Statistics Office (NSO)
11. Planning Authority (PA)
12. Restoration Directorate
13. Superintendence of Cultural Heritage (SCH)
14. Transport Malta (TM)
15. Water Services Corporation (WSC)

It was interesting to note that the above public sectors were already somewhat exposed to the importance of spatial data to address analytical, reporting or policy issues within their entity. This exposure varied from a general overview to one where spatial data are part of their standard working practices. Consequently, the entry knowledge of trainees varied from ones who had no prior use of spatial data/GIS to others who planned to expand their knowledge of spatial data to tackle in-depth applications of geomatics. Indeed, the latter was evident in the disparate variety of the trainees' respective research topics. These included geomatics applications in the fields of cultural heritage, public health, spatial planning and land use, infrastructure and safety, crime spatial dynamics, ecosystem monitoring, water and marine applications, Spatial Data Infrastructures and web GIS portals.

Overall, the value-added knowledge being acquired by these trainees contributed to upscale existing skills of these public officers for the analysis and interpretation of spatial data and aims to improve decisions based on informed results.

The way forward

The SpatialTrain Scholarships Scheme project was a first major step at a local level to provide accreditation of the public sector within the field of geomatics. Entities are experiencing a rapid development in digital technology, particularly with the growing use of cloud technology, Artificial Intelligence, and higher resolution remote sensing from both UAVs and satellites. In tandem with the increasing need to address key issues such as climate change, security and public health, public entities will need to rely more strongly on the use of spatial data for this. Indeed, this is already seen within various EU programs, such as the Copernicus, Galileo, EGNOS programs and the INSPIRE Directive (OJEU,

2007) which aim to ensure the use of spatial data to maximise socio-economic benefits for the European society and businesses. On a national level, the availability of EU funding to the public sector for projects using spatial data technologies implies that knowledge in geomatics is a key tool. The SpatialTrain project also delivered a feasibility study for the setting up of a National Intelligence Institute (NaSpI) (Planning Authority, 2020) dedicated specifically to the use, research and management of spatial data at a national scale. This study investigated the logistics, operations, business and financial requirements to set up such a NaSpI. This would act as a spatial initiative to consolidate the existing geomatics knowledge as well as to serve as a focal point to maintain research and training in the field of geomatics beyond the term of such a project.

Based on the above, future dedicated training initiatives in the geomatics sector will continue to be required at the various qualification levels. Furthermore, projects which require cross-entity contributions would require sharing of dedicated knowledge in various aspects of geomatics. It is this type of contribution which should provide the impetus for a national spatial initiative. Such initiatives would help to conduct geomatics research, training, and spatial initiatives, provide guidance on geospatial standards and policies, and build an active network in the field of geomatics. It is the integration of the knowledge gained, data sharing and standards which will contribute towards a national coherent effort in the field of spatial initiatives.

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INTRODUCTION

Where to for GI? The Who Factor

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" (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-Ħamra 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 Asciak 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 Għargħur. 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, Xgħajra, 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 endevour 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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Pivot I

The Air Domain

Forti Ricasoli
Easting: 457326.550, Northing: 3972866.930

CHAPTER 1

Suitability Analysis for Green Infrastructure in Malta (SAGIM) with focus on how COVID-19 has influenced air quality

Schembri Ariana

Keywords

Air quality, analysis, priority buildings, green infrastructure, GIS model, COVID-19 pandemic, traffic pollution.

Project Aim

The aims of this project were: (1) to develop a model to identify priority buildings in Malta exposed to traffic-induced pollution and located in densely populated regions, making them suitable for green infrastructure (GI), and (2) to analyse the differences in ambient air quality between 2017 to 2020.

Introduction

Air pollution is considered one of the key threats to human health and ecosystems worldwide (EEA, 2019). The main sector contributing to air pollution is road transport (EEA, 2019). Directive 2008/50/EC of the European Parliament and of the Council of 21 May 2008 on ambient air quality and cleaner air for Europe, the Ambient Air Quality Directive (AQD), aims to protect human health and the environment by combatting emissions at source, and lays out limit values for pollutants which are regulated by the said Directive (Official Journal, 2008). A yearly limit value for Nitrogen dioxide (NO2) is stipulated in the AQD at 40µg/m3.

Malta is considered the densest country in the European Union in terms of population with approximately 1400 inhabitants/km2 (Eurostat, 2017). Furthermore, the Maltese islands are synonymous with a very dense road network system with the total extent of the Maltese road system being about 2410km with approximately 762km of roads per 100km2 representing the densest road system in the European Union (Transport Malta, 2016). In addition, in 2018, the number of vehicles in Malta were around 385,000 (National Statistics Office, 2020). As a result, Malta is impacted by elevated levels of NO2, a pollutant mainly attributed to road transport (Environment and Resources Authority, ERA. 2021). However, this is not only the case for Malta, but also for many cities worldwide (European Commission, 2019).

The rise of the Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2), referred to as COVID-19 (WHO, n.d.), confirmed that air quality suffers as a result of traffic and congestion. Air pollution has fallen in cities all over the world as a result of partial or total lockdowns which countries implemented during the early stages of COVID-19 (European Public Health Alliance, 2020). According to the European Commission, GI refers to "strategically planned networks of natural and semi-natural areas" designed to improve ecosystems as well as to offer better quality of life for citizens (European Commission, n.d.). The benefits of GI are well known, and these range from environmental, social to economic benefits (Apud et al., 2020). Such systems help in reducing exposure to several harmful pollutants such as particulate matter, as well as promote a sense of well-being at community and household level (Environment Protection Agency (EPA), 2017). The application of GI has demonstrated a success in spatial planning and has managed to promote sustainable and resilient cities across the globe (Apud, et al., 2020). However, identifying locations for such GI, often does not take into consideration multidisciplinary approaches but are rather focused on the one main benefit that it aims to bring, for example increase in green areas (Kim & Song, 2019; Meerow & Newell, 2017).

The Health Effects Institute Panel considers people living within 500m from highways and/or main roads as being exposed to traffic-induced pollution (HEI Panel, 2010). In this context, all buildings identified by this study, falling within such zones, are considered problematic, but only those falling within the 100m mark (i.e., closer to traffic) were considered as buildings of top priority. To achieve this aim, the study used GIS to: (i) recognise which roads were considered as highly problematic in terms of NO2 concentrations in a business as usual scenario (i.e. pre-COVID days); and (ii) assess the areas that were densely populated whilst considering road traffic. This study also aimed to analyse the differences in ambient air quality between 2020, as the year where COVID-19 measures were in place, and the three preceding years (i.e. 2017-2019) considered to be years of business as usual. A three-year period was taken into consideration in order to reduce the effect of any unusual concentrations which might have been recorded as a result of a particular event.

Methodology

The methodology is divided in two sections: (i) the first concerning the assessment of changes in air quality as a result to COVID-19 and (ii) the second, the identification of buildings considered to be of top priority.

Assessing changes in Air Quality

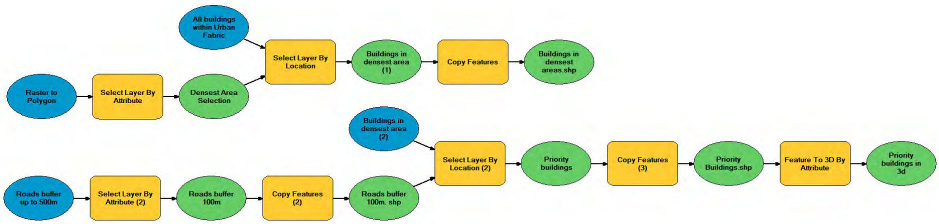
The Environment and Resources Authority (ERA) deployed 100 passive diffusion tubes, which measure NO2 concentrations, throughout Malta and Gozo. The tubes are exposed for a period of 4 weeks, for a total of 13 exposure periods in one year, after which they are sent to a laboratory for analysis. Monthly and annual NO2 averages were calculated for the years 2017 to 2020. The GIS-based kriging interpolation tool was used to predict the concentration levels of NO2 within a geographical area by using interpolation via Gaussian process regression (ESRI, n.d.). This model assumes that the distance or direction between ERA's diffusion tubes reflects the spatial correlation to be used to explain variation in NO2 concentrations across the Maltese Islands. As a result, nation-wide pollution maps were generated for all the years under review.

Identifying buildings of top priority

A GIS-based methodology 'Suitability Analysis for Green Infrastructure in Malta (SAGIM)' was developed by the author aimed to identify priority buildings whereby consideration of GI could help in combating traffic-induced air pollution. The SAGIM model is based on a land suitability model which focuses on the processes of identifying the appropriate buildings based on proximity to traffic from arterial and distributor roads, and those located within densely populated areas.

Given that national population data is only available as a total number of people residing within a locality and therefore does not reflect the spatial density distribution within a locality, this study used water meter point data provided by the Water Services Corporation (WSC) as a surrogate spatial population distribution dataset. The study only considers residential buildings. Therefore, all non-residential and vacant buildings were omitted from the analysis. The model builder application (Figure 1) was used to manage the suitability analysis aspect of the study (ESRI, n.d.). The road network line data used for this study was provided by Transport Malta (TM) and computed with the National Transport Model (NTM). All buildings identified within the buffer rings are considered to be exposed to pollution from traffic. However, those of high priority were located within the first 100m from the road network and within the most densely populated area.

Figure 1: Methodology for the self-developed GIS-based model "Suitability Analysis for Green Infrastructure in Malta (SAGIM)



Discussion

From the analysis carried out on ERA's diffusion tube data, in 2019 a total of 20 roads exceeded the NO2 annual limit value stipulated by the AQD. As a result of the implementation of COVID-19 restrictions, in 2020 the number of roads which exceeded the yearly limit value were reduced to 8. NO2 levels within these problematic roads dropped by around 10μg/m3 in just one year. The pollution maps highlighted in Figure 2 show how the concentrations of NO2 varied across the last 4 years. The 2017 to 2019 pollution maps do not indicate major changes in concentrations. However, the 2020 pollution map indicates that the harbour region experienced a significant reduction in concentrations. Concentration levels within the inner harbour region, which are normally identified by concentrations of around 40 to 50μg/m3, in a business-as-usual scenario, have decreased by a whole concentration band and are between 30 to 40μg/m3.

Figure 3 highlights the changes experienced in just one year. 2020 monthly averages were calculated and compared to the average of the 3 preceding years. One can note that, during the first 3 months of 2020, NO2 readings were very similar to the 3 preceding years. However, when the first case of COVID-19 was recorded and Malta went into a soft-lockdown, readings in NO2 dropped instantly, as a result of less traffic on the roads. When schools reopened in October 2020 and fewer people were working from home, NO2 concentrations somewhat returned to normal.

Figure 2: Pollution maps using kriging interpolation for the years 2017 to 2020

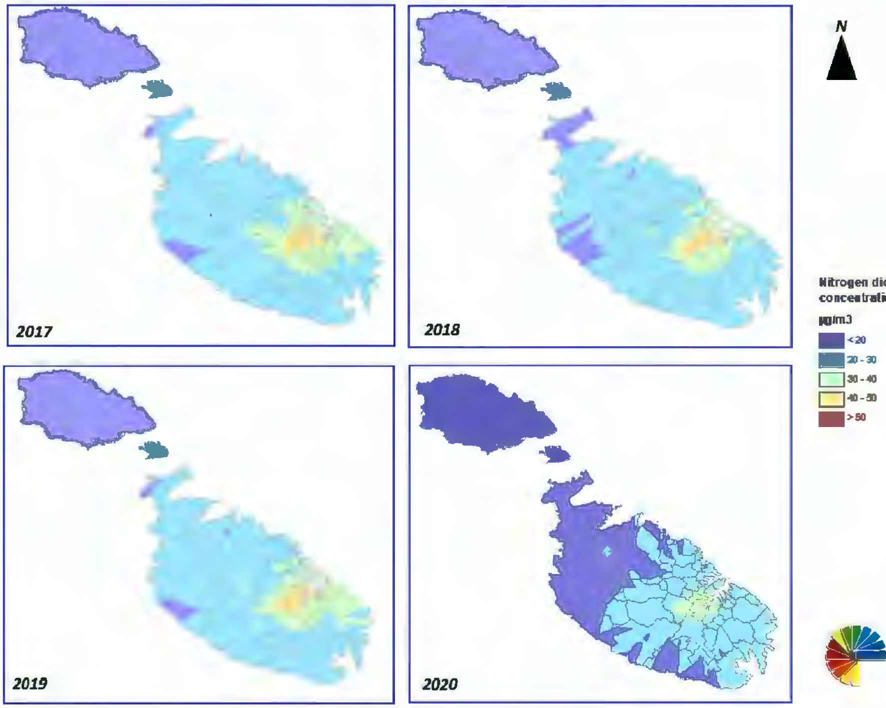


Figure 3: Monthly NO2 concentrations for 2020 compared to the 3 preceding years

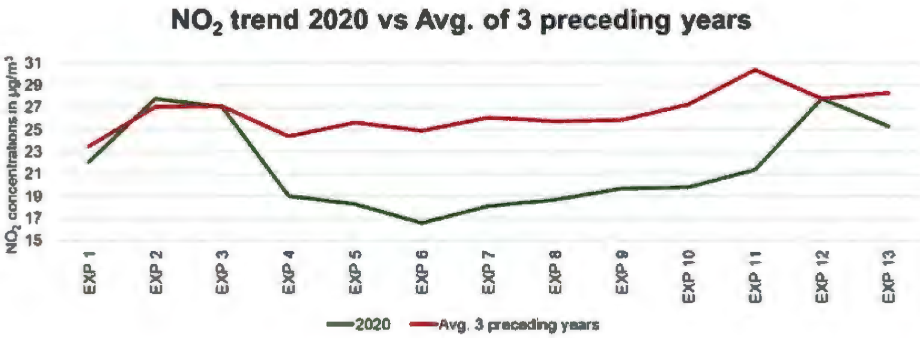
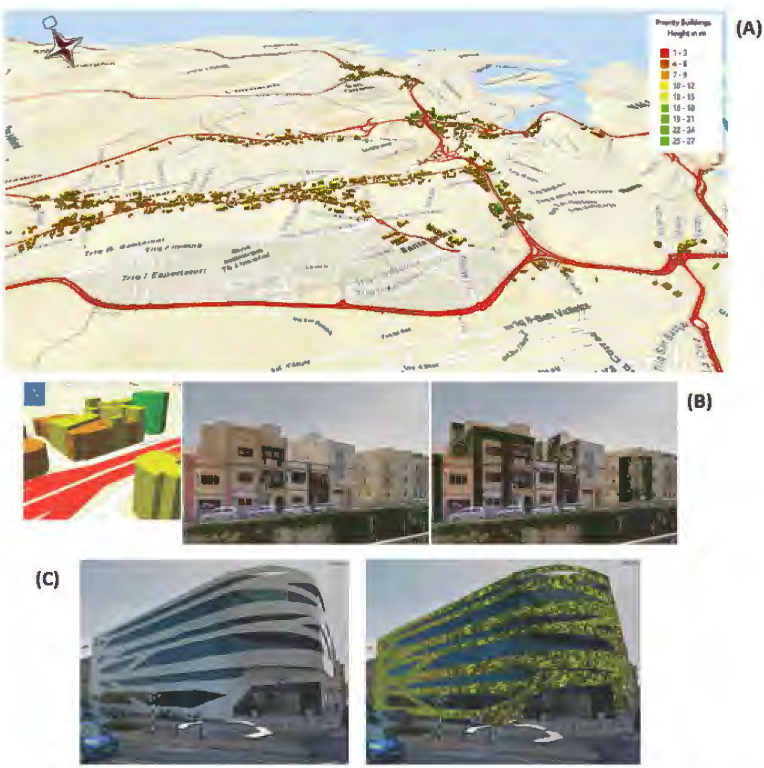


Figure 4: (A) Buildings identified by this study are considered of top priority.



Note: One may consider low lying buildings (1-2 floors, marked in red) as being more exposed than those that are higher (8-9 floors marked in green). (B) Residential buildings located in Regional Road, Santa Venera, considered to be amongst the buildings of top priority identified by this study. The first image is a 3-d render derived from ArcGlobe10.8.1 using the buildings data provided by ERA according to height. The second image (extracted from Google Earth Pro) shows the same buildings identified by the SAGIM in real life and the third image is an artistic render of how GI can be incorporated into residential buildings. (C) Render of how GI can be incorporated into public buildings, in this case the MITA offices in Santa Venera. Source: own images

Results

Many negative aspects are associated with the COVID-19 pandemic, from a crashing economy to mortality rates in the millions (Karunathilake, 2020). However, one positive issue to be extracted from the measures which had to be implemented to lessen transmission rates is the environmental benefit induced. In Malta pollution levels within the inner harbour region decreased by 10μg/m3.

Using GIS, a total of 1,736 buildings (Figure 4) were identified to be of high priority; and according to this study, this is where GI installations should be given importance. As previously mentioned, this study only considered residential buildings. However, one may also consider the use of GI for commercial buildings. considering the average time office personnel spent in the office. Figure 4 provides an example of how GI can be incorporated into the local scenario on residential buildings as well as public buildings.

Recommendations

Key recommendations to pursue are:

- to study individual species of flora and assess the spatial distribution of indicator flora which are sensitive to air pollution in a local context. It would be ideal to only consider those species which best interact with ambient air quality, and which would serve as an indicator for pollution abatement rather than as a secondary pollution source. Similar studies have already been carried out by Mamatha, et al. (2021). Chen, Kaiyang, & Richard (2020) and Feng, et al. (2019).
- to model air dynamics within street canyons that are susceptible to traffic-induced pollution by considering meteorological conditions, land cover, terrain slope and population distribution within the areas of study. Such modelling would also help to identify measures best suited to mitigate pollution concentrations.

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Pivot II
Land Domain

Floriana
Easting: 454800.720, Northing: 3972240.120

CHAPTER 2

Land Cover Classification - Mapping green open space and built-up areas in Valletta

Leanne Dalli and Jean Claude Zahra

Keywords

Valletta, OrthoPhotos, Vegetation, Built up Area, Green Urban Area, QGIS, Malta.

Project Aim

The aims of this project focused on gaining insight to select and implement GIS techniques such as digitizing and plotting Valletta. The main aim of this study was to evaluate and analyse the built-up area vs. the vegetation spaces within Valletta, the capital city of Malta. Furthermore, another two aims were: (a) to support green spaces; and (b) to provide efficient spatial planning of building construction in urban area.

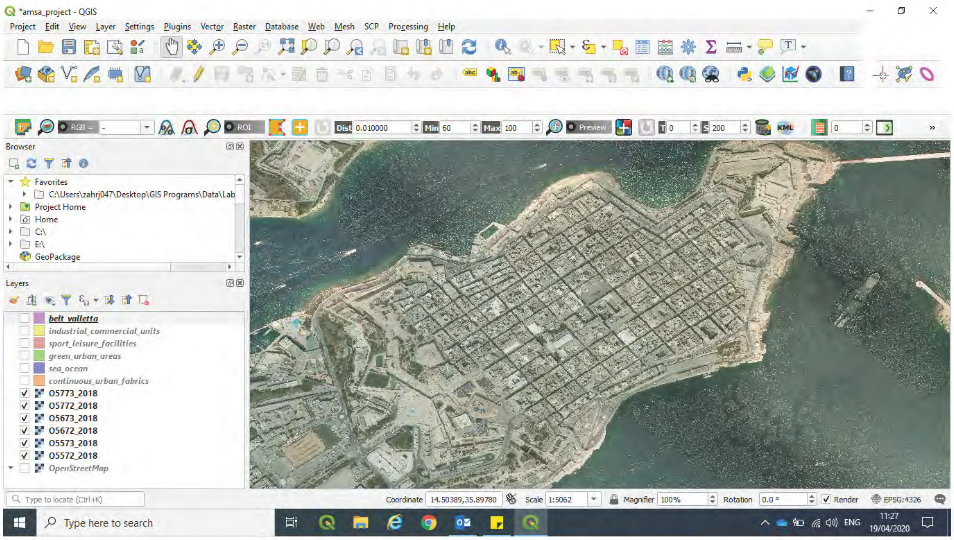
Introduction

The objective of this study was to evaluate and analyse the built-up area with respect to the vegetation spaces within Valletta, Malta. Throughout this study, 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 place to designate the areas with their respective land cover classification, according to the CLC categories.

Methodology

For this study, QGIS Desktop 3.6.3 with GRASS 7.6.1 was utilized to plot the Capital City, Valletta. The process of this project started by first uploading the 2018 orthophotos (source, Planning Authority) onto QGIS (Figure 1) Since the orthoimagery was ortho rectified, no further geoprocessing was required. Visual interpretation of the orthophotos clearly shows that the main area of Valletta is built up. Since the younger generation migrated out of Valletta, most of the population living in Valletta includes elderly people with many vacant buildings being used as Government and private offices.

Figure 1: 2018 orthophotos of Valletta



Source: Planning Authority

After the orthophotos were uploaded the process of digitization commenced based on a visual interpretation of the imagery. Vector layers were created, and named 'continuous_urban_fabric, sea_ocean, green_urban_areas, sport_leisure_facilities, industrial_commercial_units and belt_valletta'. These spatial layers were based on polygons, to polygonise the whole area of Valletta.

Digitisation of the polygons was a fundamental procedure. Therefore, the process of plotting a polygon was carried out individually whereby all the buildings were divided into different polygons with a matching colour that shows all the buildings. In addition, the vegetation was plotted in a different coloured polygon to show the different type of polygon from that of built ups. This was useful for the legend in the final exported map. When all the Valletta area was digitized in polygons the subdivision of the builtup area could be visually spatially (Figure 2).

Figure 2: Land Classification

Subsequently, fields were created to form the attribute table for every layer. The attribute table of the mentioned layers were populated using the Corine Land Cover (CLC) 2018 classifications (European Environment Agency) with their respective CLC codes for the Corine Land Cover. For every polygon, the attribute table was populated to create the details in reference to the CLC.

The fields of the attribute table for every layer consisted of 'id, lev1, lev2code, lev2desc, lev3code and lev3desc'. Together with the latter fields, another two fields entitled as 'Area' and 'Total_Area' were also included. Moreover, the green_urban_areas layer, had an extra field named garden to input the name of each existing garden.

Each layer was plotted individually, starting from the continuous_urban_fabric class which was provided with a specific colour. The same process was carried out for the rest of the layers. The difference that was made in digitization of sea_ocean was that a sample of the section from the sea to show an example of the sea was also plotted. Details including 'level1, level2code, level2desc, lev3code, lev3desc and gardens' in the attribute table for each polygon plotted were inputted. For example, for the green_urban_areas the information inputted was as follows: 'level1, also it is artificial surfaces, level2code is 1.4, level2desc is artificial, non-agricultural vegetated areas, lev3code 1.4.1, lev3desc green_urban_areas, gardens' (garden names were included).

The next step was to calculate both the area of each polygon starting from belt_valletta and the area of each polygon for every layer 'continuous_urban_fabric, sea_ocean, green_urban_areas, sport_leisure_facilities, industrial_commercial_units and belt_valletta'. Calculations were carried out using the field calculator directly from QGIS. The area of each polygon for every layer was calculated using the '$area' expression. The next step was to calculate the area of each layer using 'sum(area)' as an expression. With this expression, the 'total_area' of each layer was calculated.

After calculating all the areas, the total_area of each layer 'continuous_urban_fabric, sea_ocean, green_urban_areas, sport_leisure_facilities, and industrial_commercial_units') was deducted from the 'belt_valletta' layer. This enabled statistical information to be derived for features such as main roads, side roads, and fortifications.

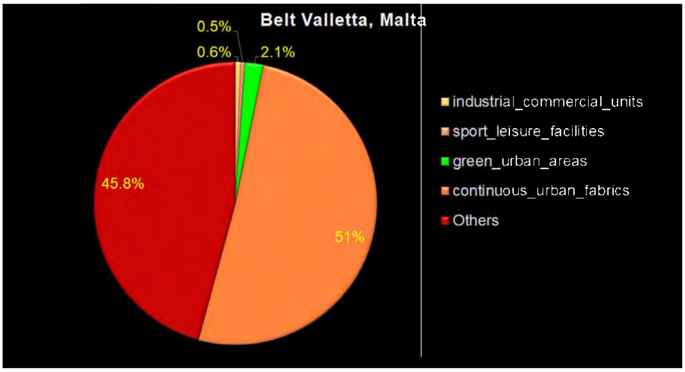
Results and Discussion

The final statistical calculation that showed that the area left in Valletta was calculated and this total to 367,890.41 sqm from the total Valletta area of 802,754.6 sqm. This means that the rest are main roads, side roads and fortifications since all buildings, green areas were calculated in the queries. A pie chart was obtained to illustrate the classification over Valletta (Figure 3). This demonstrates that Valletta consists of 51% continuous_urban_fabrics, 45.8% as 'others' since this was mixed with main/side roads and fortifications, 2.1% as green_urban_areas while industrial_commercial_units and sport_leisure_facilities were 0.6% and 0.5% respectively. A small number of vegetated areas are present. The buildings in Valletta were within the UCA (Urban Conservation Area).

In this study on land cover classification one can now see how Valletta was built in a unique way. The results demonstrated the spatial distribution of various vegetation areas of different popularity such as Upper and Lower Barrakka Gardens as well as Hastings Gardens. The public transport hub, also known also as the bus route terminus was also digitized as is found outside the Valletta city gate with an area of amounts to 4957 sqm. Some sport leisure facilities were visible including the 'Salinos football training ground near the bus terminus.

Key results of this study are:

Figure 3: Pie chart of land cover % over Valletta



1. a classification map of Valletta
2. area calculations of built up areas in Valletta
3. a pie chart providing percentages of each layer plotted in Valletta.

Recommendations

- The local council can use the classification of Valletta as a guide map to show the locations of the gardens This can be done by providing a leaflet, which then can be given to Maltese people, and tourists that visit Valletta especially during the summer period. This idea can be used by other local councils.
- This study can be carried out in more detail (e.g. the layer noted as 'others' can be divided into fortifications and side/main roads) or one can also include building heights and the use of classes (e.g. buildings such as museums, churches, shops).

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Pivot III

Water and Marine Domain

Il-Ħofriet
Easting: 460418.340, Northing 3966474.751

CHAPTER 3

Mapping the Maltese Islands before the Zanclean Floods

Godwin Borg

Keywords

Historical mapping, environment, oil exploration, future emergencies, flood prediction, Malta

Project Aim

This study aimed:

- to produce the base bathymetric model of the central Mediterranean Sea;
- to study specific bathymetric data and DEMs to find the bathymetric shift incurred after the Zanclean flood due to seabed features anomalies in Central Mediterranean;
- to build three bathymetric models on the bathymetric shift before the Zanclean flood (considerate/moderate/drastic); and
- to reconstruct the land areas before the Zanclean flood based on the three bathymetric models.

Introduction

The study workflow entailed six levels of tasks (Figure 1). The project required a large volume of bathymetric data for the Central Mediterranean to obtain a good preview of the land bridge. The bathymetry of the selected features to be observed must be dense according to the scale of the feature. Therefore, with the permission of the Hydrographic Office of Malta, various data sources were used. This included bathymetric Multibeam and Single beam surveys, Electronic Nautical Charts (extracted chart soundings) and data from the IHO open-source data (Gebco, 2020). Further analysis of a specific set of bathymetric data sources to find anomalies on the seabed floor (old riverbeds, channels, and erosions etc.) which can impact the depths of each model creation before the Zanclean floods (opening of the Gibraltar Straits) occurred. The creation of DEMs were also created for improved interpolation.

Figure 1: Workflow project chart

Methodology

Creation of bathymetric Models

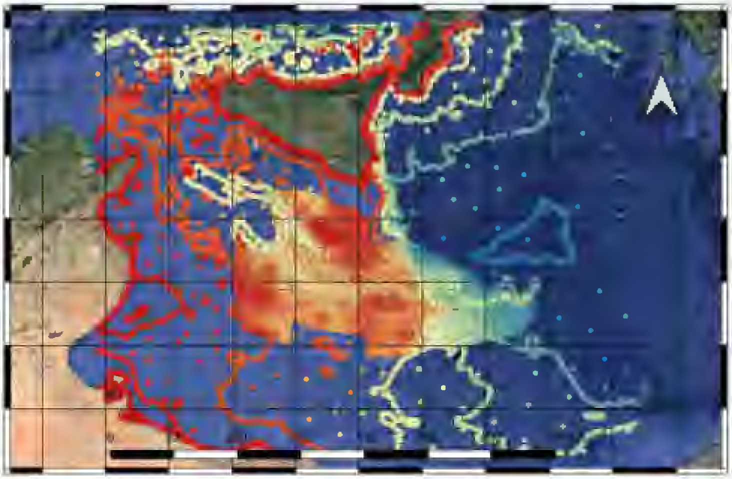
The existing bathymetric model was created for the entire central Mediterranean. This was later used to deduct the sea level rise, according to the anomaly findings and to produce the three separate models before the Zanclean flood. The three models constructed were: (i) a model with a conservative approach (the least depths), (ii) one with a moderate approach (the median depths) and (iii) one with a drastic approach (the highest depths).

The Study Area

The study area is in the Central Mediterranean (Figure 2). The area is 614,087 km^2 and positioned at 445172 E 3970008 N south of Malta which lies in the Continental shelf area (Jurisdiction Area) of Malta. The bathymetry for this area needed to be at least one sounding every 100m radius for the reason to have a better contouring around the Maltese Islands. One of the data sources for bathymetry has been the S-57 Electronic Navigation Charts (ENCs) produced at the Malta Hydrographic Office. The sounding data of these charts are at IHO standards, and the source of navigation according to SOLAS regulation.

The soundings of these charts are sparse according to their scale whereas the contour lines of these charts provide more information.

Figure 2: Study area is in the Central Mediterranean

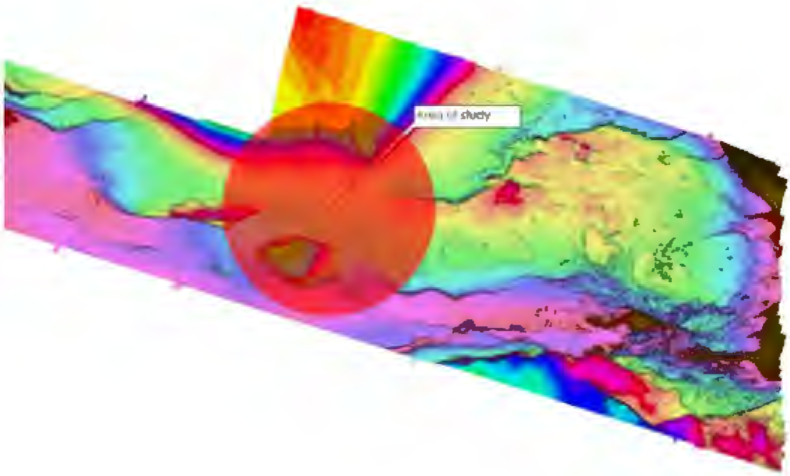


Source: Google Maps base

The Enhanced Study Area

It is exceedingly difficult to determine the sea level rise incurred in the centre of the Mediterranean basin from the flash floods through this set of data because the data is very sparse and the interpolation would be exaggerated and misinterpreted. Hence, to achieve the study objective would require having a set of data of a sea-bottom feature of at least one point per 50m radius, and this depends on the scale of the feature to be examined. From one of the multibeam surveys received, one survey conducted in 2013 by the vessel La Perouse was noted. From this bathymetric survey certain unique features were noted which exist within this exclusive data. Through contouring, raster datasets and DEMs. one could easily detect these anomalies whereas point data (xyz) is hard to detect by the human eye. The feature in question is a channel on the bottom of the sea which is 24 km in length. It runs from an underwater ridge of 195m of depth and ends at a depth of 450m to an underwater valley. The project aim was to further analyse this feature and predict and establish the sea rise difference before the flash floods to date The hypothesis behind this is that if this channel was caused by river erosion at a point in time, land should have existed around the river channel (Figure 3). The area is 7,658 km^2.

Figure 3: Channel Study



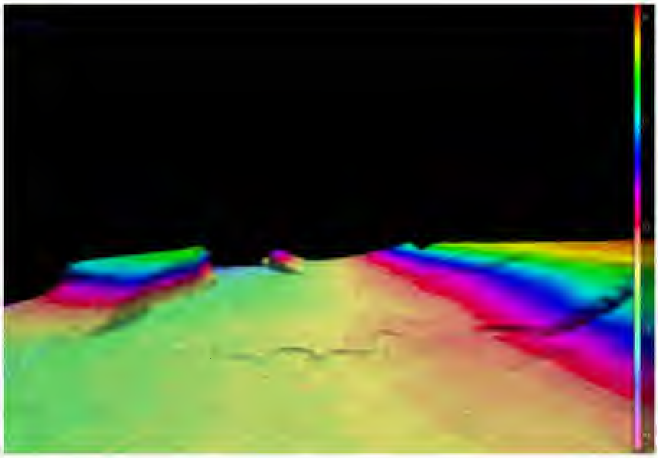
Finding the bathymetric shift in depths before the Zanclean flood

The area of interest is 70 km southeast of Malta in position: East 512452 North 3916259 (EPSG32633). The area is 1940 km^2 with sea depths ranging from 195m to 500m. The first approach is to clip the bathymetric data to an "extent" of QGIS. The data is loaded on QGIS as a text delimited file layer and clipped to the desired extent Figure 5.

Tin Creation of the Selected Area

The use of a TIN flythrough creation aids the visualisation of bathymetric data. This process is often used after post processing of data is completed in survey bathymetry. It helps to identify undesired spikes and visualisation in 3D. The fly paths for the TIN fly through were carried out using the Hypack software (Figure 4).

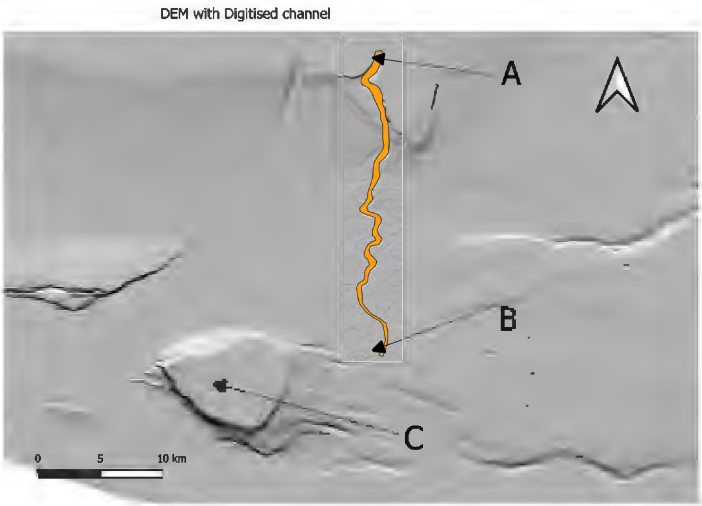
Figure 4: TIN flythrough



Creation of the Digital Elevation Model (DEM) for enhanced analysis

Next, a DEM was derived from bathymetric soundings data for further seabed feature analysis. By using the TIN interpolation tool in QGIS, vector data was exported to produce an image in tiff format at an interpolation grid of 10mx10m. Figure 5 shows the DEM (Digital Elevation Model). Starting with observations on this DEM, one can notice four channels from the North to the South. Attention is focused on the most pronounced of the channels. In Figure 5 this channel is 24 km from point A to Point B. It lies at depths at Point A of -200m from current depth and -400m at point B. The channel was digitised in QGIS. The shape of the selected channel resembles a formation of a river and further investigations were carried out using QGIS profile tool.

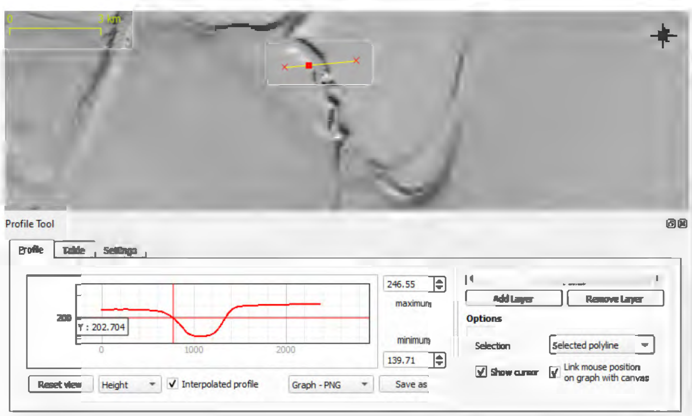
Figure 5: Digital Elevation Model

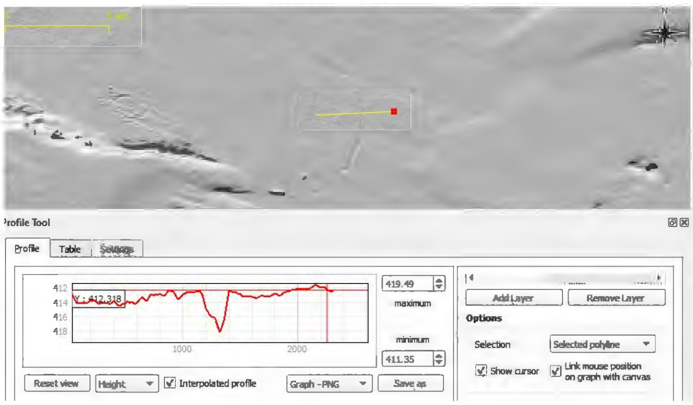


Further Channel Cross Channel Analysis and Investigations

The profile of the channel at point A indicated that the channel has a depth of 107m and is 600m long (Figure 6). The profile at point B determined that the channel depth is 8m deep and 200m across.

Figure 6: Channel profile





The bathymetric shift in depths results

From analysis and observations through the bathymetric surveys and DEM interpolations, the bathymetric shift (which occurred before the Zanclean Floods) was investigated. Considering that this feature was created via erosion of a once flowing river (further in-depth studies needed of the area e.g., bottom sampling, geological surveys etc. to prove my point), it would result that the area buffering the river was indeed land. These results show that Point A is less than 200m of the actual depths and Point B is less than 400m of actual depths.

The projected models created should have a shift, ranging from 200m to 400m from the current bathymetric data model of the Central Mediterranean created earlier. Since the shifted models would have to cover the minimum and maximum of these ranges and the median would have to be included, the following models were created: (1) Model 1: -200m from existing depths; (2) Model 2: -300m from existing depths; and (3) Model: -400m from existing depths. These models were referred to as considerate, moderate and drastic. Having deducted the respective depths from the current bathymetric data of the centre of the Mediterranean Sea, the three models created were visualised.

Discussion

Creation of the Land Areas

The -200m land bridge model (The considerate approach)

This is the conservative model created with a bathymetric level of -200m from the current depth model of the Central Mediterranean Sea. The major difference to our existing topology is that the Maltese Islands are today connected to mainland Europe through the Malta Rise and the Sicily/Malta Escarpment and Italy is connected with this land bridge model. In the northern part of Sicily and southern Italy, there seems to be minimal changes in topography. However, in the South of Sicily towards the Maltese Islands some well-defined topographic changes were observed. The most interesting observation is that the Northwest of Gozo and the Island of Linosa East of Malta were not affected by the 200m water reductions.

The most significant changes occurred in the North of Libya from the African Continent, whereby a stretch of land emerged from the South almost reaching the Central of the Mediterranean Sea. The Island of Lampedusa, the Gulf of Tunis and the Gulf of Hammamet near Sousse have all been engulfed by the rising land. Many sparse islands have also emerged in the affected region. The most prominent of these islands is that lying southeast of Malta and is one of the largest islands that have resurfaced, located south of the Malta Rise escarpment.

Although this model has significant topological changes to the existing one, it does not map the bridge land which once existed between Europe and the African Continent. Furthermore, although some land emerges at the Skerki bank area, the two continents are still separated by the sea.

The -300m land bridge model (The moderate approach)

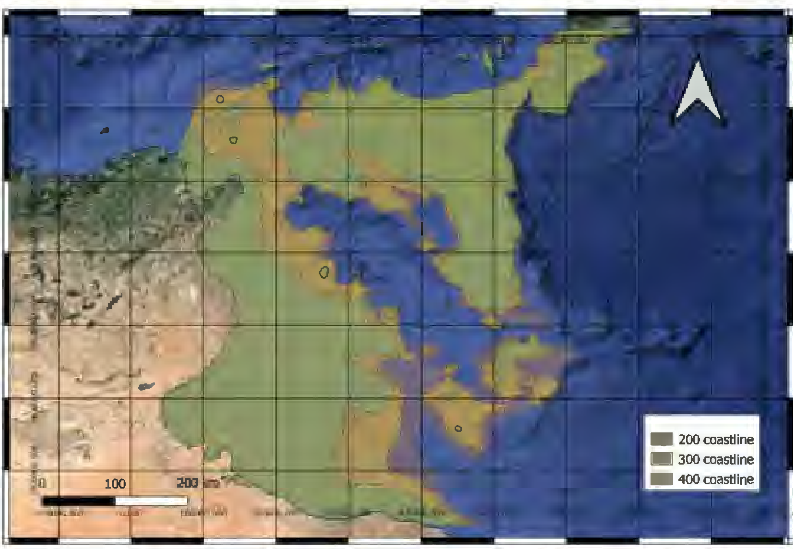
This model was created to a bathymetric level of -300m from the current depth model of the Central Mediterranean Sea. In this model, a new stretch of land has formed from the Gulf of Tunis, through the Skerki banks, to the Pantelleria Shoals and Sicily. This is now the bridge land formation connecting Europe to the African Continent. The formation of this land bisects the Mediterranean and separates it from its West side.

The Maltese Islands have reclaimed a small amount of land compared to the rest of the Mediterranean countries from this model. A new island was formed in the Northwest of Gozo. The south of Sicily gained more land in the Pinne Marine Patch, whilst the upper part of Sicily and the Italian southern coast had very minimal changes from the previous and existing model. The island formations which emerged in the considerate model, south of the Malta escarpment, have increased in size and sit prominently between the Central and the Eastern Mediterranean Sea pass. The Isle of Linosa still had no changes and remains surrounded by the sea. The African Continent has minimal changes from the previous model, except those of the Skerki bank and the Pantelleria shoals which produced the formation of the bridge land.

The -400m land bridge model (The drastic approach)

This model was created to a bathymetric level of -400m from the current depth model of the Central Mediterranean. The changes to the North of Sicily and south of Italy remain unchanged from the previous model. The bridge land at the Skeki Bank and the Gulf of Tunis remains stable up to Pantelleria Shoals and is almost identical to the previous model. In this model, changes are observed in the Pinne Marine Patch at the south part of Sicily as land formations are surrounding a stretch of a sea area almost enclosing it with the Northern parts of Gozo and leaving only a 4km channel width from the rest of the Central Mediterranean. The Maltese Islands have remained almost identical from the previous model except that of the Malta Rise in which has gained more land to the south of the Mediterranean. The once new island that was created from previous models to the south of Malta now formed part of the African Continent. This significant land emerged to the North, just leaving the Central Mediterranean Sea, a channel of 6km wide from the advancing Malta Rise area. The central Mediterranean Sea was reduced by the incoming African Continent and thus further reducing its width and size. In this model, most islands created in previous models form part of the adjacent land areas. Figure 7 depicts the three superimposed models.

Figure 7: three superimposed models at -200m, -300m, -400m



From a map downloaded from the Maltese Oil Exploration Division website and then geo-referenced (Continental Shelf Department, n.d.) it is observed that several active oil rigs in the Mediterranean and a number of attempted drillings were carried out. When the three projected land models are superimposed on this oil exploration division map, it is observed that the active oil rig wells fall within the land areas before the Zanclean flood (Figure 8).

From the three models, it may be inferred that the centre of the Mediterranean Sea was a sea area before the Zanclean period. The land emergence around the Maltese Islands from the -200m onwards does not have large significant differences compared to the rest of the surrounding countries. The only land which emerged from these models and that would impact present topology is to the East and Northeast of the Islands on the Malta Rise and the Sicily/Malta Escarpment.

The objectives of this project were to create the land bridge that once connected Europe to Africa were through the -300m and -400m models. The objective with the first model of -200m was partially achieved, as on this model the bridge land created is only that from the Maltese Islands to Sicily and mainland Europe. However, each model created could be the actual land area that existed before the Zanclean Flood although further investigations of the channel area need to be carried out to ascertain this. Extensive multibeam surveys, soil samplings and seismic surveys could help provide more information and may provide clues as to how these channels were formed. Each model of the current continental shelf area was subsequently clipped to produce statistics between past vs present in land area and coastlines.

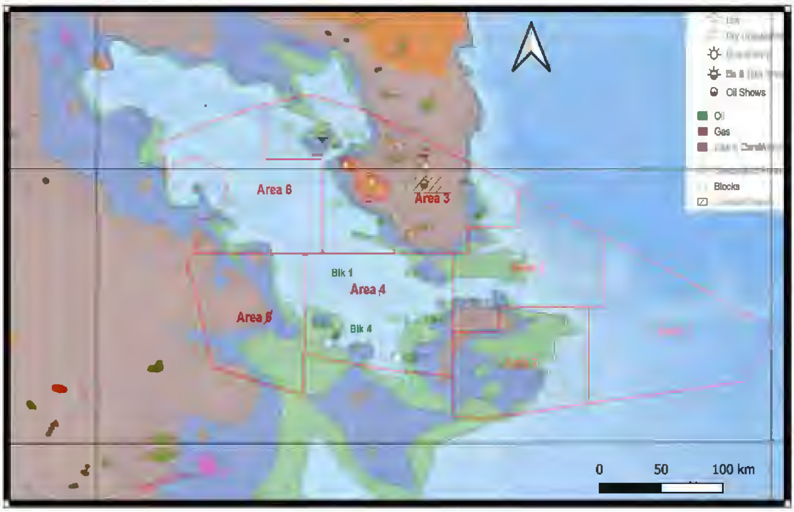
Table 1: Observations of land areas and coastline comparisons of the Maltese Islands before the Zanclan floods to the Maltese jurisdiction area to date.

	Malta	-200m	-300m	-400m
Land Area	314 km^2	11,788 Km^2	20,646 Km^2	31559 Km^2
Land % lost		97.4%	98.5%	99.01%
Coastline	153 Km	921 Km	1,735 Km	1416 Km
Coastline % lost		83.3%	91.1%	89.1%

In view of these observations, if the Zanclean Flood had not occurred and the change in the topology of the Mediterranean would have remained the same, then by binding to the geographic boundary laws, Malta would today be part of the Italian territory. The rest of the areas to the south that fall within our present Continental shelf area would have formed part of the African Continent.

From the last observation, it may be concluded that due to the devastating Zanclean floods, the end result is the creation of the present-day Maltese Islands.

Figure 8: Active oil rig wells within the land areas before the Zanclean flood



Note: All bathymetry used in this project is the propriety of Transport Malta. Data from this project cannot be used without authorisation from Transport Malta

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CHAPTER 4

An approach to mapping of coastal areas using photogrammetry

Mark Wright

Keywords
Mapping, UAV, Coast, GIS, GNSS, 3DF Zephyr Aerial, GCPs, CORS, DJI MP2

Project Aim

This project had two main objectives:

- to determine the approach to map coastal areas as well as the challenges that needed to be addressed during image acquisition and image processing; and
- to show how such an exercise may be achieved, using the correct equipment and skills.

Introduction

The Area of Interest (AOI) chosen was St. George's Bay in Birżebbuġa. This area is characterised by low lying plains. The bay's shoreline commences from Ferretti Gunpost moving anticlockwise to the opposite breakwater structure with a coastline of approximately 950 meters. The stretch of bay forms an almost closed polygon (Figure 1). The missing leg of the polygon is the stretch of sea between the end of the breakwater to the south and the Ferretti gunpost to the north. The fact that this is only composed of sea water posed the first challenge.

This is since the area over the sea is not consistent between images and therefore could create poor image stitching and processing. The most minimal of movements of the sea shifted the boats from one image to another thereby causing errors in the image processing. It was for this reason that the area covered by the exercise had to exclude the sea water areas and therefore ended up with a corridor type configuration rather than a closed polygon (Figure 2).

Ground control points (GCP's) are required as a standard part of the process to ensure overall accuracy and quality control. Before commencing with the mission planning exercise, the area needed to be inspected and a preparatory exercise was required to fix GCP's in appropriately positioned locations.

Methodology

When carrying out this exercise it was important to keep in mind important factors that would impact the final mean residual within image processing. Equal distribution of GCPs allowed for even distribution of error during the image stitching process. A total of 16 points were determined using Google Earth as a visual platform. The selected points were scouted and physically marked on site. Another important aspect that needed to be considered was the proximity of the GCP location to built-up environments. These points were measured by means of a GNSS antenna to acquire their projected UTM coordinates.

GCP readings were carried out using a CORS connection and RTK measurement. This allowed for a quicker data acquisition when compared to static readings that would have taken a lengthy 30 minute observation on each of the 16 GCP's. Multiple readings were taken on each GCP and a final mean value was established once outlier readings were removed from the computation. The resulting UTM coordinates of the GCP's were processed within the Leica Infinity software.

The mission planning process involved two attempts. In the first attempt, open source software called Mission planner was used. Mission Planner uses SRTM data, usually derived from platforms such as Google Earth. This is fed into the UAV and the latter maintains a regular height above the values being fed by the shuttle radar topography mission (SRTM) data. The downside of such an approach could come from the change in topography that would not be as yet recorded on the SRTM data. With new buildings being a frequent occurrence, it was essential to keep a visual line of sight, (VLOS_ with the UAV. This ensured that the UAV did not end up hitting an object which was not updated on the SRTM data. The height of the flight above mean sea level was set to 40 meters. The height profile of existing buildings did not exceed 20 meters above mean sea level according to the SRTM data used by the software.

Whilst the Mission Planner is a custom-made platform in terms of making the necessary adjustments to a flight plan, it is not so user friendly to link the data inputted in the software to the UAV. This is especially so for DJI drones. In this case, a DJI Mavic Pro 2 was used for the purpose of imagery acquisition. With Mission Planner being an open source software for open source hardware, DJI products may be protected by its own protocol. Upon further research done on online forums, it transpired that a way forward was possible. The option was to plan a mission in Mission planner and then export it in Litchi. However Litchi is not an opensource app and requires payment to install on one's phone which would then be used as a controller for the UAV. Given that this was an experimental approach the idea to proceed with Mission Planner was shelved and a different approach was needed to proceed.

DJI user friendly apps were considered thereby choosing Drone Deploy. The lack of possibility of using SRTM data within Drone Deploy, required the choice of a value for a constant height above the home point for each flight. A range of different heights was chosen for different flights. This varied between 40m and 60m above the home point. The ground sampling distance calculated by the app varied between 1.0cm per pixel at 40m height and 1.8cm per pixel at 60 m height. A '3D Maps' parameter was selected in the main settings. This setting allowed the user to perform a double grid flight along with the capture of perimetric oblique imagery at the end of the exercise.

The next phase involved the execution of the flight during a day with ideal weather. The UAV flew over areas which w ere outside the scope of the exercise. Drone deploy ended up simplifying the flight by flying over the sea covered portions. This was anything but ideal due to: (1) a number of recorded images would be useless since these were taken over the sea; (2) oblique imagery was being taken at a substantial distance from the objective; (3). whilst following through the final perimetric oblique imagery procedure, the UAV was at times facing the sea rather than the elevations themselves. This was beyond any settings that could have been inputted to rectify the situation. The flight process was therefore recommenced with a different approach. It was decided to split the mission into three smaller missions. However, these missions were to have a substantial overlap with one another in order to have a greater number of images covering the overlap and ensure that the stitching of the common areas between missions would be sufficiently provided for. It was worth noting that since the AOI was to be subdivided, a good number of GCPs in each area needed to be included, such that at least two of the GC's were common in adjacent missions. This ensured that the insertion of different workspaces in the photogrammetry software eventually aligned using GCP data. Each area ended up having a minimum of six to seven GCPs.

In mission 1, a total number of 308 images were taken at a height of 60 meters above the home point, capturing 7 GCPs in the process. In mission 2 a total number of 409 images were taken at a height of 50 meters above the home point. A total of 5 GCP's were captured of which two were in common with those captured in mission 1. In mission 3, a total of eight GCPs were captured with a total of 486 images being captured. The GCP Mission 3 was carried out on a different day from missions 1 and 2 due to battery power constraints.

Following the data acquisition, the next phase was the image processing part. For this purpose a software called 3DF Zephyr Aerial was used. The software achieved a 3D model and meshed output in 3 phases. One of the key settings at the beginning of the process was to establish which images within the project need to be masked for undesired elements that could cause the process to fail in its deliverables. In a coastal photogrammetry project the option to mask the images is a requirement. Following the initial project entries and selection of photos to be used, the 3DF Masquerade tool was launched. The 3DF Masquerade is an external tool within 3DF Zephyr Aerial. It allows you to remove those undesired elements that would hinder the image processing procedure.

Once the masking was completed, the masked images were elaborated to create a sparse point cloud. This was done by producing a 3D reconstruction called "structure from motion". This process defined the position and orientation of each image. The project wizard takes you from one menu to the next, outlining your preferences depending on the kind of project being carried out. In this case, the "Aerial" option was used as a preset. The sparse point cloud is defined by the number of key points that are present in adjacent imagery. The higher the detail, the longer the process took to derive the sparse point cloud. In this case, there was a good image overlap of 70% - 80%. It was suggested to decrease the key point density requirement thereby improving the processing speed

Once the sparse point cloud was generated the next step was to manually pick the control points within the images. It was essential to have as many photos of each GCP pinpointing the GCP itself. With the count of the images being over 1200 it was important to have at least 20 images of each ground control point being used for this process.

After looking up all the GCPs present in the imagery it was necessary to import the values recorded with the GNSS antenna. These values were eventually used in a 3D transformation. Prior to the transformation, the Exchangeable Image File (exif) data was used to correlate the images together in a model space. This space was eventually linked to the projected UTM coordinates by means of a 3D transformation. The latter rotated and created a bundle adjustment that placed the model in its intended spatial position.

Once this phase was complete, the next step was to create a dense point cloud. The dense point cloud was required to attain a more accurate representation of the surface. It is also the base data required for the remaining process of meshing texture onto the elaborated data. From this point onward the software wizard guided us through a selection of predefined settings. The appropriate settings were made according to the scenario of the project.

The final processing phase within 3DF Zephyr Aerial saw the creation of a meshed model. The latter is the result of the combination of RBG data derived from the imagery and the geometry data derived from the dense point cloud. The result allowed for a more descriptive product that could be eventually exported and used in other geographic information systems (GIS) based software for the purpose of further analysis. The settings that were investigated those pertaining to the desired smoothness of the mesh. This was the most demanding part of the computation, and the generated dataset took several days to generate.

Once the meshed output was complete, it was possible to extract orthophotos, DEM and DTM tif files, which were subsequently processed in QGIS.

Figure 1: AOI – St Georges Bay Birżebbuġa

Source: Google Earth

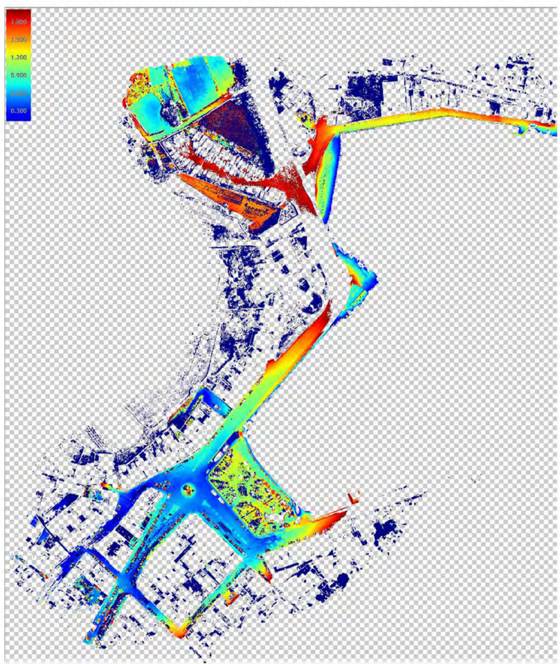
Results

Key results of this project are:

- DEM over the AOI with a 6cm ground sampling distance showing pseudocolor band values for elevation bracket between 0 and 2.00 meters above mean sea level (Figure 2).

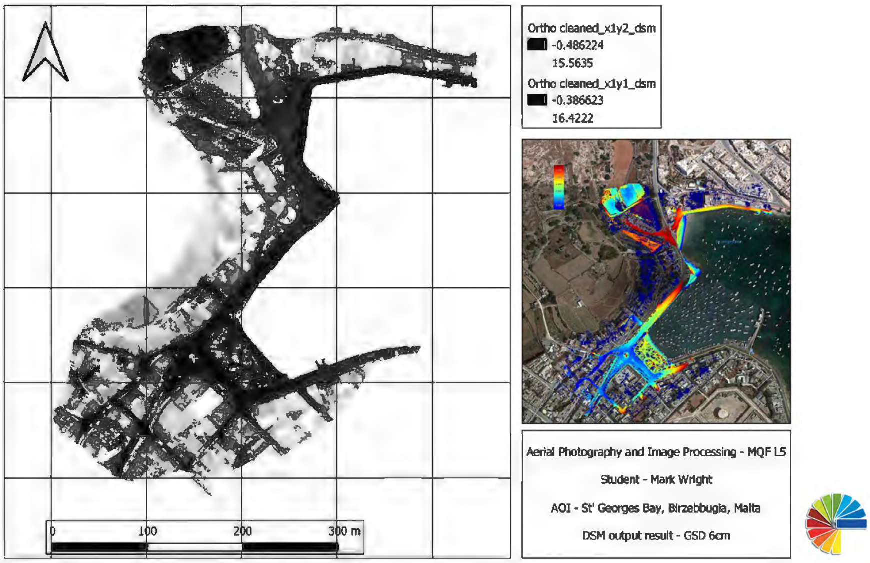
- Created DSM of AOI with a 6cm ground sampling distance. This information was used in another module related to the bathymetry of the same AOI (Figure 3)
- Noticeable deviation along the edges of the model where the ground control points were only visible in a few images. This reinforced the need to have the GCP s visible in a bigger number of images to maintain the accuracy parameters in all the areas of the AOI.
- Pros and cons aspects of the projects outlined in table (Figure 4).

Figure 2: DSM pseudocolour output at 6cm GSD for elevation bracket between 0.00 and 2.00m above MSL



Source: 3DF Zephyr Aerial

Figure 3: AOI – St Georges Bay Birżebbuġa



Source: 3DF Zephyr Aerial

Figure 4: Pros and Cons – comparative table

	Aspect	
Aspect 1	Single handed operation	
Aspect 2	Target quality of GCP's (decision to spray the marks instead of placing proper targets)	
Aspect 3	GCP measurement using GNSS antenna & CORS network	
Aspect 4	Splitting missions over carrying out a single mission in data acquisition	
Aspect 5	Splitting missions over carrying out a single mission in data processing	
	PRO's	**CON's**
Aspect 1	No need for co -ordination	Additional personnel could have helped in certain aspects
Aspect 2	No need to place or remove targets / no risk of targets being moved during acquisition process	Proper targets would have made for a better solution during the processing
Aspect 3	Easier for one person to collect data	Lack of better distribution in areas where GNSS measurement was not possible
Aspect 4	Better handling of data capture aspects / all GCP's being used at once	Need for considerable overlap between missions / less GCP's in each mission
Aspect 5	Better handling of the processing and less time required / issues with overlapping portions with varying degree of accuracy	Lengthier procedures and needs a very good PC setup to process data / no issues due to overlapping datasets being just one dataset

Recommendations

Key recommendations of this study are:

- additional imagery required of ground control points in order to avoid warping of model along the boundary;
- additional flight at a higher elevation would help in areas where structures such as a narrow pier are present and surrounded by water; and
- repeat mapping of coastal areas provides the base data for comparative exercises that can identify elements such as coastal erosion, climate change impact and long-term sea level rise.

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CHAPTER 5

Mapping Recreational Boating activity: Case study in the Maltese Archipelago

Sarah Camilleri

Keywords

Anchoring, Mooring, *Posidonia oceanica*, heat maps, bathymetry, GIS, Malta.

Project Aim

The aim of this project has been: (1) to scope for datasets to study the geospatial characteristics of mooring and anchoring activity, (2) to test geospatial tools for the mapping of mooring/anchoring activity and other relevant data, and (3) to make recommendations for further assessment and management of such activities.

Introduction

Owing to its Mediterranean climate, rugged coastline with numerous coves and beaches, and crystalline waters, the Maltese archipelago has long been a popular location for recreational boating. The boating industry experienced an important growth throughout recent years, possibly reflecting the economic boom of the islands, and their increasing popularity as touristic destination. Such growth is reflected in the increasing numbers of pleasure craft registered in Malta, the increase in granting of extensions to existing marinas, and the formalization of several unofficial mooring areas (ERA, 2020).

Amongst other environmental impacts, boating activity is also linked to the increasing physical damage caused to sensitive benthic habitats, because of the dropping and dragging of chains and anchors. *Posidonia oceanica* seagrass meadows - an endemic benthic habitat of the Mediterranean Sea, and a key element for the quality of coastal waters – constitutes one such habitat, for which physical damage by mooring and anchoring is of concern. Concrete deadweight mooring blocks, though heavy, can move around, resulting in erosion of these meadows, whereas the movement of chains linking the deadweight moorings to each other and to the surface buoys, result in the digging of furrows. Further, when raised out of the water, anchors caught between the rhizome networks of the plant, pull out whole blocks of living shoots, rhizomes and sediment (referred to as ‘matte’), further contributing to erosion of the meadows (Boudouresque et al. 2012). The recurrence of such action throughout the summer season, results in an overall degradation of the habitat.

As can be seen in several Marine Protected Areas (MPAs) in the Mediterranean, boating activities can be managed, such that the degree of impact is diminished. Measures include: (i) the installation of ecological mooring points –consisting of installations which minimize contact with the seabed, (ii) improving anchoring practices (e.g. positioning the boat vertically above the anchor before raising it) or the re-design of anchors (e.g. using a pivot system) to limit the tearing of meadows, and (iii) the designation of no-anchoring zones, or setting limits for anchoring boat densities (Boudouresque et al. 2012). However, the achievement of a sound spatial plan including the implementation of such measures must be backed by knowledge of the activity in question, gathering information regarding its spatial and temporal distribution, such as user characteristics and perception, boat, and anchor types.

Generally, the relevant studies aim at characterizing the relationship between the available resource (seabed for mooring/anchoring) and the pressure (number of boats mooring/anchoring in the area). This understanding leads to the provision of recommendations aimed at striking a balance between social and environmental needs i.e., a well-managed level of boating activity ensuring a positive user experience, and the prevention/reduction of environmental impacts as is the physical damage to sensitive benthic habitats.

Often the areas of interest are characterized through the delineation of sensitive habitats (e.g. *Posidonia oceanica* meadows) vs. non-sensitive ones (e.g. sandy bottoms, rocks) based on orthophotography and actual field surveys (Balaguer at al. 2011; Deidrich et al. 2011). Meanwhile the pressure is explored through different approaches and parameters. In Deidrich et al. (2011) and Venturini et al. (2015) data on the level of use by boaters is gathered through field surveys involving boat counts. Meanwhile, Balaguer et al. (2011) estimate the demand for anchoring based on the total number of berths in the area of interest, and through interviews with marina managers to determine an approximation of the number of regularly sailing boats.

Other datasets may also provide important information. Balaguer et al. (2011) factor in wave and wind data noting that such factors pose an additional limit on the total available anchoring space, as not all parts of the coast will be always suitable for use. Meanwhile, Venturini et al. (2015) estimate the total average swing area for boats of different sizes, intended as the maximum area that a boat swings out and around its anchoring point and Deidrich et al. (2011) carry out interviews with boat users collecting data on boater demographics, boat characteristics and on what is perceived as ideal distance between boats, effects of such distance on well-being etc. Through the integration of such data, the authors were able to make proposals including the designation of areas wherein mooring and anchoring may be allowed, optimal numbers of boats that may anchor, as well as an ideal minimum distance between boats; such that boaters are satisfied as regards crowding levels, and environmental impacts are reduced.

Taking from studies such as the ones described above, this project explored some of the available spatial datasets, as well as relevant spatial analysis tools, applicable for knowledge improvement on the intensity of boating activities for the case of Mellieħa Bay. Being Malta's longest sandy beach and a highly popular spot for boating, Mellieħa Bay accommodates both an unregulated mooring area with permanent mooring points utilized in the summer season, as well as boating hotspots wherein cruising boats throw anchor for the day. The specific objectives included:

1. scoping for datasets that may contribute to a better understanding of the geospatial characteristics of mooring and anchoring activity
2. testing of geospatial tools of value, for the mapping of mooring/anchoring activity and other relevant datasets; and
3. formulation of recommendations for the holistic assessment of such activities and their improved management.

Methodology

Relevant datasets were first sought for through the scoping of online sources as well as through personal communication with relevant Maltese authorities. The final set of data made use of consisted of:

- Google Earth Imagery (jpeg files) acquired from Google Earth Pro, downloadable from: https://www.google.com/earth/versions/.
- 2012 Ortho image of the Maltese Islands (ECW format) acquired from Malta Spatial Data Infrastructure (MSDI): https://msdi.data.gov.mt.
- LIDAR bathymetry (xyz format) from ERDF 156 data (2012).
- *Posidonia oceanica* habitat maps (shapefiles) sourced through Environment and Resources Authority (2017).
- Shapefile delineating anchoring and mooring areas (polygons) sourced from Environmental and Resources Authority (2020)

Discussion

Noting the considerable number of aerial photos available on Google Earth, this portal was explored for the possibility to provide representative imagery capturing the current extent of mooring and anchoring activity in the area of interest. To gather an understanding of the activity in its full potential, images considered were limited to those captured during the peak summer months. Hence, images captured off season, wherein boating was absent or very low, were discarded, as were images of poor quality (such as those affected by cloud cover). Further, whilst mooring was better captured during weekdays when boats were based around their buoys, weekends fared better at capturing transient anchoring activity. The search was finally narrowed=down to the selection of two images from August 2019 and June 2017. The former provided good representativeness of mooring boats south of the bay, whilst the June 2017 image was captured on a weekend, hence providing better representation of day-trip anchor vessels. The images were saved in jpeg. format at the best available resolution (4800 x 2782 pixels) available on Google Earth.

Consequently, these images were visualized in QGIS (version 3.10) and georeferenced against a 2012 orthophoto for the Maltese Islands (ERDF 156 Data. 2013) downloaded from the MSDI portal. This orthophoto was set at coordinate reference system (CRS) ED50 UTM 33N. This was also the CRS set for the QGIS project within which all analyses were carried out. For georeferencing, the plugin Georeferenced GDAL was activated and used to view the jpeg images of the AOI. Using the zooming tools, the images were examined for fixed landmarks (e.g. buildings, swimming pools, pontoons etc.) and control points were added and linked to the corresponding position on the spatially referenced 2012 orthophoto. For each image a total of 8 to 9 points were selected and the georeferencing operation was carried out using the linear transformation/nearest neighbour resampling settings. The success of the operation was evaluated by examining the quality of the overlay of the jpeg image over the 2012 orthophoto, and by evaluating the error in pixels in the GCP (Ground Control Point) table in the dX(pixels) and dY(pixels) columns. As a rule of thumb, the error in pixels were not to be higher than 10 pixels (QGIS Training Manual, 2016). Better results were also observed with the increase in the number of control points, as well as their spread over the AOI.

When both 2017 and 2019 images were overlaid, point vector shapefiles were manually digitized to allow each point to represent a moored or anchored boat in the AOI. The activity (mooring vs. anchoring) was differentiated based on delineated anchoring and mooring areas (polygons) as obtained from the Environmental and Resources Authority (2020).

Next, the digitised point data were used to generate density maps using the Heatmap (Kernel Density Estimation) tool of QGIS. This analysis tool calculates the density based on the number of points in a location, with larger numbers of clustered points resulting in larger density values, allowing easy identification of “hotspots” and clustering of points. Several trials were carried out, to test out the best tool settings to be applied in the estimation. One important setting is the Radius (in meters or map units) which specifies the distance around a point at which the influence of the point will be felt. Larger values result in greater smoothing, but smaller values may show finer details and variation in point density (QGIS Training Manual, 2016). Once the heatmaps were generated, further trials were carried out with the ‘Layer property’ settings to ensure a clear rendition of results. The heatmaps were then clipped using a polygon layer outlining the seaward extension of the bay, to improve the result.

Following, the LIDAR bathymetry dataset in xyz point format was first converted into a shapefile (also set in ED50/UTM Zone 33N) to facilitate its use in QGIS tools. Next, a raster surface representing the Digital Depth Model was interpolated using the natural neighbour tool, this considered to be a simple approach to the interpolation of raster data from the given bathymetry points. Following, bathymetric contour lines with a 5m interval were generated based on this raster.

As for the *Posidonia oceanica* habitat data made available through the Environment and Resource Authority (2017), this was mapped using the preferred symbology in QGIS however no further processing of the dataset was required. Rather this was utilised as an ancillary datasets to inform results and recommendations .

Results

Key results of this project are:

1. The heatmap for moored vessels (Figure 1) showed a total of 237 boats with densities of 5 to 21 vessels over a 100 m radius area, with higher density areas situated to the western end (inwards) of the bay, likely due to the presence of infrastructure (e.g. pontoons) and services (e.g. parking areas, beach bars) along that section of the coastline.
2. Anchoring activity is illustrated through the heatmap in Figure 2 with a total of 149 anchored boats, with densities of 3 to 20 vessels over a 100m radius area.
3. The mapped datasets for bathymetry and for the *Posidonia oceanica* habitat were overlain by the heatmaps (Figures 3 and 4). The overlays confirmed the presence of anchoring/mooring over the sensitive seagrass habitat. Furthermore, such overlays confirmed that both activities concentrate in shallower waters - up to 5m depths.

Figure 1: Heat map for mooring vessels in Mellieħa Bay based on an August 2019 scenario. Vessel positions are indicated in black points, whereas the heatmap is shown in a green gradient where the darker shades indicate higher boat densities.

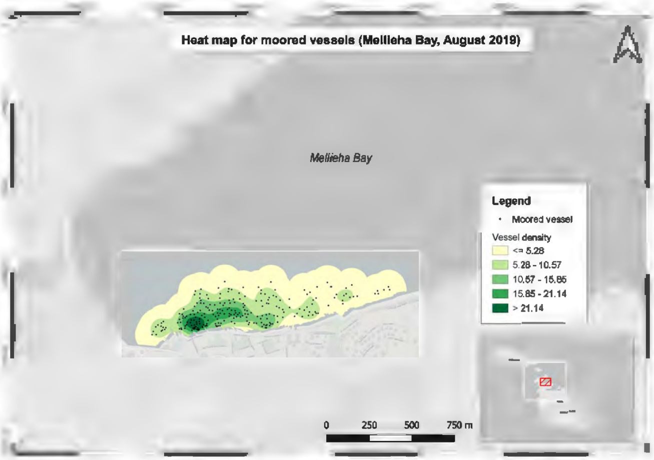


Figure 2: Heat map for anchoring vessels in Mellieħa Bay based on the June 2017 scenario. Vessel positions are indicated in red points, whereas the heatmaps are shown in a blue gradient where the darker shades indicate higher boat densities

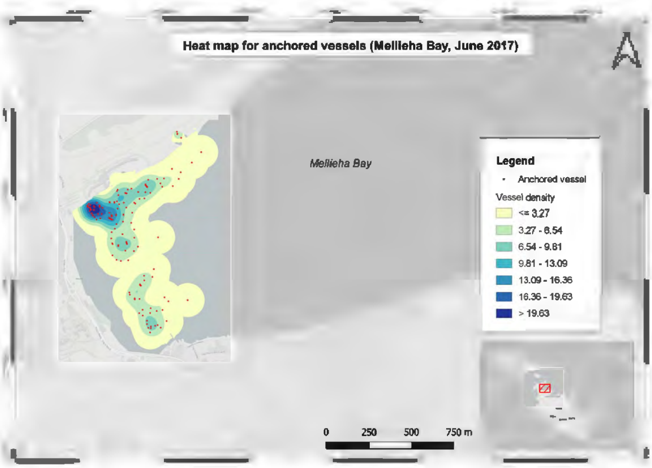


Figure 3: Overlay of heatmap for mooring vessels with *Posidonia oceanica* extent (dotted green layer)

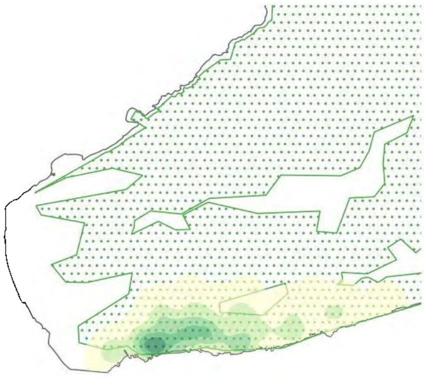
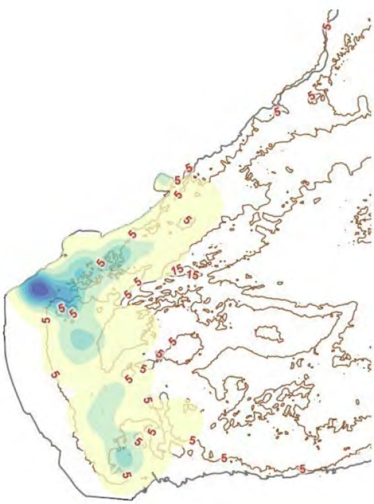


Figure 4: Overlay of heatmap of anchoring vessels with bathymetry - shown with contour lines indicating depth inm



Recommendations

Key recommendations for operational change:

- Organized mooring areas are recommended, considering the presence of sensitive habitats, and ensuring that damage by anchors is avoided. Bathymetric data may enhance such plans (e.g., placing smaller boats at shallower depths and larger boats in deeper areas) and eco-mooring is to be considered.
- The delineation of non-sensitive areas (e.g. seagrass-free sandy patches) can inform on the numbers/densities of anchored boats which could be accommodated, factoring in optimal boat densities/distances. The remaining sensitive areas would need to be subject to management measures e.g., no-anchoring zones, ecological buoys, etc.

Key recommendations for further research:

- The scenarios drawn should be corroborated using other datasets, such as drone imagery and field surveys/interviews supplementing updated and more recent information on boating patterns.
- High resolution habitat mapping would allow the delineation of high/low sensitivity areas (e.g. bare sand vs. seagrass meadows) facilitating management recommendations above.

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CHAPTER 6

Complementarity of satellite imagery and AIS intelligence for vessel detection and monitoring

Stephen Grixti

Keywords

Copernicus, Synthetic Aperture Radar (SAR), Sentinel-1, AIS, uncorrelated vessel, QGIS, Malta

Project Aim

The research serves as a proof of concept to the development of a platform that correlates reported AIS and SAR imagery and identifies vessels that are uncorrelated.This refers to vessels that have been physically detected through SAR but are not reporting their location. The main objective of this research is twofold: (1) Correlation of AIS positioning information with vessel detections through SAR, and (2) Detection and categorisation of uncorrelated vessels.

Introduction

Improved maritime situational awareness using SAR imagery received considerable attention since the availability of free and open Copernicus Sentinel-1 imagery. Considerable research has been undertaken in optimizing vessel detection algorithms in heterogeneous or strong clutter backgrounds. Notable research includes the work of Gao G. (2009), Leng X. (2015), Iervolino P. (2017), Gierull C.H. (2017), which delivered considerable detection results in complex backgrounds. Noteworthy research has also been undertaken by the European Commission's Joint Research Centre (JRC) which in 2017 released the SUMO (Search for Unidentified Marine Objects) tool, to perform ship detection on satellite SAR images (JRC, 2020).

Considerably less literature is available aimed to explore the fusion of SAR and positioning information reported by vessels. Published research, such as the work of Fabio Mazzarella (2015) seeks to optimise the quality of SAR and AIS fusion by exploiting knowledge of historical vessel positions. Other research such as the study of Chaturvedi (2019) highlights the pros and cons of SAR and AIS and asserts the complementarity of both datasets in improving maritime spatial awareness. Research by Lotfi Achiri (2018) and

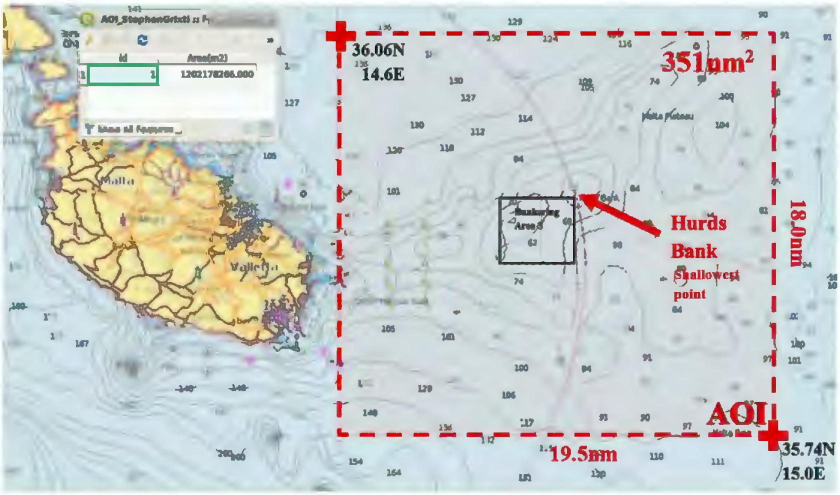
Vieira (2016) presents approaches to fuse datasets with promising results. However, the algorithms developed in the former are tested on simulated datasets with the assumption that all ships in the SAR image broadcast their AIS data with no temporal gap.

The EU Copernicus Maritime Surveillance (CMS) Service exploits EO data to provide a more complete overview of activities at sea. It makes use of SAR and optical data and fuses it with a wide range of datasets. The service makes available a comprehensive maritime picture to law enforcement and security domains. However, CMS is not publicly available, and the tool is only available to accredited Governmental Authorities (EMSA, 2020).

Area of Interest

As an island in the centre of the Mediterranean, close to busy shipping lanes, the maritime sector has always played a key role in Malta's economy (MMF; Bunkering, 2020). Malta's strategic location implies that vessels can undertake refuelling or transhipment operations in Malta with minimal deviation from the routes between Northern Europe and the Suez Canal. Such services are delivered within port limits at various terminals and offshore through ship-to-ship (STS) operations. While STS operations can take place in several designated areas within Maltese territorial waters, vessels may also opt to receive such services off territorial waters. A notably popular area in this regard is East of Malta: an area that coincides with a shallow offshore bank, named Hurds Bank. Depths in the region enable anchorage out at sea and apart from STS operations is also often used as a waiting area, amongst others. At any point in time the number of vessels anchored in these areas are in the order of 30. Consequently, Hurds Bank and the surrounding waters have been selected as the Area of Interest (AOI) for this research. The AOI shown in Figure 1, covers an area of 351Nm^2, half of which is within Maltese territorial waters.

Figure 1: The AOI and the bathymetry of Malta



Source: Navionics, n.d.

SAR imagery

All SAR datasets used are Copernicus Sentinel-1 Level-1 Ground Range Detected (GRD) products. Pixels, denote the detected amplitude of the reflected radiation (ESA, Sentinel-1 Data Products, 2020). Over the Mediterranean, Sentinel-1 primarily operates in Interferometric Wide swath (IW), mode with dual polarization (VV-VH). Dual polarisation implies that Sentinel-1 can transmit a signal in either horizontal (H) or vertical (V) polarisation, and then receive in both H and V polarisations. Irradiated targets have distinctive polarisation signatures reflecting different polarisations with different intensities and converting one polarisation into another (ESA, Polarimetry, 2020).

Due to the two satellite configurations of Sentinel-1 constellation, a minimum of two acquisitions per week is guaranteed over the Central Mediterranean. (ESA, Sentinel-1 Observation Scenario, 2020) The research was conducted on a total of 14 acquisitions, between February and March 2020. All Sentinel data products are made available systematically and free of charge to the public via the Copernicus Open Access Hub, amongst other portals, such as the Copernicus DIAS platforms. All data products are distributed in the Sentinel Standard Archive Format for Europe (SAFE) format.

AIS Datasets

As part of Regulation 19 of the SOLAS Chapter V, in 2000 the International Maritime Organisation (IMO) adopted a new requirement for all ships to carry an AIS. Such systems can automatically provide information about the vessel location to other vessels equipped with similar systems and to coastal authorities. The regulation requires AIS to be fitted and continuously operated aboard all ships of 300 gross tonnage and upwards engaged on international voyages, cargo ships of 500 gross tonnage and upwards not engaged on international voyages and all passenger ships irrespective of size (IMO, AIS transponders, 2020).

All AIS datasets used in this research have been sourced through an API service provided by MarineTraffic (MarineTraffic, Homepage, 2020). Each time the API link is called, the service returns vessels' positions within an area of your interest defined by bounding box coordinates. A typical API link is: https://services.marinetraffic.com/api/exportvessels/v:8/YOUR-API-KEY/MINLAT:value/MAXLAT:value/MINLON:value/MAXLON:value/timespan:#minutes/protocol:value

The highlighted parameters define the specifics of the call according to the description in Figure 2. The selected timespan parameter used within this research is 5 minutes, which implies that the result will discard AIS reports older than 5 minutes. The selected protocol parameter is csv; hence all vessel information will be dumped into a .csv file, which may then be imported into QGIS a delimited text point layer.

Figure 2: Parameters of the API call

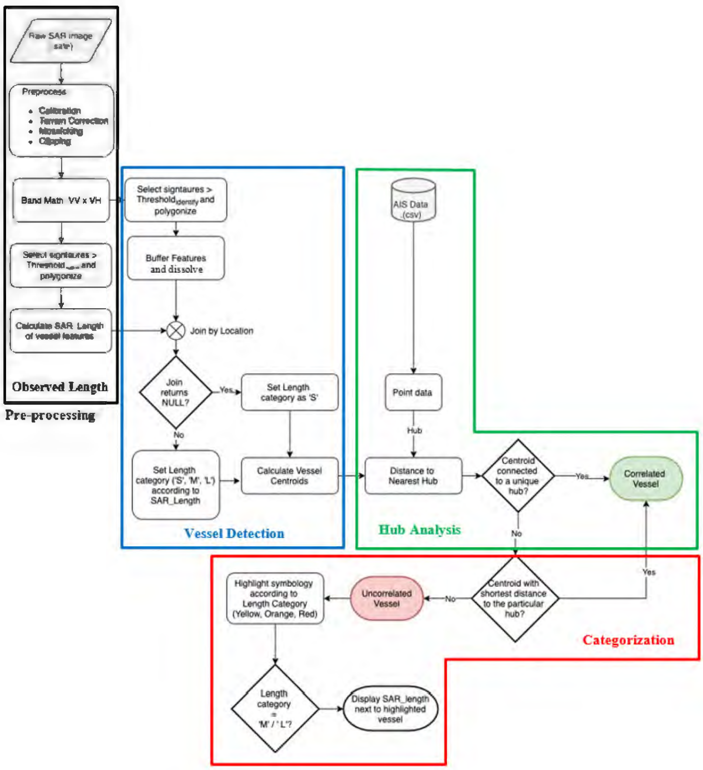
Parameter name	Required?	Type	Default value	Description
[no name]	yes	text		**API key**: 40-character hexadecimal number
timespan	no	integer	5	The maximum age, in **minutes**, of the returned positions. Maximum value is 2880.
msgtype	no	text	simple	If used with the value **extended or full**, the response includes scheduled static and voyage related vessel data report (AIS Message 5). In this case your request frequency might be limited (depending on your service terms). If omitted, the returned records include only position reports (AIS Messages 1, 2, 3/ 18, 19).
protocol	no	text	xml	Response type. Use one of the following: **xml, csv, json, jsono (object)**
MINLAT MAXLAT MINLON MAXLON	yes	float		Use as a group

Source: MarineTraffic, Homepage, 2020

Methodology

The research involves the development of a QGIS model that takes concurrent SAR and AIS datasets as input. The model output detected uncorrelated vessels, with appropriate symbology and categorization according to the observed vessel length. The high-level flowchart shown in Figure 3 splits the model into the following segments:

Figure 3: High level flowchart of the model



Pre-processing SAR acquisition:

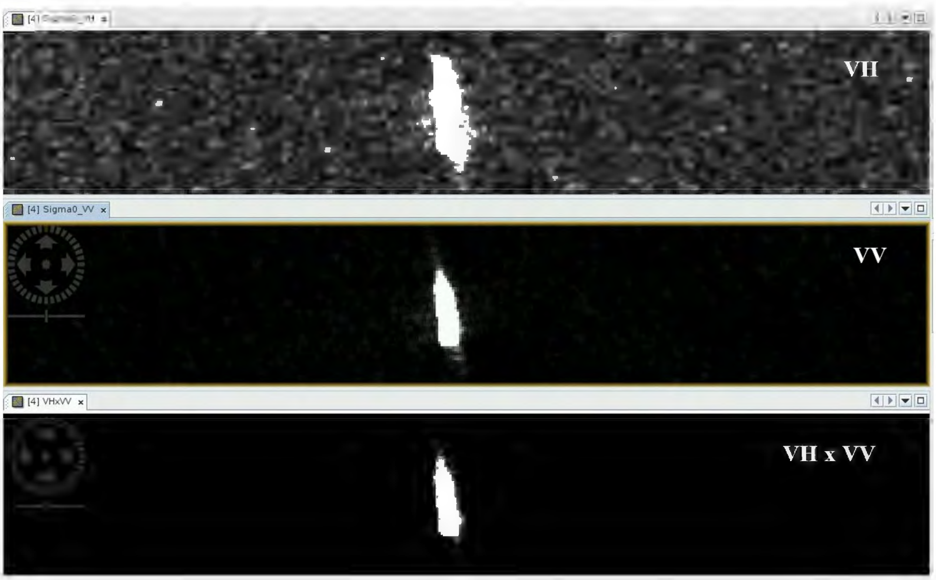
On downloading the Sentinel-1 products, several pre-processing steps are necessary to improve product quality in preparation for further analysis. The key pre-processing steps, which were conducted using the SNAP open-source toolbox (ESA, SNAP, 2020) are as follows: Subset, Thermal Noise Removal, Speckle Filter, Calibration and Terrain Correction.

Discussion

Vessel Detection

SAR polarisation is an important factor when detecting maritime vessels. Land, vessels and open water scatter radiation differently in different polarisation channels. In particular, metallic vessel corners, edges and cables often exhibit strong SAR reflections. Research on the combination of polarimetric channels for ship detection suggests that combining the co-polarisation (VV) and cross-polarization (VH) channels enhances the vessel to sea contrast (Tonje Nanette, 2013). As evident from Figure 4, the product |VV|x|VH| returns an improved and significantly sharper vessel reflection, with an attenuated speckle factor attributed to the mean sea scatter. A fixed threshold, Threshold "identify", equivalent to |VV|x|VH| = 0.01, was used to extract pixels having a relatively strong reflection compared to the background scatter reflections. Such pixels which, in this case, are associated with vessel reflections are then polygonised with 8-connectedness. As different vessel structures have different polarimetric signatures, the product |VV|x|VH| may occasionally dip below Threshold "identify" along a vessel, leading to disjoint reflections. This was counteracted by applying a calculated buffer on the detected strong reflections and dissolving the results.

Figure 4: Combining the co-polarisation (VV) and cross-polarization (VH) channels



Observed Length

The objective of this step is to approximate the length of the vessel features as detected through SAR. The use of a higher threshold Threshold “outline”, |VV|x|VH| = 0.05, enables a relatively clear definition of vessel outlines and hence, when polygonised, the extracted features are suitable for parametric calculations. A PyQGIS python script was developed to calculate the SAR_Length attribute: the length of the vessel features. The script iteratively extracts vertices of all vessel's features and employs the distance matrix algorithm to calculate the longest distance between vertices pertaining to a particular vessel feature. This distance approximates the vessel length. This attribute is then used to categorise the detected vessels by length.

Hub Analysis

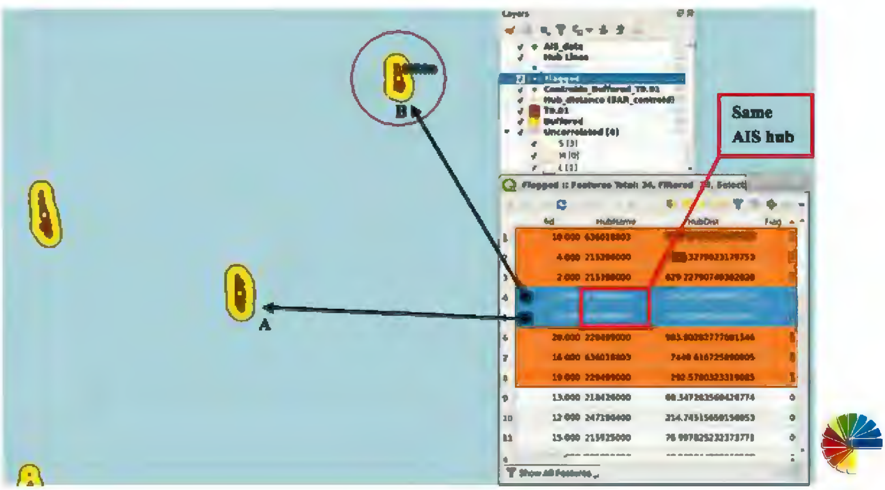
This part of the model is an integral part of the correlation analysis – a correlative analysis between the AIS data points and the centroid of the SAR vessel features detected at the same timestamp. The AIS .csv dataset is loaded into the QGIS model as a delimited text file point layer. A hub analysis, with the AIS data points as hubs, links vessel feature centroids to the closest AIS point. Any AIS point uniquely identifies one particular vessel. Hence, in principle the AIS data point-to-vessel centroid is a 1-1 mapping relationship. A 1-1 mapping implies that the vessel centroid in question may be assumed to be correlated, as illustrated in Figure 5. Additionally, an AIS point linked to more than one vessel centroid implies that one of those vessel centroids is uncorrelated. Such centroids are hence flagged for further analysis. The hub analysis was implemented in QGIS using the distance to nearest hub algorithm which calculates the distance between vessel centroids and the nearest AIS data point hub. Vessel centroids are hence ‘linked’ to the nearest AIS data point.

Figure 5: Examples of two correlated vessels – green point: AIS layer; yellow point: SAR vessel centroid

Categorisation

Whenever an AIS hub is associated with more than one vessel centroid, a reasonable assumption is that the centroid with the shortest distance to the respective AIS hub is the correlated vessel. All the remaining vessel centroids linked to that same AIS point can be assumed to be uncorrelated. The snapshot in Figure 6 depicts the concept. Vessels A and B are both linked to the AIS point HubName 2566380000 and have hence been both flagged. Comparing the distance between each vessel centroid and the AIS point, it is evident that vessel A may be considered as correlated to this AIS point while vessel B, which is further away, may be assumed to be uncorrelated. This was executed within QGIS through a series of SQL statements that extract the flagged centroid with minimum distance to a particular AIS hub i.e. the correlated vessel centroid.

Figure 6: Two vessels, one AIS point

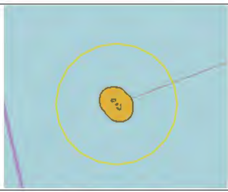
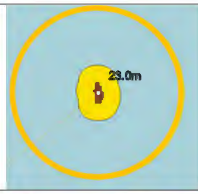
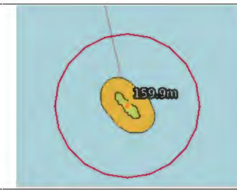


Uncorrelated symbology and labelling

The use of symbology and labelling optimises the GUI and enables a readable model output. A buffered circle outline is drawn around the centroids of uncorrelated vessel features. As shown in Figure 7, this buffer is colour coded according to the vessel length observed through SAR:

- Length ≥30m: Small (S) - Yellow
- 30m < Length <100m: Medium (M) – Orange
- Length ≥100m: Large (L) - Red

Figure 7: Symbology associated with the length category

		
SAR_Length: N/A **Small (S)**	*SAR_Length*: 23.0m **Medium (M)**	*SAR_Length*: 159.9m **Large (L)**

Results

The bar chart in Figure 8 depicts the number of uncorrelated vessels detected across the 14 acquisitions used in this research. The heat map in Figure 9 depicts the spatial distribution of all SAR vessel centroids (both correlated and uncorrelated) detected across all acquisitions. The heat map was calculated using a kernel density estimation, which, given the finite number of data points, in this case estimates how SAR vessel centroids are clustered or vary over the area of interest. In this example, a quartic kernel of 3 KM radius was used. A standard deviational ellipse clearly highlights the orientation of the trend. Recalculating the heat map on the reported AIS data, the similarity is immediately apparent as evident from Figure 10. In particular, the heat maps in Figure 9 and Figure 10 both identify two hot spots, shown in red, which illustrate areas of a relatively high degree of vessel presence within the area of interest. In principle any minor variations are attributed to vessels that have been detected through SAR but have no corresponding AIS transmissions i.e. uncorrelated vessels. Analysing the distribution with due consideration to the bathymetry indicates that the Westernmost hot spot falls within Bunkering Area 3 while the Easternmost hot spot coincides with the shallowest area of Hurd's Bank. As expected, both hot spots are associated with vessels at anchor.

Figure 8: Uncorrelated distribution across the testing period

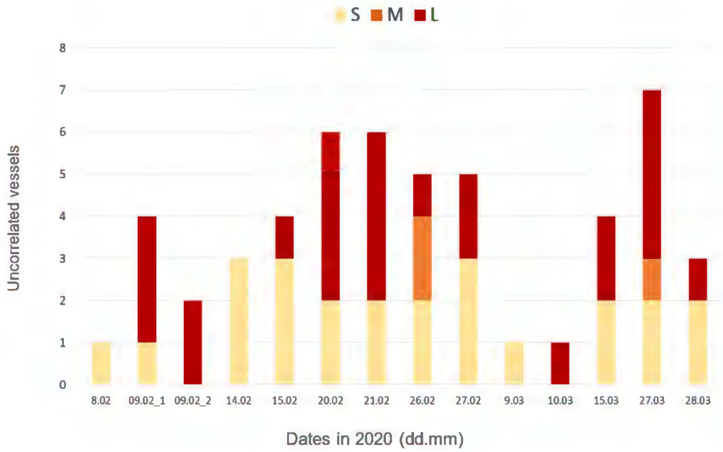


Figure 9: Heat map and Standard Deviational Ellipse of all SAR vessel centroids

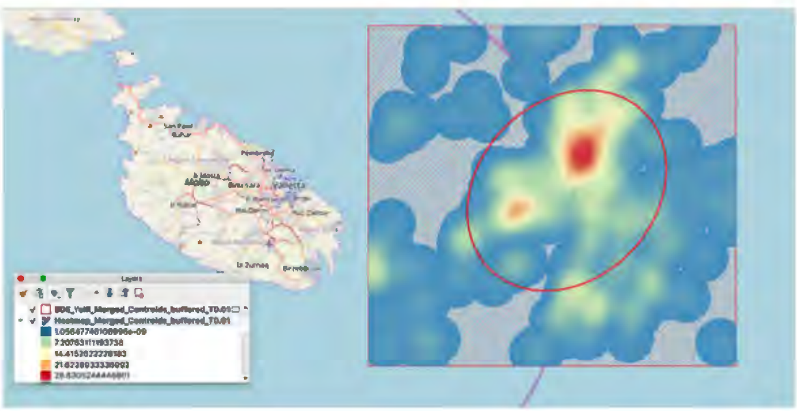
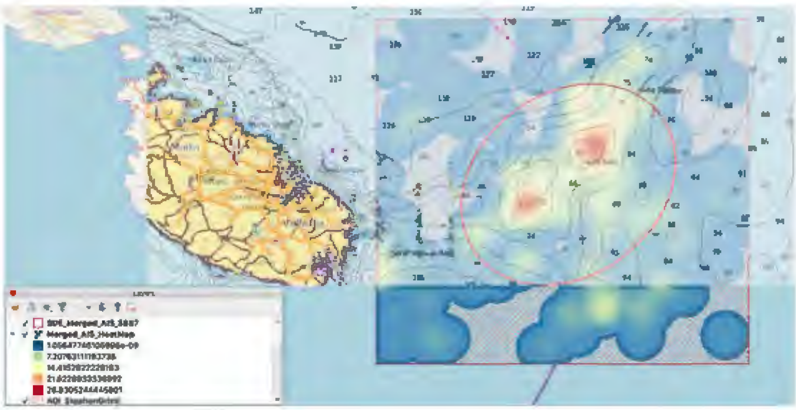


Figure 10: AIS heat map and AOI bathymetry



Recommendations

While meant to serve as a proof of concept to help expose the synergies of SAR imagery and AIS information within a local context, the research can be considered as an early TRL (technology readiness level) with promising results. Multiple additional improvements are required before such a system would be valuable in an operational context. Notable recommendations for research based on this proof of concept include the following:

- Use of higher resolution datasets: SAR imagery from Sentinel-1 does not reliably detect small vessels of the order of 20m or less. Furthermore, the spatial resolution of Sentinel-1 does not enable resolving individual vessels when undergoing STS operations. A more holistic system would certainly benefit from higher resolution datasets.
- Implementation of adaptive thresholding: While the fixed detection thresholds used in this research were selected in a calculated manner, fixed thresholding might not have been optimal across all acquisitions, particularly since background scatters vary between acquisitions. The use of adaptive thresholding, such as a Constant False Alarm Rate (CFAR) Detector, can help counteract such a limitation.
- Synchronisation between SAR and AIS timing: Minor mismatches between SAR and AIS timestamps may result in a reporting vessel being labelled as uncorrelated. Adapting the model to extrapolate the expected position of a moving vessel within the SAR image may help solve this limitation.

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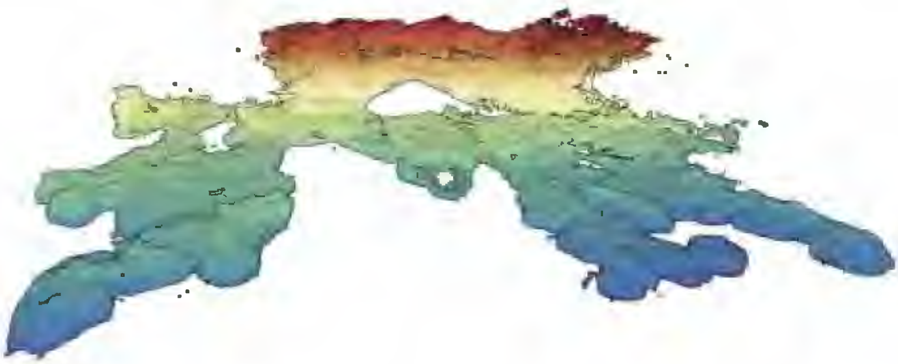
Pivot IV

Ecosystem Domain



L-Għar tal-Iburdan
Easting: 444638.350, Northing: 3970289.550

CHAPTER 7

Drone Monitoring of Anthropogenic Habitat Disturbances in Protected Areas

Marita Galea

Keywords

Drone imagery, Protected areas, Anthropogenic impacts, Habitat mapping, Photogrammetric software, Pix4D software, QGIS, Malta

Project Aim

The aim of this study was to assess (1) how the use of consumer-grade drone imagery and the methodology adopted can improve and facilitate monitoring of human impacts by generating high-resolution 2D map layers [orthomosaics, digital surface models (DSMs)] and 3D map products (point clouds, textured mesh) and (2) how photogrammetric software, such as Pix4D cloud, could be utilised to perform visual inspections and allow for the measurements of distances, areas, volumes and generation of elevation profiles.

Introduction

Continued habitat degradation due to human impacts endangers both biodiversity and ecosystem resources (Lorah, Ready & Rinn, 2018). Data collection on human impacts is highly time consuming. To cope with a vast range of ecological issues that pose a threat to biodiversity in protected areas (Jiménez López & Mulero-Pázmány, 2019) and to meet the dynamic management challenges that occur, cost-effective and innovative visitor monitoring methods which allow for high quality, long-term measurements are necessary for effective management of protected areas (Ancin-Murguzur et. al., 2019).

To detect human impacts and the ecological conditions of protected natural areas, fieldworkers must conduct extensive sampling. While these traditional techniques can be very accurate, highly skilled workers and meticulous planning are required. Traditional fieldwork is also constrained by economic and logistical limitations, resulting in temporally and spatially fragmented data on the status of the protected area, impeding successful environmental planning (Ancin-Murguzur et. al., 2019).

Usage of mid- to high-resolution georeferenced images, either from aircraft or satellite imagery, is another option that requires less field work (Kim & Daigle, 2012). However, the resolution and accuracy of measurements are smaller than those of field data (Ancin-Murguzur, et. al., 2019). These traditional remote sensing platforms are also often constrained by time intervals between images, clouds that obscure the landscape, and the inability to detect large-scale surface variation (Lentile et al., 2006).

With the launch of low-cost unmanned aerial vehicles (UAVs or drones) capable to rapidly capturing high-resolution imagery, many areas of study are turning to this technology for data collection (Ancin-Murguzur et. al., 2019). Drones have many benefits over traditional methods of ground surveying, aerial photography, and satellite imagery (Lorah, Ready & Rinn, 2018). They produce extremely informative data layers that are more precise than aerial surveys (Han, Jung & Kwon, 2017) and that can be easily archived for future research (Barnas et. al., 2019). Drones can fly slowly at low altitudes and record overlapping images, so they "bridge the gap between terrestrial and conventional aerial image acquisition and are therefore ideally suited to allow fast and secure data collection." (Tscharf et al. 2015; (Reif & Theel, 2016). Flights at lower altitudes with improved image quality would result in more accurate classifications (based on photo interpretation) than flights at higher altitudes. Flight paths are also easily repeatable over areas of interest, allowing users to perform repetitive surveys with limited variation (Barnas et. al., 2019).

Drones are increasingly being used by ecologists for a wide range of applications, including, wildlife prevention/detection, vegetation and landscape features mapping, land cover classification and changes, species reintroduction, forest surveillance and assessment of conservation effort (Barnas et. al., 2019). These studies indicate that consumer-level drones can provide high-quality data and time series for successful surveillance and management of medium-sized areas with less time spent in the field, low financial expenditure, and easy operability (Ancin-Murguzur, et. al., 2019). Drones offer flexibility, require relatively minimal training for usage and can be deployed quickly (Lorah, Ready & Rinn, 2018). Another advantage of using drone-derived orthophotos is that landscape-level disruptions like trampling and habitat fragmentation can be observed, even in remote areas (Tang and Shao, 2015; Grimaccia et al. 2015). In addition, studies have also shown that information retrieved from drones has a low error rate and produces comparable assessments of land cover as opposed to field-based sampling, resulting in similar inferences on biological processes (Barnas et. al., 2019).

Drones may thus assist in protected area management by tracking visitor use trends and related impacts, including trail conditions (width and depth), vegetation structure and disruptions, informal trail proliferation, effects of trampling, campsite formation, distribution of litter and other visitor impacts. These features must be maintained not only for the protection of biodiversity but also to provide tourists with a high-quality experience when visiting protected areas. Thus, by further applying GIS tools to drone derived-images, drones offer a new toolkit for protected area management. (Ancin-Murguzur et. al., 2019).

State-of-the-art

Locally, studies have begun to investigate the usage of drones in connection to the environment and in addition to satellite imagery. Preliminary assessments have been carried out on the efficiency of utilizing drones in (i) land cover mapping (Bellia & Lanfranco, 2019), (Bellia, Evans & Lanfranco, 2020); (ii) the optimisation of beach litter monitoring protocols through aerial imagery (Deidun, Gauci, Lagario, & Galgani, 2018); and (iii) the investigation of the use of drones for photogrammetric applications (Colica, Micallef, D'Amico, Cassar, & Galdies, 2017). The Environment & Resources Authority (ERA), as the national regulator of the environment, is also actively investing drone technology and workforce training. This will assist in policy decision making and will facilitate the Authority's commitments towards habitat monitoring, protected area management and enforcement, as well as to fulfil its EU's reporting obligations.

This study used drone-acquired imagery to preliminary examine the interaction between anthropogenic impacts and habitat coverage within a specific Natura 2000 (N2K) location on the Maltese Islands. The site chosen was Ramla il-Ħamra on the north-eastern side of Gozo. Ramla l-Ħamra, and is characterised by a sand dune system, with the marginal areas reclaimed as farmland. Anthropogenic practises such as farming, tourism, and recreational activities, have intensified the stress on the dune ecosystem, posing risks as erosion and habitat destruction. Accurate and high-resolution landscape imaging can aid in the execution of targeted land management techniques and can provide better good understanding of the natural mechanisms influencing the coastal dune complex (Suo, McGovern & Gilmer, 2019).

Methodology

Below is a brief overview on data, methods and tools used to achieve the aims of the project.

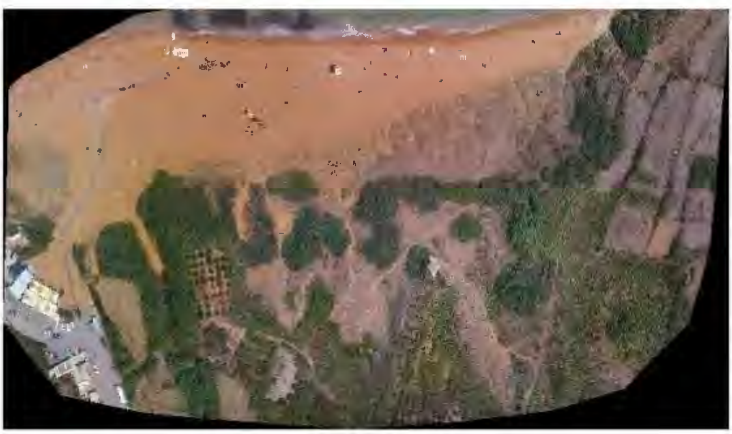
Data Acquisition

A drone linear-oriented flight mission was carried out to collect many overlapping images of Ramla l-Ħamra Bay. A total of 124 high-resolution ground images were captured via a consumer-grade drone, DJI Phantom 4, and inputted as geotagged .jpg files. Since flight control software ensured that the acquired multispectral images overlap, the image photogrammetry software; Pix4D cloud was used to initially process the .jpg images. Pix4D opts at 3 main processing steps to generate results.

Data Processing

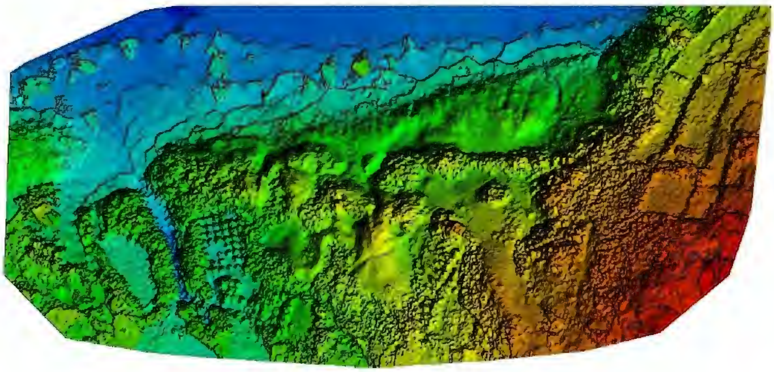
1. Initial Processing: The manual inputting of Ground Control Points (GCPs) was not required since the drone-acquired images were already geotagged. Therefore, Pix4D cloud was able to carry out automatic GCP detection to locate the specific site where the drone images were captured. Camera model optimisation took place during this initial processing step, where the internal (e.g. focal length) and external parameters (e.g. orientation) of the camera were calibrated.
2. Point Densification: The 3D point cloud map was created by point densification, whereby additional tie points are generated based on the Automatic Tie Points, resulting in a Densified Point Cloud. Based on the Densified Point Cloud, a 3D textured mesh can then be created (Pix4D Support, 2021).
3. DSM and Orthomosaic: Following point densification, an orthomosaic (Figure 1) and a DSM (Figure 2) were created. Generation of the orthomosaic is based on the DSM that is created from the Densified Point Cloud and on orthorectification. The orthorectification process includes internal, relative, exterior, and absolute orientation. This approach eliminates the perspective distortions from the images using the DSM. The DSM can then be used to analyse surface, measure volumes, and generate contour lines (Pix4D Support, 2021).

Figure 1: Orthomosaic of Ramla l-Ħamra Bay stitched from 124 high-resolution ground images



Source: Pix4D Support, 2021

Figure 2: Digital surface model (DSM) generated by Pix4D software



Source: Pix4D Support, 2021

Discussion

The photogrammetric software was used to convert the 124 raw images into a single high-resolution and large-scale orthorectified mosaic. As per data obtained from the Pix4D quality report, the total area covered by the drone flight mission was 5.7924 ha. Pix4D enabled the calculation of the area and volume occupied by agricultural fields and rooms within the protected site. This feature can be used to determine how much area is being taken by agricultural activities.

The identification of informal pathways due to trampling resulting in habitat fragmentation could be easily visualised from the orthomosaic and measurements of distances (length and width) of the pathways could be carried out directly from Pix4D, as shown in Figure 3. Pix4D also allowed for the setting up of markers which give the exact GPS coordinates. This function could be used by site managers to identify areas which could be cordoned off to prevent trampling on the sand dune habitats. In fact, Figure 4 depicts the actual cordoning currently in place within the site.

Figure 3: Identification of informal pathways and distance measurement

Source: Pix4D Support, 2021

Figure 4: Areas required to be closed off by cordoning to reduce trampling pressures on sand dune habitats identified and marked by Pix4D software

Source: Pix4D Support, 2021

Results indicate that 2D and 3D maps can be used together to assess landscape shifts and correctly place markers for site management applications, whilst having a better understanding of the mapped area. While a 2D map is best for determining area and distances, a 3D map has a more accurate visual viewpoint. The addition of depth to 3D maps also allows for the expression of altitude differences within the target location (Ivosevic, Han & Kwon, 2017).

Results

Key results of this project were:

1. Drone-acquired imagery was processed by photogrammetric and GIS tools to generate useful mapping products and data layers that can provide insights to protected area managers about conservation landscapes, restoration and management efforts required.
2. Drones can be used to track recreational impacts in a non-intrusive and effective way, while providing measurements of trail parameters such as, distance, width and informal trail proliferation, as well as more complex measurements like vegetation modifications.
3. Orthophotos, DSMs and classified maps provided high-quality information of the current state of the selected area of interest that can improve the knowledge on the landscape and lead to better informed decisions and more efficient protected land management.

Recommendations

Key recommendations of the effort are:

- Resultant orthophotos obtained from Pix4D could be further processed with QGIS software. By inputting the orthophoto as raster data in QGIS and by using the semi-automatic classification plugin in QGIS, a supervised land cover classification of the area of interest could be created to detect vegetation structure and habitat fragmentation. This will further assist in identifying main land cover groups in the study area (e.g. trails with exposed bare soil, differences in vegetation types and buildings).
- In the local context, more research is required on how drone technology and related image processing software can both contribute to informed and effective management of the site through the identification of adequate measures to mitigate and reduce anthropogenic disturbances and enable habitat restoration within impacted areas. A procedure for using drones to assess the effectiveness of conservation measures implemented within protected areas, as well as the overall effectiveness of site management could be also developed and tested as a pilot study.
- The procedure employed could be transferred and replicated for other protected areas.

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CHAPTER 8

Distribution of Crimson Fountain Grass in Northern Malta

Marko Filipovic

Keywords

Invasive Alien Species (IAS), *P. setaceum*, distribution, locations, distance, prioritisation, control.

Project Aim

The aim of this project was: (1) to plot available data on the exact locations of the Pennisetum setaceum in Northern Malta; and (2) to study distance of the closest Natura 2000 protected areas to the mapped locations, to identify populations deemed of priority for management..

Introduction

Invasive Alien Species (IAS) are organisms introduced into a natural environment where they are not normally found, with serious negative consequences for the new environment (Environment, 2015). IAS are globally considered a second major threat to biodiversity. To control IAS, the European Regulation 1143/2014 came into force in 2015.

The IAS Regulation lists Invasive Alien Species of concern (Environment, 2015). Member States have many obligations emanating from this Regulation some of which are obligation for prevention, implementation of surveillance to rapidly react once new IAS is detected, and monitoring and management of widely spread species. Member States must report to the European Commission every 6 years on the progress in implementing this Regulation, also providing baseline distribution of IAS of Union concern detected. Such information is presented in maps plotted on a 10x10 km grid (Tsiamis et al., 2019). For Malta's small surface area, the grid is reduced to 1x1 km. In its territory, Malta has 9 of currently listed 66 IAS of EU concern, with Crimson Fountain grass (*Pennisetum setaceum*) being one of the most spread species.

EU Member States submitted their national reports in connection with implementing Regulation 1143/2014 in 2019. All national reports and related information, including baseline distribution maps, are available on the EIONET Central Data Repository.

Methodology

For the present study, QGIS version 3.12 (QGIS, 2021)™ and the following datasets were used:

1. Data in CSV format related to the exact locations of Crimson fountain grass (*Pennisetum setaceum*) in Malta (with the focus on its northern region, Mellieħa area precisely). The Environment and Resources Authority (ERA) collects data on all IAS of Union concern locations present in the Maltese Islands territory through regular surveillance. Surveillance is assumed systematically, commencing from the north of the island. Hence analysis of this study focused on the Mellieħa area.

2. A map with pinpoints of *Pennisetum setaceum* locations, compiled by the group of environmentally conscious citizens, "Grow 10 trees", was provided to the ERA. This map is also publicly available on their Facebook page.

The raw data of ERA was used to create new shapefile layers: (i) points for locations where clumps of P. setaceum are growing; and (ii) polygons for areas where dense monostands are present. QGIS allows to analyse and edit spatial information, in addition to composing and exporting graphical maps (QGIS, 2021). Following the creation of a point shapefile, a geoprocessing tool buffer was used. A 10m buffer was created to better depict area where clumps are present. After buffering, a geoprocessing tool merge was used to combine points and polygon shapefiles.

In addition to the layers acquired (Spatial Train course material, PA, 2019-21), the Administrative Boundaries datasets and Google satellite orthophoto map of Malta were used. These were acquired from the Malta Spatial Data Infrastructure (MSDI) geoportal (MITA, 2021) and from the European Environment Information and Observation Network (EIONET, Central Data Repository, (CDR, 2021). Downloaded datasets were: (1) baseline distribution maps of IAS of Union concern compiled in connection with the first national report (EIONET, 2019) as shown in Figure 1; and (2) distribution of National designated areas from the Common Database of Designated Areas (EEA, 2020) as shown in Figure 2.

Figure 1: Baseline distribution of 6 IAS of Union concern in Malta

Source: The Malta Spatial Data Infrastructure (MSDI)

Figure 2: Distribution of National designated areas

Source: CDDA, 2020

Since the focus of this study was the proximity of IAS to the priority habitats (protected under Habitats and Birds Directives in the north of Malta, Mellieħa Administrative U nit) additional datasets (Malta Sites of Community Importance (SCI) and / Special Protection Areas (SPA)) were downloaded from the EIONET CDR. Downloaded shapefiles were merged, and the attribute table was amended (marine protected areas and N2K sites located in Gozo, Comino and central/south Malta were deleted)..

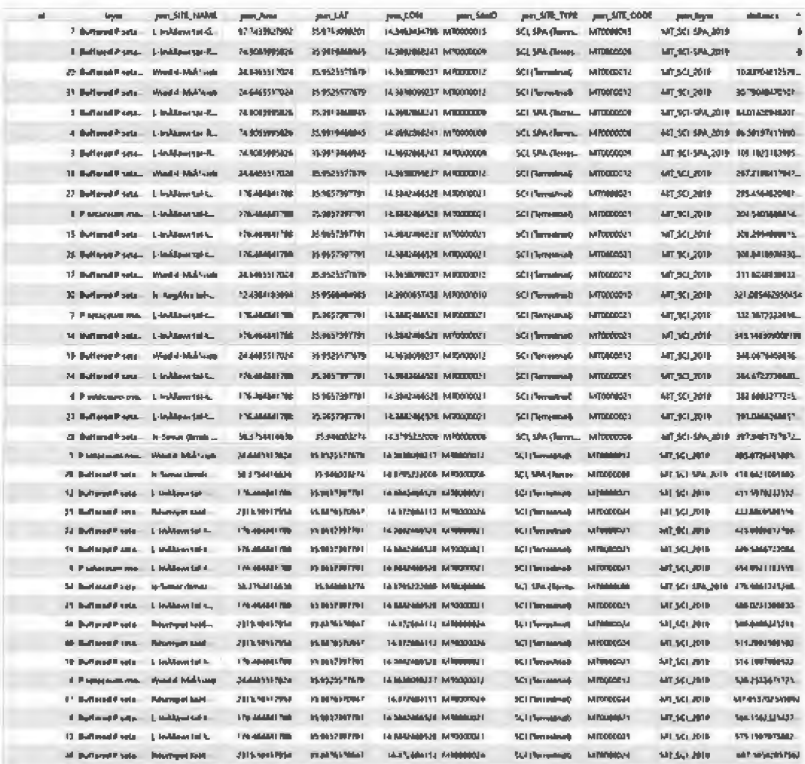
Discussion

Once shapefiles were prepared (following merging and amendments of the attribute table), the QGIS plugin NNJoin (Nearest Neighbour Join) was installed, that allowed the merging of vector layers based on the nearest neighbour relationships. A feature from the input layer is joined to the nearest feature in the join layer and the result is a new vector layer with the same geometry type and coordinate reference system as the input layer. (QGIS , 2019) The resulting layer contained both N2K areas and mapped *P. setaceum* locations (Figure 3), with a new attribute table (Figure 4) that contained the distance between the joined closest features.

Figure 3: *Pennisetum setaceum* locations and terrestrial N2K sites in North Malta

Following the merge of the N2K and *P. setaceum* locations layers using NNJoin plugin, the resulting layer contained the attribute table with the various information, including distances between all features of two merged layers. For each feature of the input layer, NNJoin added all the attributes of the nearest feature in the join layer, and a distance attribute showing the distance to this feature. Sorting the distance from the lowest to the highest value, attribute table indicated the locations hosting *P. setaceum* which are of the highest priority (Figure 4). The first two locations were within N2K sites (L-Inħawi tal-Għadira and L-Inħawi tar-Ramla tat-Torri u tal-Irdum tal-Madonna) and are of highest priority for control. However, considering that P. setaceum produces a large number of wind-dispersed seeds, all locations in the direct vicinity of N2K sites were also deemed of priority for the control. For the sake of prioritisation, all specimens found up to approximately 100m from the edge of N2K sites were controlled to create a *P. setaceum* free zone to act as a buffer.

Figure 4: Attribute table of the layer resulting from merging through NNJoin



Results

Given the objectives of this project, the following are the main conclusions and recommendations:

- Results were obtained from this project and provided a basic prioritisation in control of *P. setaceum* in north of Malta.
- QGIS is a good tool for visualisation and analysis of point data, and the map with the distribution of *P. setaceum* in Mellieħa administrative unit was successfully created.
- *P. setaceum* are located in various areas around Mellieħa. While few dense monostands (a group of plants, typically grasses, of the same species growing together in the same place in the absence of other species) were highlighted, these are currently relatively rare.
- Results from the analysis of the distance between the observed populations and adjacent Natura 2000 protected areas provided a good indication of clumps deemed of priority for control.
- Two locations (distance 0 as indicated in the attribute table – Figure 4) are within Natura 2000 sites, and an additional five, which are in direct vicinity to N2K sites, were deemed a priority for control.
- Results were useful for decision making and prioritization, and to identify populations/specimens of concerns, and therefore resources can be focused on their control following this study.

Key results of this project are:

1. Identification of the sites hosting specimens deemed as of priority for the control.
2. Specimens located within N2K sites require immediate removal to prevent further spread and negative impacts.
3. Five locations hosting *P. setaceum* in the direct vicinity of the N2K sites are to be controlled to create a buffer zone and prevent spread into N2K sites.

Recommendations

Recommendations for the operational change are:

- immediate control of the specimens within the Natura 2000 sites to prevent further spread and increase in population density; and
- control of the specimens in the direct vicinity to prevent spread and create a buffer zone.

Recommendation for the further research are:

- plotting and analysis of all available records in other parts of Malta; and
- to explore additional plugins or methods for such analysis.

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CHAPTER 9

GIS analysis of land-take processes in Malta's Natura 2000 sites

Stephanie Farrugia

Keywords

Urban areas, land-take, Natura 2000, rural settlements, overlap analysis, proximity effect, buffering, QGIS, development applications, artificialisation, Malta.

Project Aim

The aim of this project was: (1) to map and analyse the land taking processes in N2K sites, (2) to conduct spatial analyses of N2K sites' size and proximity to Urban Areas and Rural Settlements, and (3) how this affects the development application approval rate.

Introduction

Malta designated 34 terrestrial Natura 2000 sites (N2Ks) spanning over 43.6km², following its accession in the European Union (EU) (ERA, 2021). As in the rest of the EU Member States, these natural areas covering circa 13.8% of Malta's land area, are facing several disturbances and pressures from land take processes. This is more prevalent given that Malta is a densely populated island archipelago where land is a scarce resource (ERA, 2018). This need often demands take-up of agricultural land located outside the urban areas, termed outside development zone (ODZ)/rural area of which sites with Natura 2000 status, essentially form part (EC, 2015).

Recent studies classified Malta amongst EU Member States as having the largest number of urbanized areas in N2Ks (Concepción, 2020) with urbanisation and industrial activities recorded in more than 80% of Malta's N2K sites (Tsiafouli et. al., 2013). In another Mediterranean Island – Sardinia, it was found that the closer the N2Ks are to urban areas, the higher the pressure for land-take and a positive correlation was found between a decrease in land-take and the presence of size of N2Ks both inside their borders and in the surroundings (Lai and Zoppi, 2017).

It is generally assumed that the higher the level of natural protection measures, the lower the intensity of artificialisation brought about by land-taking processes. The need for this study has therefore arisen from the lack of quantitative information on the relationship between the zoning and location of N2Ks and land take mitigation. This is contextualised by the current national environmental protection regime afforded by the Environment Protection Act (CAP.549) and the Flora, Fauna and Natural Habitats Protection Regulations, (S.L. 549.44) which led to the adoption of Management Plans and Conservation Orders for terrestrial protected sites, in 2016. The operational objectives with such Management Plans are to be taken into account in a specific environmental assessment known as "Appropriate Assessment" that screens any project or plan proposed on N2Ks other than for site management and which could lead to adverse impacts on the area. Proposals on land parcels located outside the N2K boundaries also undergo the same screening if there is a risk that the integrity of the N2K at large is affected. This procedure is factored into the planning process since the conservation objectives of a protected site ensure, inter alia, that the status of a natural area is maintained by limiting land imperviousness and artificialisation from urban and rural sprawl. Therefore, this study analysed the current land take-up percentage in Malta's N2Ks mainly from rural sprawl, while seeking to determine whether proximity to urban zones is a good predictor of land take in N2Ks. For this study, land take was taken as the "change in the amount of agriculture, forest and other semi-natural and natural land taken by urban and other artificial land development" as defined by the European Environment Agency (EEA, 2021). The results also give an indication how Malta is faring vis-à-vis the EU's target to "achieve no net land take by 2050" (EC, 2011, p. 15).

Methodology

QGIS™ (V.3.10) was used. The 2018 terrestrial N2K vector datasets (EEA, 2021) were merged as one layer and clipped to the Maltese Islands boundary layer. Overlapping designations pertaining to the same sites (Special Protection Areas and Special Areas of Conservation) were omitted to avoid duplicate counts retaining 24 out of the 34 terrestrial N2Ks. The dataset of the Large-Scale Topography buildings (Planning Authority, 2021) existing until early 2016 was clipped to the extent of the N2K and the area of each building was calculated. The buildings were converted to points to find the percentage built-up area for each N2Ks and the 'count points in polygon' function was used to calculate the sum of all buildings. The datasets pertaining to the Urban Areas (UA) and Rural Settlements (RS) provided by the Planning Authority were included to elicit more site-specific spatial detail from the N2K sites.

Due to the large volume of vector data, the N2K sites were grouped into three main extents corresponding to their location – (i) Western N2Ks, (ii) Eastern N2Ks and (iii) Inland N2Ks, for better interpretation of results. An overlap analysis was undertaken to calculate the total area and percentage cover by which parts of N2K sites are overlapped by parts of RS and/or UA. The 'Nearest Neighbour (NN) join' function was used to determine the mean distance between the three N2K groups and the Urban Areas and Rural Settlements. This step established three separate buffer zones for analysis of land outside the designated protective boundaries. The points (buildings) inside each separate buffer were extracted using the 'Select by Location' – 'disjoint' function by comparing to the features within each N2K and merged to do a Kernel Density Estimation (Heatmap).

The rate of different types of development applications submitted during 2016-2020 was analysed to give an indication of the potential rate of artificialisation after 2016 given the unavailability of large-scale topography buildings dataset/s after April 2016. The planning applications were clipped to the N2K extent and converted to points to subsequently use the 'Join Attributes by Location' function to find the number of applications submitted within N2K. Each individual application's status was verified through the Planning Authority website by considering the number of approved applications and enriching the attribute table to derive the percentage approval rate.

Discussion

By early 2016, approximately 10,800 buildings were found in 24 N2Ks having a cumulative area of 0.044ha which is equivalent to 1% share of total land area of the N2K network (Figure 1). It is expected that this percentage share in artificialisation has increased since the average approval rate for development applications submitted between 2016 and 2020 in N2K is 64% (Figure 2). This approval rate should be considered as indicative of land take due to lack of Large Scale Topography buildings data available after 2016. a. Overall, by 2016, the N2K sites in Gozo had experienced less land-take than the majority of the N2K sites in Malta with the sites located on the eastern side experiencing less than 0.5% artificialisation (Figure 1). On the other hand, the percentage of development applications approval rate for Gozo's N2K sites was high ranging from 50% to 100% (Figure 2). Therefore, it is also expected that the percentage of land-take will be high after 2016. The results also indicate that most of the smallest sites located inland in Malta, namely 'l-Għar tal-Iburdan u l-Inħawi tal-Madwar', 'Għar Dalam', and 'L-Inħawi tal-Għadira' have a high percentage of land uptake. The only N2K site which registered a low rate of approval is the water body of 'Is-Salini' and the applications approved were of the infrastructural type.

Figure 1: Percentage land-take per N2K in 2016

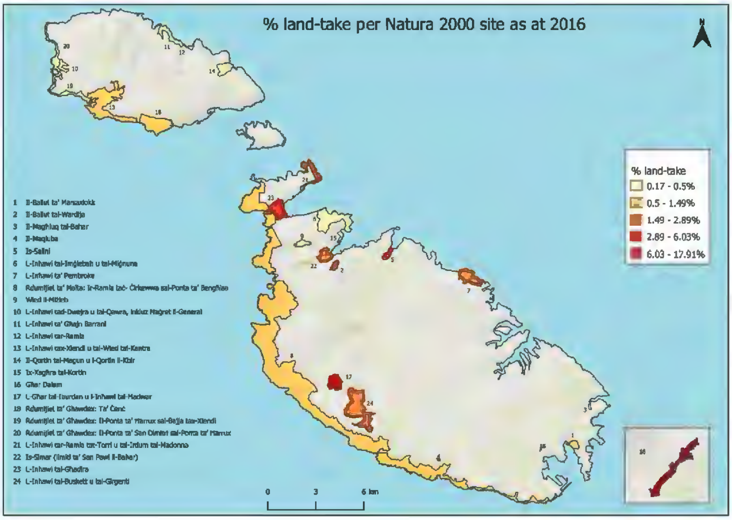
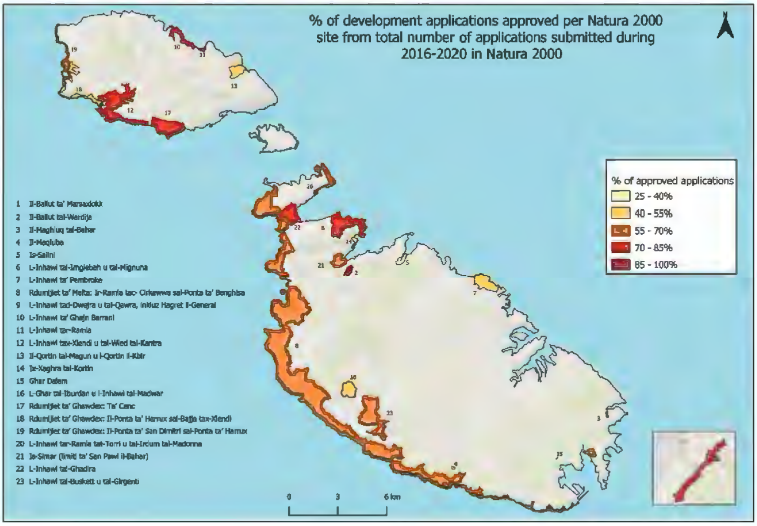
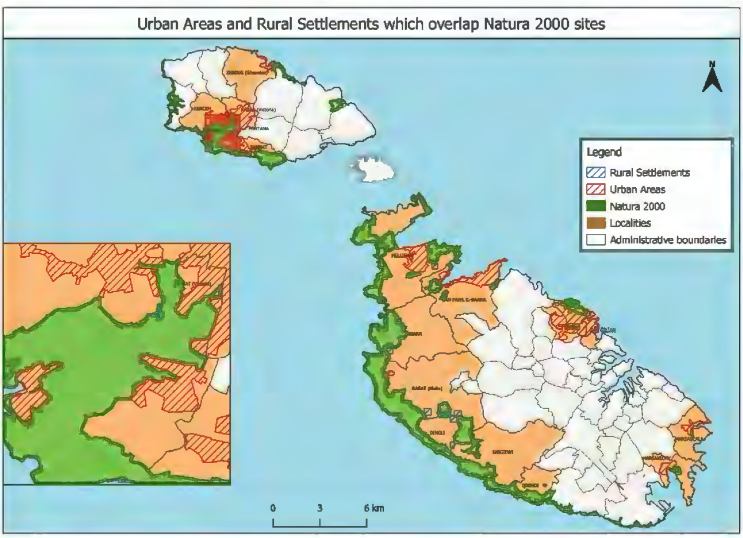


Figure 2: Percentage development applications approval rate per N2K site



As expected from the western group of N2Ks, the highest number of buildings is found in the largest N2K site located along the western stretch of Malta-'Rdumijiet ta' Malta: Ir-Ramla taċ- Ċirkewwa sal-Ponta ta' Benghisa', with c. 6000 buildings translating to c. 0.83% from its total land-cover (Figure 1). Furthermore, from a comparative analysis of development applications in this area submitted between 2016 and 2020, vs. development applications in other N2K sites for the same timeframe, it results that this area had the highest number of development applications, which had an approval rate of 58% (Figure 2). This site is also located within proximity of several urban areas, with that of Baħrija being adjacent and those of Dingli, Mġarr and Żurrieq, each being less than 200m away (Figure 43). In Gozo – 'L-Inħawi tax-Xlendi u tal-Wied tal-Kantra' experienced 1.5% artificialisation in 2016 and received the highest number of development applications between 2016 and 2020, out of which 68% were approved indicating a high percentage approval rate (Figures 1 & 2). In addition, c. 23,400sqm from the nearest four UAs and c. 4,500sqm from the nearest three RSs area overlap its boundary (Figure 3).

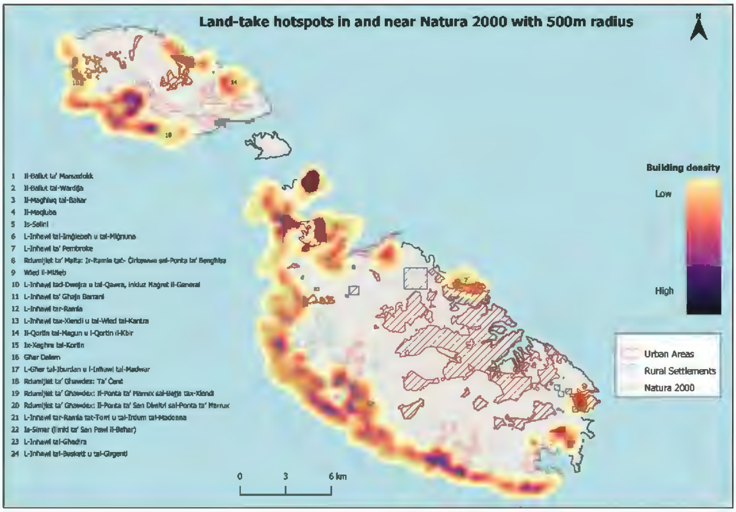
Figure 3: Urban Areas and Rural Settlements which overlap N2K sites. Gozo's largest N2K site overlap



From the inland group, 'L-Inħawi tal-Buskett u tal-Girgenti' has the second highest number of buildings collectively covering c. 3% of its total land area (Figure 1). The highest overlap percentage in Malta at c. 83%, and a corresponding high percentage of land-take of 4% by 2016 is recorded at its neighbouring site - 'L-Għar tal-Iburdan u l-Inħawi tal-Madwar' (Figure 3). Approximately half of the development applications submitted in both sites were granted development permission (Figure 2). A similar scenario due to the proximity effect can be noted for some of the sites located on the eastern side such as 'L-Inħawi tal-Għadira', which is located c. 300m from the urban area of Mellie ħa and Pembroke which is directly adjacent to the urban fringe of three urban areas. However, by contrast, 'L-Inħawi tal-Imġiebaħ u tal-Miġnuna' partially bordering the same urban area of Mellieħa, has a significantly low number of artificialisation with a percentage of 0.23. The same can be stated for 'Wied il-Miż ieb' which partially borders the same urban area, of which c. 0.4% is taken up by buildings and 'Ix-Xagħra tal-Kortin' which partially borders the urban area of Xemxija (Figure 3).

Aside from overlapping designations being a common factor between most of the N2K sites and other sites, the distance of nearly all the analysed N2K sites from the nearest Urban Area is less than 1km with the average distance being of 186m. This was further affirmed through the buffer analysis which showed that the number of buildings in all buffer zones extending to the outside development zone land parcels which are located between N2Ks and Urban Areas and the density vis-à-vis the buildings inside the N2K is generally high (Figure 4). This indicates that land take is to a certain extent dependent on the proximity of the immediate zone of influence of the Urban Area/s or Rural Settlement/s. The high approval rate of development applications submitted within such sites also indicates a positive relationship between the proximity of the N2K sites to the nearest Urban Areas/ Rural settlements and the land-taking process.

Figure 4: Heatmap: Buildings density within and around N2K sites



Results

Key results of this project are:

1. GIS is an effective tool in the analysis and determination of factors that affect land take in N2K sites.

2. Malta's N2K sites are being impacted by their proximity to urban areas and rural settlements and the rate of land-take after their designation, has continued to rise.

3. The proximity effect positively correlated with the development application's high average approval rate and with the density of development in the outside development zone land parcels in between the urban areas/rural settlements and the N2K sites.

4. The land uptake in smaller, more vulnerable N2K sites appears to be higher than in larger N2K sites.

5. The presence of a N2K site does not seem to be correlated with a decrease in land-take.

Recommendations

Key recommendations of the effort are:

- More scrutiny of projects within N2K and frequent revisions of land use policies should take place so as to keep pace with development trends in such sites e.g. by designating buffer zones around the most vulnerable sites.

- Monitoring of land artificialisation and land take could also be considered in management plans of N2K sites to optimize the conservation objectives.
- The methods used for the project can be further elaborated using regression models, aerial photography or satellite imagery and remote sensing techniques to determine the spatial pattern of land take in Natura 2000 sites and land use boundaries.
- Biodiversity data can be spatially analysed to determine where the survival of protected habitats and species is under threat becasue of artificialisation to improve the effectiveness of management efforts in N2K sites.

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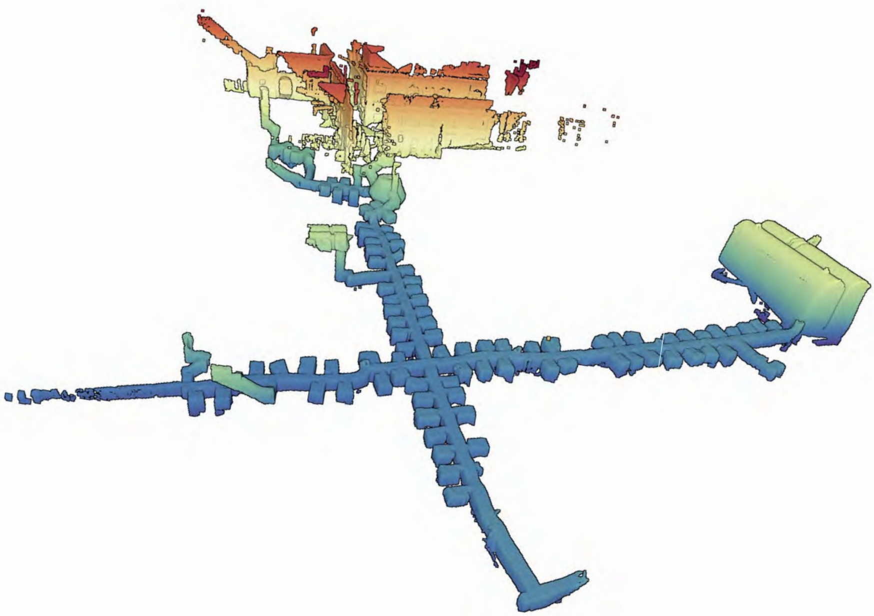
Pivot V

Cultural Heritage Domain



Valletta Subterranean
Easting: 456138.079, Northing: 3972887.521

CHAPTER 10

The Threat of Rising Sea Level: Birżebbuga Case Study

Alexandra Camilleri

Keywords

Sea Level rise, Climate Change, Cultural History, Modelling, Digital Elevation Model, Malta, Coastal Sites

Project Aim

The purpose of this project is to project the Sea Level Rise (SLR) with respect to its effect on scheduled sites. The coastal town of Birżebbuga was selected as a case study for this project. This project attempts to project the predicted SLR and the threat this may have on scheduled sites.

The main objectives are:

1. to understanding and identify the sixty sites within the administrative boundaries of Birżebbuga;
2. to implement geospatial analysis tools to create appropriate data sets; and
3. to generate a model using a Geographic Information System (GIS) to study the impacts that 1m to 6m in sea level change will have on Birżebbuga and the identified sixty sites.

Introduction

There is hardly a bay in the Mediterranean that is not a miniature community, a complex world in itself. The premise of this study embarked from this quote, postulated by the historian Fernand Braudel in his magnum opus on the Mediterranean during the Early Modern Period (1972). The imminent threat of Rising Sea Level on coastal communities is becoming a reality.

During the past years, an upward trend in Rising Sea Levels is recognised as an imminent threat to coastal sites and communities (Oppenheim et. al., 2019). The Intergovernmental Panel on Climate Change (IPCC), projects the global Sea Level Rise to be 0.43-0.84m by 2100 (Oppenheimer et. al., 2019). The increase in sea level is a result of climate change, the rise in sea temperature, and the melting of ice caps. Taking Sea

Level Rise as a solitary phenomenon is not sustainable, as various factors such as the depletion of marine life, increase in salinity which aggravates erosion, and ocean acidity contribute to this phenomenon (https://www.epa.gov/climate-indicators/climate-change-indicators-sea-surface-temperature). The importance of historical and cultural heritage sites has long been underlined as being vestments of national identity, pockets of tradition, and intangible beliefs.

The island of Malta forms part of the Maltese archipelago and is in the middle of the Mediterranean Sea, between Sicily (96 km northward) and the North African coast (290 km westward). The coastline of the island of Malta is 196 km long, and is dominated by sheer cliffs, small inlets, coves and other limestone formations (Paskoff & Sanlaville, 1978). The Maltese Islands has a total of 316 km^2, with the population estimated at 493, 559 at the end of 2018 (National Statistics Office, 2020). A predilection to coastal communities, towns and villages is historically entrenched, with most the major cities and towns in Malta found along the coastline.

The term 'scheduled sites' refers to a national repository of properties and sites that are of cultural and national importance. The sites vary from being of historical interest to being of geological or environmental importance. Different levels of scheduling are also given, depending on the merits and significance of the site.

In Furlani et al. (2012), a multidisciplinary approach to the study of sea level change was applied along the coast of Malta, whereby data collected from archaeological deposits was studied in relation to the mean sea level. This was undertaken to establish and study the fluctuations in sea level from pre-history to the modern age.

Malta's coastline and the different geological formations pertaining to it have been studied at length by Paskoff and Sanlaville (1978), Sara Biolchi et al. (2014), and Furlani et al. (2012). These studies provided a detailed classification of the Maltese coastline based on field studies, identification of coastal geomorphotypes and the creation of geomorphological maps. This study allowed for an accurate and scientific grading of the geological formations pertaining to the Maltese Islands.

In a study of SLR in Malta by Formosa (2015), the process of the encroaching coastline was delineated whilst taking several areas in Malta as a case study. Formosa postulated on several scenarios, whilst using GIS, to visualise the reality of Rising Sea Level. Formosa extrapolated that different land uses resulted in different scenarios, with massive economic and social movement proposed.

Another study which was significant for this research was Abdulahad and Abdalla's study of the impact of sea level rise on Richmond, British Columbia (2016). Their methodology and manipulation of the resultant data was applied in this study as a model.

A strong case of rising sea level vis-à-vis coastal sites of heritage importance is the Modulo Sperimentale Elettromeccanico (MOSE), a project intended to safeguard the city of Venice from its yearly flooding. Initiated by the Ministry of Public Works, the project analysed historical data of sea levels, taken from 1966 up to 2019. This study is one of the few wherein an applicable solution was proposed. Several breakwaters and water barriers were implemented, with the target date for completion being the end of 2021. (https://www.mosevenezia.eu/project/?lang=en)

While rising sea level and the threat it may have on coastal sites has been discussed at length in several publications, the decision to focus on historical sites of cultural value and importance is an innovative approach to the subject matter at hand. The resultant prognosis will engender new studies on the future viability of these sites, especially considering their protection. Results from this study will be utilised by the Superintendence of Cultural Heritage to analyse and project future scenarios. Additionally, it is expected that the data outcomes will also form part of the Coastal SAGE project (Coastal Satellite Assisted Governance (tools, techniques, models) for Erosion, spearheaded by the University of Malta (https://www.um.edu.mt/projects/coastal-sage/).This task force was established in order to study and predict the rise in sea levels the impact of climate change and coastal erosion, with studies extending to agricultural water consumption and evaporation.

Methodology

The approach in this study used GIS for the prediction of rising sea level taking into consideration natural and historical phenomena such as the link between global warming and sea level change, the natural geographical elevations of the site in question, and the historical urban sprawl pertaining to Birżebbuġa. This research identified the sites which are most at risk when simulating the 1m to 6m rise. The methodology used was divided into two sections: (1) processing of DEM datasets to create a baseline; and (2) the simulation of the 1m to 6m rise.

The following is a brief description of the process used, based on the methodology created by Abdulahad and Abdalla (2016).

The first step was to create a shapefile populated by polygons denoting the 60 scheduled sites pertaining to Birżebbuġa. A Digital Elevation Model (DEM) using a provided raster image of Malta was then created. The DEM was used as the baseline pertaining to the current sea level rise. Contours ranging from 1.25m to 10m were also applied to indicate the different elevations. The resulting DEM was then manipulated using the Raster Calculator Tool to extract the desired cells in the form of new rasters.

This resulted in binary layers using the elevation values of 1 to 6m as potential flooded areas. The creation of these rasters was pivotal in this research. These rasters consisted of cells with the values of 1 or 0. These rasters were subsequently reclassified using the Translate Tool to generate cells with Data and cells with No Data, wherein the cells with value 0 were translated into No Data and thus null values. This process was repeated for all rasters. After defining the No Data value, the rasters were transformed into polygons using the Polygonise (Raster to Vector) Tool. Vector data is easier to manipulate, hence this decision was deemed appropriate for this exercise. Therefore, 6 shapefiles were then created, each denoting a 1m increase in SLR.

Nonetheless, the resultant shapefiles still consisted of unfiltered inland water patches which would have resulted in irregularities and anomalies within this research. The Select by Location Tool was utilised to filter out these anomalies. The SLR shapefiles were compared with features from a coastal vector file, with the geometric predicate set to 'intersect'. This was repeated for each shapefile. The finalised SLR shapefiles were created using the 'Save only selected features' in the Save Vector Layer As tool. Due to an error in their geometry, these shapefiles were subsequently rectified using the Fix Geometries Tool.

The geospatial data sources used in this study were obtained mainly from online sources. The Open Street Maps layer and the ARCGIS Server layer were used as base layers in order to provide context. The coastline shapefile, used to filter out inland water patches, was also provided by Open Street Maps. The Digital Elevation Model for Malta was provided by resolution data from the Shuttle Radar Topography Mission. Tile 'N35E014' was selected for the purpose of this assignment. The Planning Authority Geoportal and the Malta Scheduled Property Register were used to ascertain and create the needed information and shapefiles for the scheduled sites in Birżebbuġa.

Discussion

This model, whilst predicting future possibilities, has highlighted the precarious situation most Birżebbuġa's sites are in. The predicted rise in sea levels will inundate the coastal town of Birżebbuġa, mainly due to its low-lying physiographical features. With the IPCC forecasting a possible scenario wherein at the end of 2100, sea levels may rise by up to 1 meter (Openheimer et. al., 2019), the rise in sea level is an exponentially upward growth, exacerbated by several other phenomena such as global warming and the melting of the ice caps.

The study demonstrated that by the end of the twenty-first century, three of these scheduled sites will be impacted by a sea level rise of 1m. 40% of these scheduled sites will either be underwater or severely inundated by a 6m rise in sea levels (Table 1). The growth of SLR is exponential, not linear, as various factors such as global warming and the melting of ice caps contribute to this manifestation. Therefore, while accurate predictions of SLR cannot be ascertained, an approximate value of this growth is continually being studied by international bodies such as the IPCC and the European Union to factorise and envision these extremely likely scenarios.

The link between global warming and the rising of sea levels cannot be denied. The future cultural landscape, notwithstanding modern-day infrastructure and urban sprawl will be greatly impacted and changed due to the rising sea levels. The Superintendence of Cultural Heritage, the regulatory body tasked with safeguarding Malta's national cultural and patrimony, will be contributing to this discussion by using this model as a pilot project to analyse the effects SLR will have on the Maltese coast. This pilot project will be enhanced upon and will be implemented as a national strategy to study, locate and identify threats to Maltese patrimony.

Results

Key results of this project are:

- The primary zone which is most affected is the area pertaining to and surrounding Pretty Bay and St George's Bay. As mentioned above, this sandy cove will be the first to be inundated due to its low-lying level. At 1m SLR, Ferretti Battery and the End of the Cold War Memorial will be immediately affected, which constitute 4% of the total scheduled sites (Figures 1 and 2).
- Bronze Age Cart Ruts, located at a small promontory with St George's Bay, will be affected, along with the previous two sites when SLR is at 2m. At 3m SLR, these three sites will remain impacted, with no additional sites affected This constitutes 5% of the total number of sites.
- At the predicted 4m rise, water ingress is seen making its way further inland, with an additional five sites being affected, conjunctively with the previous sites mentioned. This totals to 14% of the total number of sites. This indicates that at 4m, the relatively stratigraphic and geological formations of Birżebbuġa, which is mainly a port town, will be severely affected by this increase in sea levels.

- The numbers of sites affected grows incrementally, with sea levels making their way further inland. At 5m SLR, 32% of sites will be impacted, with six additional sites being affected when the sea level rise is at 6m. At 6m, a total of 40% of sites will be affected.
- In total, twenty-three out of the sixty scheduled sites will be impacted when sea level rise reaches the predicted 6m (Table 1). This constitutes 40% of the sites in total. With almost half of the scheduled sites either completely underwater or severely inundated by this rise in sea levels, the future prosperity and protection of these sites is brought to the forefront (Figure 3).

Figure 1: Detail from overall canvas showing part of Birżebbuġa with projected 1m to 6m SLR.

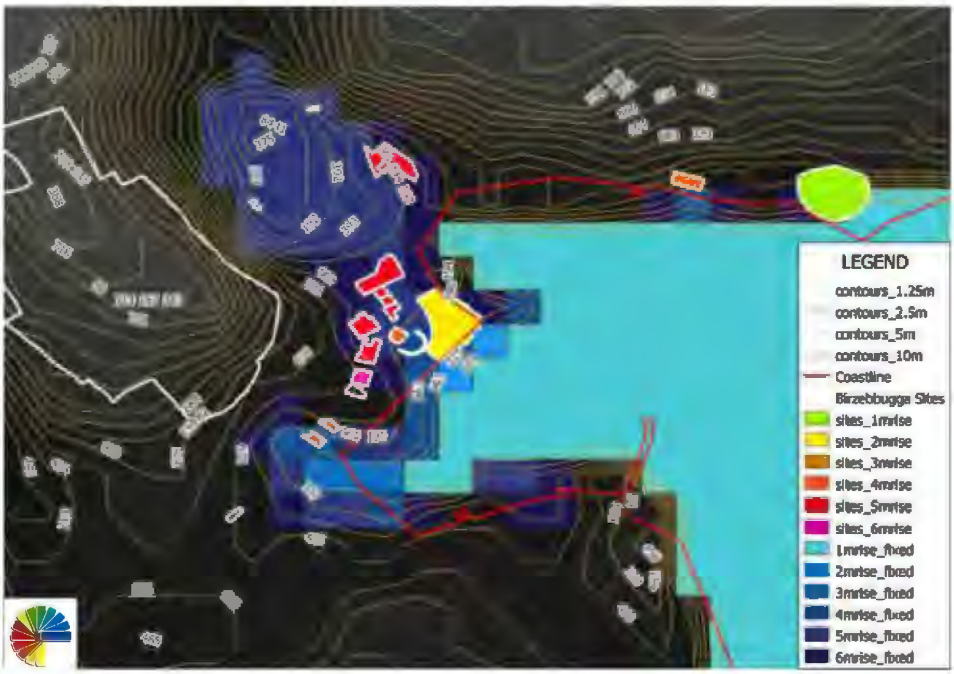


Figure 2: Percentage of sites impacted by 1m to 6m SLR.

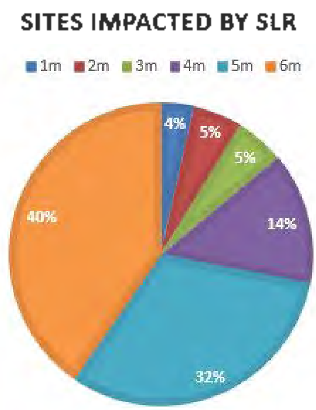
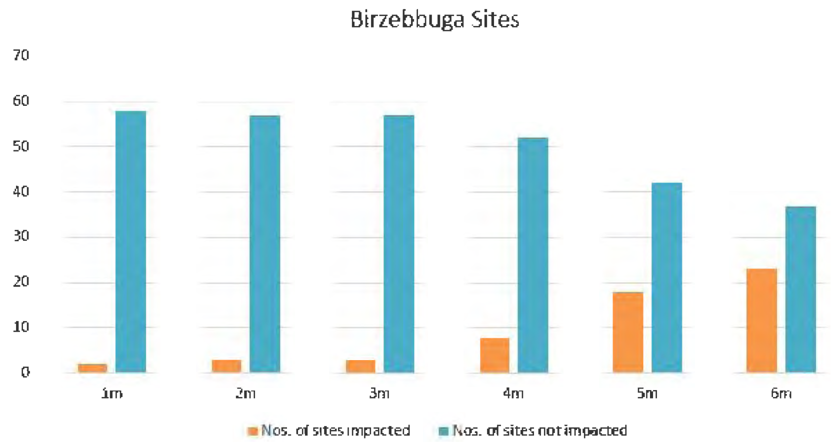


Table 1: The projected number of sites effected with 1m to 6m SLR.

Sea Level Rise	Sites
1m	Ferretti Battery, the End of the Cold War Memorial
2m	Ferretti Battery, the End of the Cold War Memorial, Bronze Age Cart-Ruts and Silos
3m	Ferretti Battery, the End of the Cold War Memorial, Bronze Age Cart-Ruts and Silos
4m	Ferretti Battery, the End of the Cold War Memorial, Bronze Age Cart-Ruts and Silos, St George's Redoubt, Dwelling No. 95 Dwellings Nos 91-92, Dwellings Nos. 11-14, St George's Church
5m	Ferretti Battery, the End of the Cold War Memorial, Bronze Age Cart-Ruts and Silos, St George's Redoubt, Dwelling No. 95, Dwellings Nos. 91-92, Dwellings Nos. 11-14, St George's Church, Dwelling N A, Dwelling N A, Dwelling N A, Wayside Shrine, Dar il-Ghaxqa, Falm Lodge, Pegasus & Kalimera, Chapel of St Joseph Dwelling No 192, Dar il-Hena, Dar is-Sliem, Dwelling N A
6m	Ferretti Battery, the End of the Cold War Memorial, Bronze Age Cart-Ruts and Silos, St George's Redoubt, Dwelling No. 95, Dwellings Nos. 91-92, Dwellings Nos. 11-14, St George's Church, Dwelling N A, Dwelling N A, Dwelling N A, Wayside Shrine, Dar il-Ghaxqa, Falm Lodge, Pegasus & Kalimera, Chapel of St Joseph, Dwelling No. 192, Dar il-Hena, Dar is-Sliem, Dwelling N A, St Andrews, Dwellings Nos. 121-123, Dwellings Nos. 95-99, *Dwelling No.* 132, Dwelling No 83, Dwelling No 4

Figure 3: Impacted and not impacted sites relative to a 1m to 6 m SLR.



Recommendations

Key recommendations of the effort are:

- A national strategy with regards to the threat Rising Sea Level will have on coastal towns and area of historical importance
- Inventory of sites at peril or danger of imminent collapse due to environmental and maritime activity
- Further research on the correlation between SLR and climate change in Malta, vis-à-vis the rise in urban sprawl and development
- Further research in the relationship between salinity and stone deterioration.
- Acquisition of further research and data on coastlines

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CHAPTER 11

The Wignacourt Aqueduct from Rabat to Attard, Malta

Anne Marie Schembri

Keywords

Water, potable, aqueduct, underground, plotting, buffer zone, scheduling, grades, masonry, history, environment.

Project Aim

The aim of this study was to facilitate an adequate assessment of a historical civil engineering and infrastructural project, which was and remains of national importance. The exercise also facilitated the rediscovery, even in the popular/national consciousness, of a feature that has been effectively lost and forgotten after its use was overtaken by later infrastructural developments.

Introduction

It may be said that aqueducts have always been synonymous with population expansion. This straightforward mechanical ingenuity uses the force of gravity to transport water from one place (be it a river or spring) to another, thus providing a controlled and reliable source of water to a place which lacks such necessity. Malta, being a small archipelago with a semi-arid Mediterranean climate, has no exploitable surface waters. In addition, the lack of rainfall during the summer months makes ground water the only natural water resource which is available all year round. A detailed study by Restall (2015) identified and plotted most of the available water management systems in Malta, which are mainly located in the western regions of the main island.

The role of the Superintendence of Cultural Heritage (SCH) includes the assessment of several development planning applications, most of which would also involve a degree of ground disturbance. Such ground disturbance may negatively impact on remains which may still be unknown to us. Luckily, for the aim of this project, the tract of the Wignacourt Aqueduct from Rabat to Attard, had been mapped on several occasions. However, for the purpose of this work, the 1968 Survey Sheets as well as Natural Heritage Malta's maps were scrutinised. The post Second World War Survey Sheets were mostly used to geographically record issued planning permits. Furthermore, these maps contribute a plethora of information on the existence of structural as well as natural landmarks.

Methodology

The exercise involved the transfer of spatial data derived from the above indicated sources onto a base map/layer using QGIS. This base map, the ArcGis MapServer, was made available to the SCH due to its collaboration with various entities, including the Planning Authority's the SIntegraM project (Planning Authority, 2017). Maps from the 1968 Survey Sheets were then georeferenced and overlain on the ArcGis MapServer base map (http://geoserver.pa.org.mt/publicgeoserver). This facilitated plotting of the underground tracts with greater reliability and precision. Through the rest of the project, the transfer of data was a manual exercise based on observation of the location within the primary source and plotting onto the base map. Following initial plotting, the exercise included a qualitative assessment of the current situation of visibility and preservation, as well as an assessment of the likelihood of survival in the presence of evident and subsequent development along the route.

Google Maps™ imagery was used due to its 2 and 3 dimensional representations. Google Maps' Streetview™, provides street level images captured in Malta in 2016. As its name suggests, Streetview is almost entirely limited to urban and rural roads. It therefore provides limited street level images in open countryside and may not provide useful information through such areas.

LiDAR data was used as another source of information to aid in the visual identification of features, while also providing information on contours and surface levels, thus permitting eventual estimation of the depth at which the aqueduct runs underground. The underground tracts of the aqueduct are usually assumed to be located between 0.5m to c. 1.2m below street level. This would depend on the terrain and the proximity to the part of the aqueduct that emerges from underground -issues that were later clarified by LiDAR. LiDAR data were obtained from the University of Malta's Cloudisle online platform (Formosa, 2018).

Discussion

Significant tracts from Rabat to Attard were plotted (Figure 5) with an appropriate degree of accuracy and reliability onto a contemporary and adaptable platform, permitting speedy and effective access to information that was previously located within primary sources but not generally or immediately available. The entire route of the aqueduct has to date been relatively poorly recorded and understood, with a consequent and negative impact on efforts directed to its protection. It is indicative that, at the time of this study, the Planning Authority has only scheduled very visible tracts through Ħamrun to Attard, together with water towers and other associated features in Floriana and Rabat. These have been treated as architectural monuments and scheduled as such at the highest level. There is a conspicuous absence of the underground tracts, even the main ducts which extend from Attard to Rabat. Being invisible and due to lack of recorded material, these have been effectively forgotten and relatively neglected. This is of considerable concern, given the continuing urban sprawl and undoubted intensity of contemporary development, especially in the light of invasive excavation works which are invariably associated with contemporary development. This indicates that more awareness is needed about the importance of geospatial data within private as well as governmental entities. This, to easily identify such features thus preventing further loss of cultural heritage.

Concerns differed greatly depending on the area that was being analysed. For example:

- ODZ (outside development zone)- Here the major threat was the excavation of wells and cisterns as well as the occasional construction of basement levels beneath agricultural rooms.
- Roads- The tracts of underground aqueducts within development zone/schemed area located mainly beneath existing roads.
- Urban/Development Zone- Here the major threat is the increase in development, a great part of which involves the demolition of existing properties such as terraced houses and their replacement by more intense development.

Various observations imply the presence of the Wignacourt aqueducts:

1. within ODZ areas, which have generally been spared from intense development, the identification of surviving tracts of the aqueducts may be facilitated by certain observable features. In particular, strips of dense vegetation may be identified, even along the recorded underground tracts -thus suggesting the presence of water still present underground or even space for the roots to grow deeper into the stone channels (Figure 1).
2. Observations suggested that footpaths within country areas may have been located (possibly intentionally) over such underground tracts.
3. Within urban areas, one may still see ancillary structures of the aqueduct system by the presence of ponds, fountains, and wash houses along the tract. Such examples are the Għajn Ħammiem wash house and the Għeriexem Fountain in Rabat.

Figure 1: Uncovered tract of the Wignacourt Aquducts in Attard crossing from Triq tal-Linja onto Triq l-Għenba.

Source: Superintendence of Cultural Heritage, 2019

The above-mentioned observations may also contribute to the spatial identification of the underground tracts. Spectral signatures can be particularly helpful when trying to identify bodies of water. Nevertheless, given that Wied Qlejja is mostly dry (except for a couple of weeks every year after very heavy rainfall) and given also that the tract is mostly underground, these could not be used as a means of assessment during this study.

The survival and continuing presence of certain tracts proved more difficult to ascertain within the Chadwick Lakes/Wied Qlejja area due to limited physical access at the time of inspection. As clearly visible on both the 1968 Survey Sheet as well the 1922 Ordnance Survey Sheet (Figure 2), tracts of the aqueduct are indicated in part by two solid lines which indicate structures above the ground, and in part by a dashed line which indicates the passage of an underground duct.

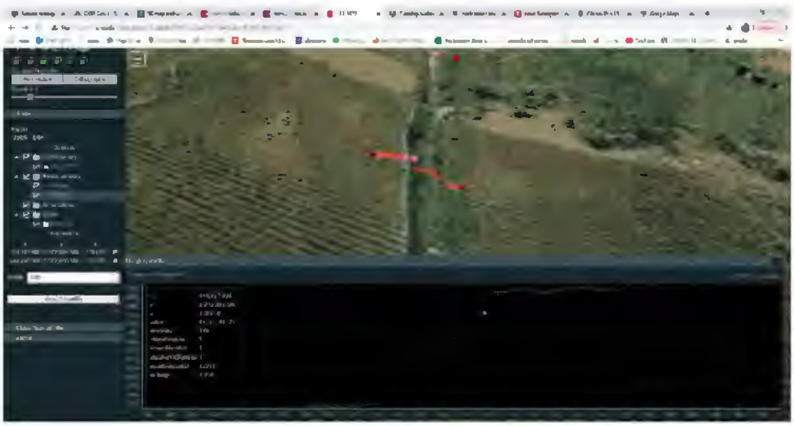
Figure 2: 1922 Ordnance Survey map indicating above-ground aqueduct structure in Wied Qlejja.

Source: Superintendence of Cultural Heritage, 2019

A site inspection with the intent of resolving this uncertainty was carried out on the 10th of March 2021. However, most of the tract as indicated on the Survey Sheet is within private lands and therefore not accessible. The area that was visible from the road did not reveal any evident structures above ground. Nevertheless, the area does not seem to have been subjected to extensive or intensive development, barring the possible creation of terraced fields that may have engulfed certain tracts, without necessarily destroying them.

The use of LiDAR may be especially helpful in such circumstances. Upon further assessment using LiDAR technology, it was evident that there was indeed some kind of continuous structure above ground, in the same location where the aqueduct had been plotted on the 1922 and 1968 maps. As shown in figure 3 generated through LiDAR at the presumed location within Wied Qlejja, this section indicates the probable survival of such above surface tracts. The continued survival of this tract within this private property is effectively confirmed by an image (figure 4) on the Natural Heritage Malta website at Naturalheritagemalta.org, which specifically shows a tract of the aqueduct at coordinates 35.88965, 14.38415. This tract appears to be integrated within a system of terraced fields, effectively following the contours of the land.

Figure 3: Screenshots as taken whilst analysing parts of the tract within the area of Wied Qlejja. LiDAR height profile tools indicated the presence of a continuous feature along the recorded tract



Source: Formosa, 2018

Figure 4: Photo showing the presence of above ground structures within Wied Qlejja/ Chadwick Lakes area

Source: Restall, 2015

Figure 5: Map output indicating significant tracts of the aqueduct from Rabat to Attard plotted on QGIS

Source: Superintendence of Cultural Heritage 2020

Results

- Using LiDAR technology, it was evident that there was still some kind of continuous structure above ground in the same location where the aqueduct had been plotted on the 1922 and 1968 maps.
- The exercise has confirmed that the unscheduled tract is almost entirely underground, with some exceptions in the vicinity of Wied Qlejja Area in Rabat.
- 6.5% of the plotted tract was tentatively graded as Grade 1-meaning aqueduct is still visible, at or above road level.
- 93.5% of the plotted tract was tentatively graded as Grade 2 -meaning aqueduct is not visible, but with a high probability that masonry structure is still present beneath the ground.
- 0% of the plotted tract was tentatively graded as Grade 3 meaning aqueduct is not visible and given recent developments there is a possibility that masonry structures have been either compromised or demolished during works.

Recommendations

- A proper inspection and verification is to be carried out in the area of Wied Qlejja. Deeper and more extensive investigations should be conducted by authorised officials to confirm the extent of the tract from Attard to Rabat. This before further negative impact, be it visual and/or physical, continues to undermine such a historical structure.

- Educate landowners about the cultural heritage located within their land. Such features within one's land should not be seen as a hindrance but rather as a resource for further learning about the historical assets and sustainable use of water within this rural area of the Maltese islands.
- Implementation of policies and boundaries/buffers to be readily available to decision makers. Officers from different entities consulted by the Planning Authority will be able to assess planning applications in a more diligent and informed manner.

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CHAPTER 12

The Effectiveness of the increase in the extent of the Rabat/Mdina Area of Archaeological Importance as approved in 2013 with a view of informing site prediction analysis

Kevin Borda, Bernardette Mercieca-Spiteri and Gordon Watkinson

Keywords

GIS, archaeology, Malta, site prediction, buffer zone, spatial analysis

Project Aim

The aim of this project has been: (1) to assess the validity of the 2013 Area of Archeoligical Importance (AAI) buffer zone for Mdina/Rabat; (2) to assess the 2013 AAI (buffer zone) changes; and (3) to identify hotspots within the 2013 AAI (buffer zone) so as to formulate a prediction model analysis.

Introduction

This paper describes a project carried out to assess the 1998 and 2013 AAIs for Mdina and Rabat, together with assessing gathered data of archaeological remains. The project was carried out using QGIS and various spatial analytical tools. There were four main data sets used for the archaeological remains:

(1) archaeological site discovered before 1998;

(2) archaeological sites discovered during 1998 to 2013;

(3) archaeological sites discovered after 2013 until 2019; and

(4) development sites carried out between 2013 and 2019 which revealed no archaeological sites.

There is growing need for archaeological data from various authorities in Malta to be gathered in a harmonised manner on a common platform, so that this can be accessed and assessed using analytical tools through mapping software, both licensed and open sources. The need for assessment rests not only to aid development but also allows researchers to design projects and make research in the field, therefore bringing potential investment to the cultural heritage sector. Spatial plotting of archaeological data can now be used as a state-of-the-art form of analytical data that can be shared globally and compared with other data outside the Maltese Islands. Also, at a local level, the sharing of data across Government Authorities will cut on processing times which will create a more efficient public services, which will in turn be transferred to the private sector by providing timely replies and decisions.

Literature Review

The use of GIS within cultural heritage applications is well established and an application on heritage having a definite geo-spatial location is of value. Similarly, urban planning relies heavily on the use of GIS for a multitude of applications on a micro and macro scale. The combination of these two aspects is the next logical step, however publications available generally stop short of effectively bridging the two. When discussing application of GIS for Urban Planning, often, heritage is not considered (Sarris & Dederix 2014). Equally, in research-based archaeology, GIS is increasingly used as a prediction model for recreating ancient landscapes and identifying the potential location of as yet undiscovered archaeological sites. However, once again the actual application of such predictive modelling beyond academia to more practical applications such as urban planning is not attempted (Constantinidis 2009; Nicu, et al. 2019; Pernice, 2014; Vines & Page 2012). A more practical application combining GIS and heritage management is that by Ruoss & Alfare (2013), where GIS is used to assess tourism impacts on heritage sites. The closest comparative publication similar to the project presented is that by Edwards, Frasch, and Jeyacheya (2019), where spatial data is analysed in Myanmar to determine the effectiveness of existing planning policies to curtail urban expansion within an archaeological landscape which is also designated as a UNESCO world heritage site. The approach is however again different in that the mapped archaeological sites remain unchanged over a span of 30 years at 5 year intervals, with the focus being the expansion of the urban extents.

Methodology

After establishing the extent of the Area of Study (which was defined by the extent of the existing AAI as published in 2013) and identifying the research objectives of this project, the next step was the identification of available data, both spatial and non-spatial, which would be required for the population of the Area of Study. Another area, Għajn Klieb AAI, was incorporated into the study further on in the analysis. This area is in the outskirts of Rabat which has a high concentration of archaeological remains (Figure 4). The data utilized in the project is discussed in more detail below.

Data Analysis

Once all the data was available in the same projection, it was possible to carry out spatial analysis. One of the first tools utilised was the heatmap analysis of all the archaeological discoveries identified (Figure 1). An average 75 metre diameter was established for each site. This was selected since local policies and legislation establish a 100 metre buffer for the very important sites, and 50 metres for the important sites (Figure 2). The resultant heat maps clearly identified the areas of high archaeological discoveries versus the areas of low archaeological discoveries within the AAI.

Figure 1: Heatmap generated around post-2013 discoveries

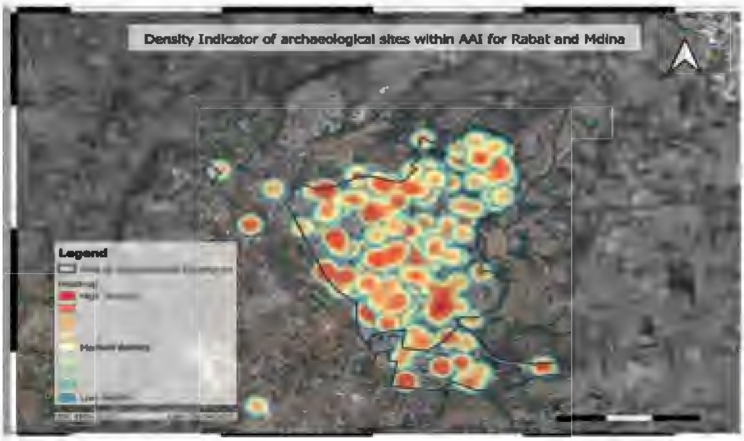
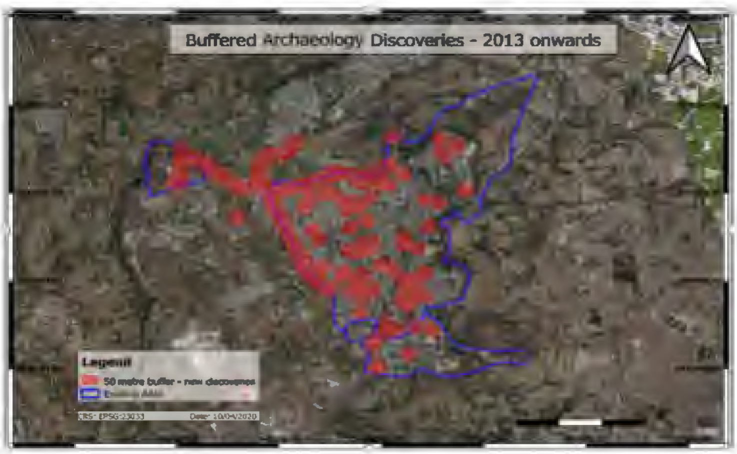


Figure 2: Buffer zones and AAIs – General layout



Another analysis was the creation of buffer zones around archaeological discoveries made after 2013, since this would address one of the main objectives of the project as to whether the existing AAI needs to be enlarged. Buffer zones were created around two layers, the 2013 onwards average centre points and the positive trenching results SCH layers, since these related to positive data. This resulted in two separate buffer zone layers which were dissolved to eliminate the overlaps in the individual layers. The two dissolved layers were remerged into one layer to create a uniformly rendered buffer zone across the AAI. The dissolved buffer zones, overlapped with the existing AAIs, permitted an identification of those areas currently outside of the AAIs, where archaeological discoveries were made and which merit additional protection.

Date Sources

The site specifics of the Area of Study and the particularities of the data required led to two principal sources for obtaining data: (1) the Superintendence of Cultural Heritage, as the regulatory body for Cultural Heritage, and (2) the Planning Authority, as the National Authority for the regulation of land use (which includes the scheduling / listing of archaeological sites) and mapping data. Although in different formats, discussed in more detail below, the data primarily gives information on the nature of the archaeological discovery and its location.

Planning Authority Data

Following a preliminary analysis at early stage, the authors decided that point geometry would be favoured. This was decided since the SCH data was rather crude data stored in excel format without spatial references. It was therefore decided that using point geometry would be the best solution to obtain standardised data from all utilised sources. Thus, as an applied solution, the polygon shape file was converted into a point shape file utilising the Mean Coordinate(s) tool which created a new point geometry shapefile layer. The drawback to this is that the new point layer only has three attributes - average eastings, average northings and the selected unique Id Field. By utilising the Join attributes by field value tool, it was possible to create a join of the attributes of the polygon layer with that of the average point layer, joined on the common Object ID attribute, to create a new point layer having both attributes, thus saving the tedious task of re-inputting the attribute data. Following this step, the correct CRS applicable to Malta was assigned to the layer (EPSG: 23033). This process was carried out for both shape files provided by the Planning Authority. However, the AAI as plotted had to be retained as a polygon, and not converted into an average point. It was not possible to alter every coordinate for this large polygon (1.55 km2), so the only way forward was to re-plot the AAI boundary. Through these steps, it was now possible to project the layer in its correct geographic location and use in conjunction with available base-layers such as OSM or google satellite.

The main challenge with the data provided by the Planning Authority was that, although in Shape file format, the layer provided was not editable in any way, thus any changes required to the content of the attribute data was not possible.

Early on, as discussed above, the authors decided that for this project, point geometry would be favoured. Thus, as an applied solution, the polygon shape file was converted into a point shape file utilising the Mean Coordinate(s) tool which created a new point geometry shapefile layer. The drawback to this is that the new point layer only has three attributes - average eastings, average northings and the selected unique Id Field. By utilising the Join attributes by field value tool, it was possible to create a join of the attributes of the polygon layer with that of the average point layer, joined on the common Object ID attribute, to create a new point layer having both attributes, thus saving the tedious task of re-inputting the attribute data. Following this step, the correct CRS applicable to Malta was assigned to the layer (EPSG: 23033).

This process was carried out for both shape files provided by the Planning Authority. However, the AAI as plotted had to be retained as a polygon, and not converted into an average point. It was not possible to alter each and every coordinate for this large polygon (1.55 km2), so the only way forward was to re-plot the AAI boundary. Through these steps, it was now possible to project the layer in its correct geographic location and use in conjunction with available base-layers such as OSM or google satellite.

Superintendence of Cultural Heritage Data

The data available was cruder, in that although the data was spatially related (addresses were included), it was stored in an excel format without any spatial references (co-ordinates). The processing of this data thus required two main interventions. Firstly, a harmonisation of the data in the excel format was required since this data had been inputted over several years by different operators, giving rise to several errors and inaccuracies. This process required a substantial number of hours since the accuracy of the data would affect any analysis which would be carried out on it as part of this project. Once the harmonisation process was completed, the next task was to identify centre point coordinates for each entry. This data was obtained manually by copying coordinates from the Planning Authority website and appending the 4 and 39 to the Eastings and Northings respectively to resolve the coordinate truncation issue as already discussed above. Following this step, the excel sheets were saved as CSV files and added as point layers in a very straightforward operation.

Some of the finds represented as point geometry resulted from trenching works carried out for the laying of services, and it was decided by the authors that it would be better to plot these as line geometry. The lines were plotted manually with a single attribute, site code, which is also available in the point data. This was done so that once again a join using the Join attributes by field value tool could be carried out between the attributes of the newly created line layer and the attributes of the point layer on the common Site Code attribute. A variant of this data processing was the conversion directly of some points into line geometry. The processing tool point to path was utilised to create multiple scratch layers representing every transformation from point to path. The resultant 5 paths were then merged into a permanent line geometry layer using the Merge vector layers tool. In this process, attributes are not automatically copied, so again a join of the new created line layer with the original point layer using the tool Join attributes by field value was used.

Discussion

Once all the data was available in the same project, it was possible to start carrying out spatial analysis. One of the first tools utilised was the heatmap analysis of all the archaeological discoveries identified. An average 75 metre diameter was established for each site. This was decided since Local Policies and Legislation establish a 100 metre buffer for the very important sites, and 50 metres for the important sites. The resultant heat maps clearly showed the areas of high archaeological discoveries versus the areas of low archaeological discoveries within the AAI.

Another analysis was the creation of buffer zones around archaeological discoveries made after 2013, since this would address one of the main objectives of the project as to whether the existing AAI needs to be enlarged. Buffer zones were created around two layers, the 2013 onwards average centre points and the Positive trenching results SCH layers, since these related to positive data. This resulted in two separate buffer zone layers which were dissolved to eliminate the overlaps in the individual layers. Then, the two dissolved layers were again merged into one layer to create a uniformly rendered buffer zone across the AAI.

The dissolved buffer zones which overlapped with the existing AAIs, permitted an identification of those areas, currently outside of the AAIs, where archaeological discoveries were made and which merit additional protection.

Results

Key results of this project are:

- The 2013 AAI extension has been justified.
- The tool developed by the authors has increased the ease and speed of locating archaeological features within the study area.

- Hot spots of particular features within the AAI were identified by using the select by attribute to establish where concentrations of particular features were located. This enabled the researchers to identify where specific archaeological features such as tombs, structural remains or ancient quarries were concentrated.

Reflections on the project and future aim

Overall, it is clear from the results produced that the project has been a very useful exercise. For the first time, all the recorded discoveries from multiple sources within Rabat and Mdina have been uploaded within a single platform (Figures 3 and 4). This tool has the potential to greatly increase the ease and speed of locating archaeological features. This would enhance the work of the Superintendence in several areas, not least when assessing the possible impact of development applications. It is hoped in the future that this project can serve as a basis for expanding it to cover the entire Maltese islands. The knowledge gained should allow this to develop more smoothly than would otherwise have been the case.

Figure 3: Proposed extension to Rabat and Mdina AAI

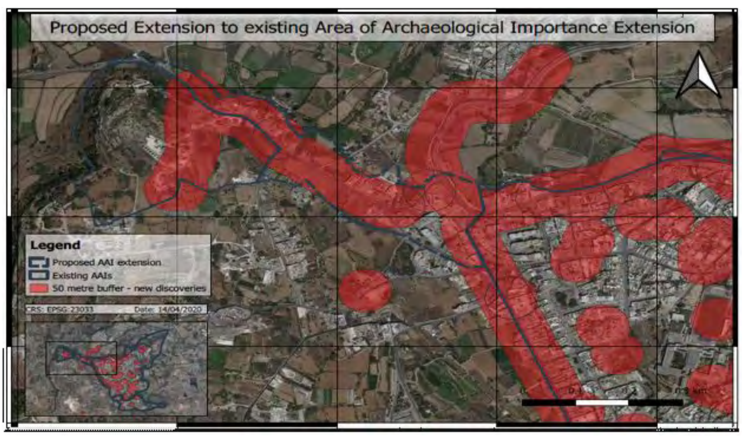
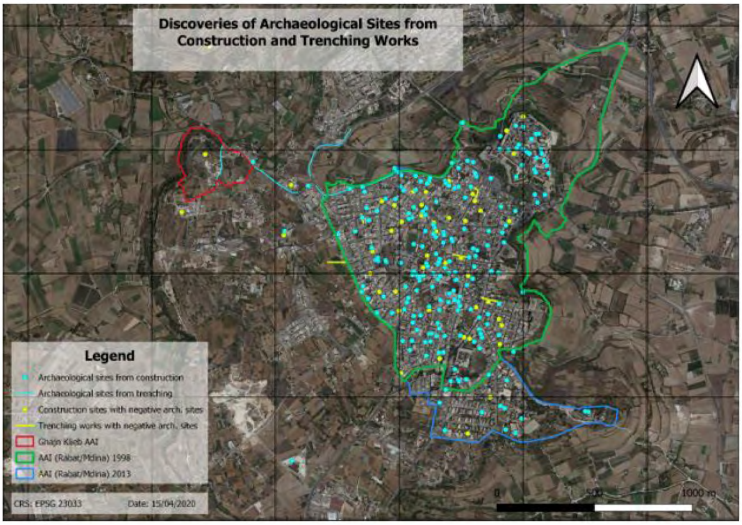


Figure 4: Archaeological discoveries resulting from development



Recommendations

- The AAI should be enlarged to incorporate Għajn Klieb AAI within the Rabat/Mdina AAI.
- It is recommended that the area to the northwest of Mdina is kept under review until sufficient data results are available to enable a more informed decision about its possible removal from the AAI.

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CHAPTER 13

Heritage Data and Public Trails: Utilising Geomatic Data and Processes to Reconnect with Our Cultural Heritage

Daniela Formosa

Keywords

Cultural heritage, conservation, scheduling, networking, public trails, heritage data, map, planning, tourism, research

Project Aim

This project aimed to promote awareness of cultural heritage using Geomatic data and spatial analysis tools. More specifically, it aimed to encourage better utilisation of heritage data, in this case on scheduled sites, by creating a platform wherein networks between these scheduled sites were created as public walking trails.

Introduction

Malta's rich history left a legacy and a very rich inventory of cultural heritage sites, which in turn created a tremendous amount of cultural heritage data in modern times. Cultural heritage is defined as monuments/groups of buildings/sites that have "outstanding universal value from the historical, aesthetic, ethnological or anthropological point of view" (UNESCO, 1972). Apart from this official definition, one of the most popular associations is that heritage provides a sense of identity and collective experience to the population, thus making it imperative to understand and conserve these sites in the face of a changing environment and various other threats (European Union, 2018).

The notion of recognising, conserving and protecting an inventory of heritage sites primarily led by cultural heritage public bodies is common across the world; in the Maltese context, this is referred to as scheduling. This is one of the Malta Planning Authority's (PA) protection mechanisms which seeks to officially recognise that a site has important values, such as architectural, historic, social, natural or even artistic values, that make it worthy of conservation and protection in the face of impending development, decay or any other threats. The notion of protecting these important sites began in 1932 with the Antiquities

(Protection) List, whereby a basic list of important sites and features was merely drawn up (Attard & Vella, 2014). However, with the advent of the Development Planning Act of 1992 and the PA, this "list" took on a more official and informative approach with scheduling and is now well established. Extensive research is undertaken by the PA and the Superintendence of cultural heritage (SCH) to determine which sites merit protection and in which scheduling grade (1 to 3) these will be protected. Once approved, these scheduled sites are then published on the PA's geoportal, an online Geographic Information System (GIS), and the Scheduled Property Register (SPR), a database with each scheduled site's attribute data.

However, the use of Geomatics goes beyond simply displaying the extent and attribute data of these scheduled sites on an online GIS. With the recent technological advancement in digital tools such as 2D and 3D imaging, relational databases and web-based systems, the documentation aspect, one of the primary aims of the conservation field, has been greatly affected as it is now more accurate, cheaper, faster to produce, and slowly becoming legally mandatory. In the 1990s, Italy launched a pilot programme in which a risk map of cultural heritage was drawn as part of a philosophy of predictive formulation based on studying the vulnerability and conditions of a cultural site, which would in turn help authorities formulate prevention and safety strategies. This was achieved through recording by means of orthophotography and photogrammetry, and monitoring of aspects such as the building fabric, climate, and pollution. The data was then transferred to a GIS and thematic maps delineating where these risk areas are were produced as part of the final risk map (Tucci & Bonora, 2015).

Methodology

Locally, the use of Geomatics features within the developing concept of e-heritage, the integration of data onto one knowledge-based system to support decision-making and world-wide access and collaboration within the heritage sector (Cannataci et al., 2003). Nevertheless, simply utilising one process without integrating it with other geomatic applications and using further analysis and extraction tools is not enough to reach the maximum potential of incorporating geomatics and cultural heritage (Cannataci et al., 2003). Although several cultural heritage entities make use of geomatic processes, data is not often shared and therefore, this was identified as a gap in the knowledge which this project aimed to fill.

In the international context, networking and cooperation opportunities between heritage stakeholders has been much discussed and encouraged in order to raise awareness among the public about these important heritage sites, which in turn promotes research, education and tourism (Veldpaus, Fava, & Brodowicz, 2021). The Council of Europe's Cultural Routes was one of the results from these discussions. This initiative connected several European states through their shared heritage (Council of Europe, 2021). Examples such as the Portuguese Museum Network demonstrate the networking, accreditation, and cooperation opportunities available to heritage entities on a more local level (Património Cultural). Since no examples exist in the Maltese context, this was yet another gap identified as there has been no great initiative to connect heritage sites collectively using geomatics and spatial analysis tools to disseminate this information.

Therefore, with these gaps in the literature identified, this project aimed to utilise the spatial data on scheduled sites found on the PA's GeoPortal to extract further meaning using various spatial analysis tools which could then be integrated and shared. Given the time limitations of this project, its aims could not be applied to the entirety of the Maltese islands and therefore, only Valletta was chosen as the study area. Valletta, Malta's capital city, has 303 scheduled properties, 160 of which are Grade 1 (the most important sites in terms of scheduling). For this study, fifty most recently scheduled Grade 1 sites were chosen as the dataset by utilising the PA's Geoportal and SPR. Locality and grade filters were inputted on the SPR to display the appropriate attribute data for the features to be included. The spatial extents of these sites were checked on the geoportal. Ultimately, These were manually plotted using the OpenStreetMap (OSM) basemap and inputted on a new polygon layer (Grade 1 Scheduled Buildings) on QGIS .

The QGIS plugin called Open Route Service (ORS) Tools was used. This tool performs analysis such as routing, isochrones and matrix calculations from point layers and produces attributes for output files. For this project, it was used to perform networking spatial analysis to devise three public walking trails to visit these sites. In order to do so, a centroid layer for the Grade 1 Scheduled Buildings polygon layer was produced and then filtered according to the type field found on the layer's attribute table. This field aimed to determine the primary use of the building and the three different type fields identified were the civil, monument and religious types. The filtered centroid layer was then inputted in the ORS tools plugin and three distinct line layers which pass by these three types of buildings were created according to the parameters inputted, one of which specified that walking routes are required. Once the data was saved, the trail lines' symbology was amended, and three distinct maps (Figures 1 to 3) were created to showcase these public trails.

Discussion

The three results obtained showcase the three different public trail maps produced for this project: the religious trail (Figure 1), the monument trail (Figure 2) and the civil trail (Figure 3) maps. The attribute data of the line layers created by ORS tools contained the distance and time it would take to complete this trail, along with the average speed of 5 km/h, which was calculated using the distance speed time formula. Each trail had different buildings to offer each grouped according to their use as specified in the type field: buildings with purely religious functions were the focus of the religious trail; the monument trail featured commemorative structures; and buildings with secular or civilian functions, such as granaries, law courts and Government buildings which were placed on the civil trail. Some of the architectural gems featured in this project include the Sacra Infermeria Chapel, St. John's Co-Cathedral, the Tritoni Fountain, the monuments within the Grandmaster's palace internal courtyard, Auberge de Bavière and La Castellania. Each trail also had distinct durations due to the different number of features within each of the trails. To sum up, the three trails produced would allow a visitor to explore these sites all around Valletta at an average speed of 5 km/h covering a total distance of 10.2 km in about 2 hours (without any pauses) (Figure 4).

Figure 1: The Religious Trail Map

Figure 2: The Monument Trail Map

Figure 3: The Civil Trail Map

Figure 4: All the Trail Lines Formulated for this project

Results

The results obtained with this project demonstrated that geomatics could prove extremely useful in extending the scope of heritage data. This project's use of networking and routing services on QGIS produced new meaning out of the raw scheduling data inputted by the author aimed to facilitate networking, routing, accessibility, cooperation and ultimately, awareness, education, and tourism. Moreover, despite not being able to fully customise the trail lines with specific starting and ending points, the ease with which this was achieved and customised is also commendable. The ORS Tools plugin and the filtering functions of the GIS enabled the customisation of the walking route according to the demands of the author, and this can be altered accordingly. For example, should a time era field be created for each site, a trail dedicated to specific time eras can be created.

Moreover, the results produced met the objectives outlined above. Through these trails, awareness on several cultural heritage sites were raised among anyone willing to explore them, including the local population and tourists for either leisure, education or even research purposes. They also clearly demonstrate the potential geomatics has on sharing of heritage data not just among the general public, but also across public entities and owners/users of these heritage assets. The latter can benefit greatly from such ideas as this would increase visitors to these sites, thereby creating economic opportunities and cooperation opportunities with other owners/users. Beyond the scope of this project, this study can be taken further to cater for the visitors' specific likes and interests. Since scheduling data can be found across the entire Maltese islands, such public trails can be created for other localities and areas depending on the data and attributes at hand. Furthermore, these trails can be enriched by extracting and linking further information, such as other amenities of the area (restaurants, bars, bus stops, hotels, etc.) to these maps. This would increase the amount and nature of the information available to the public, thereby enhancing possibilities for the users. This was the subject of the author's other project, which sought to link restaurant and café data, the trail lines, and heritage site data and images on an online interactive map (https://arcg.is/1GHPD41).

A more inclusive approach could be taken using spatial analysis tools such as aspect and slope analysis of a Digital Elevation Model of the area. This could be used to identify where people with accessibility issues might have a problem and provide an alternative route.

Key results of this project were:

- The Religious Trail: this featured 16 buildings with religious functions including churches, convents, sacristies and oratories. According to the attribute table produced for this particular trail line, the route is 2.5 km long and takes roughly 30 minutes to complete at an average speed of 5 km/h;
- The Monument Trail: this included 20 commemorative structures, here referred to as monuments, around Valletta, such as fountains and statues. This trail is longer as it is 4.2 km and takes around 50 minutes to complete at an average speed of 5 km/h;
- The Civil Trail: The route takes the visitor around 14 buildings with secular or civilian functions. These include places such as granaries, law courts and several Government buildings. This trail is 3.5km long and takes around 45 minutes to complete at the same average speed of 5 km/h.

Recommendations

Key recommendations of the effort are Operational

- The features and public trails ought to be uploaded on an online platform and made available to members of the public, schools and other public bodies.
- The full potential use of spatial analysis tools is utilised by cultural heritage entities which might possess and make use of heritage data.
-

Key recommendations for Further Research

- These trail lines can be created for other localities and areas across Malta and Gozo given the vast amount of heritage data at hand. These can also have different focuses depending on the attribute data associated with the heritage data.
- These types of maps could be enriched by other amenities and any other data which would be informative to the user.
- Further spatial analysis tools to better understand the elevation data of the area could be useful to certain users with accessibility issues.

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CHAPTER 14

Establishment of a Cultural Heritage Identification Portal

Fabio Scicluna

Keywords

Cultural heritage; public participation; communal value; heritage identification, field study

Project Aim

The aim was to study the potential of a PPGIS system to record the lesser-known heritage sites and features, through the development of a public portal; design and validate the approach through a prototype live system and infrastructure and provide an equal opportunity to all factions of society.

Introduction

Culture is the complex that characterises a society. It is a multifaceted compilation of factors which shapes the identity of a social group. Culture does not only constitute art, but also beliefs, traditions, values and more. It is the unique and specific that enriches us (Serageldin, 1999). The cultural identity and its studies cannot be investigated without recognition of the communal aspect that defines it and vice-versa.

As a subset of culture, cultural heritage implies an association of humankind with a place or feature. It materialises from the interaction between human beings and a produce which transcends generations. By time, the functional aspect that initially tied a community to a place or object might become obsolete, but the spiritual and emotional association will only become stronger. Communities can identify with function-less places or objects, which often cannot be understood by outsiders. Smith (2006) explores the idea that heritage is not so much as a 'thing', but rather a social process rooted in the act of remembrance. By introducing Public Participation GIS in the field of Cultural Heritage, this study achieved the foundations for a dialogue between the community and its heritage. A similar concept was introduced by McClelland in Ireland, where in a Horizon 2020 funded project he first attempted to capture 'unofficial' heritage values and collective memories. However, McClelland identifies the intersection of the two fields as minimal (Maynooth University, 2017).

PPGIS is the distinct practice resulting from spatial analysis whereby researchers, developers and practitioners believe there is a potential tool for community induced changes and influences in the visual language of GIS and in its capacity for detailed analysis. The definition of PPGIS has been long debated but is generally taken to mean a system of sourcing geospatial information from non-professionals/experts and the general public, often through web-based applications (McClelland, 2017).The practice is practical for addressing a diverse range of issues, such as landscape studies, planning issues and policy challenges. It has been applied in park planning, flood risk management, marine planning and much more. With an ever-growing demand for PPGIS, the analysis of its employability is now lagging its actual deployment as suggested by Babelon et al. (2016). Despite the extensive implementation of the practice, exploration of its benefits for Heritage inventorying has been minimal. PPGIS' adaptation for such applications is only expected to increase as local communities are being increasingly active in heritage management (McClelland, 2017).

"The concept of community has never been so powerful". (Waterton & Smith, 2010). The dominant notion of community in heritage is one that overlooks 'different' factions, often denying or assimilating any differences. As Waterton and Smith (2010) argue, this talk of community often mystifies power struggles and define society as heritage professionals and white middle classes, with no place for anyone else. This is frequently corroborated by the cultural participation patterns observed. This is directly affecting the heritage experience, leading to disparity in engagement whilst giving rise to a belief that heritage is for the elite. This homogeneity is often assumed in Malta where decisions on communal value can easily disregard minorities. There is also a crooked definition of what heritage is, believed by many to be reserved solely for grandiose and majestic masterpieces. The ongoing drive to recognise and promote different significances in heritage brings a new challenge in understanding different associations between a community and an object or place which this study undertook.

With the introduction of PPGIS, the terms 'Public' and 'Participation', which shaped the implementation of this system had to be defined, but also the medium and methodology to be applied. Literature on public participation demonstrates a variety of methods, combining both online and offline engagements which can be applied to PPGIS. Whilst focus groups and sampling are an option which is occasionally used, the more common approaches are key informant interviews, community workshops and self-administered surveys. (McClelland, 2017). The latter is an important, non-resource-intensive tool for several studies and ideal for achieving wide geographical coverage and their anonymity works great when dealing with sensitive topics. In addition, there has been considerable progress in developing apps for smart devices such as phones and tablets. (Marcano Belisario, et al., 2015). A crowdsourcing data model proposed by Nummi (2018) is built on the idea of setting the expert-driven inventory under public evaluation, whilst sourcing place-based memories and experiences. The study utilised social media in conjunction with web-based map-questionnaires without relying on a sampling method.

In defining 'participation', several practical determinations were necessary, including the choice of attributes to be mapped and the location where the mapping is carried out. Whilst the first was constant throughout, and can be seen in Figure 1, the location was varied for comparative purpose. As for the definition of 'Public', it was necessary to decide who is eligible to participate and the sampling strategy (or lack of it as seen in Nummi's crowdsourcing of 2018). These all needed to reflect the purpose of the study (McClelland, 2017). Since the purpose of this paper is to study the benefits of such practice in an identification process, the prototype system developed was based on Nummi's crowdsourcing model, without the social media aspect. To assess the success of the prototype, it was necessary to isolate the data gathering façade of this model from that of public evaluation of existing or identified assets or the collection of personal experiences. For the prototype system, 'Public' is defined as anyone living in Malta, whether they come across the portal intentionally or by accident. In recreating this for the study's purpose a representative group of individuals was required, and a snowball sampling methodology was opted for after careful identification and classification of potential users.

Methodology

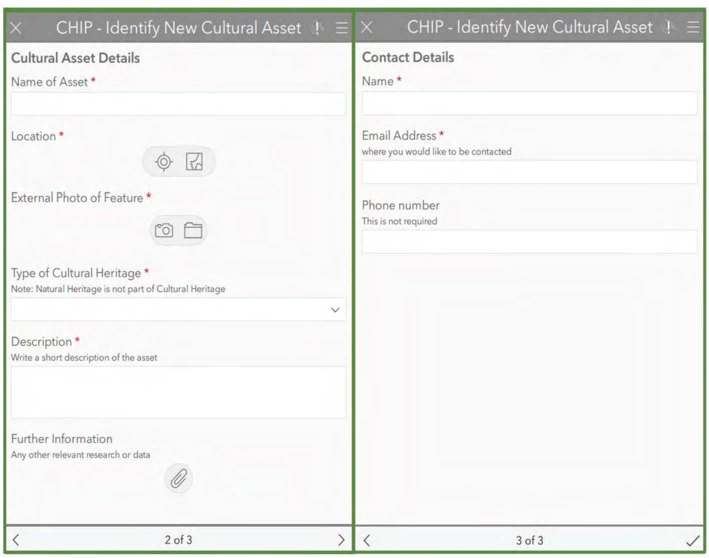
As a bi-functional portal, the prototype 'CHIP' (Cultural Heritage Identification Portal) sources its data from self-administered, map questionnaire, using ArcGIS Survey123 to later feed into a Web Map. The questionnaire was published online, on an open access website designed specifically to host this prototype. Additionally, the questionnaire was also made available on the ArcGIS Survey123 Field App for an eventual comparison, creating two different mapping locations. A limited set of attributes was chosen for this prototype. These were divided into two pages Asset and Personal attributes as per the schema in Figure 1. Out of the entire list of attributes, the 'Further Information' and 'Phone Number' were not ticked as a required question in the validation process of the submission.

Figure 1: Schema of the CHIP survey

Label	Name	Field type	Field length
Page 1 of 2 Cultural Asset Details			
Name of Asset	name_of_asset	esriFieldTypeString	255
Location	location	esriFieldTypeGeometry	
External Photo of Feature	external_photo_of_feature	esriAttachment	
Type of Cultural Heritage	type_of_cultural_heritage	esriFieldTypeString	255
• Architecture (Buildings, monuments, niches, etc)	Architecture_Buildings_monument		
• Archaeology (sites, remains, etc)	Archaeology_sites_remains_etc_		
• Movable (paintings, sculpture, etc)	Movable_paintings_sculpture_etc		
• Industrial (machinery, etc)	Industrial_machinery_etc_		
Description	description	esriFieldTypeString	1000
Further Information	further_information	esriAttachment	
Page 2 of 2 Contact Details			
Name	name	esriFieldTypeString	255
Email Address	email_address	esriFieldTypeString	255
Phone number	phone_number	esriFieldTypeDouble	

All submitted results during testing were automatically imported as layers on the Web Map, allowing for the unrestrained viewing of the geospatial aspect (point on a map) and the Asset attributes, whilst reserving the right to view the personal attributes. The entire portal was put live, free and with real time updates for the public's use as seen in Figure 2.

Figure 2: Online Portal



The prototype was shared with a representative sample, to qualitatively assess its employability. The testing was split into Alpha and Beta, the latter further divided into three types of users. In the Alpha Testing, the developer and author of the paper tested the infrastructure through both platforms for any bugs and modified it accordingly. The Beta Test was made up of a six-person sample, representatives of the lay public first, then the cultural heritage professionals which both used the field app seen in Figure 3. Finally, the GIS users who utilised the web-based interface (Figure 4), pursued their mapping from a constant and familiar location. The aim of the Beta Test was to gather feedback and recommendations. During the Alpha Test, sixty (60) entries were collected whilst the Beta yielded seventy (70) more, all uploaded in real time on the hosting website.

Figure 3: Field Exercise

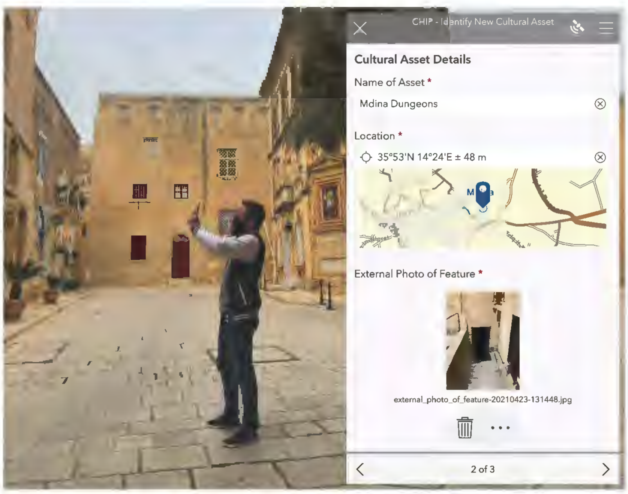


Figure 4: Published Questionnaire

Discussion

The prototype successfully reached its objective as an automated platform for public data gathering. Moreover, it provides a structured approach and the right tools which could replace the existing system. Feedback from the Beta Test was mostly positive, confirming its ease of use. In addition, the Beta Test yielded some suggestions and constructive criticism on the restrictions set in place during the development process and the possibility that the adopted open access for all philosophy could result in duplicate or wrong data if not subjected to a verification process.

A comparison between the two mapping locations had major results. This study demonstrated that using a field app can allow for more of the lesser-known features and assets to be recorded. The tendency confirmed by the last group of the Beta Test is for desk-top users to submit more grand and popular assets, except for few endangered or hidden finds. The user on the field, however, will identify a lot more. This theory was validated by the heritage professionals' group, who in testing the field app, identified features in familiar areas which they never noticed before, according to feedback. This is enough to conclude that whoever is doing the desk-top study, even if it's often a professional in the field, there is a clear benefit in employing a field app system. Through this testing and comparison, the study can conclude that PPGIS, with its ability to gather data on the field, has potential uses and benefits in cultural heritage identification.

Unfortunately, whether this improves the democratic and fairness of the identification approach remains inconclusive.

Results

Key results of this project are:

- Such a portal can have significant and long-lasting effects in the field of cultural heritage in the country of Malta. This is evident from the feedback gathered in the testing process
- The portal CHIP successfully reached several objectives despite being a prototype, and the methods and tools involved have been verified through a qualitative study.
- A tangential takeaway is the need for more field apps to ease and improve the work done by web-based platforms. The use of self-administered questionnaires in conjunction with the field app can contribute towards a more complete data.
- A PPGIS system for recording the lesser-known heritage, using a public portal is not only possible but has a lot of potential.

Recommendations

Key recommendations of the effort are:

- The prototype was successful in its function as such, but additional features and functions to better serve the purposes outlined should be developed.
- The notion of a public and democratic cultural heritage portal should be adopted by the relevant authorities.
- The public engagement through PPGIS (amongst other methods), studied through this study should be embraced and encouraged in the cultural heritage field.

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CHAPTER 15

Effect of additional volumes at roof level on the views and skyline of the UNESCO World Heritage Site of Valletta from 2012-2018

Gillian Asciak

Keywords

Valletta, viewshed, skyline, urban development, urban planning

Project Aim

The main objectives of this study were:

- to identify recent examples of development within the city of Valletta which have been completed
- to assess the impact which the development has on its current surroundings by comparing 'before and after' viewshed analysis results; and
- to gain an understanding of the capabilities and limitations of the viewshed analysis tools in QGIS as applied to the city of Valletta.

Introduction

The city of Valletta was designated as a UNESCO World Heritage Site in 1980, due to its outstanding universal value (UNESCO, n.d.). This value is linked with the historical events leading to the foundation of the city in the 16th century, and the subsequent growth. It boasts a significant amount of historical buildings and monuments from various periods and today, represents a popular tourist attraction. However, the pressures of modern development are increasingly threatening the iconic skyline, viewsheds and landscape of this historic city. As a busy capital, Valletta serves as the location for several government and private offices, bars, shops and, more recently, high-end guesthouses. Those responsible for the urban planning of the city face several struggles between modernisation and preservation.

Efforts towards the preservation of the all-important, sometimes rather abstract, concepts such as viewshed, skylines and landscapes are often hindered by the fact that it may be very difficult to assess how a development may impact them, until it does. This is not to say that all development which is visible creates a negative impact, but the historical setting and layout of the city creates restrictions that are not present in other urban areas. To conclude that a development would have a negative impact on its surroundings and recommend against it may be construed as standing unnecessarily in the way of modern development, which is undoubtedly essential for the survival and relevance of the city itself. On the other hand, accepting that a development takes place and subsequently realising that this may have irreversibly altered or obstructed important views which cannot be recovered constitutes a failure on the part of the authorities responsible for the preservation of the historic context. For this reason, proper understanding of the effects of proposed developments is essential and has motivated this research into the available tools for viewshed analysis.

Methodology

The concept of viewsheds relates to the view of an area from a specific point, and is a term used in several disciplines. In GIS, viewshed analysis is a calculation of a surface or area which is visible from a given point, based on a digital elevation model (DEM) or digital surface model (DSM). Given the importance of the skyline of Valletta as explained above, viewsheds are one of the aspects which should always be kept in mind when regulating development. The incorporation of viewshed analysis in landscape and urban planning is not a new concept in many countries (Tong et al. 2016, Wheatley, 2000) but is not currently utilised in Malta for planning from a heritage perspective. GIS is not employed by heritage regulatory authorities in Malta. While certain aspects of geomatics are employed by some state agencies and private companies, such as photogrammetry and drone imagery, the specific use of GIS tools for urban planning in relation to heritage management is a new approach.

The work presented in this study applied the viewshed analysis tools available in QGIS to understand the limitations, reliability, and applicability of the tools for urban planning in this situation. Valletta is an ideal area for this pioneering approach, due to its status as a UNESCO World Heritage Site and the struggle associated with preserving the layout, skyline and roofscape of this city in the face of ever-increasing development. The successful integration of the tools utilised in this work in the day-to-day assessment of development applications may serve to provide a better understanding of the potential impact of proposed projects, allowing planners to make well informed decisions.

The main sources of data for the implementation of this work were two surface models of Valletta. The most recently available model is that of 2018 (Formosa 2019a) and an older model from 2012 (ERDF156, Malta Environment and Planning Authority, 2013, Formosa, 2019b) was also acquired. Both surface models were created based on LiDAR scans of Malta. The 2018 LiDAR scan was carried out as part of a project called SIintegraM, aiming to obtain spatial data that would be available to all government organisations on the island (Formosa, 2017, (Planning Authority, 2017). The LiDAR data was converted into DSM's through the use of LAS tools. A total of four case studies were selected from planning applications which were approved and built between 2012 and 2018, the time frame selected being based on the available DSMs. Approved drawings related to planning permits are publicly available data with details for each permit disclosed in this project being solely the permit number and location.

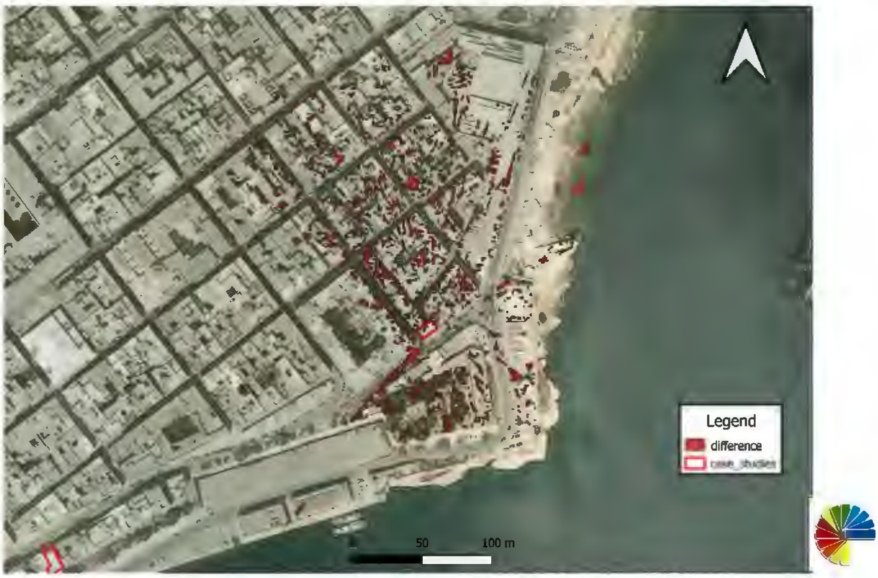
Discussion

Following the above conversion of the LiDAR data into surface models, the case studies were plotted on orthoimages of Valletta (Orthophoto_2018_1sqkm_tiles) taken in 2018. The orthoimages were commissioned as part of the SIintegraM project (Planning Authority, 2017) with data access being provided for the purpose of this project. For each case study, binary viewshed analysis was carried out on the 2012 and 2018 surface models. This was done using QGIS' visibility analysis plug in (version 1.2). 200m radius was used for viewpoint creation with a 1.6m height for both the observer and target height. This would represent an average person standing on top of the building used in each case study, and an average person standing at all points from which this is deemed to be visible in the results obtained. Following the creation of two separate raster layers for the viewsheds, one for the 2012 and one for the 2018 context, a difference layer was created by subtracting the raster layers. This creates a simple visualisation of the change over time for comparison purposes. The resulting difference layer was then analysed to assess the implications through comparison with Google Earth images of the case study areas. This helped to confirm or deny the results of each case study. The profile tool, also available as a plugin (version 4.1.8) was also used in each case study. This tool creates a section tracing the height of the buildings. For comparison purposes, sections were also taken using the point clouds from the LiDAR scans, which are available online (Formosa, 2019a, Formosa, 2019b).

Case Study no.1 – PA 01988/14

The first case study selected is on the corner of Triq il-Mediterran and Triq San Duminku in Valletta. The proposal submitted in 2014 was for additional rooms at roof level. This area of Valletta includes the Lower Barrakka Gardens, an important and legally protected garden area which offers views of the Grand Harbour. The creation of a section using through the use of the profile tool and the point cloud data for this example immediately indicated that the proposal created volumes which are higher than the adjoining building, a generally undesirable situation. While only one section was taken in this case, a holistic assessment should constitute sections taken through other areas. Following the creation of two viewsheds, one for 2012 and one for 2018, the difference layer between the two results was created and overlaid on the orthophoto of the area (Figure 1). The red polygons in this result indicate the areas from which the development became visible between 2012 and 2018 when the additional volume was built. Views from particular angles were checked on available aerial imagery from Google Earth, in order to compare the reliability of the results with the real situation.

Figure 1: Case study 1 viewshed overlayed on orthophoto



Source: Planning Authority, 2017

Case Study no.2 – PA 00482/13

The second case study selected is located in Triq il-Batterija, in an area of Valletta overlooking the harbour. This area is known to be highly visible from several viewpoints, even across the harbour. This development consisted of the construction of an additional floor overlying the building in question. The sections created using the profile tool and point cloud data in this case indicated that the proposal blended well with the other buildings and respected the slope of the street. With regards to height, this would constitute a successful integration of the new development with its surroundings. Figure 2 indicates the difference layer between the 2012 and 2018 viewsheds. Most of the areas from which the development is indicated to be visible are low lying areas close to the shore, which is an expected outcome given the location of the site. In the more elevated areas, the development is only visible from rooftops. In this case, although visible from the low-lying areas, this does not create a negative visual impact or a significant change to the skyline. These results were compared with available aerial imagery from Google Earth to confirm the existing situation.

Figure 2: Case study 2 viewshed overlayed on orthophoto

Source: Planning Authority, 2017

Case Study no.3 – PA 00631/14

The third case study selected is located in one of the most prominent and visible areas of Valletta, along the St. Barbara Bastions. The area is prominent in both short range and long-range views, and any additions are likely to have an undesirable visual impact. This project proposed an additional floor above the building in question, receded from both streets which it overlooks. Sections taken using the profile tool and the point cloud data reveal that the project did not create volumes that exceeded the height of the other buildings within the area, although this does not rule out the possibility that the resultant visual impact is a negative one. Figure 3 indicates that the development created quite a significant impact on the viewshed of the immediate area, being visible from both streets although the development was receded on both sides.

Figure 3: Case study 3 viewshed overlayed on orthophoto

Source: Planning Authority, 2017

Case study no.4 – PA 00962/14

The fourth example selected is located in Triq San Pawl, a narrow, sloping road. The proposal included a substantial increase in height of three receded floors which increases the impact of this development on its surroundings. The sections taken immediately indicated that this development resulted in the building in question significantly exceeding its surroundings in height, a situation which is undesirable and avoided in planning in Valletta. The resulting difference in the viewshed analysis (Figure 4) were somewhat surprising. Despite the significant increase in height, the viewshed analysis indicated that this is not visible at any point at street level. This was tested using Google Earth imagery and no angles could be found from which the development was visible. This is likely due to the street in question being a narrow one, and the extra floors being built receded from the street.

Figure 4: Case study 4 viewshed overlayed on orthophoto

Source: Planning Authority, 2017

Results

- Most of the viewshed analysis results indicated that developments were visible from rooftops of surrounding buildings. In most cases, these are not views which are important to be preserved from a heritage perspective. The viewshed results which concern planners are those which indicate that the development may be visible from street level.
- A correlation was noted between the number of pixels grouped in one area and the visibility of a building. The larger the number of pixels in the resulting viewshed, the more reliable the result is in that case.
- The presence of trees complicated the process. Tops of the trees were interpreted by the algorithm as a surface. Results of this type must be considered when analysing results.
- Viewshed analysis does not always indicate impacts on streetscape and skylines, especially in narrow streets.
- Overall, the resulting viewsheds were confirmed to be relatively reliable through the comparison of the results with street views on Google Earth. The general

results indicate that the available tools of viewshed analysis in QGIS are reliable and helpful, although by no means should be used as the sole method of analysis.

Recommendations

- Viewshed analysis can be a helpful aid and should be integrated in the planning process when considering the impact of proposed developments in such a sensitive area.
- While this study investigated short range viewsheds, the inclusion of DSMs of other areas, such as Sliema, Manoel Island, Birgu and Isla can allow for long range viewsheds and shed light on impact of development in Valletta as seen from these areas, which have some of the most iconic and recognisable views of Valletta.
- Another possible avenue for research is the application of viewshed analysis in reverse, indicating which buildings are visible from one particular point, rather than the other way around. This would help to identify those projects which have the most damaging and adverse impact on the skyline and viewsheds.
- The combination of viewshed analysis with other approaches, such as 3D analysis, would enable a well-rounded approach to development planning in a historic city such as Valletta.

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CHAPTER 16

Improving interconnectivity and visitor experience in Heritage Malta sites

Josef Caruana

Keywords
Heritage, Trails, GIS, Cultural Heritage, Viewshed Analysis, Malta

Project Aim

The aim of this project was to:

- design heritage trails according to their geographic location and themes;
- identify amenities accessible within five minutes walking distance of Heritage Malta sites; and
- connect Heritage Malta sites found in Valletta visually by means of street banners

Introduction

Whilst specific tourist-oriented modes of transportation exist with which tourists visit Heritage Malta sites, such as open top buses, these services do not cater for the personal interests of visitors, but instead move visitors between the maximum number of sites they possibly can, based on spatial considerations, convenience, and popularity. These services also do not visit small non-renowned sites which are not commercially viable for them, thus leaving their users with lacunas in their experience. Other more personal modes of transport such as taxi services do not maximise visitor experience, since they are dependent on the driver's knowledge of relevant cultural heritage sites.

Providing visitors with a variety of heritage trails based on geography, themes and amount of time available allows visitors the flexibility of choosing what to see based on an informed choice, which is useful for visitors using independent modes of transport. The creation of heritage trails for use by site visitors was considered important and was the aim of this project.

Methodology

GIS was used in this project due to the advantages such a system has over non-spatial information systems when the context is a spatial one. For this project three different base maps were chosen depending on the particular applications that were needed for during the project. All maps were projected in WGS84 / Pseudo Mercator which is the projection used in most popular Web mapping applications, some of which were used in this study. Google Satellite was selected as a base map due to its resolution and thus the ability of the researcher to match satellite photos with known features. The identified features were used in order to create a shapefile 'Sites', with all Heritage Malta sites open to the public daily having been listed within it. The attributes inserted into the attribute table (Figure 1) of this shapefile were compiled from published sources (Heritage Malta, 2019) or through the author visiting the respective sites and completing missing data where lacunae were present.

Figure 1: Attribute table for 'Sites.shp' showing sites and their attributes

Sites :: Features Total: 18, Filtered: 18, Selected: 0

	id	Site	Type	Location	Num Visit	Vst Dur	WHL ACC
1	1	Tarxien_Temples	Prehistoric	Grand Harbour	87599	1.0	Yes
2	2	Hagar_Qim_&_Mnajdra	Prehistoric	South	201106	2.0	No
3	3	Maritime_Museum	Knights	Grand Harbour	26090	1.0	Yes
4	4	Fort_St_Angelo	Knights	Grand Harbour	60207	1.0	Yes
5	5	Hal-Saflieni_Hypogeum	Prehistoric	Grand Harbour	33033	1.0	Yes
6	6	Borg_in-Nadur	Prehistoric	South	3355	0.5	No
7	7	Ghar_Dalam	Natural	South	56766	1.0	No
8	8	Saint_Paul_Catacombs	Roman	North	119998	1.0	No
9	9	Roman_Domus	Roman	North	39940	0.5	Yes
10	10	Natural_History_Museum	Natural	North	28225	1.0	No
11	11	Ta'_Hagrat	Prehistoric	North	4596	0.5	No
12	12	Skorba	Prehistoric	North	4089	0.5	No
13	13	Nat_Museum_Archaeology	Prehistoric	Valletta	93192	2.0	Yes
14	14	MUZA	Knights	Valletta	5185	1.0	Yes
15	15	Palace_Armoury	Knights	Valletta	219628	1.0	Yes
16	16	Fort_St_Elmo	Knights	Valletta	129651	1.0	Yes
17	17	Fortress_builders	Knights	Valletta	10438	1.0	Yes
18	18	Inquisitor's_Palace	Knights	Grand Harbour	50563	1.0	No

Show All Features

To select the desired sites to be included in specific Heritage Trails, such sites were selected according to the desired attributes in the attribute table with respect to the heritage trail being designed. These attributes were 'Type' (Period), 'Location' (Geographic region), 'Num_Visit' (Number of visitors in 2018), 'Vst Dur' (estimated visit duration), and 'WHL ACC' (whether the site is wheelchair accessible). By means of these different selections, various heritage trails were produced, with their themes ranging from a chronological (specific period in history) (Figure 2) or spatial (geographic region) (Figure 3) theme, to trails highlighting specific attributes (number of visitors and wheelchair accessibility).

Figure 2: The Prehistoric Heritage Trail Base map

Source: © OpenStreetMap contributors)

Figure 3: The 'North Heritage Trail' one of the spatially based trails produced.

Source: Base map: © OpenStreetMap contributors

The API (Application Programming Interface) Openrouteservice was used to calculate routes for heritage trails by means of the QGIS plugin 'ORS Tools'. Routes were calculated between sites selected according to the heritage trail theme desired. To ensure accuracy, OpenStreetMap (OpenStreetMap contributors 2015) was used as another base map in order to confirm that the location of the Heritage Malta sites in the shapefile 'Sites' corresponded to the correct position and that the projected routes when superimposed on OpenStreetMap were correctly positioned spatially. The time spent on a Heritage Trail was calculated by taking the sum of the visit duration of the sites in the Heritage Trail and adding it to the estimated driving time of the created route which was obtained by means of 'ORS Tools'. The result then categorized the route into one of three options: Half Day Trails (heritage trails less than 4 hours in duration), Full Day Trails (heritage trails between 4.1 and 8 hours in duration), and Multi Day Trails (heritage trails that were over 8 hours in duration).

The above methodology resulted in the production of ten heritage trails. The subject of each respective heritage trail was either Geographic, Theme or Attribute based. All heritage trails except the Valletta one (walking) were based on the fastest driven route between sites, not the most direct. This was chosen to maximise the number of sites a visitor could visit in a given route in the shortest time possible. The layout of these routes, since they are superimposed on an OSM map, will already be familiar to some of the users of these heritage trails, since OSM is gaining ever increasing popularity in everyday use. This fact should make the adoption of these heritage trails by visitors even easier. Heritage trails such as the 'Least visited sites' one produced, offer visitors a different perspective not normally available in such trails. Calculating the time taken for each heritage trail ensures that visitors using the map are well prepared in terms of time commitments and can also modify and skip items accordingly. This is especially important as it helps personalise the heritage trails further according to their needs. Time is usually the biggest constraint visitors have when visiting such sites.

The OpenStreetMap dataset was also used to extract layers of information to be used in this project such as parking areas and restaurants. This was done by means of the QuickOSM plugin. ORS tools were also used, in conjunction with the shapefile 'Sites' in order to determine the area that could be walked from particular Heritage Malta sites in five minutes. This was done by means of isochrones. A five minutes walking distance limit was chosen as an arbitrary value based on what visitors are normally comfortable walking for in order to access an amenity in the hot Maltese summer sun, when site visits are normally amongst the highest of the year. The resulting isochrones from sites were then superimposed on the restaurant and parking spaces layers extracted from OSM to visualise the parking spaces and restaurants which were within a five-minute walk from specific Heritage Malta sites. This is important as from the researcher's experience visitors to heritage sites often look for amenities close to the same site, and whether a particular amenity is available might decide if a site visit occurs or not. QGIS was utilised in this project to obtain and display such information which would be beneficial to the site visitors, especially in rural sites which might not have ancillary facilities typical of other Heritage Malta locations.

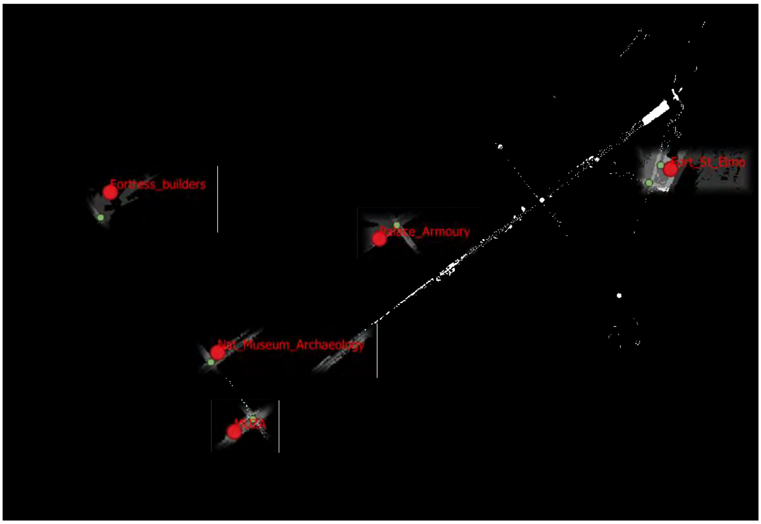
Discussion

The use of isochrones to identify restaurants and parking areas within 5 minutes walking distance from sites means that persons travelling to the sites can plan where to park, and also any refreshments they would like to take before or after visiting the site. Due to the high opening and closing rate of restaurants, such maps need to be updated every few months in order to ensure that they are still relevant to the area in question. The results obtained from the above methodology showed that a GIS by means of an API is well suited for the purpose of designing heritage trails and exploring nearby facilities. This is due to the spatial nature of such systems, together with their ability to link to a database from which required data can be extracted.

Linking heritage attractions is an important part of heritage management. Linking heritage sites visually by means of banners positioned in strategic positions in a city focuses visitors on the pre-planned path they had decided to take, serves as a visual cue against distractions and as a marketing tool for the same sites. Such visual linking is more feasible in cities with a grid layout and where the distances involved are not great, thus making Valletta an ideal candidate for such a study. In order to achieve the third objective of the project (Valletta street banners objective) a clipped digital surface model (DSM) of the Maltese islands was used (ERDF:156 2013).

To calculate the required number of banners and their viewshed, several banner locations were created between Heritage Malta sites and viewpoints were created using the QGIS Toolbox. The parameters used to create the viewpoints were an observer height of 1.6 meters and a target (banner) height of 3 meters. 3 meters was chosen as this is the typical length of a Maltese building storey, thus the skyline of Valletta was preserved by ensuring that all banners arose up to only one Maltese building storey. A viewshed analysis was then conducted from the created viewpoints (Figure 4) the result was observed, and more banner locations were added, or existing banner locations were moved to improve the banners' visibility whilst at the same time keep the number of banners needed to a minimum. This process was repeated until the desired coverage was achieved. The Earth's curvature was not considered in this analysis due to the area of interest covered being less than 1,000 meters, which makes the effects of the earth's curvature on the study negligible.

Figure 4: Visibility analysis of banners linking Valletta sites.



Source: Base map: ERDF 156 Data. (2013).

A total of eleven banners are needed to produce the desired coverage in Valletta and visually link all the cultural heritage sites under the responsibility of Heritage Malta. Since the city of Valletta is inscribed in the World Heritage List with very restrictive building regulations and a scheduled skyline, this analysis should remain valid for the foreseeable future, and if further sites are added to Heritage Malta's portfolio, such an analysis can be redone in order to include them, although if such sites are in the two main streets of Valletta, the present analysis would have covered them as well.

Results

Key results of this project are:

- Ten heritage trails were produced for Heritage Malta sites which open daily. These heritage trails were themed according to different attributes such as geography, period, accessibility, or time taken to complete the trail.
- The useful amenities available within five minutes walking distance from some Heritage Malta sites were also mapped spatially as a proof of concept. Such studies,

other than aiding visitors, also identified amenities which are lacking in certain areas or might need improvement.

- Linking different Valletta Heritage Malta sites by means of a relatively small number of banners that do not rise higher than the current streetscape was possible.

Recommendations

- From an operational perspective it is recommended that the Heritage Trails and Banner placement results obtained in this study are integrated within the operations of the agency to improve visitor experience. The Heritage Trails produced could also be used to identify the best places to install street signs that guide visitors to Heritage Malta Sites.
- Heritage Trails could be integrated within an app since the latter is interactive, changing according to road closures, traffic, number of current visitors in the site and other variables which might interest visitors. Further research into the development of such an app is recommended. A QR code for useful information can be integrated with the banners in Valletta, thus increasing the multi-function characteristics of such banners.

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CHAPTER 17

Data Inputting for historical buildings restored in Valletta

Kenneth Incorvaja and Allan Ellul

Keywords
Restoration, Valletta. GIS, Architecture, Tourism, Heritage Trail, Pollution

Project Aim

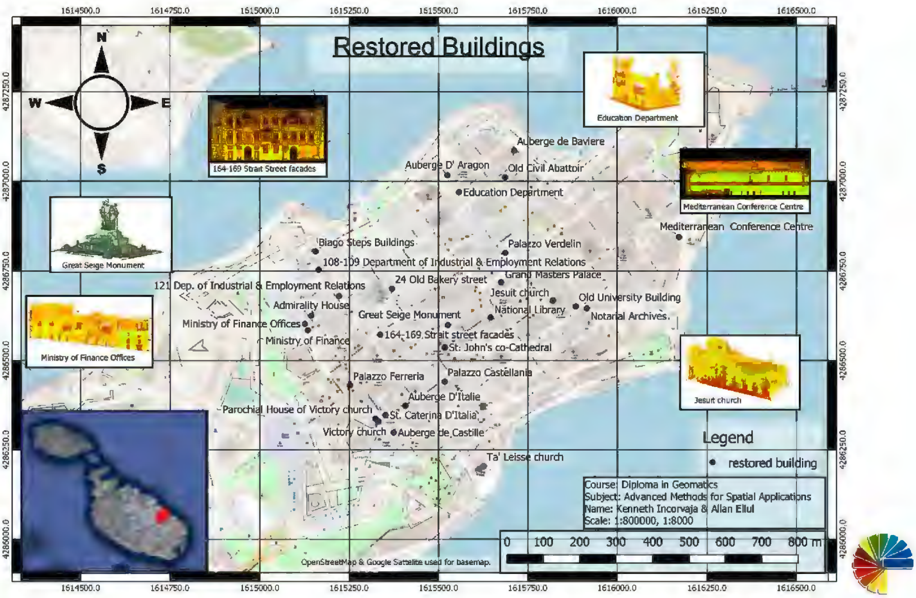
This project aimed to collect and input data of all the buildings in Valletta that the Restoration Directorate has restored. Output results were analysed spatially in a GIS. The analysis provided a good picture of the various interventions throughout the restoration process.

Introduction

Before starting to restore a building, the latter must be meticulously documented. The Restoration Directorate invested in methods to document these historical buildings. Software such as Metric Single Rectification (MSR), Laser Scanning, photos, and other investigation techniques are used to create 3D models. One can extract detailed elevations, and sections determine the height between two floors and the orientation of the building with reference to its surroundings.

Once the scaled images are imported in ACAD, a line drawing with all the details is drawn. This lengthy process is intended to document and map out the deteriorated areas in a building. This enables an estimation of costs for the restoration works. A GIS allows one to have all the data sorted in one place, thus facilitating research. (Figure 1).

Figure 1: General Layout indicating the restored historical buildings at Valletta



Source: Restoration Directorate

Advantages of using GIS Software

The use of the GIS has many advantages. When data is inputted in a GIS, the information about the work carried out throughout the years and from different sections can be found in one location without duplication. Additionally, a GIS provides the spatial distribution of the restored buildings inside the Valletta fortifications and enables the determination of elevations of each building from the layer's attribute features. When specific elevations have a large area of biological colonization, the building is likely to be North facing. Other elevations exposed to coastal elements most probably have a significant powdering/ back weathering area or severely deteriorated courses. The use of GIS/spatial analysis is beneficial in this exercise because the information in the attribute table is geo linked to the location of the building, thus making the identification of the areas that need to be restored and what type of intervention is required a quick and straightforward process. With the results obtained from this exercise, one could also determine which part of Valletta an edifice is situated from the deterioration noted. For instance, a large portion of a façade with crust suggests that the area has been exposed to exhaust and other fumes for a considerable amount of time.

Methodology

QGIS 3.6.3 with Grass 7.6.1 software was used for this project. The Open Street Map with a Coordinate Reference System as EPSG 32633 – WGS84/UTM Zone 33N was used as a base map over which various vector models (points, lines and polygons) were digitised over all the restored buildings in Valletta in a shape file (shp.).

Classification of Intervention

QGIS 3.6.3 with Grass 7.6.1 software was used for this project. The Open Street Map with a Coordinate Reference System as EPSG 32633 – WGS84/UTM Zone 33N was used as a base map over which various vector models (points, lines and polygons) were digitised over all the restored buildings in Valletta in a shapefile (shp).

In the restoration process, every building is categorized according to the level of interventions which can be applied. Each building requires a specific type or types of intervention. Certain structures that are more exposed to pollution have, while other structures exposed to natural elements have more weathered areas. Some interventions are:

- Biocide application. Biocide is used to control or eliminate biological growth (Nugari et al, 2017)
- Stone Consolidation. Consolidation of stone aims to preserve the historical building as much as possible
- Epoxy injection. Epoxy is applied to repair and fill in cracks (The Malta Independent, 31st July 2019)

Point Pattern Analysis

Point Pattern Analysis is used to determine whether the points in the study area are in a particular pattern, such as dispersed, structured, uniform, random, or clustered.

Clustered refers to when objects are close to one another. 2) Dispersed refers to when objects are spread out from one another. 3) Random refers to when objects are neither in a clustered nor in a dispersed pattern (Yuan et al, 2020).

The data used, that is, the location of the restored historical buildings, showed that said buildings are situated randomly. This result was expected, as in Valletta, there are other privately owned buildings.

Density based Analysis

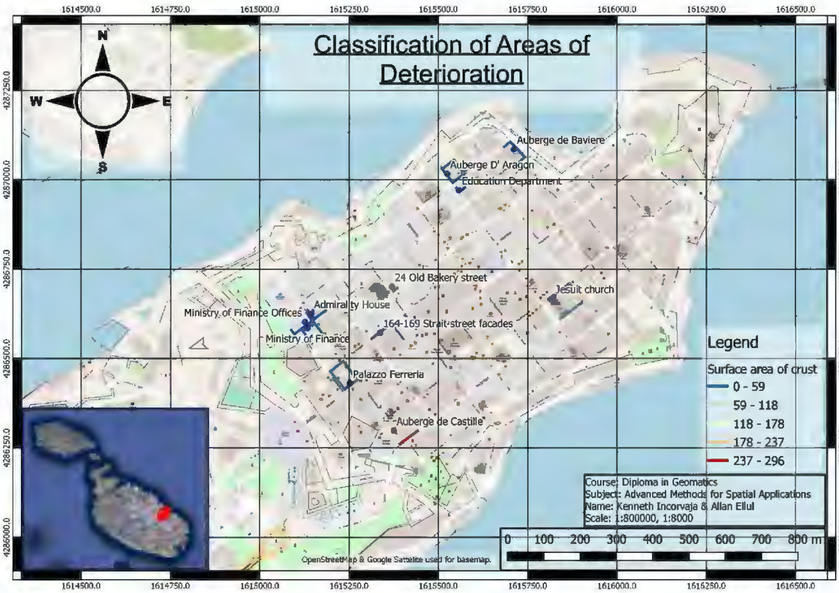
Density techniques characterize the pattern of its distribution vis-à-vis the study area. A density map can give an estimate of some concentrated features within the geographic radius. Heat maps indicate which areas require urgent interventions. Here too, the data was the location of the buildings. In this case, the results showed a cluster of buildings, namely Ministry of Finance, Admirality House & Ministry of Finance offices, as these buildings formed part of the Collachio area.

Vornoi Polygons

A Voronoi diagram is partitioning a plane into regions based on the distance to points in a specific subset of the plane. Voronoi diagrams can be shown as colourful charts to indicate the area associated with each point. This algorithm from a point layer creates a polygon layer with the Voronoi polygons corresponding to the points. In this case, the data used was the dates each building was built. The aim was to create an alternative footpath that allows one to see each restored building in chronological order. The results show that some of the oldest buildings (1560-1633) are located in Marsamxett Harbour and near the Grand Master's Palace. In comparison, the Great Siege monument is the only item built in 73 years, between1853 and 1926. It is interesting to note that one would expect the oldest buildings near the Grand Harbour. The results show otherwise. This could be because of the ongoing improvements of the facilities in that busy area. Another possible reason could be that said area would have been constantly at the centre of potential attacks.

Some areas in Valletta have been pedestrianized. However, others are exposed to a considerable amount of traffic daily. This causes damage to the buildings exposed to emissions from vehicles. The data collected from the documentation of restored buildings revealed that the side elevation of the Auberge de Castille in St. Paul's Street had the most significant amount of crust because it is situated in one of the main entrances to Valletta. Similarly, the Auberge de Castille, located a few metres away from the Upper Barakka, is popular with tourists. Consequently, traffic is very heavy in that area (Figure 2).

Figure 2: Output: highlighting the facades restored by Restoration Directorate.



Note: The areas in blue show the least amount of deterioration caused by curst, whereas the areas in red show where the greatest amount of crust was found.

The primary material used for the most significant buildings is the soft and yellowish Globigerina Limestone, which erodes quickly when exposed to the air and the elements. One such example is the main façade of the Auberge de Baviere in St. Sebastian Street, which façade revealed itself to be heavily affected with powdering. This is probably because it is situated near the sea and facing North East, making it susceptible to prevailing winds (Figure 3).

Figure 3: Highlighting the areas most affected by powdering on the restored buildings carried out by Restoration Directorate

The data inputted in the QGIS enabled the identification of the mean centre - the area which is approximately in the middle of a larger area, which in this case, was in the middle of the buildings considered for the trail. The mean centre is ideal for setting up a tourist information point. Additionally, Standard Distance enabled one to calculate the approximate distance from the mean centre (the tourist information point) to the various sites indicated in the trail. This function ensured that the distance between the centre and the different buildings was 5 to 10 minutes by foot. The distance from the centre to every building in the trail was also established. Of all the twenty-nine buildings selected, the closest one is The Great Siege monument which is 69 meters away, while the Mediterranean Conference Centre is the furthest point at 695 meters.

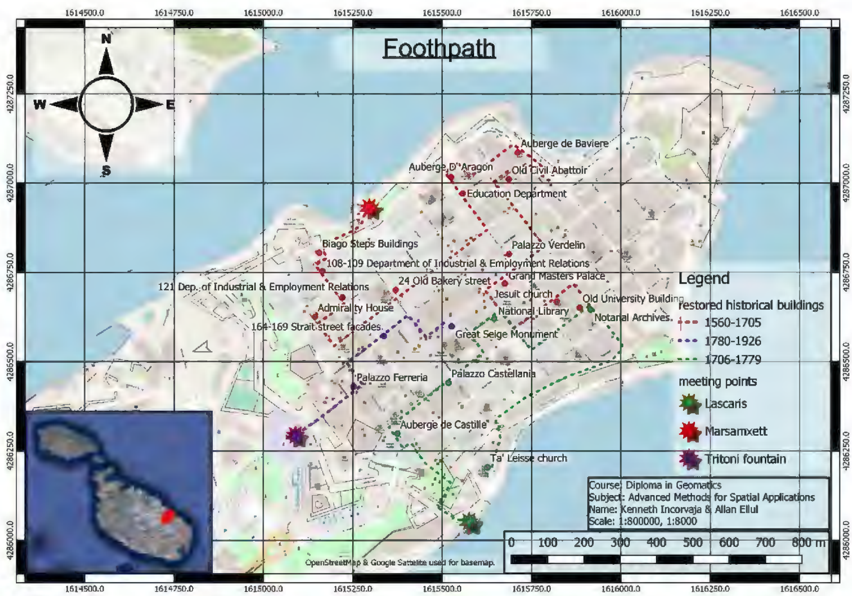
Discussion

Air pollution is a significant issue in Malta. Studies of monitoring air quality in Malta have consistently revealed poor air quality. While many other European countries are experiencing a downward trend in CO2 emissions, it is quite the opposite in Malta. One study showed an increase in carbon dioxide emissions of 6.7%. "Malta's emissions are primarily caused by petrol and diesel-powered vehicles used on the island. Malta has consistently failed to reach EU emission reduction targets since 2013" (Hudson David (8 May 2019)). Another contributing factor are cruise liners. Studies in 2017 have shown that in 2017, 203 cruise liners emitted 62 kilotonnes (62 Kt or million kilograms) of sulphur oxide (SOX), 155 Kt of nitrogen oxide (NOX), 10 Kt of particulate matter (PM) and 10,286 Kt of carbon dioxide, while in European waters (Marinelli David (22 September 2019)). Harmful pollutants such as carbon dioxide and sulphur dioxide emissions are detrimental to our health (Times of Malta (14 November 2018)) and contribute to global warming and affect things exposed to them. "Air pollution not only has an impact on human health, but also on natural heritage (e.g., ecosystems) as well as on cultural heritage (e.g., buildings)" (Schembri Orland Kevin (25 November 2018)). Air pollution is directly correlated to the amount of emissions from ongoing traffic. A recent study revealed a significant drop in air pollution: up to 70% from February 19th to March 15th 2020 and from March 16th to –19th, 2020. This decline is because there was a substantial reduction of traffic on the roads since schools were closed. More people were teleworking to prevent the spread of the coronavirus (Watson Gordon (21 March 2020), Watson Gordon (26 March 2020), Times of Malta (28 March 2020), Air pollution in Malta: Real-time air quality index visual map). Ideally, Valletta should become a pedestrian area to preserve all the buildings from damage. Figure 2 shows that the areas which have been pedestrianised have a low level of crust, while in St. Paul's street, there are indications of high levels of pollution due to traffic. Limiting access to commercial vehicles to specific time frames would offer a solution.

The restoration of a façade requires the use of scaffolding. This would often necessitate traffic deviations. This calls for meticulous planning in traffic management and control. Lines indicate where the works will be carried out, and the width of the street will reveal whether traffic flow will be affected or not.

Apart from data inputting, this project is also related to tourism. Valletta, declared by UNESCO as a World Heritage site, has always been attracted tourists because of the various historical landmarks, grand architecture, excellent restaurants, idyllic streets, and the beautiful sights it offers. This project aims to create several tourist information points in different areas of Valletta, for instance: 1) Marsamxett Area: Ferry terminal Valletta – Sliema (red information point), 2) Grand Harbour Area: Ferry terminal Valetta – Three cities (green information point), 3) Valletta City Gate: Triton Fountain (purple information point), 4) In front of the Court of Justice building (Figure 4).

Figure 4: The proposed footpaths, grouping the restored buildings into 3 groups, according to the period in which they were built.



The Restoration Directorate is one of the leading entities contributing to restoring various historical buildings around Malta and Gozo. This project aims to make Valletta and its restored gems more accessible not only to the tourism sector by designing footpaths that lead to particular historical buildings. From the footpath, one can calculate the distance from one building to another and the total distance, thereby indicating the time required to complete it. Furthermore, these footpaths can be used to create Heritage Trails for students. Various examples of possible footpaths are:

1. Historical footpaths according to the date of construction of a building (Figure 4). Starting from: 1) Marsamxett area restored buildings built in 1560-1780 (red dotted line), 2) Lascaris area restored buildings built in 1706-1780 (green dotted line), 3) Tritoni fountain restored buildings built in 1780-1926 (purple dotted line)
2. Footpaths for restored buildings only. Starting from: 1) Marsamxett area (red dotted line), 2) Tritoni fountain (purple dotted line)

Additionally, with the creation of a DEM (Digital Elevation Model) of Valletta, the terrain can be determined and the slopes assessed. A footpath could be categorized according to the slopes, thus enabling interested individuals to choose the most adequate to their needs.

Using GIS enables one to obtain:

- the length of each footpath;
- an estimate of the time needed to complete it;
- the identification of places of interest; and
- information regarding the difficulty and or accessibility of each footpath.

Results

Key results of this study are:

- The identification of the various types of deterioration according to the location of the building and the environmental impact. For instance, areas exposed to heavy traffic are significantly affected by crust, whereas buildings facing the sea suffer from powdering.
- The identification of the interventions needed.
- The facilitation of planning traffic management and control during the entire restoration process always requires scaffolding.

Recommendations

Recommendations for policy/operational change and further research:

- Since vehicle emissions have a substantial impact on buildings, it is highly recommended that only electric vehicles are allowed in Valletta (Embarq Turkiye (June 2015), Embarq Turkiye (June 2014)).
- It is recommended that the height of buildings be restricted to protect Valletta's visual aesthetics, thus saving a neat skyline.
- More funds should be allotted for further restoration projects. There are numerous abandoned dwellings in a neglected state in Valletta.
- It is recommended that all historical buildings in Valletta be documented using ta GIS. This would provide an exhaustive collection of all the data in one place, thus facilitating research and further studies.
- Creation of a footpath that trails all the buildings which have been restored. Such a footpath would include the history of each building, the deterioration it was subject to, and the interventions made. It would also enable one to indicate the shortest path to the next building and give an indication of the time needed to complete it.

Note:

All data obtained by the Restoration Directorate has been used by permission.

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CHAPTER 18

GIS in Archaeology: Analysing the Threat that Modern Day Construction Imposes on World War II Shelters

Luke Brightwell

Keywords

WWII, Shelters, Development, Threats, GIS, Archaeology, Spatial Analysis, Plotting, Heat Maps

Project Aim

The objectives of this project is to implement GIS tools to a known archaeological record, particularly WWII shelters, and analyse the threat that modern day construction imposes onto these features. To do this, the following tasks are to be executed: (a) selection of one particular area in Malta, particularly that of Naxxar; (b) using QGIS™ to plot all WWII Shelters located in Naxxar; (c) generation a heatmap showing all shelter locations; (d) execution of spatial expressions related to how many of these shelters fell under roads, public spaces and private houses, and (e) identification of those shelters which are under greater or lesser threat to modern day construction.

Introduction

GIS is an adaptive and transformative scientific tool that can be of great use to multiple scientific disciplines especially that of archaeology. GIS is useful for archaeological application to provide a window into past and even present human behaviour by observing spatial relationships between people and landscapes (Renfrew et al. 2020). When it comes to modern day construction, much of Malta's archaeological heritage is at risk of and/or destroyed. GIS and archaeology can collectively be combined into one tool and used to their full potential as measures of prevention before construction works commence.

Humans have always been developing ways to ensure one's own safety and survival during times of peril. World War II shelters are underground rock-cut structures built specifically to serve as protection against enemy bombardments during World War II. WWII shelters are cultural heritage features and should be treated as such in keeping with the Cultural Heritage Act 2019 (CAP 445). Modern day construction works, including road works, are threatening archaeological features however construction works cannot be halted because of archaeology. Preventive measures need to be taken to ensure that Malta's cultural heritage is being protected accordingly. This study focused on one locality of Malta. However, it may eventually be utilised for the entire extent of both Malta and Gozo with their broad range of archaeological remains. Such a project would bring together a national heritage repository depicting the exact location of the already discovered archaeological remains. Government entities, such as the Superintendence of Cultural Heritage, would thereby enable to provide insight, solutions, recommendations, and conditions to the construction workforce before works on site commence, thus ensuring the safety of these remains.

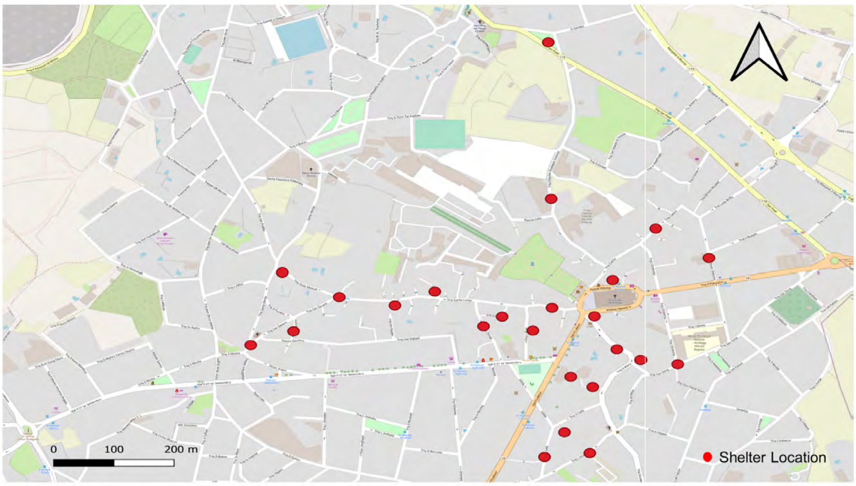
Methodology

This project aimed to implement 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. To do this, the following tasks were executed: (a) selection of one particular area in Malta, particularly that of Naxxar; (b) using QGIS™ to plot all WWII Shelters located in Naxxar; (c) generation of a heatmap showing all shelter locations; (d) execution of spatial expressions related to how many of these shelters fell under roads, public spaces and, private houses, and (e) identification of those shelters which are under greater or lesser threat to modern day construction.

Information on WWII shelters was acquired from the Research Unit of the Superintendence of Cultural Heritage. The data acquired consisted of a WWII shelter index and detailed plans depicting the exact location of these shelters. The collected data was reviewed which effectively led to choosing an ideal locality for this study. The locality chosen was that of Naxxar. Naxxar was found to consist of a total of 25 shelters. One of the shelters locations, shelter No.5, was found to be missing from both the acquired plans and the WWII shelter index. For this reason, shelter No.5 will not be included in this study.

Subsequently, the exact location of Naxxar's WWII shelters was plotted as a new map layer. For this project a point geometry type was used. The relevant name fields that were to be assigned to each plotted point, in this case (id, street, context) were then added . Once saved, the layer was renamed to "Shelter Location", followed by p lotting of all 24 shelter points. For each point feature added, the shelter number, as retried from both the WWII shelter index and Naxxar local plan, was inputted as well as fields pertaining to street and context. Once all 24 shelter points were plotted, the size and colour of the plotted points was adjective to enable a visually detailed shelter location map (Figure 1). Sequentially, the relevant X and Y Co-ordinates for each of the plotted shelter location points were derived.

Figure 1: Naxxar's Shelter Locations



The study was linked to GIS spatial analysis tools to indicate which of the plotted shelters were under greater or lesser threat to modern day construction. To do this, a heatmap was generated to visualise shelter location density. Expressions were run to see how many of these shelters fell under roads, public spaces and private houses. To do this, parameter "Weight points by" was clicked and then inputted the following expression – "context" = 'under road'. Then clicked "Apply" followed by "OK". Having completed this task, a heatmap showing all shelters located under roads together with their location density was generated. The same process was applied to generate a heatmap for those shelters located under public spaces and private houses by adjusting the expression. For shelters located under public spaces the following expression was used - "context" = 'under public spaces', and for shelters located under private houses the following expression was used - "context" = 'under private houses' (Graser, 2016). It is important to note that data from the Planning Authority's Public Geoserver was also used to have a visual aid depicting any development constraints assigned to the locality of Naxxar (2021).

Discussion

The results obtained from this exercise clearly depicted a pattern. The very first map created for this study was the Shelter Location layer whereby using points, the exact location of all Naxxar's WWII shelters were plotted onto the added map tile XYZ layer. On reviewing this map, it was noted that there is a cluster of shelters located in very close proximity to Naxxar's main public square which is that of Pjazza Vittorja. Additionally, having combined this data with the heatmap showing the location of all shelters, the resulting map confirmed this observation, the reason being that the closer the shelter is to the main public square the more intense the density of the heatmap.

Next, by running these expressions, three individual heatmaps were generated. The first heatmap showed (Figure 2) that most of the plotted shelters are located under roads, totalling 15 shelters. Visually, the shelters are scattered throughout Naxxar with an approximate distance of 40-500m between each shelter location. Upon examination only two cluster densities are visible; here the approximate distance between each shelter is that of 30-35m. The second generated heatmap (Figure 3) indicated that shelters located under public spaces are at a minority, totalling to only 3 shelters. Visually, it is clear there is a cluster density of shelters located directly beneath Naxxar's main public square with an approximate distance of 80m from each other, and one other shelter located under a secondary public square particularly Darnino's square located 540m away from the main public square. The third and last heatmap (Figure 4) depicted those shelters located under private houses are also at a minority, totalling to only 6 shelters. Visually, there is only one cluster density of shelters located approximately 26m apart while the others are all scattered with an approximate distance of 240-280m from each other.

Figure 2: Heatmap Showing of Shelters Located Under Roads and their Location Density

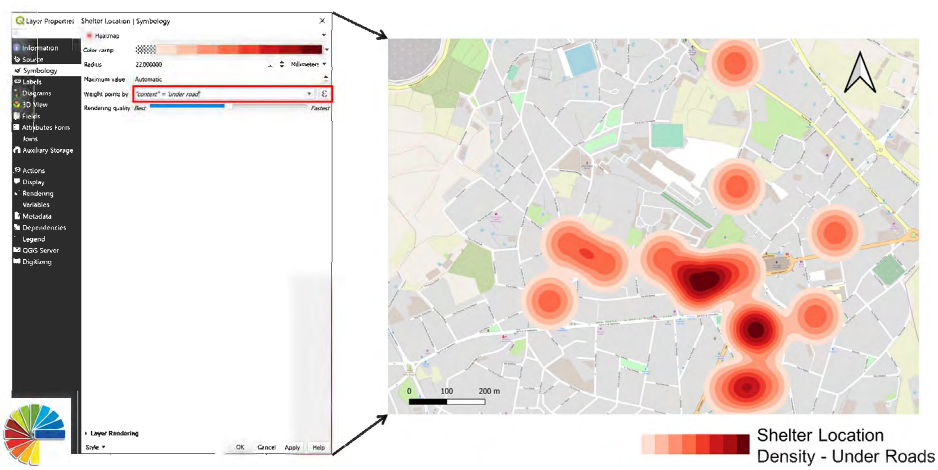
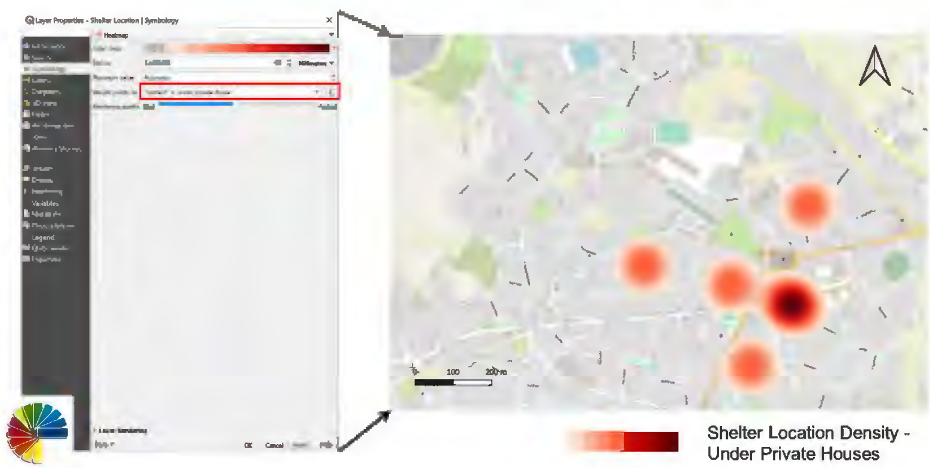


Figure 3: Heatmap of Shelters Located Under Public Spaces and their Location Density

Figure 4: Heatmap Showing Shelters Located Under Private Houses and their Location Density



The next step involved identification of shelters which are under greater or lesser threat to modern day construction. The Planning Authority's Public Geoserver shows that the locality of Naxxar has an Urban Conservation Area constraint. By reviewing the generated heatmaps alongside the map depicting the Urban Conservation Area of Naxxar, is it noted that the majority of the UCA extends over almost all the shelters located in Naxxar. Only shelters 12, 15, and 25 are not protected by UCA regulations. However, knowing their context and proximity to Naxxar's UCA, government entities like the Superintendence of Cultural Heritage would be able to provide the construction workforce with all relevant conditions before the proposed development works commence thus ensuring the protection of these remains.

This study enabled the use of GIS analysis as a tool to help ensure the safety of WWII shelters from modern day construction.

Results

The key results of this project were:

- The majority of the UCAs extend over almost all the shelters located in Naxxar.
- Only shelters 12, 15, and 25 are not protected by UCA regulations.
- Knowing their (shelter 12, 15, and 25) context and proximity to Naxxar's UCA, government entities like the Superintendence of Cultural Heritage will be able to provide the construction workforce with all relevant conditions before the proposed development works commence.

Recommendations

Future research to enable a more complete approach to analyse the threat that modern day construction has on WWII shelters may include to:

- plot the entire extent of all WWII shelters located in the Naxxar area by using lines instead of points;
- plot the entire extent of Naxxar's UCA;
- utilise various geospatial software applications to create superimposed maps showing multiple layers on top of each other for more accurate interpretations and extrapolating GIS analysis tools for other cultural heritage aspects as well.

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CHAPTER 19

Analysing the Fortification Walls of Valletta and Mdina

Mark Cassar

Keywords
Valletta, Mdina, fortification, deterioration, mapping, weathering, bastion, wall, area, stone, Malta

Project Aim

The aim of this project was: (1) to identify forms of deterioration occurring on selected fortification of walls using a GIS; (2) to detect the main causes of deterioration with which such processes are occurring; and (3) to investigate the problems that exist and understand why they persist.

Introduction

The architectural legacy of Malta spans over several centuries and has since helped to shape the island's unique identity. Amongst the megalithic temples and traditional houses, one can also identify the fortification walls found all over the island, to be an important feat of local architecture. Such walls span throughout many areas, an element that characterised the Maltese landscape. However, due to the constant damage caused by several battles throughout history and the long state of neglect for several years, most of the building fabric has suffered from deterioration. As a result, the stone used for construction has been eroded, causing weak structural conditions and eventual collapses to occur. For this reason, a study based on the state of the fortification of walls was carried out to better understand the present issues related to these historic structures.

In this study, the fortification walls chosen for analysis were selected over Valletta and Mdina. To obtain a variety of results, the chosen walls were in areas at distinctive locations. In this respect, walls were chosen around Valletta's coastline; whilst selected walls in Mdina are surrounded by an agricultural landscape. The locations selected in Valletta were the German curtain, the St. Sebastian curtain, the English curtain, and the French curtain (Figure 1). The locations chosen in Mdina were the St. Peter's bastion, the Magazines curtain, the St. Mary's bastion and the Despuig bastion (Figure 2).

Figure 1: Map showing all the selected fortification walls in Valletta

Source: Map produced by author on QGIS™

Figure 2: Map showing all the selected fortification walls in Mdina

Map produced by author on QGIS™

Since several restoration projects by the Restoration Directorate were carried out, the chosen fortification walls were based on recent work assumed by the Restoration Directorate. Projects were completed in the last 10 years as part of the European Regional Development Fund for Malta 2007-2013; together with the Parliamentary Secretariat for the EU Presidency 2017 and EU Funds, as well as the Ministry for Justice, Culture and Local Government. Therefore, the respective surveying and documentation work had already been completed and mapped out using AUTOCAD™. The forms of deterioration were identified using a reference system obtained by the International Council of Monuments and Sites (ICOMOS), the Association that works on conservation and protection of cultural heritage places all over the world.

In 2008, ICOMOS produced a glossary, classifying the different types of deterioration that can occur on any building, together with the terminology of each possible condition. Such representation was used to define any deterioration mapping produced by the Restoration Directorate. For this, a legend referring to several deterioration processes was created where for each condition, a unique hatch was created to identify different forms of deterioration occurring. This proved to be quite beneficial when inputting data onto QGIS, as the different types of deterioration were identified individually based on their geographic location. Thus, the way with which deterioration was visually recorded on AUTOCAD™ software helped to facilitate the data inputting on QGIS.

The project began by acquiring the relevant documentation needed to analyse the deterioration conditions of the case studies considered. Following the analysis obtained from the drawings created on AUTOCAD™, it was noted that the deterioration processes such as back weathering, accretions, missing stone, biological weathering, alveolar weathering, vegetation and powdering were visible throughout all the chosen fortifications' walls. Since the total area for each type of deterioration was already available via AUTOCAD™, the data was transferred onto QGIS™ where it was mapped geographically according to the location of each studied wall. With this GIS software, a series of points were selected to represent each wall being studied, and for each point, the 7 different deterioration mechanisms were listed and recorded onto their respective attribute table.

Methodology

The work further carried out on QGIS™ by creating a new shape file layer, whereby the selected walls were geographically identified onto a map. The layer was given several fields based on the name of the fortification wall, together with the seven chosen deterioration processes that were observed for this study. Thus, whenever a point feature was added onto the map, the name and respective area of every type of deterioration analysed was inputted. When this task was completed, the process of applying the heat maps was commenced to provide a better visual understanding of the severe issues that each wall had before the restoration took place.

In Figure 3, the values with the largest area of deterioration have been highlighted. One can notice that out of all the highest values recorded from the selected fortification walls in Valletta, the French curtain wall had the largest areas of damage. To better understand the reason as to why this phenomenon had occurred, a consultation with Maltese military historian Dr. Stephen C. Spiteri was made. From the research gathered, it resulted that the construction of this wall was already of inferior quality since its construction in the 1680s. This is due to the poor globigerina limestone used for construction that was obtained from a nearby ditch in Valletta. This led to rapid deterioration processes taking place, causing regular repairs to be made every 100 years. An additional parameter that was noted is that when one notes of the geographic orientation of the French curtain wall, this faces the North-West direction of Valletta. Since the wall is surrounded by a coastline, strong winds and large waves would constantly hit the wall throughout the windy days of the year. This form of erosion would accelerate the deterioration.

Figure 3: Table showing the highlighted results from the total area of deterioration in metres squared (m^2)

Fortification wall	Back weathering	Accretions	Missing stone	Biological weathering	Alveolar weathering	Higher Plants/ Vegetation	Disintegration / Powdering
French Curtain, VLT	313.03	365.43	6.41	714.33	58.63	16.67	684.59
English Curtain, VLT	158.48	93.33	6.24	880.48	151.73	138.13	292.08
St.Sebastian Curtain, VLT	98.98	0	2.1	1033.5	47.56	144.71	127.81
German Curtain, VLT	17.3	5.3	1.68	2325.25	27.44	0.33	235.37
St.Mary's Bastion, MDN	16.05	13.97	1.39	3243.18	54.67	916.81	50.59
Magazine Curtain, MDN	30.12	2.03	0	2236.44	409.2	28.16	17.03
Despuig Bastion, MDN	19.05	0.25	0.88	1898.23	177.36	22.55	14.25
St.Peter's Bastion, MDN	17.74	0.9	237.07	2197.29	70.09	20.1	8.43

Discussion

Whilst the results of the walls studied in Valletta were all based on historical and visual observations, the analysis for the outcomes in Mdina was approached quite differently. Once again, the analysis for the selected walls in Mdina were carried out using QGIS™, whereby the chosen walls were identified on the geographical map and the seven deterioration processes were observed accordingly. As one can observe in Figure 3, most of the walls in Mdina had undergone high areas of deterioration, indicating that more analysis needed to be observed. To obtain further information, the use of existing data from other sources was needed. In this regard, the use of the Malta Inspire Goeportal was quite beneficial as it provided the opportunity to make use of collected data produced by experts from different fields of research. By applying a map of the geological strata of Malta, obtained from this platform, it was observed that the edges of the top geological layers, such as the Upper Coralline Limestone and the Greensand layer are close to the boundary of the surrounding fortification walls. This can be observed in the map produced in Figure 4. Unfortunately, at the time of its construction, there was no awareness of the geological implications over which Mdina is built upon. In fact, Mdina faces many structural issues, most of which require urgent attention.

Figure 4: Map showing all the selected fortification walls in Mdina, with the geological strata layer showing above this layer

Whenever the foundations of a building are supported at the edge of geological layers, structural damage is bound to happen. Constant seismic activity and earthquakes taking place over time would eventually lead to the weakening of the foundations, resulting in structural cracks, or even collapses to happen. In fact, such a scenario did take place at the bastion wall and ramparts at D'Homedes bastion in Mdina. The constant ground movement took place over many years has not only created a series of fissures on the walls but has also caused considerable damage at the rear façade of the Vilhena Palace, an 18th century Baroque magisterial palace resting on top of the bastion. With the help of geotechnical engineers, a means of reducing this movement was implemented. By applying a series of steel and concrete piles and anchors, the unstable ramparts were braced, preventing any further damage from happening. This issue has also happened with some of the chosen fortification walls studied at Mdina.

The Despuig Bastion and its adjoining ramparts have also suffered from visible fissures, whilst the Magazines curtain wall had extensive fissures, especially at the vaulted casemates located internally. Both problems were also resolved by applying piling works and anchors to secure and stabilise each wall. In conclusion, the use of mapping out the data acquired for this project has helped to provide a much better visual analysis of the state of the fortification walls being studied.

Therefore, with the aid of QGIS™, as well as other available data and information from external sources, a visual understanding of the problems pertaining to this project was possible. Even though the chosen fortification walls have already been restored, the use of QGIS™ helped to provide a better way of identifying problems related to restoring deteriorated buildings in a much more understandable manner.

It was interesting to note that at the first instance, one would associate damage to occur on a building based on visible forms of deterioration. However, with the cases shown in Mdina, the conditions to which a building can undergo damage may also be caused by other hidden problems. This was where QGIS™ helped to outline all the possible outcomes. By adding the geological strata layer, the visual analysis exposed an important concern that requires its own attention. Such an approach can be of great use to the restoration sector. As an example, one can create a shape file layer to map out all the locations of historic buildings found all over the island and classify them according to their grade of protection provided by the Planning Authority.

That way, such data can then be shared onto the Malta Inspire Geoportal platform and be used by other people as a layer for further research. Here, one can also apply the geological strata layer on top of this proposed layer, giving light on other historic buildings that require further observation. Another essential use could be inputting information such as the materials and restoration methods applied on each wall, as well as the year of restoration. That way, one would be documenting the work for any future reference.

Results

Key results of this project are:

- To convert data created from AUTOCAD™ software onto QGIS™ software This was done by acquiring the total area of deterioration produced for each wall and record it as data onto QGIS™.
- To map out and analyse the state of deterioration of fortification walls using QGIS™ software. With all the data gathered onto QGIS™, the information was geographically identified and analysed further, applying the necessary commands to give a better picture of the analysis being studied.
- To apply multiple shapefiles from online resources to better understand the results given. With regards to the results acquired for the selected walls in Mdina, the additional shape files obtained from the Malta Inspire Geoportal helped to better identify the geotechnical issues that surround these walls.
- To confirm results given on QGIS using relevant research and documentation. To further understand why the data revealed such results, the analysis was backed up by historic records and documents.
- To provide the best solutions possible for restoration and preservation based on the results given. The research produced in this project would help to serve as a tool that would further encourage the use of GIS in the architecture and conservation sector.

Recommendations

Key recommendations of this study are to:

- map out other buildings and structures which are of historic significance on QGIS software,
- provide such data to the public in order to be used and integrated for other types of analysis,
- implement further studies based on structural risk assessment around several historic buildings and structures around Malta,
- prioritise restoration and structural repairs based on buildings that are at high risk of collapsing due to their deteriorative nature; and
- apply further research that will look at ways to prevent and/or mitigate any rapid deterioration.

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CHAPTER 20

Aerial Imagery to record and document an Archaeological site

Paolo Spadaro

Keywords
Archaeology, Photogrammetry, Remote Sensing, GIS, Aerial Imagery, Greece

Project Aim

This project is fusing aerial photo and AUV/UAV data with remote sensing and GIS technology and is aimed to provide an overview of basic steps required to record and document an Archaeological site.

Introduction

This project focused on the use of photogrammetry technology in the field of archaeology. The data in archaeology are represented by any type of cultural heritage identified during the complex and delicate task of the archaeological investigation. The cultural heritage as exposed during such action could be made of several types of objects, structures, layers of soil, osteological materials and more. The use of the tools of Geomatics has proved to be a successful mean to the understanding of archaeological sites in their complexity. Geomatics provide a wide range of remote sensing approaches to archaeology, which become essential in the contemporary concept of non-destructive archaeological investigation. The exploration of drone imagery and orthophotos have given a deep insight into the potential of documenting a whole archaeological site before its actual excavation. The application of specific software and tools, as it will be discussed in this paper, based on processing of an imagery set of data, coordinate system setting and photo interpretation have widened the archaeological study.

Methodology

Photogrammetry is an important tool for surveying and documenting of ancient monuments, as well as other types of archaeological and cultural feature. Photogrammetry represents an innovation and a revolution within the world of an archaeological investigation, giving the archaeologists an essential tool to process quickly but with accuracy, the archaeology of a site. This is also evidenced in the continuous publication of results from joint use of remote sensing and archaeology tools, with a definitive step forward into the inclusion of photogrammetry within the standard approaches in the archaeological practice.

Discussion

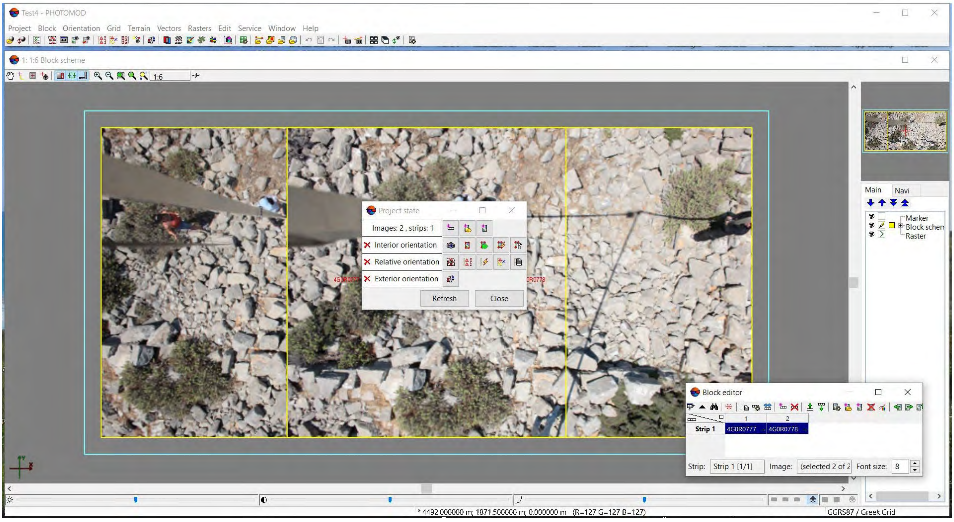
This project used photogrammetry techniques and their application in the implementation of an archaeological project:

1. Direct learning and application of the photogrammetry principles and techniques, to improve the recording of an archaeological site. This first objective was to give a general approach to what is intended for photogrammetry, orthorectification, ortho-mosaic, distortion, relative and absolute orientation in an archaeological study. Training of a dedicated software to develop photogrammetry: Photomod Lite 6.5 version, whose main applications and specification include the building of continuous, colour balanced and brightness homogenous ortho-mosaic with high accuracy, starting from separate images. Geometric and photometric distortions are adjusted during the creation operation, while providing an output product (ortho-mosaic), which could be presented as a single frame or a set of sheets in specified cartographic projection.

2. Ability to identify a set of data, which include aerial imagery, to process and analyse the given imagery, to provide spatial analysis information about an archaeological site.

The project involved a specific site of Vassilika, within the major archaeological site of Kymissala in the island of Rhodes, Greece. The region has been under investigation for several years and the specific site of Vassilika, covering an area of 1,630 sqm, shows evidence of a large structure built with ashlar masonry, defining a possible shrine The starting point of the project was the data set, consisting of short distance images taken on site, then developed by processing them with the use of the dedicated software, Photomod 6.5. Aerial p hotographs were provided by Epsilon Malta Ltd as part of their internal datasets. Since these aerial images were acquired from long or short distance of a certain ground or surface, they had a geometric displacement, that is due to the difference in the height between the camera and the surface, and the inclination for the horizontal displacements. These two principles represent the issues which a photogrammetric software is required to solve: to process the given imagery and apply proper analysis (Figure 1).

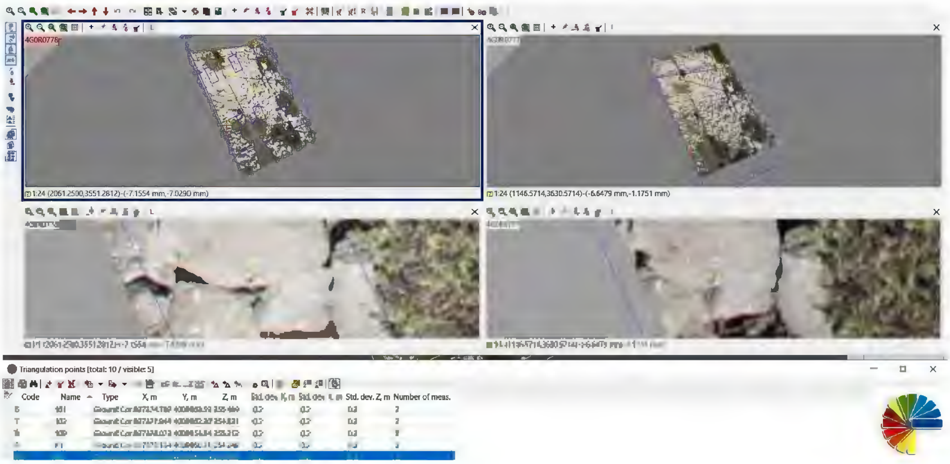
Figure 1: Basic steps of photo processing and overlapping.



The distortion in the photos was corrected through orthorectification. The methodology involved primarily Ground Control Points and Coordinates (Figure 2). These specific features are crucial to interpret the result of the mosaic construction into the real world. The mosaic of photos is tied through the process of overlapping images and is after linked to the real points and coordinates in the space. This process is essential for any study on the object. The overall process of orthorectification involved basic steps as part of the methodology & data. Such steps can be summarized as follows:

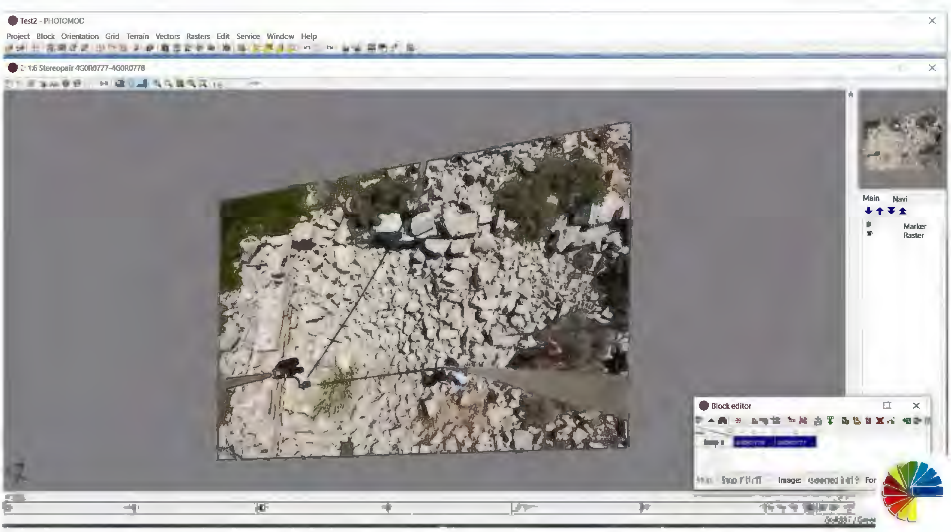
- the Interior or Internal Orientation
- the Relative Orientation
- the Exterior Orientation
- the Absolute Orientation

Figure 2: Performing of Tie and Ground Control within the overlapped images, in order to create an internal orientation.



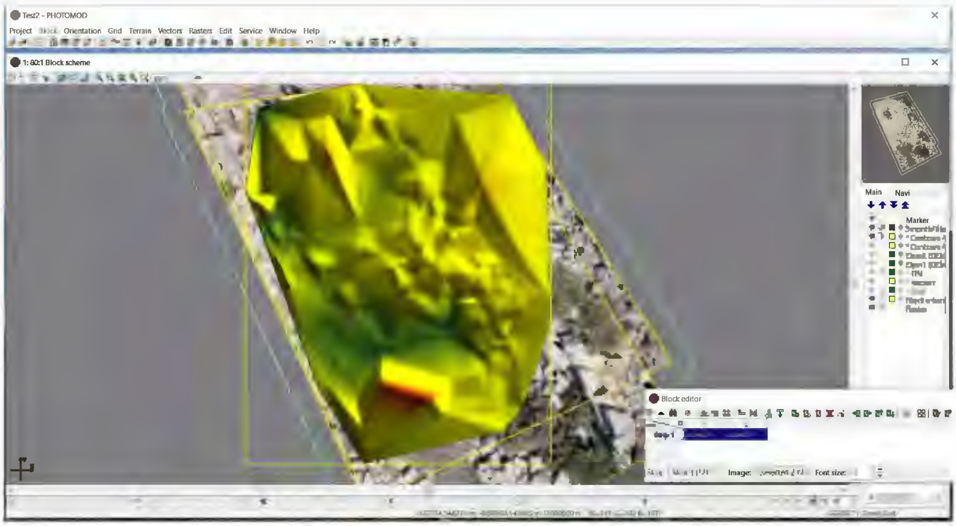
Once the above steps were performed with the Photomod Lite 6.5 software, the orthorectified Imagery was created (Figure 3). The resulting rectified image allowed the interpretation and application of Spatial Analysis tools, among the most useful we can mention the creation of DEM and Contours.

Figure 3: Outcome of the Ortho-mosaic, after performing internal and external orientation.



The computing of the internal correct points, followed by the creation of a TIN (Triangulated Irregular Network) model within Photomod, was crucial to the representation of the DEM and contour features which were performed as essential part of the project (Figure 4):

Figure 4: Performing one of the crucial tools of Photogrammetry: DEM (Digital Elevation Model).



Results

The analysis of the process applied to aerial photographs over the study area created an ortho-rectified image and the subsequent outputs: DEM helped to identify areas of high concentration of features as having different elevation, as well as concentration of soil/deposits to be removed, which is crucial during an archaeological investigation. Such outcomes are evidence of archaeological activities happening in the study site, leading to an initial interpretation of the use of the site. The preliminary evaluation of the quantity of soil and area to be investigated become crucial in the eventual planning of any archaeological investigation.

Contours, performed together with the created DEM, allowed a better interpretation of the Photogrammetry, by showing clear alignments of stones possibly forming structural walls and areas of collapses which may have resulted from a destructive event hitting the archaeological site. These provide the archaeologists a very important tool that can be translated into an initial database of stratigraphic units (which are defined as sequence of human actions and interactions, essential for the interpretation of the site) to be in correlation with the actual outputs of the photogrammetry.

Recommendations

The steps in this project highlight the important applications to the field of archaeology.

- Photogrammetry can be used as the main surveying method in archaeological excavations, improving drastically the recording and interpretation of heritage, as showed in recent publications on the application about remote sensing techniques and their use in the archaeology field. This can be a standard methodology during any archaeological investigation, particularly those involving public projects and commercial driven excavation, where accuracy, reliability and rapidity are crucial to the success of the project itself. This is as demonstrated in literature on development-driven archaeological investigations and research archaeological excavations.
- The results of a combined approach between photogrammetry and archaeology, by creating an ortho-mosaic, could be used to create a 3D model of the site under investigation. This would enable a new way of communicating archaeology to the public and for the recording of cultural heritage features.

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CHAPTER 21

The Malta Railway- Its Original and Surviving Routes (1883-1931)

Yasmin Cassar

Keywords

Railway, Historic Maps, Original Routes, Identifying Features, Buffer Zones, Scheduling, LiDAR, GIS, Georeference, Malta

Project Aim

The aims of this project were to:

1. introduce the case study of the Maltese Railway;
2. provide a brief review of the status of the application of GIS on local linear railway heritage studies;
3. present a geodatabase design for the Maltese railway heritage management; and
4. map the route's scheduling.

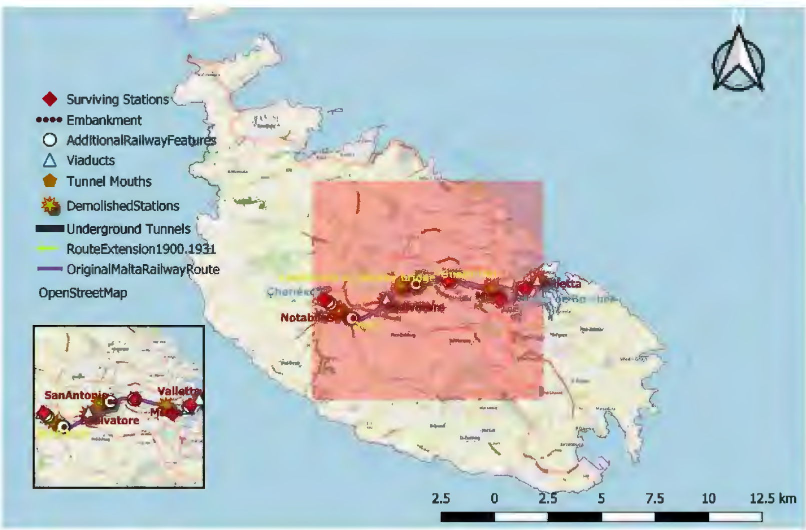
Introduction

The rate of infrastructural development at a local level is at an all-time high (NSO 2017), and thus the protection of both archaeological features and culturally significant structures is presently more significant. The safeguarding and preservation of cultural heritage elements is an integral part of conserving our cultural identity. In doing so, the widespread awareness will aid in educating the public and will also facilitate the dissemination of information which is presently limited to the select few.

The recording of data and information in relation to the old Maltese Railway and correlating features identified incomplete lacunae and was almost entirely composed of primary sources, including ordnance sheets and historic images which were not entirely available to the public for referential access. Bearing this in mind, the substantial gaps of readily available data hindered the efficient identification of plausible remains of the original route. The Planning Authority's GeoServer held a limited record of related features, which posed a risk for officials and consultees analyzing development proposals which fall within the route's proximity, by risking failure to identify such remains and structures. The 1968 Survey Sheet layer, also available on the GeoServer portal, recorded very little of such elements if any.

The free access Rail History Spotter Malta, however, recorded the Malta Railway, tramway and harbour rail, and thus allowed for the verification of the identified route and elements once extracted from the historic maps (Figure 1). The Malta Railway route was also recorded on a free international access map, Abandoned & Out-of-Service Railroad Lines, which was created using Google My Maps. This map was crowd-sourced, and was thus continuously updated, including disused railroad lines across the world, tourist trains and heritage railways, unbuilt railroads, and reactivated railroad lines. Even more pressing was the issue of scheduling, or lack of. In assessing the route and its surroundings, it was noted that very little of the remains merited such protection in the past. Related structures and tunnels are yet to be protected by varying grades of importance. Pending this measure, the safeguarding of such features remains limited and sporadic.

Figure 1: Malta Railway Map



Methodology

This desktop exercise initially consisted of georeferencing primary sources, mainly the 1900s Ordnance Survey Sheets provided by the Superintendence of Cultural Heritage, and plotting corresponding features marked on existing maps including stations, bridges, tunnel mouths and viaducts (Figure 2). Such an exercise enabled spatial analysis and identification of surviving elements, to understand how these may be impacted by both ongoing and future development. Images of related remains and their location were consequently used to confirm the features' survival and create adequate buffer zones with varying grade of importance depending on whether the identified part is above ground or below ground, extant or destroyed. The dataset source included readily available historical documents, topographic and thematic historical maps, photographic imagery, and digital elevation models namely NASA DEMs, LiDAR Data and Satellite imagery Data extracted from Cloudisle and Google Earth Pro Satellite Imagery.

Figure 2: Georeferenced Ordnance Sheets with superimposed Original Route and Features

Discussion

The analysis of the railway route which spanned from Valletta to Mdina, as shown on historical maps, was essential to identify route development and correlating features. After plotting the original route and related elements, further topographic analysis was carried out using readily available programmes such as Cloudisle (Formosa, 2018), Geoserver and Google Earth Pro as reference. The final stage allowed buffer zones to be created for presumed remains, both for on-land features and those supposedly underground. The plotted elements and features remain hypothetical, pending in-situ investigation and verification. Several layers were created in relation to the identified railway route features to establish adequate buffer zones, including 25m for archaeological and presumed underground features, as established by the Superintendence of Cultural Heritage, as well as a 50m scheduling setting buffer for existing structures, on land. Known destroyed features, although recorded, were not given a buffer area. The analysis resulted in the 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. This enabled a better understanding of the amount of spatial data related to the heritage route.

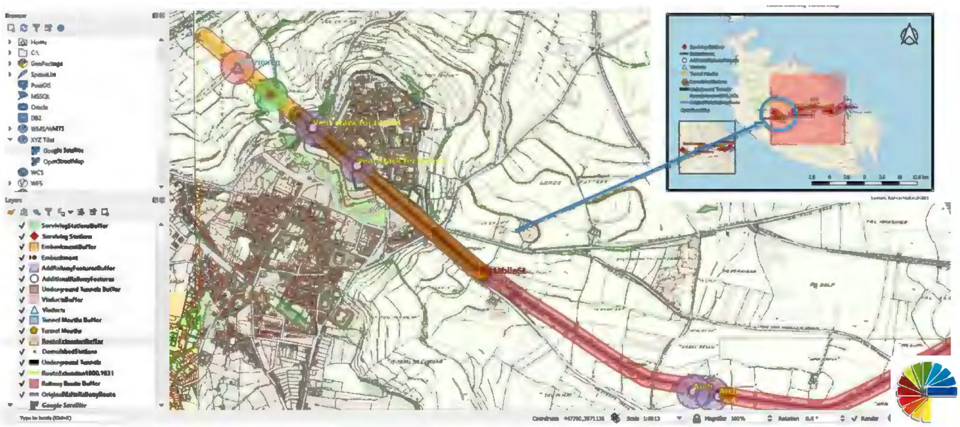
Prior to utilising the Malta 3D Lidar Rendition, known as Cloudisle, an attempt was made at using one Digital Elevation Model (DEM) to define the area under analysis. This topographic data was generated from NASA's Shuttle Radar Topography Mission (SRTM) and manipulated using the Aspect Function and Hillshade tool on QGIS. However, these raster files were limited in terms of required detail to analyse remaining features and were only sufficient for a generic understanding of the route's placement. Very little of the railway route and features were marked on readily available modern-day maps. However, the embankment remains in Ħ'Attard are clearly recorded. Notably, the 2D imagery did not allow for an adequate analysis of the topography.

The remotely sensed data available on Cloudisle allowed for a more in-depth examination of real space. The territorial LiDAR Map for 2018 was used to survey features running alongside the railway route. Deselected vegetation classification filters were manipulated to enable a better understanding of built features, including the surviving embankment running alongside the Corinthia Hotel in Attard.

The height profile measurement tool was used to extract height profiles showing the extent of surviving features (Figures 3 and 4). Several such features were analysed using similar methodologies to verify their existence. However, one must always be mindful that extracted point clouds may not be up to date, and that this analysis remains somewhat hypothetical pending real-life verification.

Figure 3: Using Height Profile tool on Cloudisle

Figure 4: Detail showing Buffer Zones in Mdina Region



This geodatabase remained incomplete and any recorded data and digital site investigation required in situ verification and consequent updating, subject to ongoing rural and urban development. It is recommended that future acquisition of additional data through the manipulation of LiDAR sources, alongside site inspections as a means of proper verification, will enable the office of the Superintendence to attain a priceless source of evidence. The establishment of this geodatabase will provide technical support for effective management of most spatial and non-spatial data related to this railway, as well as quantitative spatial analysis of the railway environment and landscape.

Results

Key results of this project are:

1. GIS, alongside other complementary spatial tools, proved to play an increasingly essential role in the study and analysis of this large-scale heritage site.
2. The process of constructing a Maltese Railway heritage geodatabase, realised by the stratification of raster, vector data, attribute tables and other data forms.
3. Through the analysis carried out in this study, the Superintendence of Cultural Heritage acquired enough material to propose additional scheduling of the Railway route, at least in part, and that of related structures.
4. Raster data were limited in terms of required detail to analyse remaining features enabling only a generic understanding of the route's placement. The remotely sensed data available on Cloudisle allowed for a more in-depth examination of real space.

Recommendations

Key recommendations of the effort are:

- Further research: The European Union celebrated the International Year of the Rail, 2021, and during this year's European Heritage Days (EHD), Member States were encouraged to explore heritage perspectives of rail transport.
- Policy change: It would be an ideal conclusion to this project if our national agency for the protection of Cultural Heritage ultimately manages to propose scheduling in conjunction with EHD days as a permanent lasting plan.
- Further research: This geodatabase is not still complete, and any recorded data and digital site investigation require in situ verification and consequent updating, subject to ongoing rural and urban development.
- Further research: The acquisition of additional data is recommended through the manipulation of LiDAR sources, alongside site inspections as a means of proper verification, will enable the office of the Superintendence to attain a priceless source of evidence.
- Operational change: The establishment of this geodatabase will provide technical support for effective management of most spatial and non-spatial data related to this railway, as well as quantitative spatial analysis of the railway environment and landscape.

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Pivot VI

Social Wellbeing Domain

Zebbug Gozo
Easting: 431241.749, Northing: 3992117.950

CHAPTER 22

Analysing the Accessibility of Pavements for People with Visual Impairment

Elaine Camilleri

Keywords
Accessibility, Pavements, Obstructions, Visual Impairment, Environmental Safety Measures

Project Aim

The aim of this project was: (1) to reinforce awareness so that the pavement surfaces are to be left clear from hurdles; (2) to improve pavement's design by including safety and security; and (3) to easily identify the current situation of pavements from spatial maps by an extrapolation statement from Naxxar to all Malta.

Introduction

The implementation of the planning process must evolve both environmental and social standards for sustainable growth, which seek to "achieve a long-term equilibrium between economic development, environmental security, effective utilisation of capital and social equity" (Salado et al., 2008; Salado et al., 2011). Every pavement has to be accessible for all pedestrians, including people with disabilities (Camilleri, J. and Zammit, A., 2010).

Visually impaired people are those who are blind or with loss of vision that are challenged with various obstacles and inaccessible barriers. Orientation and Mobility are essential skills which can be implemented by qualified trainers to assist people with visual impairment to learn how to navigate safely in the environment (Brasher & Holbrook, 2006). A survey in Malta that was part-funded EU project (2008-2010), 'The Mobility and Orientation Project for Blind and Visually Impaired Persons' (MOBAVIP) was directly enquired to people who are blind or visually impaired. The main obstacles were found due to inaccessibility while using roads and/or pavements. The experience of people with visual impairment is of minimal access due to lack of accessibility for they cannot navigate freely and be autonomous and/or independent (ECMT, 2006). The key element for a sustainable pathway is the provision of accessible barriers that include a safe pedestrian environment and informative signage. The aim of the study was to raise social and educational awareness, identify potential accessibility barriers and provide more educational training. Through spatial maps, one can easily indicate and identify obstacle locations.

According to the 'Commission for the Protection of Individuals with Disabilities' in Malta there are 1,663 registered who are visually impaired. Their ages vary from young children to elderly persons aged over 90. In 2016 a new centre was launched in Ħamrun (Malta), to assist people who are blind or visually impaired to provide mobility training while enhancing their quality of life.

Literature Review

People with visual impairment require specific adaptive technology for their daily living skills. There are several assistive technologies which are expensive and are not easily available in the local market. People with loss of vision have to put extra effort towards independence. According to Kant (2009), "Autonomous people are considered as being ends in themselves in that they have the capacity to determine their own destiny, and as such must be respected". In a study conducted by Müller (2000), emphasis the construction of the Maltese pavements. He suggested guidance and structural information in building well-planned pavements. The thickness and other measurements of pavements are to provide the best quality to meet all the requirements needed. According to the 'Commission for the Rights of Persons with Disability' (CRPD), 'Access for All – Design Guidelines' highlights the importance of safety measures.

A universally designed building aims to cater for everyone's needs by constructing it in ways that can be accessed by everyone. All buildings and pavements are to be designed with tactile markings with light coloured ramps, whilst the zebra crossing and traffic lights should be with beeping sound and lighting while crossing the road. Hence, tactile paving for accessible routes should be provided to warn and guide persons who are blind and/or partially sighted. The switch button of the traffic lights should be in braille and with embossed buttons giving visual and audio feedback in good working condition. Informative signage should be well visibly labelled in clear format, large fonts, formulated in an easy way to be understood by everyone. This will result in ease of access; it lessens or eliminates the need for assistance and thus enables the person to be more independent.

While walking and crossing the roads tend to be very dangerous due to heavy traffic. Even when walking on the pavements, they encounter various obstacles such as doorsteps, garbage bags, poles and pots. Hence, people with loss of vision are not encouraged to travel independently since they are afraid of being run over by drivers. The 'Training for Orientation and Mobility' skills are essential for people with visual impairment to learn how to navigate independently and safely in their environment, and hence increase their motivation and self-determination (Brasher & Holbrook, 2006). People with visual impairments need opportunities to develop self-determination skills in the community. Self-determined learning theory suggests opportunities and adjustments that maximise engagement, control, and learning through interventions (Mithaug, Campeau, & Wolman, 2003).

Discovering new challenges through opportunities in choice-making and problem-solving. Self-determination can be implemented by professionals and family members during daily activities so that people with visual impairment have the opportunities for self-direction; self-awareness, encouragement to attain intrinsic goals, and providing opportunities for risk-taking (Ankeny & Lehmann, 2011; Deci & Ryan, 1985; Ryan & Deci, 2000).

Methodology

This study focused on a particular busy area, in Naxxar (Malta), width 473.40 metres lenght pavement where several restaurants, cafeterias, and shops are located. Prior to data collection, a database in QGIS software including shapefiles and dataset was created and extracted to QField to acquire all the relevant data and information which was inspected on site.

A mobile-application, QField app, was used on site. This is a performance tool connected to the GIS fieldwork data which extracts the dataset in a more efficient and accurate manner. An open-source software, QGIS, was used to build and create maps after collecting all the necessary data by using the QField app. For this study, data was collected by a smartphone mapping application to identify, mark and locate all the obstacles found on site. Then all the collected data was transferred to the computer by using QGIS software.

After transferring all the data collected, a 'point shapefile' was created to mark the exact location and input all the necessary information found on the 'Attribute Table'. Another shapefile polygon feature was created to demonstrate the whole study area. The area of interest (AOI) was 2350.38m2. During site inspection, photos were captured, and 61 records were collected on site, which included both the obstacles and safety measures. Subsequently, the database was transferred from the smartphone onto the computer. All the data were analysed with the QGIS software and several functions were used to create colour coded maps. A heatmap (Figure 3), a 'single band pseudocolor from green to red colour contrast was analysed, and a ‘Point Layer Map’ to show the level of obstacles was derived (Figure 4).

Discussion

Geomatic analysis and findings were identified. The main obstacles shown in Figures 1 and 2, were flowerpots, tables and chairs, trash on the pavement and potholes. More educational awareness is needed to support people with visual impairment for they continuously are challenged in spatial and visual cues. Citizens have to respect others by providing accessible space so that people who are blind or visually impaired, can roam safely. More enforcement is needed so that the surface of pavements are to be left clear without any hurdles. Figures 3 and 4 show the classification of accessibility pavements' maps. From the legend and colour coding identifies which are the most and least level of accessibility. The red points are the obstacles, whereas the green points are the safety measures.

Figure 1: Obstacles and Safety Measures

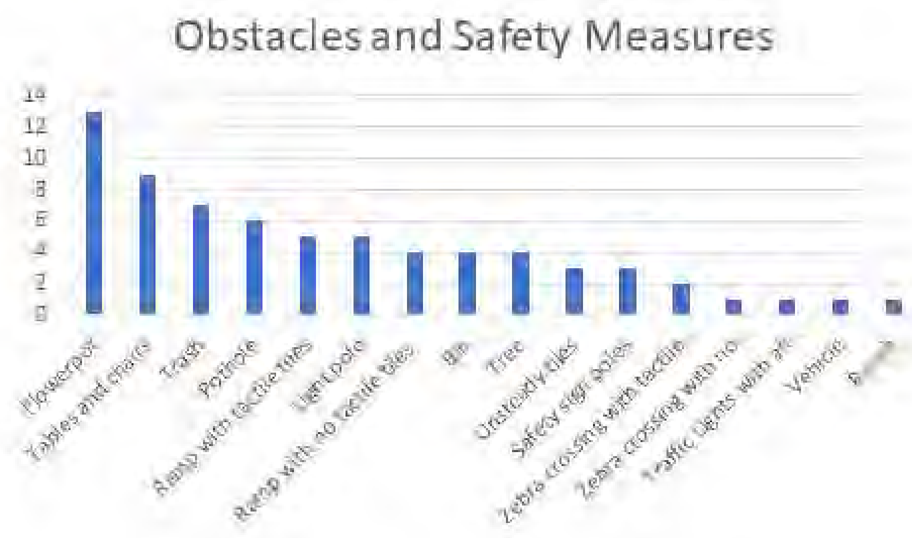

Figure 2: Pavement Accessibility

Figure 3: Heatmap of the Accessibility Pavements

Figure 4: Accessibility Pavements' Map

Those marked in red as 'Danger', are the most dangerous obstacles which include the potholes/trees/light pole/bench/unsteady tiles. Those marked in orange are the 'Bad' for these obstacles are less risky to be injured which include ramps with no tactile tiles/bins/tables and chairs. The 'Fair' level marked in yellow are also hurdles that can be easily removed such as flowerpot/vehicle/trash. The light green marked as 'Good' represents the safety sign poles, although they are still obstacles, they are placed at the far end of the pavement. Finally, the dark green colour represents the 'Excellent' level which is safe and can be easily accessible. These safety measures include zebra crossing and traffic lights with all the adequate safety features including ramps with tactile tiles and beeping sound to alarm to be able to cross the road safely.

During the study, some limitations were identified to complete the analytical process. From the results and created maps, it was difficult to create a symbol for each obstacle. Therefore, the classification was divided into different levels of accessibility using colour coding to differentiate the outputs. Symbology may also aid the spatial distribution and identification of obstacles.

Results

Key results of this project:

- Figure 1 provides a quantitative overview of pavement obstacles in the study area which comprised flowerpots, tables and chairs, trash on the pavement and potholes.
- In Figure 2, a pie chart indicates the current situation of pavements. 29% are the most dangerous obstacles; 33% bad; 23% fair; 5% good and 10% excellent, which includes all the safety measures.

As a result, very few percentages are marked as a good state of pavements including various hurdles and obstacles on the pavement. Those marked in red indicate that most obstacles consist of protruding flowerpots which may easily lead to someone tripping. These maps highlight the current situation of the Maltese pavements where immediate action for drastic change needs to be considered so that people with visual impairment may be respected and improve their quality of life with respect to pavement accessibility issues.

Recommendations

Key recommendations of the effort:

- 85% of pavements need to be monitored in order to improve the quality and accessibility so that people with visual impairment are safe.
- To include tactile tiles in all ramps for safety and security. Ramps are to be built and designed with safety slope surfaces with smooth, perceptible, and anti-skidding surfaces.
- More enforcement is needed so that the surface of pavements are to be left clear without any hurdles.
- Informative signage should be well visibly labelled in clear format, large fonts, formulated in an easy way to be understood by everyone.
- The training for the orientation and mobility skills are essential for people with visual impairment to learn how to navigate independently and safely in their environment.
- More action and awareness are needed: to motivate authorities for additional education and support.
- To improve data outputs and planning of accessibility solutions by including pavement measurements in the geospatial analysis.
- Improve policy implication for accessibility. This could include quantification of accessibility within urban peripheries. With this measure, a peripheral region may be quantitatively compared to different countries.

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CHAPTER 23

Study for Accessible Pavements in Central Paola Malta

Gary Lee Ronayne

Keywords

Paola Malta, accessibility map visualisations, urban accessibility, wheelchair users, sidewalk's accessibility.

Project Aim

The aim of this project was to: (1) to generate a map to identify inaccessible pavements, no pavements or even-levelled pavements of the town and which include regularly visited important places of interest; and (2) to detect flaws such as inaccessible and accessible pavements in the area of interest and determine the cause of these flaws, and determine the course of action to take.

Introduction

This paper analysed and mapped the town centre accessibility of Paola Malta, focusing mainly on sidewalks accessibility. It is important to have accessible sidewalks and public areas, especially in the town centres as these are essential for accessibility of town services.

In the late 1940's the first curb ramps started to appear around the world (Terndrup, 2021) and at the time people considered these ramps as an accessibility assistance. Nowadays, these ramps are no-longer considered as something to use only if you have a disability but a commodity for everyone. People use these ramps if they are carrying heavy objects, pushing a stroller and they make it easier for people with visual impairments to transition from one surface to another.

This Project developed a map of the local Centre of Paola, a town in the south area of Malta. This map includes several Places of interest which a person can visit in this Town. Apart from the Places of interest, this map was enriched with the locations of accessible sidewalks and non-accessible sidewalks and more relevant information, such as levelled sidewalks which users can benefit from and location of different important establishments, to aid the users to plan the journey from one place to another.

Legal issues on sidewalks accessibility were researched locally. According to The Kummissjoni Nazzjonali Persuni b'Diżabilta, pavements should be of a minimum width of 1200mm with a height Curbstone of 150mm maximum above the road level. The surface of such pavements should be even and in non-slip material, should drain well and with no gaps in it. Furthermore, these pavements should be kept free from obstacles at any time (KNPD, 2012).

Similar research studies have been carried out, such as accessibility issues for wheelchair users by identifying obstructions which such users encountered in their day-to-day routine. This study investigated the accessibility in UK city centres and took into consideration streets, public transportation, and shopping activities. This study identified the main areas of activity in these city centres and envisaged where accessibility could improve using the involvement of the end user (Comai et al. 2015). Beale et al. (2006) showed how navigation around urban areas is often hectic and difficult for the mobility-impaired, due to urban landscape or lack of planning. This leads to the need to develop tailor-made maps for these individuals. This study identified and developed a GIS network model for the creation of accessibility maps for wheelchair users. In this study a spatial database was created which contained the pedestrian route network and barriers on pavements. In addition, this study tested the map with wheelchair users and the route selection generated which was very close to the route these users established through experience.

Virtual Acoustic Map are resources developed whereby virtual map whereby items found on such maps are converted into different sounds. Heuten (2007) proposed the use of auditory torches to limit the level of detail (to avoid confusing the user) and enhance the usability. The end user could control the distance range of the surroundings. This approach is ideal for those users who are visually impaired.

Langston (2017) researched the exploitation of the smartphone applications for pedestrian transportation routing. Through this research at the University of Washington, a smart phone application was developed called AccessMap. This mobile application creates customized directions for the City of Seattle. This Mobile application provides pedestrians and wheelchair users, routes to avoid hills, construction sites and other accessibility difficulties. Another smartphone application located in Japan named WheeLog (Accessible Japan, n.d.) allows wheelchair users to clearly identify accessibility in public spaces. WheeLog is also interactive allowing users to alter their route as they feel best and share their experiences online. Users can also create new virtual guideposts for other users to use and explore. This means that "as stated by this application developers" that WheeLog is created and sustained by everyone.

Methodology

The study in this paper used the GIS software QGIS and a mobile application called Qfield. The first step was to identify the area of interest which then was plotted onto QGIS, followed by calculation of the area. Subsequently, places of interest were plotted based on the use of such locations by the general public:

- Churches and chapels (Areas were people gather to worship);
- Public Schools (Which are used mostly by children and by parents with small infants in pushchairs);
- Cafeterias;
- Public Gardens (includes the use of strollers or bikes by the public);
- Clinic and Pharmacies (used by everyone but mostly vulnerable people);
- Banks (used by Everyone); and
- Others such as (parking, public library, police station, postal office, stationary, old people's home, shopping arcade and a UNESCO world heritage site)

The location of these places of Interest were georeferenced, to a WGS84 format and a 5.00m buffer zone around the places of interest was introduced so that places of interest would be clearly visible on the physical map. This new file project was then transferred to the software Qfield for use on a tablet. Onsite data onsite input comprised the GPS coordinate locations along sidewalks, as well as whether the sidewalk was accessible or not. (Figure 1). The data gathered on Qfield was then imported to QGIS. Some points were slightly overlapping due to short distance between points and to GPS inaccuracies. This data was corrected manually on QGIS whereby coordinates were corrected using the field calculator inside QGIS.

Figure 1: Qfield Mobile application Screenshots while gathering onsite data

4 different scenarios were captured and mapped:

- Public Pavements with accessible ramps.
- Public Pavements with NO accessible ramps.
- Areas where there was no Pavement, or it was very difficult to manoeuvre.
- Areas where the floor was levelled to easy access for all.

Once all this data was captured, refined, and plotted, the physical "Accessibility Map" was constructed by using QGIS. This map (Figure 2) Shows all relative data captured and displayed in the legend, with additional information such as:

- Grid with an X and Y intervals of 5.00cm each
- A North Point
- A double box style scale bar
- An inset Map
- Map Title, author and logos

Once the "Accessibility Map" (Figure 2) was produced, an analysis of the areas in which public pavements no ramps for accessible were carried out. This was done by using the reprojected layers and by means of interpolation and using heatmaps. Two specific areas were noted which included flaws in the output.

Figure 2: Central Paola Malta Accessibility Map

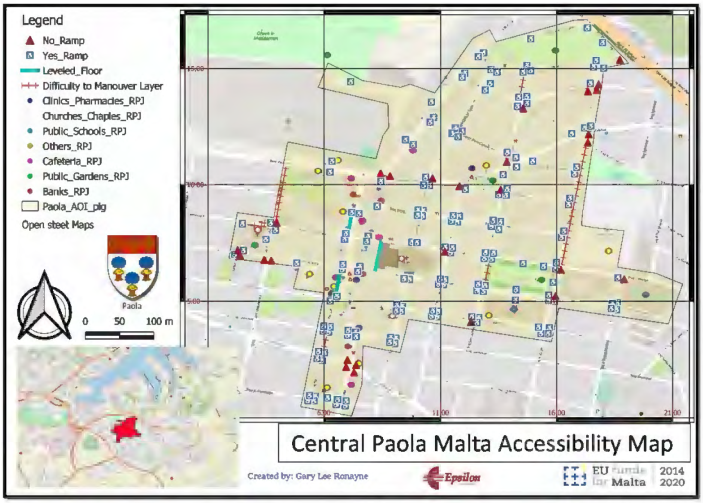


Figure 2: Central Paola Malta Accessibility Map created during the project.

Discussion

The produced heatmap (Figure 3) indicated that the first cluster of flaws was situated in one of the oldest parts of the town, near and around the old chapel. Apart from no accessible ramps being present there are a cluster of roads which do not have any pavements at all. This happens because as already mentioned this area is one of the oldest in the town, which dates back hundreds of years, so the road infrastructure was not built to withstand modern roads and traffic. It was built with narrow roads and parts of them are not evenly levelled. A result of this, unfortunate wheelchair users and people with mobility problems need to use and share the road with the cars. Luckily, this area is not heavily frequented since it is found a few meters away from the main piazza therefore most of the traffic passes from there.

The other area with a heavy cluster of no ramps, as observed in the interpolated heatmaps (Figure 3), forms part of the main piazza road. This part of the main piazza is a very dangerous crossroad where often traffic accidents happen, justifying the lack of accessible ramps. Further along the four roads leading to the junction, there are safe pedestrian crossings, and all the pavement leads one to this area. This implies that no pedestrian, especially those in need, may cross from this junction but are required to cross the road from the safe pedestrian crossings.

Figure 3: Heatmap results

Results

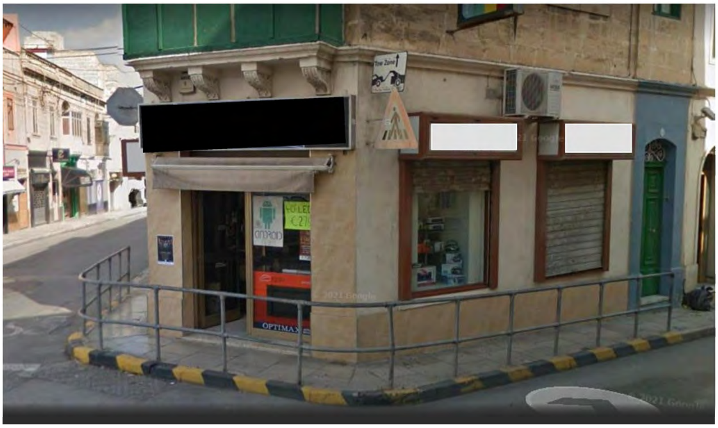
Two key results were obtained - an accessibility map and heatmaps. One of the results is the gathering, refining, georeferencing and plotting, and presenting a physical map of the centre of this locality with a lot of aids for movement impaired persons. This map included a lot of places of interest and need which everyone needs for his/her day-to-day endeavours. In addition, plotting of all accessible ramps leading to sidewalks were plotted and made visible along with sidewalks which are not yet equipped with an accessible ramp. In this map was also included, Areas where there was no pavement, or it was very difficult to manoeuvre and areas where the floor was levelled to easy access for all.

Heatmaps and analysing the layer "Public pavements with no accessible ramps" identified two specific areas where flaws were occurring.

Recommendations

The output maps enable suggestions for improved accessibility. Along the dangerous crossroad it is recommended to install some physical barriers (Figure 4) along the four corners of these four roads so that all pedestrians are forced to cross from the safe pedestrian crossings. This could be beneficial to visibility impaired people.

Figure 4: Physical barriers in Paola



Source [Google Maps]
https://www.google.com/maps/@35.872919,14.5079144,3a,75y,37.16h,89.19t/data=!3m6!1e1!3m4!1sDfjENcHKOnixFxBeRa4QGQ!2e0!7i13312!8i6656

Another recommendation refers to further usage of the information gathered during the literature review and developing a mobile application which could be very helpful. This app could run a GIS application model whilst providing a user-friendly interface to define and calculate routes through the pedestrian route network that take account of impedances to accessibility. An embedded digital elevation model could be easily introduced in this GIS map so that routes are calculated according to the user pre-defined settings, for instance a particular user would like to avoid hills as much as possible. Furthermore, this app could be made more interactive and user customizable, with all users having the facility to input data to their respective app and enabling the user to remember a particular route or impedance. This data could then be forwarded to the application managers which then could verify this data and if found relevant will be uploaded for everyone.

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CHAPTER 24

Spatio-temporal analysis of obesity in Malta & Gozo

Marika Borg

Keywords

obesity; spatio-temporal analysis; spatial autocorrelation; Malta; GIS; health; LAU levels; EHIS

Note: Acknowledgements: The data for this study was provided by the Directorate for Health Information and Research.

Project Aim

The aim of this project was to:

1. Study the spatial distribution of obesity amongst adults living in Malta & Gozo using maps
2. Carry out a spatio-temporal analysis of obesity prevalence between 2002 and 2014
3. Do spatial autocorrelation analysis of obesity for 2002 and 2014

Introduction

Obesity is an increasing public health concern that many countries around the globe are facing, with Malta being no exception. Obesity is often defined as a body mass index (BMI) equal or above 30kg/m2. It is a risk factor for many other chronic health conditions like diabetes, hypertension, cardiovascular disease, and cancer (WHO, 2021).

Since 1975, the prevalence (proportion of the population) of obesity worldwide has increased three-fold, with over 13% (650 million) of the adult population being obese in 2016 (WHO, 2021). The prevalence of obesity has also tripled in the European region since the 1980s and it is responsible for around 2-8% of health costs (WHO Regional Office for Europe, 2021). In the latest European Health Interview Survey (EHIS) of 2014, Malta had the highest level of obesity from all EU countries, with a prevalence of 25.0% in 2014, compared to 15.9% EU average (EUROSTAT, 2021). EHIS is a survey carried out amongst all EU countries for adults aged 15 years and over.

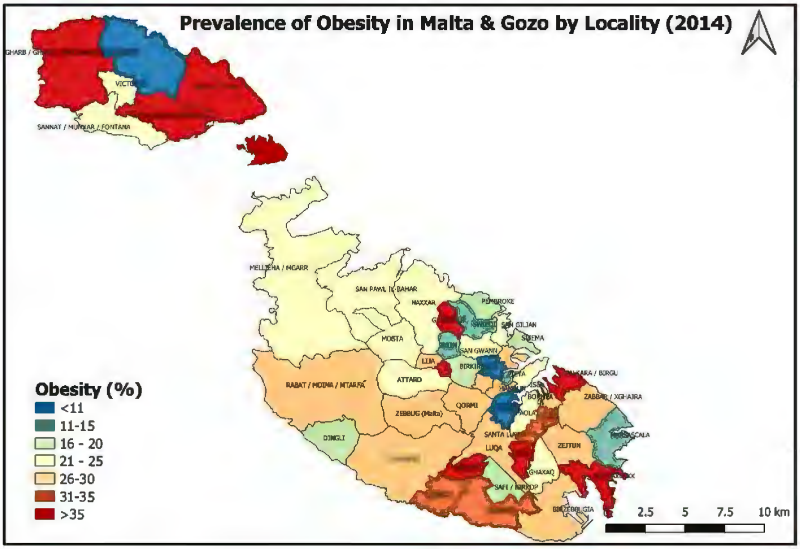
A literature search was carried out to identify local gaps and international studies on the research topic. Throughout the years there have been multiple attempts to address the rising trend of obesity in Malta, including the "Healthy Weight for Life" strategy published in 2012 (Superintendence of Public Health, 2012), but we have not managed to control it and the obesity rate continued to increase (Cauchi et al., 2015; WHO, 2013). Geographic Information System (GIS) technology has been used by other countries to analyse the spatial distribution of obesity with the aim of guiding resource allocation, as well as to see temporal trends. This has not been done locally so far. In South Africa a 1.5% decline in childhood obesity was observed over a 9-year period, with differences between provinces depicted using choropleth maps (Sartorius et al., 2020). Choropleth maps were also used to display geographical variation in childhood obesity in the UK (Sun et al., 2020). In Czech Republic the prevalence of obesity increased significantly from 2002 to 2014 among both adolescent males and females (Sigmund et al., 2015). In Canada geographical variation in overweight and obesity with significant hot spots were found using Moran's I indicator (Penney et al., 2014).

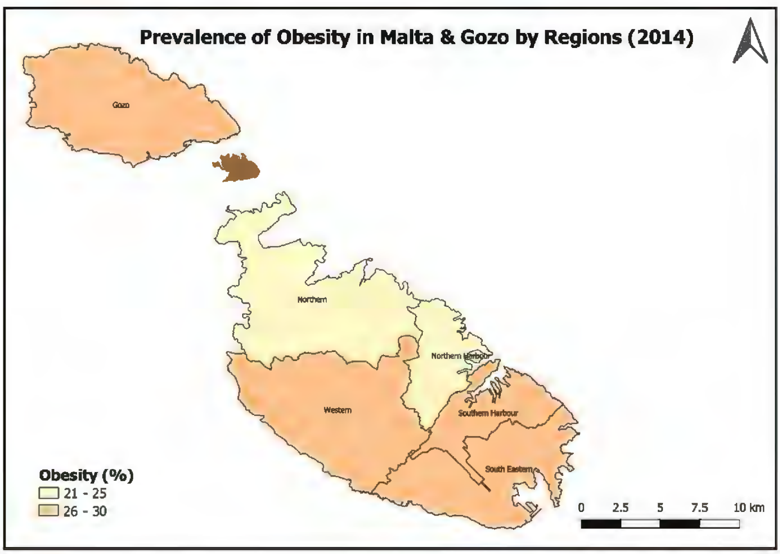
Methodology

Data was obtained from the EHIS study of 2014 and 2002, kept by the Directorate for Health Information and Research. Around 4000 respondents aged 15 years and over participated in each survey. The estimated number of residents 15 years and over living in each locality with obesity were calculated from the NSO Demographic Reviews of 2002 and 2014 respectively (NSO, 2002, 2016). Data obtained from EHIS was prepared in an excel sheet and cleaned. Two spatial data files (polygon shape files) were obtained from the Malta Spatial Data Infrastructure portal and uploaded onto QGIS - locality polygons at the Local Administrative Unit (LAU) level 2 (Admin Unit Boundaries) (INSPIRE Annex I), and regions (LAU1 level) (INSPIRE Annex III).

A methodology was devised to join localities with less than 20 participants, 20 being the number considered for data parametricity. If two adjacent localities were small, they were joined together. If they still had less than 20 participants, they were joined to a third locality. On the other hand, if all localities surrounding a small locality had more than 20 respondents, the small locality was joined to the locality with the shortest distance between its centroid and perimeter of small locality using "Distance to nearest hub (points)" tool. "Merge Features Attributes" tool was used to join small locality polygons in the Administrative Units Boundaries (LAU2) shape file spatially. In total 20 localities with less than 20 participants were joined, as can be seen in Figure 1.

Figure 1: Choropleth thematic maps showing the prevalence of obesity by LAU2 (locality) (top) and LAU1 (region) level (bottom) for 2014





A centroid layer for the locality polygons was created. The database with results from EHIS was saved as a CSV (Comma Separated Value) file to be able to upload into QGIS as delimited text and joined with the locality polygon and centroids layers (Table Join – 'Join Attributes by Field Values'), with the common field being the locality name.

The sum of persons with obesity as well as total residents for each region (LAU1) was calculated using a Spatial Join -'Join Attributes by Location (Summary)', using the Intersect geometric predicate for the locality polygon layer (LAU2). The Field Calculator was then used to calculate the average prevalence of obesity by region.

Discussion

The prevalence of obesity at the LAU1 and LAU2 level for 2002 and 2014, as well as the percentage change in obesity prevalence over the years was displayed using choropleth thematic maps with 'Graduated' classification in the Symbology layer properties. Heatmaps were also produced from the Symbology layer properties. Spatial autocorrelation analysis was done using the Local Indicator of Spatial Association (LISA) and Moran's I tools to see if there were any statistically significant clusters or dispersed areas of obesity distribution, and the change over the years (2002 to 2014). Limitations of this study include that temporal analysis could only be done for 2 years since data by locality was only available for those years. Data of the most recent EHIS study of 2019 was not yet available. In addition, the small number of participants in some localities could give rise to over/under estimation of prevalence statistics. For this reason, data for small localities had to be joined together.

Results

The overall average prevalence of obesity in Malta increased by 2% between 2002 and 2014, from 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 (Figure 1). The obesity prevalence was lowest in Marsa and Msida at 10% and highest in Mqabba at 59% (Figure 1). Gozo region had the highest obesity prevalence (28.4%) in 2014, while it was lowest in the Northern Harbour region (22.2%). There are big differences in the obesity prevalence at the locality level even within a region. For example, in Gozo, which is the region with the highest obesity prevalence at 28.4%, the prevalence of obesity is high at the right and left side of the island, however the prevalence is lower at the middle part, with Xaghra / Zebbuġ area having a prevalence below 11% (Figure 1).

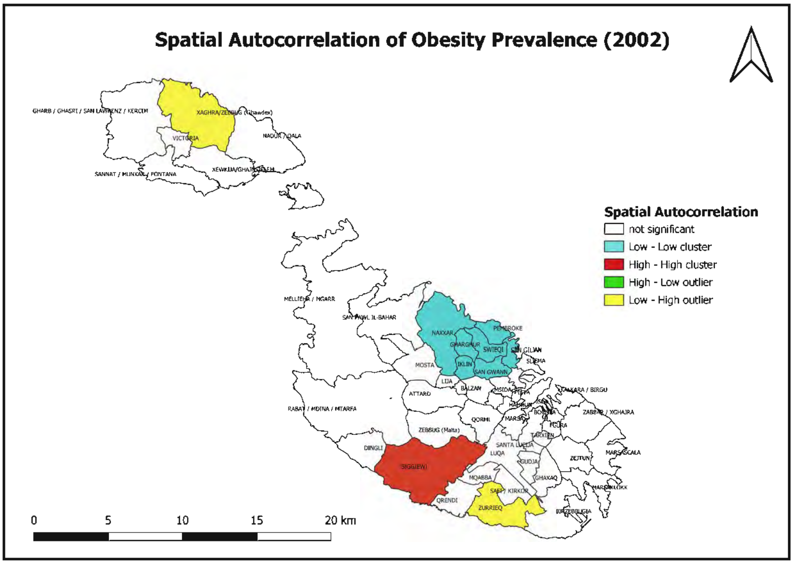
In 2002 only 3 localities had a prevalence of obesity higher than 35% compared to 9 localities in 2014 (red in the maps). Overall, the prevalence of obesity increased by only

2% over a 12-year period, however there were a number of localities where the obesity prevalence increased or decreased by more than 14% (Figure 3). The largest increase in obesity prevalence occurred in Gudja (+26%) and Mqabba (+21%) (bright red), while the largest decrease occurred in Marsa (-26%), Nadur/Qala (-22%) and Pieta (-13%) (bright green) (Figure 3).

The heatmap (Figure 4) showed a hotspot of obese persons in the Southern Harbour region (Paola / Tarxien / Fgura), despite that the choropleth map showed that Gozo had the highest obesity prevalence. In Gozo even though the obesity prevalence is high, the number of adult residents with obesity is low because fewer people live there. This is important when designing interventions aimed at the population level because one would want to reach the biggest number of people possible with an intervention.

Although Malta is geographically a small island, the LISA and Moran's I indicators showed that there are still statistically significant differences in the distribution of obesity across the islands. Figure 2 shows the spatial autocorrelation maps for obesity prevalence in 2002, with an area of 7 localities having a low obesity prevalence surrounded by those with low obesity (light blue) shrinking to only 2 localities in 2014. With regards to the other significant clustering or dispersion there were minimal changes over the twelve-year period, except that there is no longer any spatial correlation in the distribution of obesity in Gozo in 2014. Residents living in neighbouring localities are likely to share similar lifestyles including dietary habits and physical activity (Qin et al., 2019). The decrease in the obesity pattern clustering over the 12 years period could be explained by the generalisation of localities with the increased availability of large chain supermarkets and food outlets across the island and more use of cars making the whole island accessible.

Figure 2: Statistically significant clusters and dispersed areas of obesity prevalence for 2002 (top) and 2014 (bottom)



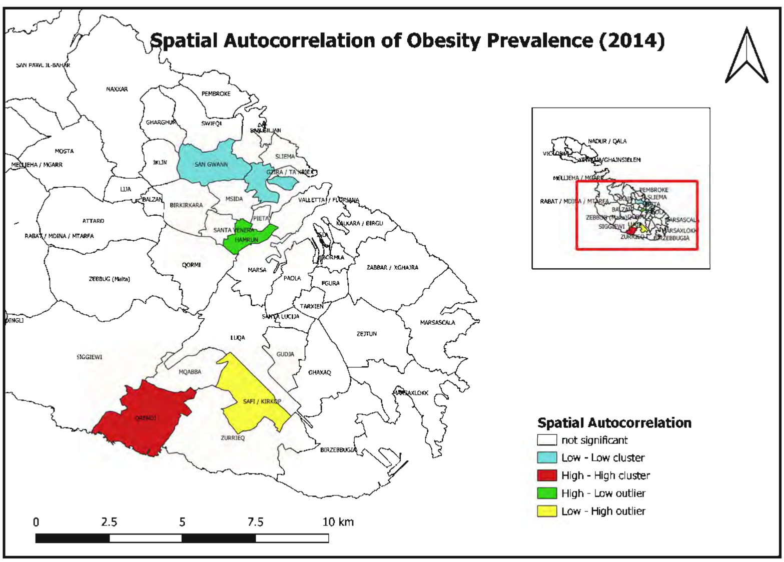


Figure 3: Choropleth thematic map showing the change in obesity prevalence between 2002 and 2014

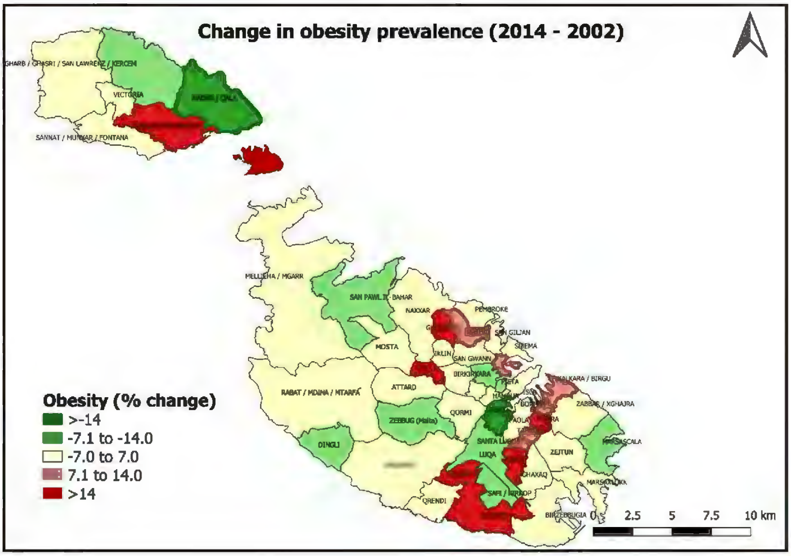
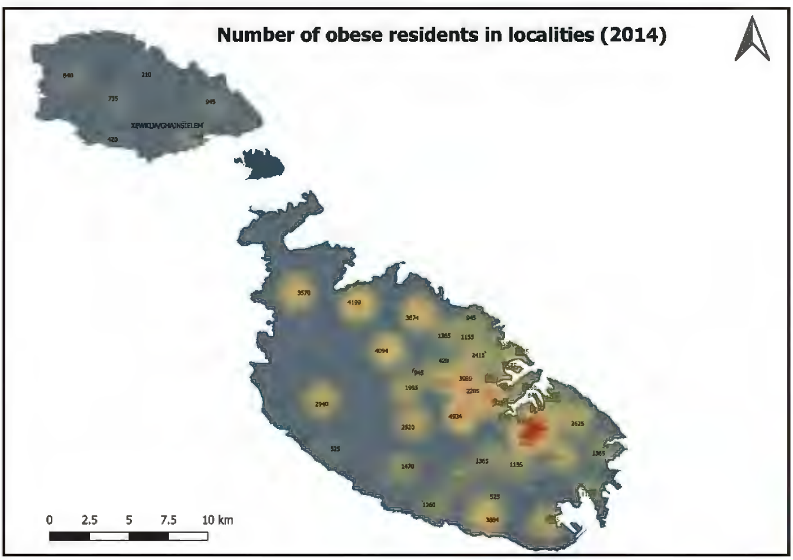


Figure 4: Heatmap showing the estimated number of obese residents living with obesity in 2014



To conclude, obesity is a multifactorial and complex problem and there is no easy solution to address it. GIS techniques can help to understand health data better and guide resource allocation. As shown earlier, more detailed results can be obtained if health data is studied at the locality (LAU2) level than at the region (LAU1) level; the obesity prevalence in 2014 varied by 6.2% only at the region level, while it varied by 49% at the locality level. Although overall the prevalence of obesity only increased by 2% in the span of 12 years, at the locality level, there were localities where obesity increased or decreased by more than 14%.

Recommendations

Recommendations include collecting data on locality of residence in future health surveys to be able to do spatial analysis. Furthermore, further research can be done including incorporating data for the EHIS 2019 study when this data is available, performing regression analysis to remove the effect of confounding factors when studying the causes for obesity, and specifically focusing on childhood obesity. In addition, the study findings will be presented to the respective health department (Health Promotion and Disease Prevention Directorate) to help in designing interventions and policy to address obesity.

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CHAPTER 25

Mapping Malta's Public COVID-19 Testing and Vaccination Centres

Tania Cardona

Keywords

COVID-19, Geographical distribution, Mapping, Testing centres, Spatial analysis, Vaccination centres

Project Aim

The aim of this project was to analyse the distribution of the testing and vaccination centres to assess for equitable access and to provide a map that can be uploaded to a website and utilized to locate the different centres in each locality.

Introduction

The COVID-19 pandemic is thought to have started sometime in December of 2019 in Wuhan, China (Page, et al., 2021), spreading to Europe and the rest of the world by March 2020 (ECDC, 2020) and causing havoc and disruption of normal life (Haleem, et al., 2020). This was the first pandemic affecting countries on such a large scale since the Spanish flu pandemic of 1918, and the first one caused by a coronavirus (Liu, et al., 2020).

Initially, the only way of controlling the spread of the virus was by testing suspected cases, isolation of positive cases, and tracing of close contacts to initiate quarantine and prevent further spread (Kucharski, et al., 2020). This has led to changes in the way that people worldwide lived, as movement of people was halted with travel within countries and across borders being affected (Haleem, et al., 2020). It also led to the rapid setting up of various testing centres in countries to cater for the increased demand in testing across the world (Kucharski, et al., 2020).

Following the development of various COVID-19 vaccines that started being approved for use in humans since mid-December of 2020 (Brothers, 2020), the focus turned to vaccination of the population to help protect those most vulnerable and at risk of developing complications and help stop the spread of the virus. The main aim of vaccination was to reduce the severity of infection in the most vulnerable section of society while helping to reach herd immunity as soon as possible to pave the way towards achieving normality (Levine-Tiefenbrun, et al., 2002).

In Malta, the first coronavirus testing centre was opened in Luqa on the 10th March 2020 (Azzopardi, 2020), with this being followed by another six centres within a few months to help with the increase in workload (Ministry for Health, 2020). The first vaccination centres were opened in the public general hospitals and the public Health Centres with the arrival of the first vaccines in late December 2020 (Berger, 2020). The Health Centres helped with the distribution and administration of vaccines that required special storage conditions while helping to avoid crowding at the general hospital (Pfizer, 2020). Various other centres were opened in February and March of 2021 as vaccines that could be kept at room temperature were imported to help increase the vaccination delivery across the Maltese Islands (Magri, 2021; Smith, 2021).

The following study aimed to analyse the distribution of the testing and vaccination centres in different regions of the Maltese Islands to assess whether there was equitable access to these resources to all regions and localities of the country, while also providing a map that can be uploaded to a website and utilized to locate the different centres in each locality.

The objectives of this project were the following:

- carry out data capture using a mobile application to create a point layer with the location of the testing and vaccination centres;
- analyse the distribution of these centres per locality and region; and
- create a shareable map with information about each centre that can be uploaded to a website for use by the population.

Methodology

- Data capture to record the points of interest was carried out using the mobile application "Input: Field data collection" version 0.9.0 developed by Lutra Consulting for Android (Lutra Consulting, 2019).
- The dataset "AU.AdministrativeUnitBoundary" provided by the Department of Local Government and available from the Malta Inspire Geoportal (Department of Local Government, 2013), was used to help map the distribution of clinics in terms of the town and region.
- The population of each region for 2019 was extracted from the National Statistics Office website (National Statistics Office, 2019).
- The GIS software used for this project was QGIS version 3.10 (QGIS.org, 2021).

A polygon layer delineating the boundaries of the 68 localities of the Maltese Islands was obtained from the Malta Inspire Geoportal (Department of Local Government, 2013). This was used to create a new polygon layer delineating the six regions of the Maltese Islands using the "Dissolve" and "Merge" functions in QGIS, given that such a layer was not readily available. The regions were created as per Eurostat's Nomenclature of Territorial Units for Statistics (NUTS) (National Statistics Office, 2020).

The location of the various testing and vaccination centres was captured using a mobile application "Input: Field data collection" version 0.9.0 developed by Lutra Consulting for Android (Lutra Consulting, 2019). Each point was enriched with information, which included the name of the centre, the locality, address, the region and code, the type of service offered (whether testing or vaccination), and the type of building where the centre was housed. A geopackage vector point layer was generated by the app and uploaded to QGIS, with the information collected by the app being converted to columns in the Attribute Table. This point layer was then used to map out the location of these centres on QGIS and compare the number of centres in each region and locality.

The population by region and locality for 2019, extracted from the National Statistics Office (National Statistics Office, 2019) in the form of an Excel file, was used to calculate the percentage population per region. This was subsequently converted to a comma separated values (.csv) text file and uploaded as a layer in QGIS, where a table join function was used to enhance the polygon layers of the localities and regions of Malta. This helped to compare the population distribution to the number of testing and vaccination centres for different regions and localities. The number of centres in each region and locality were analysed using the "Count Points in Polygon" function, with the results visualised using the various options available in QGIS.

A shareable map with information about each centre was produced using the plugin "qgis2web". The location of each centre was visualised using a base map and data from OpenStreetMap and OpenStreetMap Foundation (OpenStreetMap Contributors, 2021), whilst each point was customised to show information about each centre and identify the service provided (testing or vaccination). The information that was displayed was obtained from the Attribute Table and included the same information collected by the mobile application "Input". Customisation from the plugin was carried out to allow only relevant information to be shown to the user.

Discussion

This study has established that the highest proportion of COVID-19 public testing and vaccination centres are located around the Central and Harbour areas of the islands, therefore matching the area that houses the highest proportion of the Maltese residents. By ensuring that there is an adequate number of centres in each region, accessibility to these centres is improved given that less crowding is expected at any time. Besides this, a faster roll out of the vaccine can also be planned, as an increased number of centres in the most densely populated area of Malta allows for an increase in the number of appointments that can be booked simultaneously without compromising safety due to crowding. Furthermore, the availability of a map showing the geographical location of the centres and information about each centre can help people find the testing and vaccination centres easily, while reducing unnecessary calls to the general helpline.

As Schoch-Spana, et al. (2020) explain in their paper, this is significant and can affect the uptake of COVID-19 vaccination and testing (Schoch-Spana, et al., 2020). This is because the uptake of a service does not simply depend on providing a service, but it is affected also on the public perception surrounding this service (Larson, et al., 2014; MacDonald and SAGE Working Group on Vaccine Hesitancy, 2015). By providing more centres and reducing crowding, there is more perception of safety and improved accessibility, and therefore this can help increase the uptake and acceptance of the COVID-19 testing and vaccination programme and strategies (Schoch-Spana, et al., 2020). Improved access to vaccination and testing services is important especially to increase the uptake of these services by the elderly and those vulnerable who may otherwise opt not to participate in this essential service that aims to reduce the morbidity and mortality resulting from infection with COVID-19 (Schwarzinger, et al., 2021).

Results

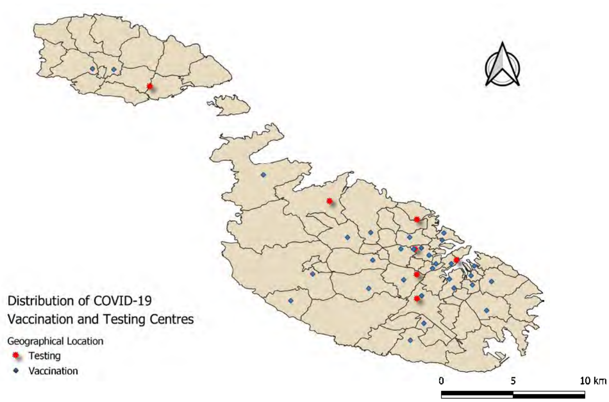
The highest number of vaccination and testing centres were located around the Harbour area of the Maltese Islands (Figure 1), with the Northern Harbour region having the highest number of centres in the Islands with 3 Testing and 10 Vaccination centres. This region also had the highest population percentage, with 33% of the population living in this region. On the other hand, Gozo and Comino had the lowest population percentage, with 6% of the population residing here, and the lowest number of vaccination centres per region (Table 1).

Table 1: Population, testing centres and vaccination centres by region

Region	Percentage Population (%)	Number of Testing Centres	Number of Vaccination Centres
Southern Harbour	16.5%	2	9
Northern Harbour	33.1%	3	10
South Eastern	14.5%	0	3
Western	12.2%	0	4
Northern	17.0%	1	3
Gozo and Comino	6.7%	1	2

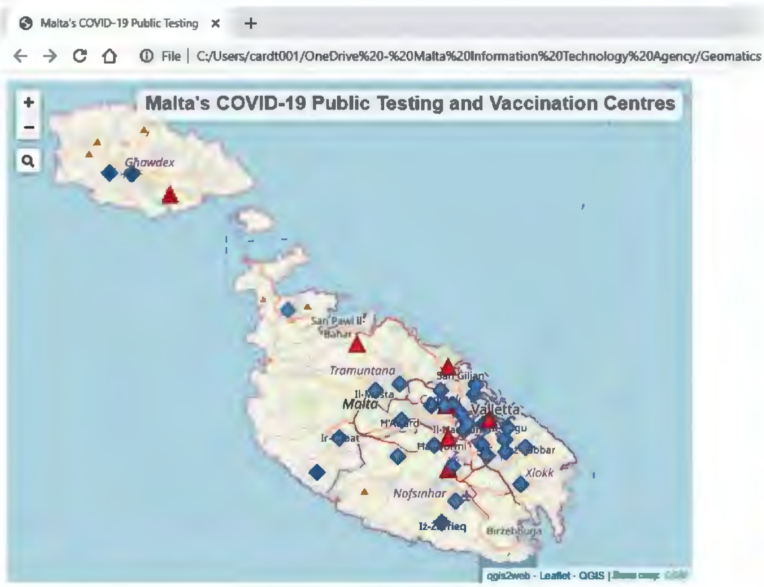
The output of the shareable map produced can be visualised in Figure 2. The different markers indicate the type of service provided, with red triangles showing the locations of testing centres and blue diamonds showing the location of the vaccination centres. Customization of the settings allowed for a popup window to show selected information about each centre when the mouse hovers on a marker (Figure 3). The information provided includes the centre name, address, type of service provided (testing or vaccination), and type of building where the service is being provided. Users can also zoom in to an area of interest to view a higher definition map of the area. This map can be uploaded to a website of choice where it can be made available to the population to use as needed.

Figure 1: Geographical distribution of the vaccination and testing centres in the Maltese Islands.



Source: QGIS v.3.10

Figure 2: The output of the qgis2web plugin.



Source: qgis2web

Figure 3: Detail from the shareable map showing a popup with information about each centre.

Source: qgis2web

Key results of this project are:

- The Northern Harbour region houses most of the population in the Maltese Islands, whereas Gozo and Comino have the smallest population.
- The distribution of the testing and vaccination centres matches the distribution of the population, with a higher number of centres in the most densely populated regions, and the least number of centres in the least densely populated regions of Malta.
- A shareable map was generated that can be used by service users to locate the different centres. This can improve the access to these centres while providing useful information, such as the closest centre to their locality, which service is offered, and the exact address of the centre.

Recommendations

Key recommendations:

- The location of new centres should be chosen by taking into consideration the number of existing centres and the population distribution in the area, to improve access and reduce crowding.
- The shareable map should be updated regularly to ensure that correct information is provided to the public.
- Further research can be carried out using QGIS to locate the best location where further testing and vaccination centres can be set up, by taking into consideration traffic patterns, population distribution, and the location of nearby centres.

Conclusions

Appropriate distribution of testing and vaccination centres across the Maltese Islands is important to improve the public perception and acceptance of the COVID-19 services while reducing the geographical barriers that may affect the accessibility of these services. It is important to ensure that the number of centres in different regions of the Maltese Islands match the population distribution so that people in different areas have equal access to resources, whereas mapping of these centres can help provide guidance to the clients making use of these services and avoid confusion about where they need to go. All these measures are important for the widespread effort against the virus to help end the pandemic and reach normality faster.

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Pivot VII
Infrastructure and Safety Domain

Marsalforn Gozo
Easting: 433396.370, Northing: 3992290.550

CHAPTER 26

The use of GIS to identify effective transmission sites for sound broadcasting services

Adrian Galea and Amadeo Vella

Keywords

Radio Frequency, Coverage, Viewshed analysis, QGIS, HTZ Communications, Transmission sites, Broadcasting, Frequency planning, Malta

Project Aim

The aim of this project is to make use of QGIS™ and identify potential candidate sites to host broadcasting stations. This project explored the use of the viewshed analysis plugin to compare and contrast results with professional path specific propagation GIS tools.

Introduction

Terrestrial sound broadcasting technologies provide an effective means to convey information to several users within a given area (ITU, 2020). FM sound broadcasting is the dominant terrestrial technology for the Maltese islands, where 13 Nationwide stations and 21 long-term community radio stations are available (Broadcasting Authority, 2021). According to an audience survey conducted in December 2020, 64% of the population are radio listeners (Broadcasting Authority, 2020).

In Malta, the Broadcasting Authority is the competent authority responsible for regulating sound and television broadcasts, through the powers conferred by the Constitution (Government of Malta, 1964) and Chapter 350 of the Laws of Malta (Government of Malta, 2018). The radio frequencies where FM sound broadcasting (FM radio) operates, fall within the 87.5 – 108 MHz range in accordance with Malta's National Frequency Plan (Malta Communications Authority, 2020). This frequency range falls within the Very High Frequency (VHF) band and transmissions propagate in a line-of-sight manner. For a radio station to deliver optimum radio coverage, the transmission site should be as high as possible (Louis and Frenzel, 2018). In addition, VHF radio wave propagation also tends to propagate well into buildings (Sverian et al., 2013).

Simulation and prediction of radio coverage using Geographic Information Systems (GIS), can assist in radio network planning (Davis, 2021). In order to enhance the accuracy of a coverage simulation, a detailed Digital Elevation Model (DEM) with high resolution (e.g. 1m) must be used at least for the urban areas. This project explored the use of QGIS to identify appropriate transmission locations to set-up a radio station.

Literature Review

Basic and sophisticated software tools make use of GIS applications to analyse the coverage of radio transmissions. This section will provide a literature review concerning similar activities in the field of coverage prediction. FM sound broadcasting service is subject to instruments adopted under the auspices of the International Telecommunication Union (ITU). The Final Acts of a conference held in 1984 include a number of propagation curves to predict the amount of field strength that is received at a certain distance away from the transmitter. The key criteria to assess the propagation of FM frequencies was the transmit power and the height of the transmit antenna above ground level for a specific scenario. This implies that these characteristics determine the size of the coverage area (ITU, 1984).

According to ReMartinez (2009), to perform coverage simulations in an accurate manner, three spatial relationships must first be established. These include the transmitted power, the power and distance travelled by the electromagnetic wave in relation to the changes of elevation and third the interactive behaviour of such waves with the terrain. In this study carried out in Peru, spatial relationships were calculated using the Longley-Rice Irregular terrain model and ESRI ARCGIS 9.1. The study concluded that the coverage of FM broadcasting stations could be predicted using the Longley rise model and viewshed analysis (ReMartinez, 2009).

Another study carried out in by Chen et al. (2012) in Vietnam explore the use of GIS-based models for the prediction of signal strength of cellular networks using a developed model called COST-231-Walfisch–Ikegami model (WIM). The authors argue that when it comes to radio coverage prediction of mobile communications, GIS models are very useful. However, for accurate simulations, high resolution maps are required and terrain cadastral maps are also vital.

The open-source Geographical Resources Analysis Support system GRASS™ can be also used for radio signal coverage prediction. In a different study, it is claimed that commercial planning tools are very expensive and inflexible therefore GRASS modules were developed for this purpose. The developed GRASS prediction software enabled a high level of flexibility and adaptability (Hrovat et al., 2010).

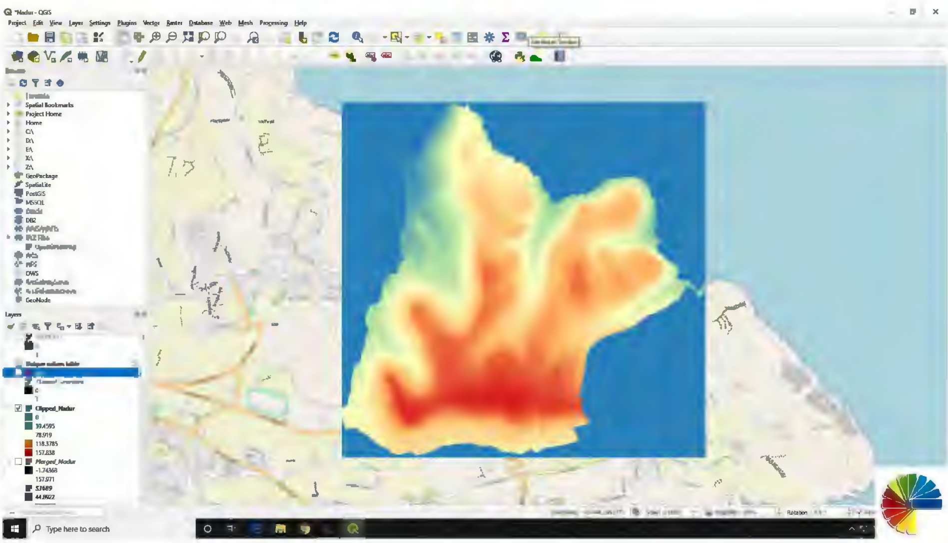
A number of companies developed software tools dedicated for RF design and spectrum planning. One of the main software tools used in this area of specialisation is ATDI's HTZ communications. Apart from simulation coverage prediction, this tool has an integrated GIS engine allowing Digital Terrain Models, Digital Surface Models and building/clutter layers to be created using GIS data. (ATDI, 2020).

Methodology

The administrative boundaries were downloaded from Malta Spatial Data Infrastructure (MSDI), to identify the boundary area of the localities to be analysed (MSDI, 2021). For this paper, the service area of interest is the locality of Nadur (Gozo), and its administrative boundary is shown in Figure 1. The administrative boundary of Nadur Gozo was extracted to identify which DEM tiles cover this locality. All DEM tiles located within Nadur's administrative boundary were merged to create one single DEM raster. The render type of the DEM was selected to be single band pseudocolor with an inverted spectral colour ramp, in order for the high-altitude locations to be clearly visible. The areas in red represent the highest altitudes, while those in blue the lowest. Figure 2 illustrates this representation.

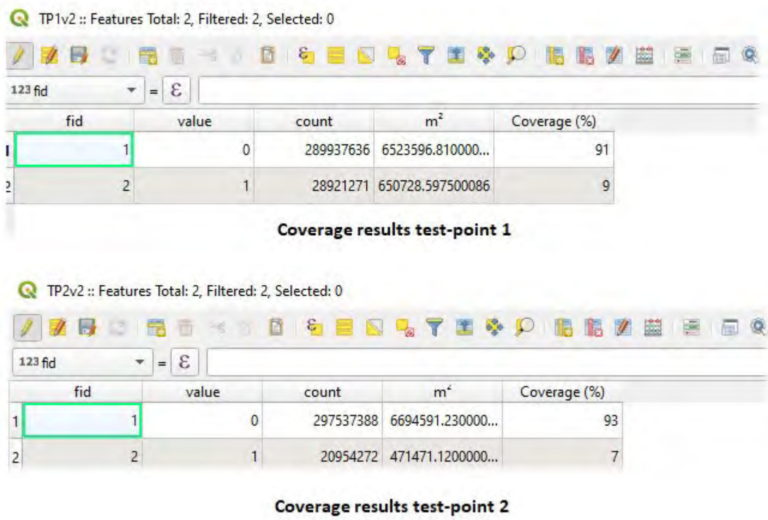
Figure 1: Nadur administrative Boundary

Figure 2: Nadur Digital Elevation Model



A visibility analysis was carried out at every location using a QGIS plugin Visibility Analysis V1.5 (Cuckovic, 2021). However, before using the viewshed analysis tool, a point shape file layer was created for each point under investigation. The shape file contained the height above the surface of the analysis point (field name: observ_hgt) and also the radius of investigation (field name: radius). These two fields are important parameters required by the plugin in order to create a viewshed analysis. It should be noted that these parameters were entered manually and were based on a typical antenna height (which is around 10m) and coverage radius for community radio stations in Malta. Due to the relatively short distance, the earth's curvature was not taken into account in the viewshed calculation. Figure 3 illustrates the viewshed analysis attribute table from the 2 test-points. It should be noted that a value of 0 represents the areas which are not covered (i.e. black) and a value of 1 represents the covered areas (i.e. in white).

Figure 3: Viewshed analysis attribute table for the two test-points



TP1v2 :: Features Total: 2, Filtered: 2, Selected: 0

	fid	value	count	m²	Coverage (%)
1	1	0	289937636	6523596.810000...	91
2	2	1	28921271	650728.597500086	9

Coverage results test-point 1

TP2v2 :: Features Total: 2, Filtered: 2, Selected: 0

	fid	value	count	m²	Coverage (%)
1	1	0	297537388	6694591.230000...	93
2	2	1	20954272	471471.1200000...	7

Coverage results test-point 2

Discussion

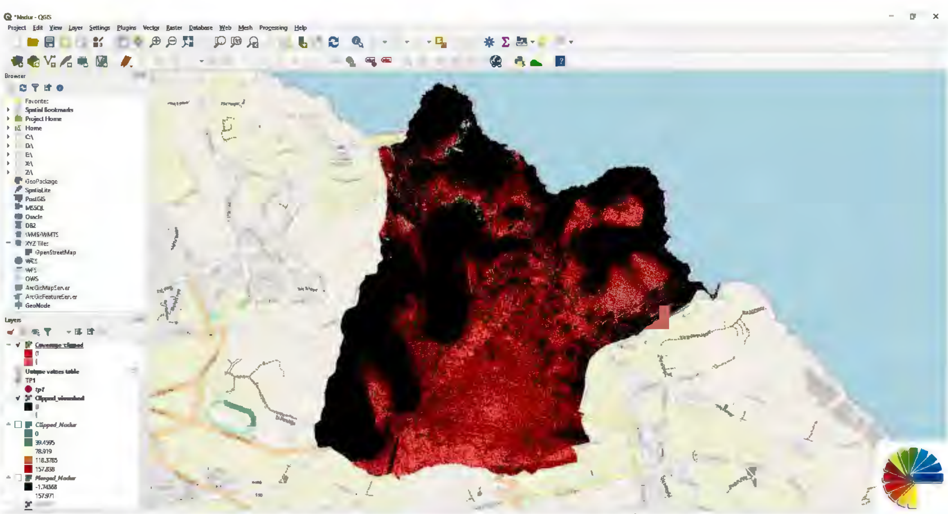
By implementing the established methodology, it was possible to obtain a series of results which contribute to identify effective transmission locations. From the analysis, the viewshed coverage percentage established for the test-points located on Nadur's church and on a dwelling in Triq Dun G. Camilleri are 9 and 7% respectively. The two test-points are located at a height above sea level (asl) of around 200m and 143m respectively. In practice, the installation of a transmitting antenna on the dome of the church is highly unlikely due to aesthetics and regulatory considerations. However, installations of antennas at the church steeple level already exist, especially in the island of Gozo.

It must be noted that from a radio frequency coverage perspective, the simulated results using a software tool, would be more optimistic due to specific propagation phenomena. For example, radio frequency waves travel through walls, can be refracted/scattered, and reflected by buildings (Institute of Radio Frequency Engineering and Electronics, 2008). In a visibility analysis, these propagation phenomena are not taken into account hence underestimating the potential radio coverage area. One important observation to make is that the viewshed analysis performs the assessment of the viewed location at ground level. In practice radio receivers are not placed on the floor but are generally situated at a height of around 1.5-2m above ground level (for outdoor coverage), such as radio receivers within vehicles or pedestrians making use of such receivers. Taking this into account, the viewshed analysis would have most probably provided a more optimistic result, in terms of radio coverage.

Another important aspect is that Nadur's topography is composed of several hills and valleys. This is visible in Figure 2 where the DEM confirms that the south part of the locality is located on a relatively wide hill. On the other hand, valleys are located around the boundary of the locality with some medium altitude hills. In addition, the cliffs located between the hills and valleys are quite steep (have a large gradient), which can be noted due to the rapid change in colour in the DEM. This high dynamic in altitude causes various challenges to provide coverage around a locality.

ATDI's (2020) HTZ communication was used to view the simulated radio coverage at the candidate sites. The propagation model established in recommendation ITU-R 1812-5 (ITU, 2019) was selected, outputting coverage files to GEOTIFF format. These files were imported into QGIS and overlaid on the viewshed analysis. It should be noted that the resolution of the analysis performed using HTZ communications is limited due to hardware and computational power limitations. The results of this operation at test-point 1 is found in Figure 4. As can be clearly seen in Figure 4, the HTZ communications coverage prediction provides better coverage when compared to viewshed analysis (areas in black also covered in prediction). It should be noted that the minimum usable field strength was set to 66 dBμV/m in line with table 1 of ITU-R recommendation BS.412-9 (ITU, 2010).

Figure 4: Viewshed (white shade) vs ITU-R P1812-5 (dark red) – Test Point 1. Light red represents areas covered by both test-points



However, Nadur is composed of both urban and rural areas. In the latter case, the minimum usable field strength should be relaxed to 54 dBμV/m, providing a better coverage map. Therefore, although the HTZ communications simulation provides a worst-case scenario in terms of radio coverage within the service area, the coverage is still far better than that produced using the viewshed analysis. For the purpose of this study, measures aimed to mitigate the presence of any cross-border harmful interference were not considered. In such an event, the minimum usable field strength would have to be increased by a certain amount, depending on the interfering frequency and unwanted field strength level arriving in the service area.

Results

Referring to the previous section, the key results of this project are:

- With the aid of QGIS, it was possible to perform a viewshed analysis on a DEM at a defined observation height and radius.
- Visually inspecting the viewshed and HTZ coverage files, there seems to be positive correlation between both generated maps.
- The QGIS Viewshed plugin is appropriate to use on flat terrain, where propagation phenomena have the least impact on coverage predictions. In cases of urban environments, the viewshed analysis will only display visible locations which is quite limited. Radio waves tend to be reflected, refracted and scattered by buildings which would increase radio coverage prediction in areas not visible in a viewshed analysis.
- Although the viewshed analysis will not provide an accurate analysis in terms of radio coverage for urban or hilly environments, the tool still serves to provide a good indication in determining effective transmission site.

Recommendations

The key recommendations are:

- Viewshed analysis can be used by prospective broadcasting licensees to assist in the process of site identification. Although the analysis accuracy may be limited, this tool can still be useful to find the site which will yield good radio coverage for a particular set-up.
- As future work, one can continue building on this project and perform a viewshed coverage analysis based on population coverage instead of territory coverage.
- The development of a deterministic or empirical model radio propagation plugin would be ideal to perform radio coverage. These kind of models take into consideration certain radio frequency propagation phenomena (ATDI, 2008) which are not considered in the viewshed analysis and therefore provide better accuracy at the planning stage of the broadcasting station when compared to the viewshed analysis.

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CHAPTER 27

Radio Transmitting Equipment and Health Related Concerns

Clara Scerri Delia

Keywords

EMF, Radiation, Radio Base Stations, Mobile Communications, 5G, MCA, QGIS, Malta

Project Aim

This project contributes to gaining a better insight of GIS technology through the adoption of the latter to analyse the association between the number of complaints received by the MCA during the last few years and the location of mobile base stations spread across the island, whilst it also analyses complaints by locality. Furthermore, the use of buffering techniques helped to determine the complaints which fall within a specific area from base stations. This, again, addresses the relationship between base station location and complaints received.

Introduction

Radio base stations, spread across the Maltese islands including Comino and Gozo, permit mobile communication service providers to facilitate a nationwide mobile service. Currently, Malta benefits from privileges the service of three providers. Every one of them owns its individual mobile network implying; that with such a dense population of radio communication equipment, networks are replicated multifold. The MCA, as the regulator, has an updated list of all the base stations installed including together with their technical characteristics. By law, service providers need to inform the MCA accordingly every time they install a base station or make changes to existing ones.

Malta adopted international standards like the ICNIRP standards (ICNIRP, 2020), for Electric and magnetic field (EMF) monitoring and measurements. The MCA is the Authority responsible to ensure that all radiation emitted from telecommunication equipment lies within these prescribed limits. The Authority carries out periodic and routine measurements across the island, thus guaranteeing that EMF levels are confined to the defined margins. The safety of the public is its priority. The MCA often receives requests, from the public, to carry out investigations on specific base stations. The reason for these requests is multi-fold. However, most of them eventually boil down to one subject – health. The public wants reassurance that neighbouring radio transmitting equipment is not causing harm. Following a complaint, the MCA audits the respective sites and gathers the necessary technical parameters related to the transmitting equipment. Only on rare occasions do measurements exceed the stipulated threshold levels. Complainants are informed accordingly.

This study considered the locations of the base stations (for all three service providers) and the complainants as its principal inputs. The data related to base station location is collected and forwarded to the MCA by the individual service providers. As a result, the data received by the Authority has, to date, been set in a format preferred by the providers. The latter does not happen to be the same for the three service providers. The presentation and the technical details provided are all different. Therefore, as a first step, this data had to be integrated together and represented in one common format. The resultant file was converted to a .csv file for ease of transfer.

A similar issue was experienced with the information related to the complaints received. The MCA keeps record of all the complaints it receives. Not all complaints are mobile-related. Also, not all are associated with EMF. Consequently, for this study, and using the MCA's data, the latter had to be filtered and exported to a separate file, a .csv file, to only represent the required complaints. Complaints received by the Authority between the years 2014 and 2019 were considered. These were considered as one common data set. The complaints for the different years were incorporated together to give a better picture of the distribution of the complaints with respect to their positioning to the base stations. The location of the base stations has remained approximately the same during the last few years.

Methodology

Both the complaints and the Radio Base Station files were imported to QGIS™ 3.10 as point layers. This tool was adopted to capture and visualise the data. Its functions and resources suffice for the purpose of this assignment and the data analysis required.

Several analysis and geo-processing tools were considered for this study, each addressing the situation from a different perspective.

The Administrative Boundaries map was used as the base map for Malta. It was utilis ed to visually display the base station and the complaint locations as well as the outcome of the spatial analysis. This map divides Malta into several polygons with each polygon depicting a different locality. Hence, the map best fitted the scope of this assignment.

The following is the procedural analysis considered:

1. The Count Points to Polygon analysis tool was used to deduce the number of complaints received by locality. The aim of this exercise was to determine the distribution of complaints. This tool counts the number of points within a polygon. In this case, the polygons characterised the various locations in Malta and Gozo while the points represented the location of the complaints.
2. The Distance to Nearest Hub tool was utilized to estimate the distances from the location of the complaints to the nearest base station. The base stations were considered as different hubs for this exercise, and the distances from the distinctive complaints to these hubs were computed. The outcome served to indicate whether people near a base station were the most concerned.
3. The Basic Statistics for Fields tool was subsequently run on the outcome of the latter to attain statistics related to these shortest distances.
4. In the process of the study, more complex statistical tools were considered and experimented with. The Standard Deviational Ellipse tool was one such tool. However, for this study, the output of this last tool did not provide more valued and worthy results to those attained from the Basic Statistics for Fields tool. Consequently, this study concentrates on the latter tool with regards to statistics.
5. The Buffer tool was adopted to create a buffer zone around every base station, to distinguish the complaints which fall within a predefined distance from a base station. The diameter of the buffer area was set to 200m. This diameter was selected based on technical parameters. In general, and for base station installations in Malta where antenna heights are approximately all congealed to the same value, the electromagnetic propagation of the base stations is strongest within 200m from a base station. Hence, the set buffer zones. The introduction of buffering helped to narrow further the complaints to the base station areas. It thus added more weight to the conclusions made in the previous exercises.

Discussion

Due to the numerous articles which portrayed EMF as harmful in recent years, one would have assumed that the outcome of the study would be skewed since people would be prejudiced on the subject. This suggests that most complaints are made by people located closer to radio transmitting equipment. Indeed, several interesting results emerged.

Figure 1 depicts the distribution of base stations across Malta and Gozo. The map clearly illustrates that there is a large concentration of base stations around the Valletta-Sliema area. Apart from residents, these areas also house businesses and entertaining facilities. Hence, more bandwidth coverage is required. Furthermore, the bastions, high buildings and narrow streets in Valletta, together with the many high buildings in the Sliema area, all contribute to greater signal loss due to a lower propagation of the radiating signal. This again increases the need for more bandwidth.

Figure 2 illustrates the location of the complainants communicating with the MCA regarding EMF. At a first glance, most of the calls appear to be concerted in the Northern region of Malta.

This supposition is further confirmed in Figure 3 which depicts the outcome of the Analysis tool, Count Points to Polygon. The darker shades of red, implying more complaints, are largely in the Northern part of Malta.

Figure 1: Malta's mobile network

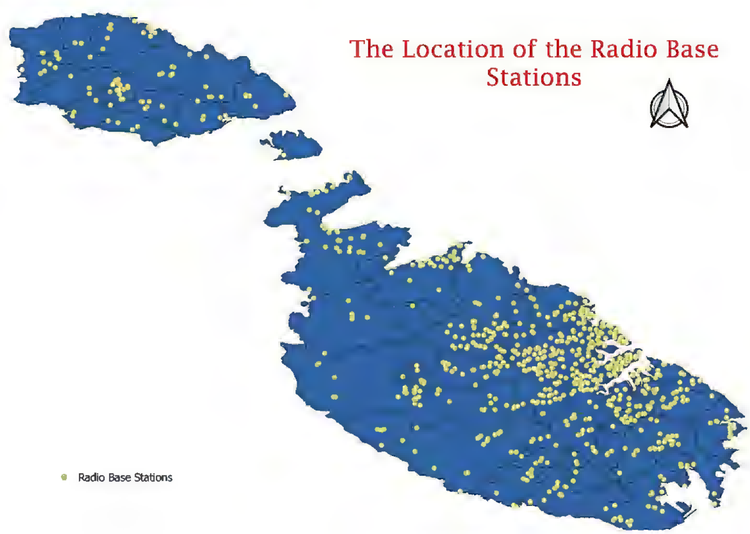


Figure 2: Locations of complaints

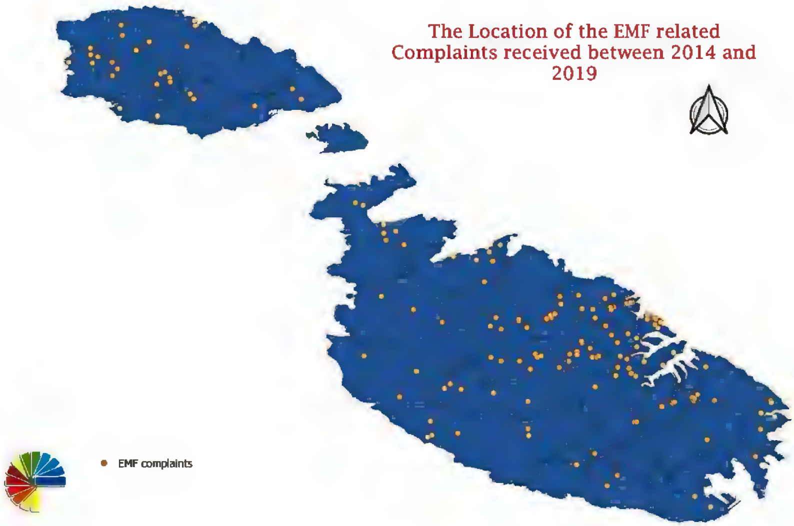
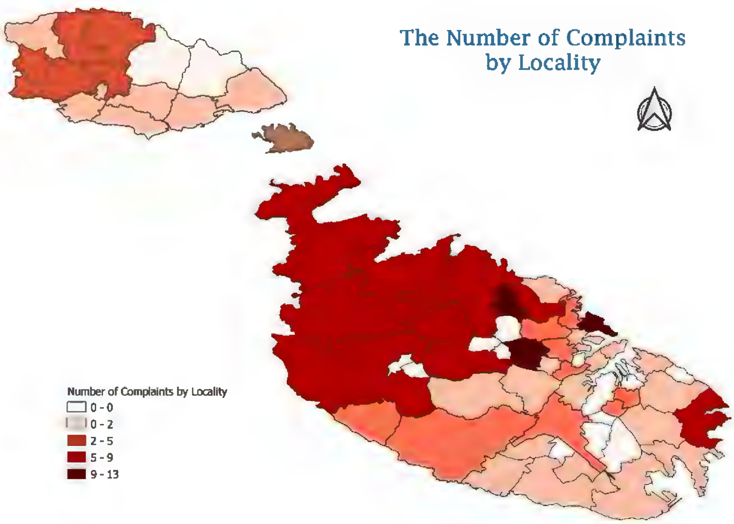


Figure 3: Distribution of Complaints by Locality



Observations

Figures 1, 2 and 3 led to several some noteworthy observations.

1. The distribution of base stations is not mirrored in the distribution of complaints. Whilst Sliema, one of the localities with the most base-stations, also appears to be the most saturated in terms of complaints (refer to Figure 3), other base station dense regions barely have any complaints. The opposite holds for the Northern and Western part of Malta. In this case, the number of base stations is much less. Yet, the number of complaints received is higher. This leads to the conclusion that the location of the base stations and that of the complaints are not correlated. Several reasons may exist for this.

2. Regional statistics issued by the National Statistics Office (NSO) in 2019 (NSO, 2019) indicate that people residing in the Northern, Northern harbour and Western regions of Malta, tend to further their studies more than people living in other regions. A quick glance at Figure 3 indicates that these three regions also happen to be the ones with the most complaints. An initial explanation for this assumes that since people in these regions have more schooling, they are inclined to read more, and subsequently understand more, the EMF health concerns raised in certain articles. This leads to more complaints emanating from these regions.

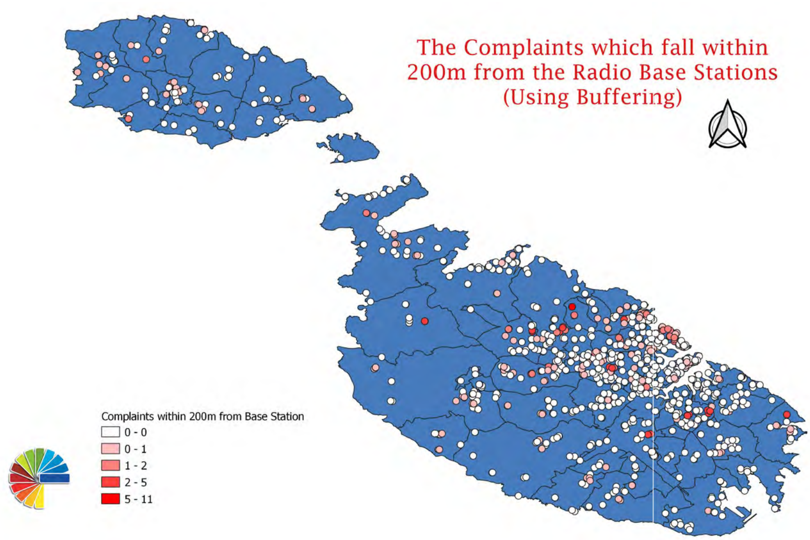
3. Another factor potentially affecting the location of the complaints is the dynamicity of the regions. Indeed, the NSO's Regional Statistics show that certain regions, especially the Northern and Northern harbour regions, accommodate a large, and constantly growing, population. Furthermore, the physical demographics of these areas are also very fluid with high rise buildings constantly on the increase and with buildings towering higher and higher. This change in building composition is resulting in base stations, previously having a clear path in line of site, being obstructed by other higher buildings. In this case, the base stations would need to be relocated to not directly point to another person's lodging. Under such circumstances, the complainant's concerns are unquestionably justified. In such cases, the concern is specifically tied to the fact that the base station is directly facing a residence. It is not related to having a base station in the surrounding area. So, often the health-related fears fade away once the base station is repositioned to a higher location (even if on the roof of a neighbouring building).

The introduction of buffering around the base stations further confirmed the above conclusions.

5. Figure 4 maps the outcome of the Buffer tool. It epitomizes the complaints which fall within 200m from a base station. The map clearly illustrates that, for most base stations,

no complaints were filed within these zones. This again is proof that there is no direct connotation between people's health concerns due to EMF and the location of the base stations.

Figure 4: Complaints which fall within 200m from the Base Stations



6. Statistical analysis was run on the outcome from the Distance to the Nearest Hub tool. Values related to the mean, median, standard deviation, minimum and maximum were estimated. The results again acted as indicators depicting the distribution of complaints in relation to the location of the base stations.

7. The mean distance from a complainant's location to that of a base station, as estimated by the statistical tool, was 224.6m. This value complements the results achieved with the buffer tool, that is, most complaints are located at a distance greater than 200m from a base station. This reinforced the conclusion that people living closer to base stations are not making more complaints.

8. This study is founded on the EMF related complaints received by the MCA during a 6-year time-window. The aggregate complaints received during this period amount to approximately 186 complaints. In converse, the total number of base stations present in Malta is slightly more than a thousand. These two figures, in themselves, already serve to support the conclusions made.

Results

Key results of this project are:

- In view of the increasing misleading, and non-scientific, information related to EMF and health issues, one would have assumed that most complaints would be made by people located closer to base stations. However, this study shows that the hypothetical assumptions regarding the relation between the location of base stations and that of the complaints may not be correct.
- Complaints were not concentrated in the areas dense with base stations. Also, most complaints were made by people dwelling more than 200m from a base station.
- Education plays a significant role when it comes to health concerns and electromagnetic radiation from base stations. The study shows that the people who complain the most on the subject are the ones located in the Northern part of Malta. According to NSO Statistics (NSO, 2019) this region is the one having people with higher levels of educational. This could, therefore, hint to the conclusion that people living in this region might read, and understand more, on the subject.
- The specific QGIS tools used for this study perfectly served their purpose to depict the correlation between the location of the base stations and the location of the complainant.

Recommendations

Key recommendations of the effort are:

- Educate the public about electromagnetic radiation since EMF is an extremely complex topic. People might therefore interpret the subject in their own way. Thus, the MCA could periodically issue easy-to-comprehend leaflets and articles. This will serve a two-fold purpose. People will apprehend more the relation between EMF and technology, and, at the same time, become more aware of misleading information. In addition, being more versed with technology, people may reap more its benefits.
- Continuous assessment and measurements of EMF - The MCA could publish, and possibly map, its findings. Transparency in the results would help to give a clearer picture of the situation.
- Continue building on this study – This would help to give a better understanding of people's concerns with regards to EMF. It therefore assists in preventing, and possibly mediating, any apprehensions on the subject. Surveying would add further weight and subjectivity to the conclusions made. It is thus worth considering in a future study.

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CHAPTER 28

Assessing children's public recreational areas for exposure to electromagnetic fields emanating from radio transmitting equipment

David Scerri

Keywords

EMF, electro-magnetic fields, exposure to EMF, health and EMF, children, EMF in public spaces, Malta 5G and EMF, mobile communications health risks.

Project Aim

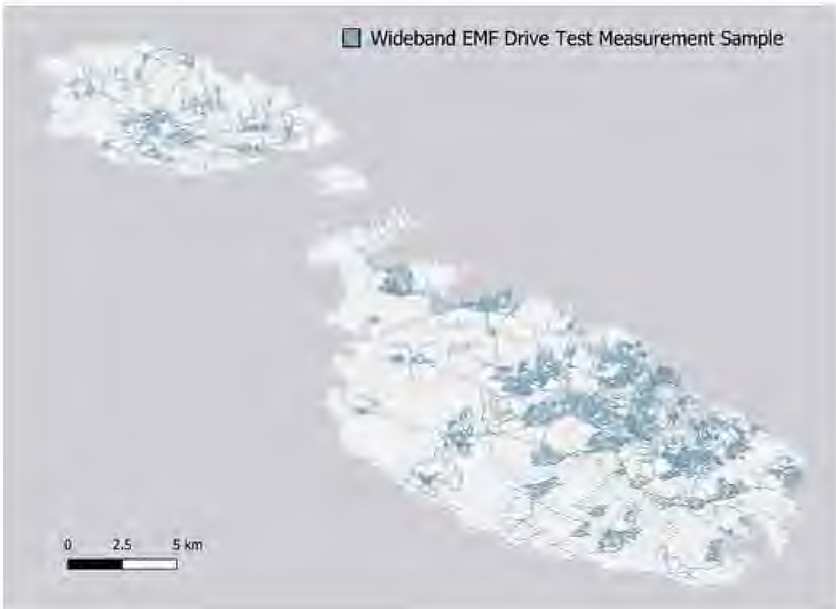
The aim of this project was:

1. to produce a high-resolution EMF exposure map for all the Maltese Islands, with a particular focus on children's recreational areas;
2. to select an appropriate spatial interpolation technique which provided an accurate interpolated data set; and
3. to select an appropriate graphical representation which was easily understood by the public.

Introduction

As part of the Malta Communications Authority (MCA) EMF monitoring activities, EMF measurements were taken in real time, over two thousand and five hundred kilometres (2500kkm) of carriageways and pathways across the towns and villages of the Maltese Islands. The measurement sample consisted of 414,215 real time measurements (comprising 358,106 measurements in Malta and 56,109 measurements in Gozo). EMF intensities emanating from the myriad of radio transmitting equipment deployed all over the islands were measured. Figure 1 shows the exact location where the actual EMF measurements were carried out. All EMF measurements were taken during daylight hours.

Figure 1: Carriage ways encompassed in the nationwide wideband EMF measurements



EMF measurements were conducted in accordance with the ITU-T K.113 Recommendation (ITU-T recommendation K.113 (11/15)) and the IEC 62232 Standard (IEC 62232 ED2, 2017). Recommendation ITU-T K.113 provides guidance on how to make radio-frequency electromagnetic field (RF-EMF) maps for assessing existing exposure levels over large areas of cities or territories and for an appropriate public disclosure of the results, in a simple and understandable way. The measurement method employed was the drive test measurement method as identified in Section 6.1 of the ITU-T K.113 Recommendation. The drive test method consists of continuously collecting the cumulative E-Field strength values in volts per metre (V/m) from a moving vehicle. This method required the installation of the measuring instrument equipped with a global positioning system onto a vehicle as depicted in Figure 2. Measurements were completed within 5m for urban areas and within 10m for non-urban areas.

Figure 2: EMF Measurement Setup

The movement of the vehicle did not permit measurements to be taken over an average time of six minutes, as recommended by the ICNIRP 2020 Guidelines (ICNIRP, 1998) and IEC Standards (IEC 62232 ED2, 2017). However, the measurement methodology employed did give an approximation of the RF-EMF levels over large areas that otherwise would have been impossible to cover. To overcome this limitation, static measurements were taken as reference to ensure that the order of magnitude of the static and in-motion measurements were similar. Instrumentation measurement uncertainties as specified by the measurement instrument supplier were included on top of the actual real-time measurements.

Methodology

Measurements were carried out using a Narda AMB – 8059 Multi-band EMF area monitor. This instrument was equipped with a calibrated wide band measurement probe (Narda EP-1B-03) covering the radio frequency spectrum from 100KHz to 7GHz; the radio frequency spectrum in which all radio transmitting equipment deployed in Malta operates. The measurement equipment provided an overall E Field exposure level in V/m; the total EMF exposure level was then expressed as a relative value in terms of percentage of the permitted reference levels established in the 2020 ICNIRP Guidelines. All values of EMF exposure as measured by the MCA were relative to the lowest permitted reference levels for EMF exposure at 27.7V/m or 2W/m2 as identified in Table 5 of the ICNIRP Guidelines. The recorded EMF exposure levels reflected the emissions of the combined signals present at the measurement location at that point in time. It is important to acknowledge that the values present at the time of measurement may not have been the maximum EMF levels from the radio transmitting sources present in the vicinity.

Estimation of values at unmeasured locations were carried out using values of neighbouring measured locations and spatial statistical interpolation techniques (Li and Heap, 2008). Such an approach created a surface that covered both measured and estimated points. This was intended to best represent best empirical reality. However, different spatial interpolation methods can result in different estimates and thus the surfaces created vary slightly (Legendre and Legendre, 1998). In view of this fact, the selected interpolation method was evaluated accurately against actual EMF measurements across several test points.

There are two main types of interpolation methods: deterministic and stochastic (H.D. de Andrade Electronics Letters April 2020 Vol. 56). The latter provides an assessment of prediction errors with estimated variances, while the former does not. Basically, radial basis (RB), inverse distance weighting (IDW) and polynomial are deterministic interpolation methods, while regression techniques and Kriging are stochastic methods. The RB completely regularized spline and Empirical Bayesian Kriging (EBK) spatial statistical interpolation methods are usually used for mapping. (Goodchild, 2015). The RB and spline functions can simply be determined as a weighted linear function of distance from grid point to data point without smoothing and bias factor.

Discussion

The propagation of electromagnetic energy results in a decay of the signal which is equal to the square of the distance travelled (inverse square relationship). To predict the EMF exposure levels across the entire geographic area of the Islands of Malta and Gozo, the measurement sample was interpolated using the Inverse Distance Weighting interpolation technique with a weighting power of 2. A total of 414,215 real-time EMF measurements covering 2,500Km of carriage ways in Malta and Gozo provided an appropriate measurement sample. For the IDW, the weighting is given by the Euclidean distance between the interpolated point and a sampled point, with the nearest points having more influence than the most distant ones by the specified weighting factor. Such an algorithm was selected since it reflects the propagation characteristics of electromagnetic waves (Boz and Denli, 2018).

The interpolated values achieved were then compared with the EMF measurement values obtained at 150 different static test points located around the Maltese islands. The variance between the interpolated data set and the actual measurements was well within the expected error obtained through the interpolation technique adopted. In addition, the raster histogram of the EMF Intensity map depicting the interpolated values, reflected a leftward shift, similar to the raster histogram of the original data sample. Considering the minimal degree of error between the interpolated data set and the in-situ measurements, as well as the similarity of the raster histograms for the real-time measurements and the interpolated data points, the EMF exposure map depicting the interpolated data set reflected to a very high degree of confidence the EMF emissions as experienced by the general public at street level.

The target of the project was to determine and assess the EMF exposure levels in children's public recreational areas. Using an OSM script, a more in-depth analysis on the exposure levels at children's public recreational spaces throughout the entire geography of the Maltese Islands, was carried out accordingly.

The distribution of the EMF emissions obtained from the IDW Interpolation technique is reproduced in Figure 3. The map shows that the EMF emissions across the whole of the Maltese Island were well below the EMF safe reference levels as stipulated in the ICNIRP Guidelines. The extrapolated E Field exposure levels are below 20% of the ICNIRP reference exposure level of 27.7 V/m, with the vast majority of the extrapolated E Field exposure levels well within 2% of the ICNIRP lowest reference exposure level of 27.7 V/m The ICNIRP general public reference exposure levels vary according to the radio transmission frequency: 27.7V/m or 2W/m2 for radio transmission at frequencies between 30MHz to 400MHz (used primarily for radio broadcasting) and up to 61V/m or 10W/m2 for radio transmissions at frequencies above 400MHz (used primarily for TV broadcasting and mobile services).

Figure 3: E Field Exposure Level (V/m)

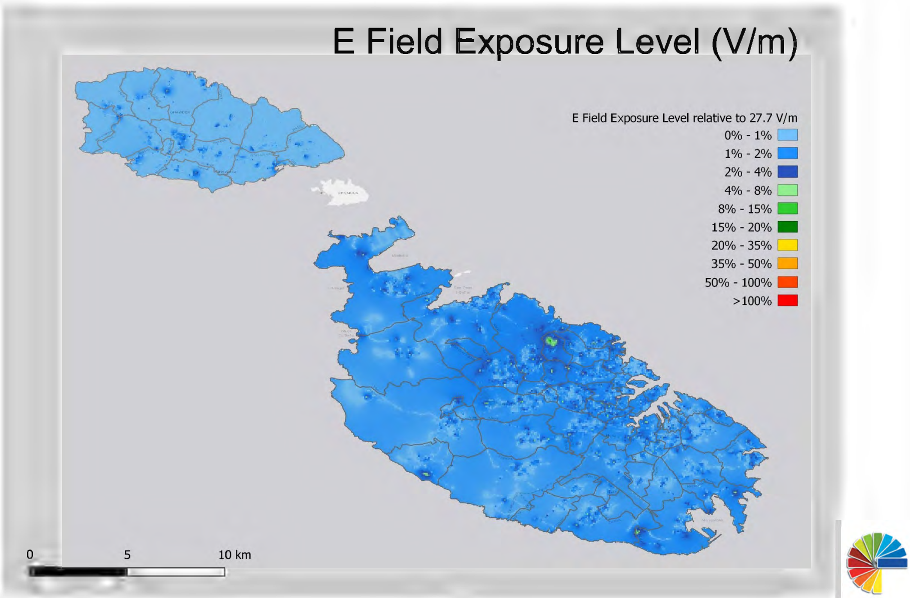


Figure 4 depicts the intensity of the EMF exposure levels in V/m at the Ta' Qali National Park in Malta. The interpolated EMF exposure value was just 2% of the ICNIRP safe reference level of 27.7 V/m. The analysis showed that the EMF exposure levels across all the parks situated across the Maltese Islands were similar in value to the EMF exposure levels as measured in the Ta' Qali National Park in Malta.

Figure 4: EMF Exposure in Ta' Qali National Park

This project, through the real-time EMF measurements and the appropriate interpolation techniques, reconfirmed and provided the necessary assurance that the EMF public exposure levels at public recreational parks in the Maltese Islands were well within the EMF safe reference level for exposure to the public as established in the ICNIRP Guidelines.

Results

Key results of this project are:

- For all the 414,000 real-time EMF measurements carried out across 2500 km of carriage ways across the Maltese Islands, the EMF levels were, in general, found to be at a small percentage of the EMF reference level for exposure to the general public in the ICNIRP Guidelines.
- All the measurements were extrapolated to publicly accessible areas demonstrating that the public exposure levels attributed to emissions from the radio transmitting apparatus were well within the EMF reference level for exposure to the general public established in the ICNIRP Guidelines.
- Further analysis was carried out on children's public recreational areas where it was found that on average the EMF exposure value in the respective recreational

areas were just around 2% of the ICNIRP safe reference level of 27.7 V/m or equivalent to 0.04% of the ICNIRP safe reference level of 2W/m2. Such findings therefore indicate that EMF values to which one is exposed at the children's public recreational areas are well below the safe reference EMF exposure levels as recommended by ICNIRP.

Recommendations

Key recommendations of the effort are:

- Mobile network traffic and the resulting EMF emissions vary by location during the day. Establishing the network peak hours where the EMF emissions will be at its maximum for the respective administrative units in the Maltese Islands would have provided further insight onto the maximum EMF exposure levels which the public is exposed to.
- The installation of fixed EMF monitoring equipment at the children's public recreational parks would provide continuous 24/7 monitoring of the EMF levels present at the respective parks. Such a monitoring activity will provide the necessary reassurance that the EMF exposure levels at any point in time during the day, the EMF exposure levels are well within the safe reference limit as reflected in the ICNIRP Guidelines.

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CHAPTER 29

Analysing the EMF exposure levels in the vicinity of Over the Horizon Transmitting Tower

Kevin Aquilina

Keywords

Electromagnetic Field, Transmitting Tower, Radio Station, GIS, EMF exposure, Għargħur

Project Aim

In view of the potential risks to continuous EMF exposure to the public residing in the vicinity of such a high-power radio transmitter, the analysis carried out in this project identifies potential areas where the exposure of electromagnetic fields emanating from such a transmitter are relatively high when compared to the surrounding areas. Through in situ EMF measurements carried out in the area under investigation, the data collected was analysed and displayed using GIS. The identification of potential hotspots where there may exist high levels of EMF, will, through the installation of permanent EMF monitoring stations, monitor and ensure that the EMF exposure to the public is within the applicable safe EMF levels in Malta.

It is important to note that the EMF exposure within the surrounding areas of the tower which is accessible to the public is well within the safe EMF exposure levels applicable in Malta.

Introduction

FM broadcasting is a method of radio broadcasting using frequency modulation (FM). FM broadcasting is capable of higher fidelity—that is, more accurate reproduction of the original program sound—than other broadcasting technologies, such as AM broadcasting. Therefore, FM is used for most broadcasts of music or general audio (in the audio spectrum).

In Malta, there are currently more than twenty FM radio stations, thirteen of which are broadcasted from the Għargħur transmitter. As in most countries throughout the world, the FM broadcast band utilised in Malta falls within the VHF part of the radio spectrum; 87.5 MHz to 108.0 MHz which is classified to form part of the non-ionizing radiation.

The output power of a FM broadcasting transmitter is one of the parameters that governs how far a transmission will cover. The other important parameters are the height of the transmitting antenna and the antenna gain. The transmitting power currently employed at the Għargħur tower is around 3KW. By the laws of physics, the electromagnetic fields generated by such a high-power transmission are relatively high. To cater for such a risk, the area in the immediate vicinity of the transmitting antennas is controlled by virtue of it being inside the perimeter fence. However, due to the high transmitting powers involved, albeit within the applicable safe EMF levels, the exposure in the surrounding areas beyond the perimeter fence are usually still relatively high when compared to the background EMF radiation levels present.

The International Commission on Non-Ionizing Radiation Protection (ICNIRP) provides scientific advice and guidance on the health and environmental effects of non-ionizing radiation (NIR). The ICNIRP Guidelines establish thresholds that safeguard from exposure to EMF. These thresholds are founded on known health effects. The ICNIRP Guidelines also facilitate reference levels to help determine whether these basic restrictions are likely to be exceeded. Compliance with the reference levels will ensure compliance with the basic restrictions. The ICNIRP Guidelines set different limits for the protection of workers (occupational exposure) and the protection of the public. The limits for workers tend to be higher than those for the public. The guidelines set by the ICNIRP also vary for different frequency ranges. The operating frequency range of the FM radios station is from 87MHz to 108MHz., due to the comparable reasonable wavelengths to the human physical characteristics that fall within the minimum safe level of EMF exposure. According to the guidelines, the safe EMF exposure level for such operating frequencies shall not exceed 28V/m which is relatively low when compared to 61V/m for mobile telephony technologies.

The Malta Communications Authority (MCA) is the competent Authority in Malta responsible to ensure that all radio transmitting equipment comply with the EMF exposure limits applicable at Law. In carrying out such a task, the MCA carries out street level "in situ" EMF measurements at static points spread around all Malta. The surrounding area of the FM transmitting tower is one of the static test points which the MCA audits regularly.

Recently, the MCA has invested in a mobile EMF measurement equipment, whereby through drive testing campaigns, a continuous real-time monitoring across the area covered is provided. Such EMF drive tests were carried out across the island of Malta, including the area of Għargħur. Such a measurement campaign will assist the MCA to portray a high-resolution picture (30cm resolution) of the EMF exposure levels presented in the respective village of Għargħur.

The measurement campaign has provided the MCA with thousands of EMF measurements whose data set was eventually converted to an EMF intensity map generated using GIS software solutions. The high-resolution EMF exposure maps generated therefore provide the general public with a complete picture of the EMF exposure levels around the streets of Għargħur. They also assist the MCA to identify any particular hotpots where the EMF exposure is relatively high when compared with the surrounding area under study. These hotspots will serve as the ideal locations where to carry out in-situ EMF audits as well as for the placement of fixed EMF Monitoring Probes.

The primary objectives of this project are two-fold, namely:

(a) In view of the concerns among the general public about electromagnetic fields generated by the high-power transmitter, the aim is to generate a detailed map clearly indicating the real-life EMF exposure levels in the surrounding perimeter of such transmitting infrastructure as well as the neighbouring areas.

(b) to determine hotspots where the EMF exposure level is relatively high so that permanent monitoring stations with the aim to provide continuous measurement of electro-magnetic fields are permanently installed. The real time monitoring information shall then be made available over the internet for public consumption.

It is imperative to note once again that the EMF exposure levels in areas which are accessible to the public fall within the EMF safe limits as prescribed at law.

Methodology

The data was collected by means of a dedicated mobile EMF measurement system that was installed on a vehicle. The frequency range of the monitoring probe covers the frequency bands between 20 Khz and 40 Ghz. All measurements were carried out according to the International Telecommunications Union (ITU) Recommendation on Generation of radiofrequency electromagnetic field level maps – ITU - T K.113. The data set containing the EMF measurements collected during the drive tests were converted from .txt format to .csv format and imported as a vector layer in QGIS.

In view that the study area is concentrated in the surrounding area around the transmitting tower, a buffer of 1000m, centre point being the transmitting tower was generated (Figure 1). Any data points falling outside the perimeter of the buffer, by using the clip function in the vector geoprocessing tools, were excluded from the analysis. The EMF measurements under analysis were categorised according to the measured EMF exposure level (Figure 2). A buffer was created around the EMF data points which fall within the areas of maximum EMF exposure. The EMF exposure levels which were at this stage being analysed varied between 1.69v/m and 9.97v/m (Figure 3).

Figure 1: 1000m buffer zone indicating the EMF measurement under analysis

Figure 2: EMF measurements under analysis after being categorized according to the measured EMF exposure level.

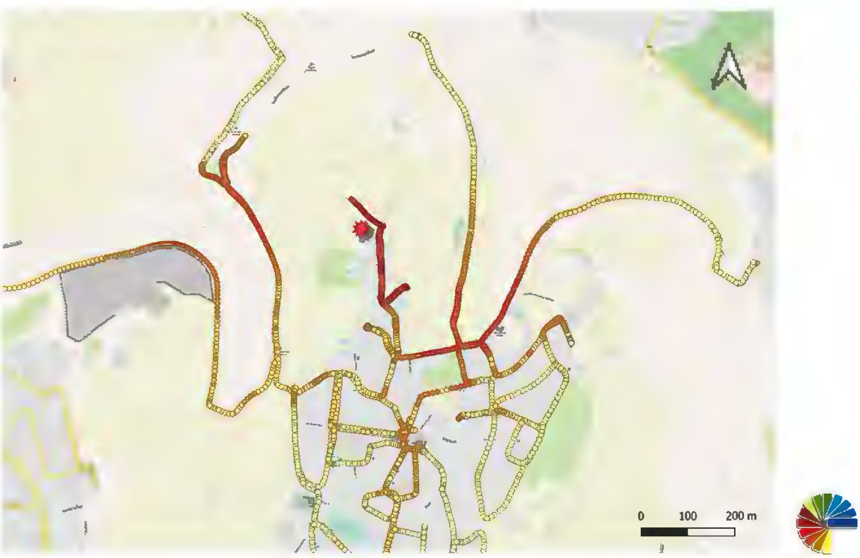
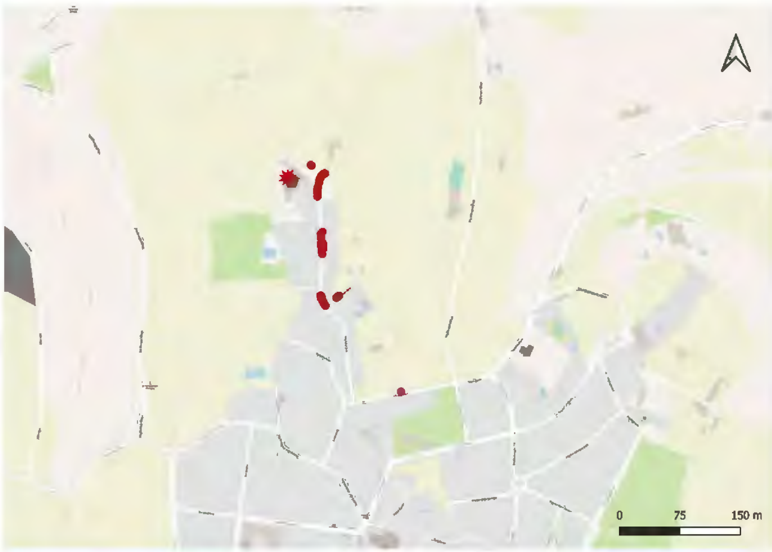


Figure 3: Buffer around the EMF data points which fall within the areas of maximum EMF exposure

Discussion

Figure 4 identifies the locations within a 1000m radius from the transmitting tower where the EMF exposure levels are the highest and therefore pose the highest risk of any significant danger when compared to the surrounding area. The areas marked in red in Figure 4 represent areas where the EMF exposure levels exceeded an exposure level of 7V/m; being approximately 10% of the 28V/m safe EMF exposure level applicable at the respective FM transmit frequencies. This analysis also confirmed that the EMF exposure levels around areas which are accessible to the public in the entire town of Għargħur, as emanated by the high power over the horizon transmitter, fall well within the EMF safe exposure levels applicable in Malta.

Figure 4: Identified hot spot areas of relatively high EMF exposure levels



To corroborate the findings through the spatial analysis as described above, EMF audits were carried out at the identified hotspots using narrow band spectrum analysers which in turn analyse the separate spectrum components which make up the combined EMF level present. From the measurements obtained when using the narrow band spectrum analyser, it clearly showed that the main contributor for the EMF radiation was indeed the FM spectrum.

Results

The analysis carried out showed that the levels of EMF primarily generated by the transmitting tower varied between 0.11V/m to 9.97V/m. The ICNIRP limits vary according to the frequency of the emission. The limit for FM Radio is 28V/m ICNIRP (2020). These hotspots will serve as the ideal locations to carry out in-situ EMF audits as well as for the placement of fixed EMF monitoring probes.

Recommendations

- Educate and publish such findings to assure the public that there is no inherent danger. The data obtained from the fixed EMF monitoring probe sensors are collected in a centralized database and will be available through a user-friendly web portal. The web portal will present results of investigation for each sensor showing the overall level of EMF.

- Although the EMF exposure levels, as generated by current over the horizon radio transmitter infrastructure in the residential area of Għargħur, did not exceed the permissible EMF safe limits, it is recommended that such high- power broadcasting radio transmitters are preferably located in areas which are less cohabited with the general public.

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CHAPTER 30

Protected Areas Connectivity & Spatial Analysis for Strategic Integration of Green Infrastructure in Malta

Anna Gureva-Mihova

Keywords
Protected areas, connectivity, green infrastructure, spatial analysis, clustering, urban areas

Project Aim

The aims of this project were: (1) to assess connectivity/clustering of terrestrial PAs and urban areas in Malta using GIS analytical tool; and (2) to identify strategic locations for integrating GI in urban areas and along major roads to support PA cohesion by using buffers.

Introduction

According to data from the European Environment Agency (EEA), Malta has the highest percentage in the EU of soil sealing and has among the lowest percentage of GI and green open spaces. At the same time, the large number of people living in urban areas rely on ecosystem services provided by the nearby natural environment. GI essentially refers to using green and environmental features to help reap multiple social (e.g. more attractive and greener villages and towns, health benefits) and environmental benefits (e.g. natural climate and flood regulation, removal of pollutants) from the same area of land by promoting a multifunctional landscape. The European Commission defines GI as natural and semi-natural areas with other environmental features designed and managed to deliver ecosystem services.

This study provided GIS analytical evaluation of clustering of terrestrial PAs and urban areas in Malta as a sign for their connectivity. The spatial clustering was assessed by using the Nearest Neighbour Analysis tool of QGIS, version 3.6.3. The applied methods included literature review, use of analytical tools, application of geometry and geoprocessing functions such as clip, buffer, dissolve and intersect. As a part of the literature review process, several indicators for PAs connectivity and urban GI were researched as well as information related to the links between human health, biodiversity conservation, urban resilience, and green open spaces together with recommendations in these regards by the World Health Organisation (WHO), EU, official national entities and other credible sources. The literature review also included a thorough review of studies about GI and methods for identifying locations using buffers and geospatial analysis tools. Based on the literature review and considering the intended outcome of the study, different research methods were selected.

Methodology

The analytical tool applied in this project is the Nearest Neighbour analysis performed to evaluate whether there is clustering of the terrestrial PAs and urban areas as a sign for spatial proximity or connectivity. In this connection, to complete the Nearest Neighbour analysis centroids layers for both, the PAs and urban areas datasets were generated. This action was necessary as the Nearest Neighbour analysis uses point layers to assess spatial relationship between features (Figures 1 and 2).

Figure 1: Centroids Urban Areas

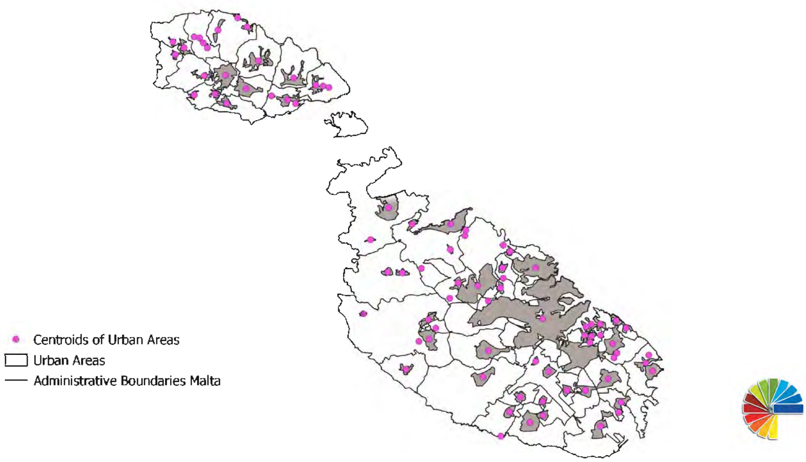
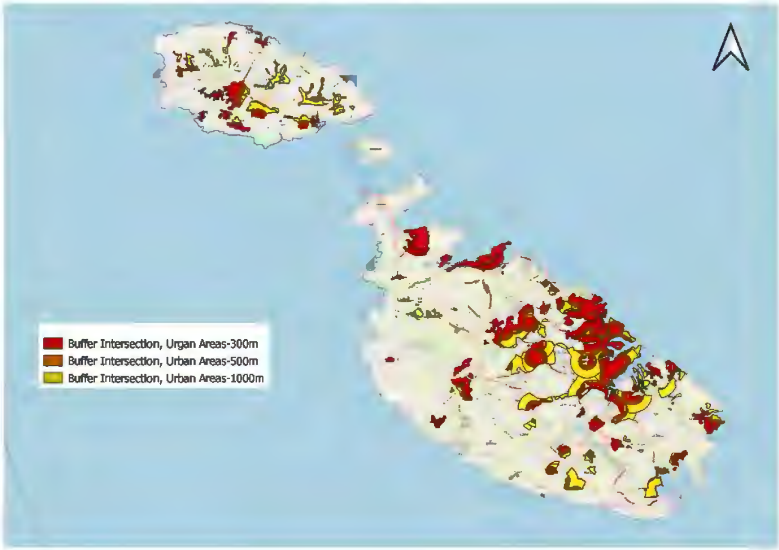


Figure 2: Urban Areas Identified for GI Projects



Geoprocessing functions were applied among the other research methods. To remove all marine PA polygons for the analysis, the Clip function of the vector Geoprocessing tool was applied to keep only the PA polygons which lay within the terrestrial boundaries of Malta. Moreover, buffers were generated around terrestrial PAs to support the identification of nearby urban areas and areas along major roads that can be further examined for implementation of GI features. Considering various studies that examine the importance of having urban areas near natural areas and the local context, three different buffer options (300m, 500m and 1000m) were created. From an environmental perspective the greener open spaces there are, the better. However, due to the relatively small size of Malta and the many competing interests for land use, the relatively small buffer sizes were considered appropriate for the purposes of this project.

In addition, the Dissolve function of the Geoprocessing tool was used to remove all overlaps of the generated buffers for better visual representation of the outcome, while the created and dissolved buffers were intersected with the urban areas' polygons, as well as with the TEN-T roads layer. The new datasets with the intersections represent the areas identified for potential locations of GI projects. The outcomes were proposed as different strategic locations, based on environmental, health and social benefits of having more urban green open spaces bordering existing PAs with the aim to promote spatial multifunctionality and better cohesion.

Figure 3: TEN-T Road Network Areas Identified for GI Projects

Discussion

The performed analysis and the literature review suggested that both PAs and urban areas in Malta show clustering, whereby the occurrence of these spatial categories was typically concentrated in proximity areas with similar spatial features. However, integration of GI features was proposed as a possible way for enhancing PA connectivity, mitigating land-use fragmentation, while strengthening urban resilience and promoting community development. Even though PAs seem to be connected in Malta, the natural resources together with the biodiversity are under significant pressure due to limited territory and high population density. Creating opportunities to promote and safeguard biodiversity should be ensured not only in PAs but also in urban areas via the provision of green open spaces and deployment of GI.

In the national context, aspects of GI are addressed by several national governmental entities due to its cross-cutting nature. The Malta Environment and Resources Authority (ERA) addresses issues related to Natura 2000, biodiversity, and ecosystem services, whereas the Planning Authority focuses on spatial planning. Other national authorities that contribute to the implementation of the GI concept include the Malta Competition and Consumer Affairs Authority, which leads on standardization projects such as the National Green Roofs Standard, and Ambjent Malta, mainly responsible for the upkeep and maintenance of public green open spaces in various localities. The lead entity to consolidate national efforts and to ensure that national, EU and international targets on GI development and implementation are met in a timely manner, still needs to be identified whilst remits and responsibilities of the various stakeholders are yet to be established.

Furthermore, based on EEA aggregated data, Malta is at the top of the charts for imperviousness in the EU and a significant part of the land is built-up, which leads to increase in the risk of flooding, soil degradation and biodiversity loss. Therefore, it was recommended that strategic measures are taken to increase green open spaces in urban areas to support biodiversity, to improve human health through better access, while alleviating the risks of extreme weather events such as excess heat and floods. The identified potential locations for strategic GI projects within urban areas in this research could be considered as a preliminary attempt to find suitable sites within urban areas that are in proximity of PAs, where their greening could also potentially support national biodiversity conservation objectives.

In relation to road infrastructure, GI elements along roads could provide a source control for main contributors of stormwater runoff causing often floods and pollution. Additionally, GI could be successfully used along roads to mitigate noise, excess heat, to improve the landscaping and provide habitats for biodiversity, such as pollinators and birds. The identified GI locations along major roads in this study could be considered as a starting point for further suitability analysis based on various factors.

Globally there is an increasing understanding for the need of green spaces in urban areas to mitigate urban sprawl and promote ecological coherence with PAs, as well as to support the proper functions of the ecosystems. GI and nature-based solutions are gaining momentum and popularity as potential answers to multiple social, health, economic and environmental problems, if such projects are planned and implemented properly. Moreover, considering the ongoing COVID-19 global pandemic, urban green spaces were highlighted as an important public health asset by the WHO, governments, and the research community.

Results

In conclusion, the results of this study were generic and did not consider all aspects related to deployment of GI, such as land ownership. Thus, further shortlisting of areas suitable for implementation of GI features would require detailed analysis based on several different factors such as existing vegetation, population density and planning issues to assess the proposed locations on a case-by-case basis.

Key results of this project are:

- The analysis of the Nearest Neighbour Index (NNI) showed, as a result for both PAs and urban areas, that there is spatial clustering. In addition, the Z-scores of these areas also showed clustering.
- Several urban areas were identified resulting from the intersection with 300m, 500m and 1000m buffers around PAs. The urban areas within 300m from PAs could be considered for further evaluation as the first step towards wider national greening of the urban environment.
- Since a large part of the TEN-T road network in Malta is located within 300m distance from PAs, such areas should be prioritised for implementation of GI projects along major roads.

Recommendations

Key recommendations of the effort are:

- To take strategic measures for increasing green open spaces in urban areas, within at least 300m from PAs, to support biodiversity, to improve human health and to foster PA connectivity, while at the same time reducing pollution and alleviating the risks of extreme weather events, such as excess heat and floods.
- To start with considerations for integrating GI features along major roads at 300m from PAs.
- It is suggested that the specific conditions and the complexity of each proposed site are further evaluated on a case-by-case basis to maximise the potential of GI projects.

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CHAPTER 31

Use of LiDAR data to analyse the Solar Potential of building envelopes in the Maltese Islands

Charmaine Zahra

Keywords

Photovoltaic solar panels, irradiance, building envelopes, renewable energy, Digital Surface Models, LiDAR, UMEP plugin, SEBE tool, QGIS, Maltese Islands

Project Aim

The aims are: (1) to implement the correct processing techniques of LiDAR data using non-commercial GIS software tools, (2) identify the best location and site of solar panels, (3) to estimate the solar energy potential on building envelopes, (4) to produce of a solar irradiance map.

Introduction

State-of-the-policy

Urban living constitutes more than half of the worlds' population, and this is projected to continue to increase (UN DESA,2018). Populations consume energy in fact around 40% of the total energy consumption in the European Union (EU) is from buildings. However, given the possibility of integrating photovoltaic systems, the same building can also generate energy from the sun (In Focus, 2020). The increasing thought given to environmental matters, growing awareness and attention to solar energy applications and promotion of construction of sustainable buildings in the EU, has probed the design of buildings as one way of helping in the pursuit of global sustainability (In Focus, 2020; Owen Lewis et al., 2013). The generation of energy from the sun for whole cities is nowadays possible given the high performance of current technologies (Aste et al., 2017). The aim of the 2030 EU Framework for climate and energy, is to attain at least 32% share of renewable energy consumption and a minimum of 32.5% improvement in energy efficacy (European Commission).

Malta is mainly reliant on fossil fuel for energy requirements (Franzitta et al., 2016; Yousif and Scerri, 1996; Buhagiar et al., 2007), and this makes it prone to any variations in the fossil fuel market. Furthermore, the consumption of electricity is rising. In Malta, the energy conservation and renewable energy sector has been gaining grounds, given that the government has issued grants to encourage and help the public to invest in solar energy. Investing in photovoltaic energy is ideal in Malta as the Islands receive a plenty of solar irradiance (Buhagiar et al., 2007; Yousif and Scerri, 1996). Solar panels would preferably be decentralized in view of land shortage and therefore rooftops would be ideal in both residential and commercial buildings whether private or public (Farrugia et al., 2005). Moreover, buildings and roofs are very often flat, easily accessible and roofs are used namely for hanging washed clothes (Yousif and Scerri, 1996), and for recreations, although the type of buildings that are nowadays being constructed such as apartments and penthouses has decreased the roof space (Times of Malta, 2014).

Studies on solar irradiance in Malta are lacking. The first study on solar radiation in Malta and solar measuring instruments was in 1965 which was followed by a study of the radiation climate. Other studies were carried out at the University of Malta and at the Austrian-Maltese Research Centre (Yousif and Scerri, 1996).

LiDAR is a powerful technology for collecting 3D spatial data and information providing accurate height, angles, and coordinates of buildings. Several tools can be used and have been used to calculate the solar potential on building envelopes (Freitas et al., 2015; Brito et al., 2019; Suomalainen et al., 2017). In 2012 and 2018, LiDAR technology was used to construct a 3D map of the Maltese Islands (Formosa, 2013, 2014, 2021). To the author's knowledge the use of LiDAR data for the solar potential analysis of building envelopes using the Solar Energy on Building Envelopes (SEBE) tool is a relatively new application to the Maltese Islands. Given the relative ease of use of this tool, scaling up to cover whole villages and the building of a solar potential map can be achieved effortlessly (Prieto et al., 2019). This will help professionals, authorities, and citizens alike to decide whether to install, integrate and invest in solar energy systems on buildings even if one is not acquainted with an advanced science background (Freitas, 2018).

LiDAR data has been shown useful for studying solar potential on buildings and ground areas (Prieto et al., 2019; Freitas et al., 2015; Brito et al., 2019; Suomalainen et al., 2017). This study uses LiDAR data and non-commercial Geographic information systems (GIS) tools for analysis following the published method by Prieto et al., 2019.

Methodology

This section follows the method published by Prieto et al., 2019. The tool manual by Lindberg et al., 2019 was used as a guidance.

Software and data required

The following software tools were used in this project:

- Quantum Geographic Information System (QGIS)™ 3.16.4; an open-source s/w used for processing of geographic data
- Urban Multi-Scale Environmental Predictor™ (UMEP) (Lindberg et al., 2018); a QGIS plugin used for environmental services
- UMEP MetPreprocessor; used to prepare the weather data in the format required by the SEBE tool
- UMEP Aspect and Height; used to analysis the compass direction and heights of the walls and buildings from Digital Surface Model (DSM)
- SEBE Tool (Lindberg et al., 2015); used to calculate the pixel-wise potential solar energy potential

The initial data required include:

- DSM (Planning Authority, Malta); LiDAR file with elevation information
- Weather Data (POWER, 2021); detailed weather information

Defining the study area

The study focused on an area in the Maltese Islands. Only part of the town of Rabat was analysed (Figures 1-4). The area contains residential development, commercial development, and open areas. The DSM files used for this project were obtained from Planning Authority, Malta (SIntegraM data, 2018).

Figure 1: Height raster shows the identified wall pixels

Figure 2: Aspect raster shows the compass direction of the walls and buildings

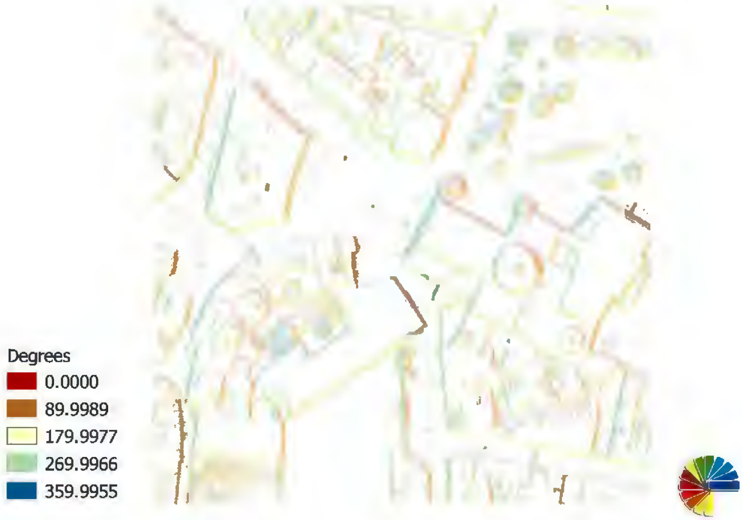


Figure 3: Raster showing the annual cumulative incident radiation per square meter for roofs

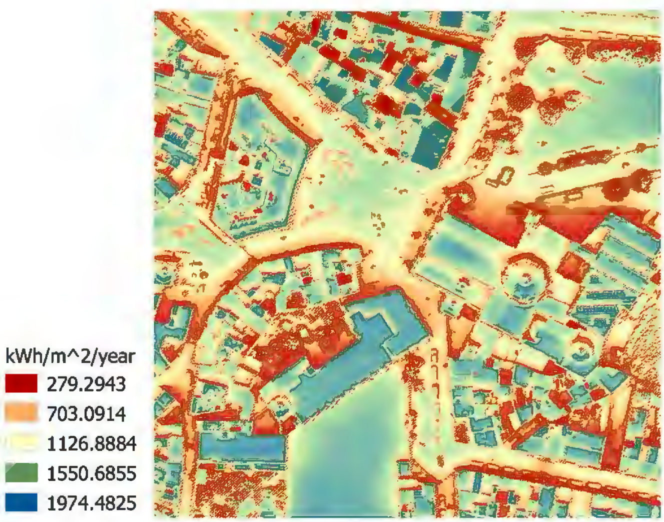
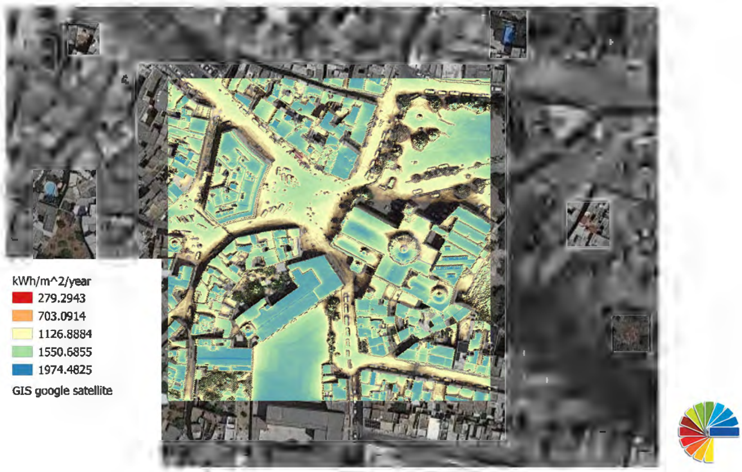


Figure 4: Raster showing only the pixels above 900kWh/m2/year



Study area split

The study area (original DSM tile) was split by creating a VRT mosaic (How to in QGIS, 2016) for further processing as the UMEP tool is not able to complete calculations with large raster files. The max columns and max rows were defined as 1000 in the 'save raster layer as' dialog box VRT tiles section. All the other settings were left as default.

Aspect and height

The raster file (split file) obtained in the previous section (study area split) was processed further to calculate the orientations and heights of the walls and buildings. This process was performed using the UMEP tool, specifically the aspect and height function. In the dialog box, the DSM file was loaded, the lower limit of wall height was specified, and the output folder is selected. The lower limit of wall height was specified as 2m. Since walls were unclear, a lower threshold was used. This affects only the wall irradiance and not the rooftop irradiance (GitHub, personal communication, March 2021).

Meteorological Data

The UMEP requires a description of the meteorological data/conditions as one of the inputs. Weather data was downloaded from POWER project https://power.larc.nasa.gov/beta/data-access-viewer/ (POWER, 2021). POWER project provides hourly weather data as required by the UMEP tool. The following options were specified in the dialog box:

- User Community: renewable energy
- Temporal Average: hourly

- Malta was selected using the point icon on the map
- Time Extent: 01/01/2015 till 31/12/2019
- Output file format: Comma-Separated Values (CSV)
- Desired parameters were selected

Data was processed to acquire UMEP meteorological weather file because the tool recognizes the weather file in a specific format. This was performed using the UMEP MetPreprocessor tool, 'prepare existing data' function.

In the dialog box of the MetPreprocessor tool, the downloaded weather file was loaded, the time related variables and the meteorological variables were selected. The POWER weather data and UMEP meteorological parameters were matched as shown in Table 1.

Table 1: UMEP meteorological parameters

UMEP tool variables	**POWER data file parameters**
Year	Year
Month	Month
Day of month	Day of month
Hour	Hour
Minute	Minute
Incoming shortwave radiation (W/m^2)	All Sky Surface Shortwave Downward Irradiance (W/m^2)
Windspeed (m/s)	Wind Speed at 10 Meters (m/s)
Relative Humidity (%)	Relative Humidity at 2 Meters (%)
Barometric pressure (KPa)	Surface Pressure (kPa)
Air temperature (°C)	Temperature at 2 Meters (°C)
Rainfall (mm)	Precipitation Corrected (mm/hour)
Incoming longwave radiation (W/m^2)	All Sky Surface Longwave Downward Irradiance (W/m^2)
Wind direction (°)	Wind Direction at 10 Meters (Degrees)

The output file was saved as a .txt file. This is the UMEP meteorological file, which was subsequently used in the SEBE tool.

Estimating the solar energy potential

The SEBE plugin was used to calculate the solar energy potential at the pixel level. The inputs required include DSM (split tile obtained in step called 'study area split'), aspect raster and height raster and the prepared weather file. The albedo was left as default (0.15) whilst the UTC offset (hours) was set as 1. The SEBE calculation needs to be performed for each section (split tile) of the study area using the same parameters and weather file.

Discussion

Determining the suitable location of solar panels

For solar panels to be valuable, the location chosen must be suitable and appropriate, with specific characteristics. To identify the best location where to place solar panels requires defining the necessary characteristics, namely elevation (height) and aspect (compass direction). The height raster (Figure 1) shows the wall pixels and their height from the DSM file. The symbology chosen is hill shade for better visualisation of the building and wall pixels.

The aspect raster (Figure 2) shows the compass direction of the pixels of the study area chosen. Malta is in the northern hemisphere and thus solar panels, located on south-facing areas will have a higher solar power output than those located on north-facing areas, as the solar panels will face the sun all day long and therefore the maximum possible time to collect sunlight and convert it into energy. Figure 2 shows only the south facing areas from around 100o to 260o for better visualisation.

Solar Potential Analysis

The solar radiation map represents the annual cumulative incident radiation per square meter for roofs in kWh/m2/year (Figure 3). The red values represent areas of minimal sun exposure (lowest irradiance), while the blue values correspond to high irradiance. To better visualize where to place solar panels, the amount of energy received needs to be cost effective. As irradiance below 900kWh is considered low for solar energy production, only the pixels of interest are shown in figure 4, superimposed on the google satellite image. As can be observed, most roofs shown have a blue colouration indicating that the annual cumulative incidence on these roofs reaches 1974 kWh/m2/year. These roofs have a great potential for the application of solar energy technologies.

The UMEP tool is versatile, easy to use with a wide range of analysis capabilities. The results are affected by the parameters specified, weather data and vegetation. In this study, the results might have been affected namely by the vegetation as the vegetation was included in the original DSM. The SEBE tool can consider the vegetation in the analysis which can be uploaded separately as a vegetation canopy DSM. However, given the number of issues encountered throughout the study, time did not permit one to create a vegetation canopy DSM. To quantify vegetation/greenness and indicate its health, the

Normalized Difference Vegetation Index (NDVI) is required. Healthy vegetation reflects near infrared light but reflectance in the red waveband is low as this is absorbed, whilst the opposite occurs when vegetation is sparse or unhealthy. The NDVI is calculated by subtracting the spectral reflectance in the red band from the spectral reflectance measured in the near infrared and divides this by the sum of the near infra-red and red waveband reflectance (Earth Observatory, 2000).

Another factor that needs to be considered is the actual useful surface of roofs. Roofs might contain structures that would not permit placing solar panels such as a skylight. The age of buildings is another factor that needs to be taken into consideration. Old buildings might not be able to withstand the load of panels or are of heritage value and therefore placing of solar panels would not be allowed.

Results

Key results of this project are:

- The height raster obtained identified the wall pixels
- The aspect raster identified the compass direction of the walls and buildings.
- The annual solar power (irradiance) of building roofs at the pixel level was obtained.

Recommendations

The two key recommendations for future work are:

- The tool SEBE can estimate irradiance of building walls not only roofs, and thus would increase the usefulness of buildings in terms of energy potential.
- The solar potential analysis can be replicated for other villages, following the described workflow, ultimately to produce an irradiance map of the whole of Malta.

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CHAPTER 32

A Web-Based GIS Waste Data Management System

Claudia Attard and Sergio Tartaglia

Keywords
Waste Management, Real-time Data, data collection, Data visualisation, Malta

Project Aim

Taking into consideration Malta's vision as set out in the Long-Term Waste Management Plan 2021 – 2030 (MECP, 2020), the two combined research projects aimed to:

1. identify the key issues related to waste data management;
2. understand the benefits and potential application of ArcGIS Online© as a tool for gathering and visualising spatial information on the collection of recyclables in the Maltese Islands;
3. design a prototype of a system which facilitates waste data collection and visualisation; and
4. valuate the effectiveness of the system.

Introduction

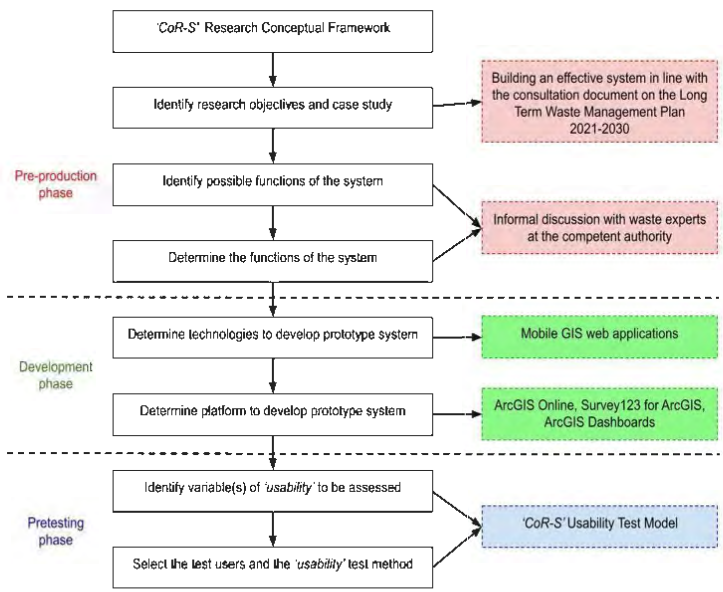
The consultation document on the Long-Term Waste Management Plan 2021-2030 (MECP, 2020) acknowledges that the current processes related to waste data management face several weaknesses in terms of frequency, reliability, and accuracy. In view of such deficiencies, the policy document emphasised the importance and need to design and develop an integrated nationwide waste data management system, making waste data management in Malta smarter, faster and more effective (MECP, 2020; p. 205).

Digital technologies are transforming the way people organize, interact, and operate together, as they connect individuals with each other and with their surrounding environments (Bibri et al., 2017). Geographic Information Systems, GIS, technology is envisaged to be an effective tool for providing sustainable solutions and services to both public and private organisations. Resource management (in this case, waste) and the challenge of gathering and visualising reliable information in a timely manner have become a critical part of any waste management system (Mavropoulos et al., 2013). The role of GIS in solid waste management is very broad since many aspects of its planning and operations depend on spatial information (Kyessi and Mwakalinga, 2009). Systems which are based on GIS are considered as a new means of efficiently managing services and infrastructures within smart cities, as well as sharing, exchanging, and communicating information in a progressively conversing information world.

Kerzner (2001) explains that effective GIS project management requires a detailed documented plan. During the planning, design and development stages it is critical to understand "what needs to be done and what it will take to get it done" (Tomlinson, 2007, p. 8), linking all the stages together (Somers, 2001). In this context, a spiral approach was adopted to build an effective model and investigate the factors that affect the design and development of the Collection of Recyclables System, CoR-S, prototypes. Based on the Atkin and Freimuth Step-by-Step Plan (1989), the CoR-S Research Conceptual Framework (Figure 1) was prepared, describing the main processes for the design and development of CoR-S as below:

1. The 'Pre-production Phase' covered the main functionalities of the proposed system and how such features were identified and determined,
2. The 'Development Phase' focused on the technologies used to develop the CoR-S, including a description of the spatial techniques applied, and
3. The 'Pretesting Phase' proposed a framework for the usability test of the CoR-S.

Figure 1: CoR-S Research Conceptual Framework



Methodology

1. The pre-production phase

During the pre-production phase, a case-study approach was utilised to investigate waste data management in a local context. The consultation document on the Long-Term Waste Management Plan 2021-2030 (MECP, 2020) for the Maltese Islands was chosen as the case study for this research, with an emphasis on the chapter dedicated to Data Management. The functionalities of the CoR-S were based on the main principles outlined in this paper and aim to propose a business model for the implementation of the following measures:

- To establish a mandatory electronic, web-based reporting platform for all waste operators, and
- to develop, continuously maintain and update a nationwide Integrated Waste Data Management System.

Kerzner (2001) believes that communication with a variety of stakeholders/users is a key factor to foster a successful GIS project management and as such, the users' requirements for the CoR-S were gathered through comments received following meetings conducted with waste management experts within the Environment & Resources Authority. The ideal system should allow:

- waste carriers to report information on the amount of recyclables collected from a specific local council, including information such as the destination of such waste;
- the producer responsibility organisations (PRO) and local councils to remain updated on the yields of recyclables being collected, keeping in mind their contractual and legal obligations; and
- the government and competent authorities to monitor in real-time the collection of such recyclables, enhancing monitoring and ensuring evidence-based policy making.

Defining the scope of the system entails establishing which data to obtain, how it would be obtained, when it would be required and how it would be presented (Tomlinson, 2007). Following an in-depth analysis of the case study, the CoR-S was categorised into two components:

- E-forms (hereinafter referred to as the CoR-S e-Forms) specifically designed and developed for waste carriers to report information (Figure 2), and
- Real-time dashboards (CoR-S Dashboards) designed and developed for the government, the competent authority, local councils, and economic operators to visualise the spatial information reported by the waste carriers through the CoR-S e-Forms.

Considering that this paper discusses two separate research projects, it is worth noting that two versions of both the e-form (Figure 2) and the dashboard (Figures 3 & 4) were developed. One targeted towards the collection of recyclables from bring-in sites and the other focused on the door-to-door collection of recyclables, with the aim to provide real-time data on the collection of dry recyclables in Malta and Gozo initiative.

Figure 2: CoR-S e-Forms using ArcGIS Survey123©

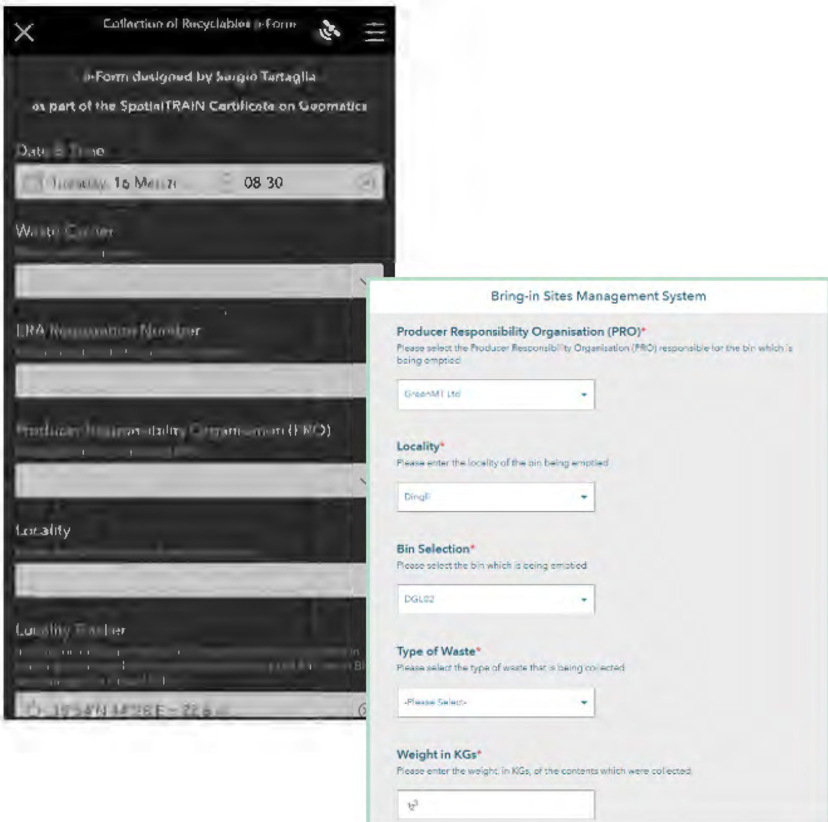
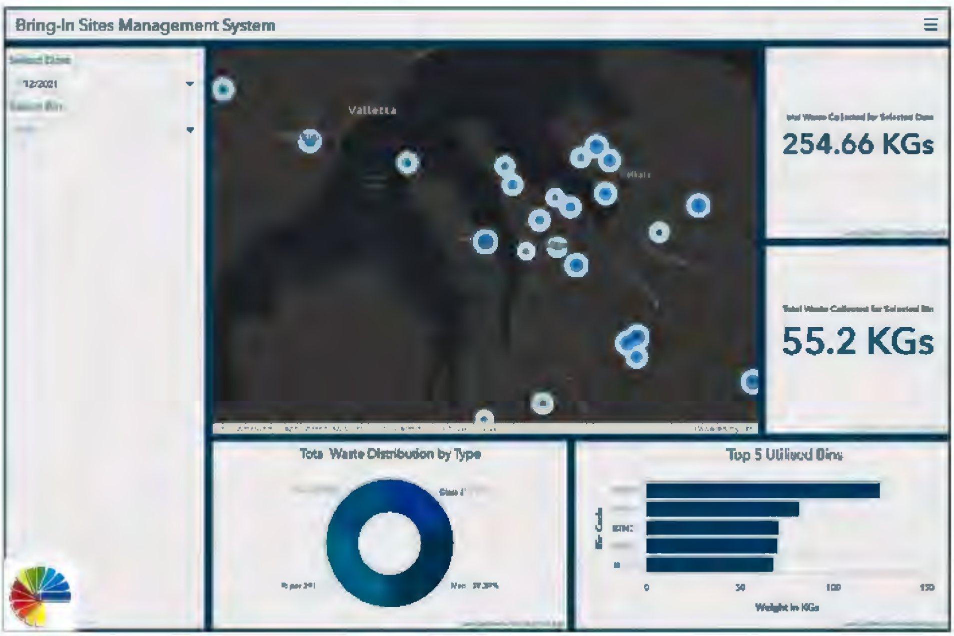


Figure 3: ArcGIS Dashboard© for the door-to-door collection system of recyclables

Figure 4: ArcGIS Dashboard© for the bring-in sites management system



2. The development phase

The first part of the development phase was about converting the system requirements into a product, requiring the researchers to determine the technology and the platform to use for developing the two main components of CoR-S. During the system design phase, one would identify the GIS components, such as the software requirements needed to support its specific GIS functions (Clarke, 2000). The identified requirements were:

- A complete, scalable and secure cloud-based technology for collecting information to make and share maps; and
- An optimised platform accessible through desktop computers and mobile devices.

Following research on the current available technologies and platforms, it was decided to create the CoR-S using ArcGIS Online© infrastructure, mainly for the following compelling reasons:

- a software-as-a-service (SaaS) that can be used anytime, anywhere,
- securely stores and manages vast amounts of spatial information,
- a complete mapping and analysis solution, which allows the researchers to easily share and access their work as well as to integrate it across all the tools offered by the platform,
- allows the researchers to develop custom apps for those in the field to reference or use for data collection, which can ultimately be used in apps and dashboards to create data and maps, and
- includes a variety of tools for the researchers to create interactive maps and which feature custom basemaps, multi-attribute symbology, and precise labelling for a better data visualization experience.

Three ArcGIS Online© applications were used in the creation of the CoR-S, namely:

- ArcGIS Survey123© for the development of the CoR-S e-Forms;
- ArcGIS Dashboards© for the development of the CoR-S Dashboards; and
- ArcGIS Map Viewer©, acting as a back-end for storing, analysing and managing of the data collected through the CoR-S e-Forms, with a view to publish and visualise such information on the CoR-S Dashboards.

ArcGIS Survey123© is a simple, intuitive form-centric data gathering solution which allows the creation, sharing, and analysis of surveys in simple steps (Kerski, 2018). Another software which was used is ArcGIS Survey123 Connect©, which is a desktop application that allows for the creation of more elaborate e-forms, when compared to the web-version of Survey123 (ESRI, n.d. a and ESRI, n.d. b).

Once the survey is filled in by the waste carriers, its results are stored in the ArcGIS Online© platform and can then be processed through the resulting ArcGIS Online Map Viewer©, through which data can be symbolized, classified, queried, analysed, and published accordingly (Kerski, 2018). One of the core elements of this research projects was that to identify the correct spatial tools required to amalgamate the data collected through the CoR-S e-Forms with other separate predefined datasets, namely the local council boundaries, waste management facilities and bring-in sites base layers. The datasets were opened and published as hosted feature layers, thus enabling spatial analysis to be conducted through the ArcGIS Online© platform.

For the door-to-door recyclables system, the researchers applied two one-to-one joins, one between the local council boundaries dataset and the dataset related to the CoR-S e-Form and another between the waste management facilities dataset and the CoR-S e-Form dataset. For the bring-in sites waste management system, two different types of joins (mainly a one-to-one join and a one-to-many join) between the dataset related to the CoR-S e-Form and the bring-in sites dataset were applied. Whilst the one-to-one join layer was mainly used for visualisation purposes of the map, the one-to-many join layer allowed for the calculation of statistics in the dashboard. The resultant join layers were also published as hosted feature layers to allow the data to update itself automatically whenever a new entry is received from any of the two e-Forms (ESRI, n.d. c). These datasets were then symbolised accordingly via the ArcGIS Online Map Viewer©, with the final map product featuring as one of the main elements on the CoR-s Dashboards.

Once the map elements were finalised, the last part of the development phase consisted of designing the actual CoR-S Dashboards. The map was the first element to be added to the dashboards, as the maps already available through the ArcGIS Online Map Viewer© could be utilised as a data source for the other elements (ESRI, n.d.d). An important aspect of the dashboards is that they enable the user to select and filter the data accordingly. In the door-to-door recyclables dashboard (Figure 3), the user can filter data by the local council or by waste management facility. In the bring-in-sites management system (Figure 4), the user can filter the data either by the date of waste collection, by the bring-in site code or both, with the indicators on the dashboard changing their values accordingly.

3. The pretesting phase

A usability test is an effective method applied to evaluate whether users can make effective use out of specific systems (Zhang and Adipat, 2005). It assists developers of a system in determining whether the test users can relate to the actual system, highlighting any features/processes which can be improved (Kaikkonen et al., 2005). A CoR-S

Usability Test Model was prepared, proposing the main steps that are to be performed throughout the usability test of such a system. For the scope of this project, the researchers recommended that:

- Field-based 'usability' tests would be the best approach for assessing the usability of the CoR-S mobile GIS web systems in a 'real-time' environment, and
- The sample population should consist of waste carriers, waste experts from the competent authority, and representatives from the PROs and local councils.

Results

The combined research projects analysed the novel concept of designing and developing an integrated waste data management system, illustrating the potential use of mobile GIS web applications as 'enablers'. The research delivered knowledge of those features of a GIS that can be modified and automated, such as data collection, data formatting, data validation, data uploading, data analysis and data visualisation, using different tools for the collection and editing of spatial data from the field, primarily through the application of ArcGIS Survey123© and ArcGIS Online Map Viewer©. Furthermore, a valuable discovery was the understanding on how to integrate geospatial information within a GIS interface, mainly using ArcGIS Dashboard©. These projects affirmed that ArcGIS Online© is a persuasive and smart cloud-based mapping tool to collect, disseminate and portray waste data to interested entities in an interactive and integrative manner. This dialogue has proven that GIS solutions have the potential to redefine waste data management as situational, collaborative, and lifelong.

Recommendations

Based on the analysis of the prototype CoR-S, it is recommended that endeavours should focus on:

- Conducting a field-based 'usability' test, ensuring a proper evaluation of a prototype system;
- Consulting all stakeholders involved (waste carriers, PROs and local councils), ensuring to capture all the users' needs;
- Expanding the systems beyond the collection of recyclables, also focusing on data gathering of other waste streams;
- Expanding the systems to cater for real-time tracking of the waste carriers' vehicle fleets, provided that all registered waste carriers install GPS trackers;
- Inclusion of additional indicators/elements in the ArcGIS Dashboards© to include further spatial analytics and statistics;
- Make available both e-forms in Maltese for better accessibility; and
- Combine the two CoR-S systems (door-to-door initiative and bring-in sites) into a single mobile GIS web-based application.

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CHAPTER 33

Analysing Impacts of Sea Water Level on Road Infrastructure Along Triq ix-Xatt Sliema, Malta

Joseph Bianco and Susanna Bonello

Keywords

Sea water, tides, inundation, flooding, coastal zone, road infrastructure, Malta

Project Aim

The aim was (a) to model the impact of flooding from different sea levels - tides and effects of seiches which occur in the area, and (b) study the zones most prone to flooding. In this way one can model the present situation and predict mid-term and long-term future scenarios, to aid engineers and planners when designing infrastructures and the planning of land uses in the area.

Introduction

An interesting feature in the sea level signals observed in Malta consists of a band of high frequency signals that is when the mean sea level pressure drops down suddenly and comes up again, creating water level variations, with periods ranging from several hours to a few minutes. These non-tidal short period sea level fluctuations are an expression of a coastal seiche, known by local fishermen as the 'milgħuba' (Drago 1999).

Measured water levels inside Marsamxett Harbour (Svasek 2001) show water level fluctuations of several decimetres with a period of about 20 minutes. These water level fluctuations are called seiches and are caused by internal resonance of atmospheric pressure fluctuations inside the bay.

From the data gathered by the Malta Hydrographic office, the measured seiche heights for November 2019 range from amplitudes of some centimetres to more than 0.40m. Seiches thus can be observed day by day during the years, however in this study we investigated the years of 2017, 2018 and 2019. It was clearly visible that during the months of March 2018 and November 2019 seiches (Figure 1) went over the 0.60m level in the Sliema Ferries Road and are presumed to be important for this study to find a limit of the most prone areas.

Figure 1: Triq ix-Xatt Sliema seawater inundation event -30th December 2019

Source: Malta Independent News portal

Methodology

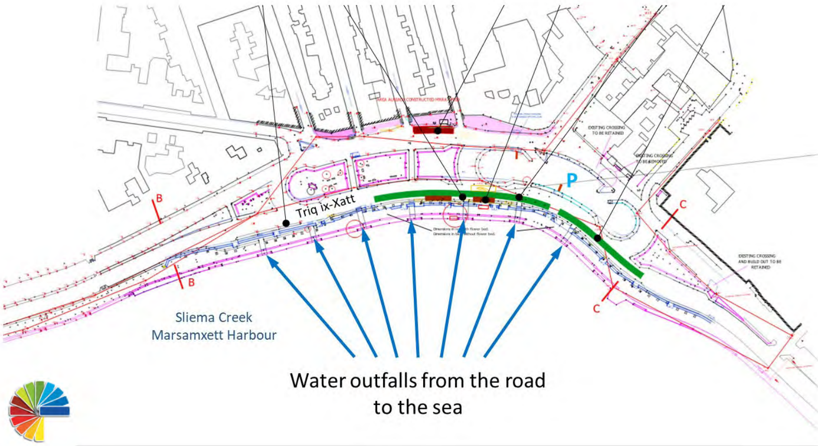
An AutoCAD Drawing in .dwg format was obtained from Transport Malta with an accurate land survey of the area however when coming to spot levels there seemed to be a lot of discrepancy possibly due to different surveys carried out. In view that this survey had an accurate layout of the current road configuration, therefore it was useful to determine the extents of the existing infrastructure.

The drawing included the survey of the area and the proposed layout for upgrading of the area which was implemented at the end of 2012 and the beginning of 2013. It includes built-up areas, promenade, roads and lane widths, footpaths, bus lanes and lay-bys, parking area and surface water run-off outfalls into the sea. (Figure 2) The Acad vector file contains points, lines and polygons and had no coordinate system. Therefore, the coordinate system of the drawing was transposed in AutoCAD™ prior to importing it in QGIS™. It was referenced to WGS84 EPSG 32633, then imported into QGIS and superimposed on Open Street map™.

A LIDAR survey was carried out by the Malta Planning Authority in 2012 through ERDF 156. The data was acquired in .las format as point data . The LAS tools™ plugin was downloaded. Once installed, all data was saved in the same folder and imported in QGIS with the LAS tools plugin.

The LAS tools have several features and the first process was to visualize the data. The LiDAR could be viewed as an aerial view to visualize the data and elevation in different colours. 3D visuals were also generated using the triangulate function from LAS tools menu in the lasview in QGIS.

Figure 2: Triq ix-Xatt Sliema, general road layout and land uses

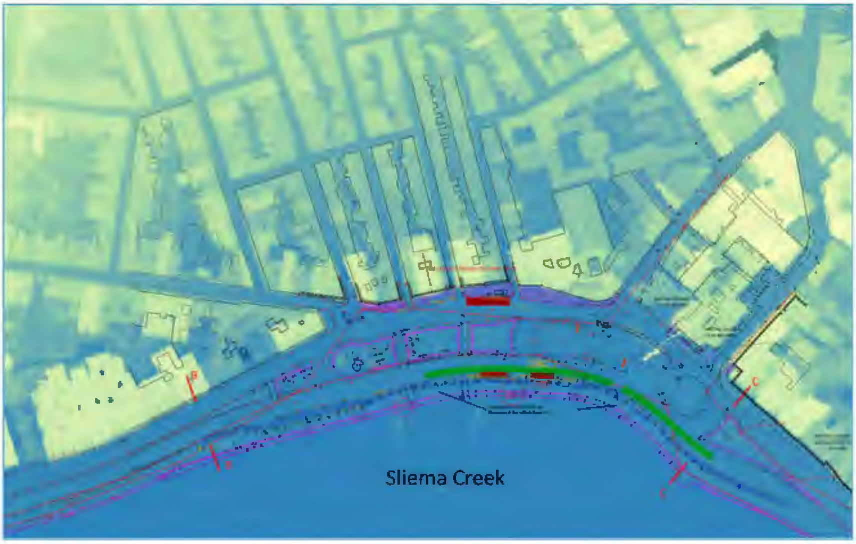


Source: Transport Malta archives (2012)

Using 'triangulate' command then the 3D is generated for the selected area. The different elevations indicate the road, landscaping, buildings, vehicles, and all structures which were captured by LiDAR, both temporary and permanent. After viewing and evaluating the area from the Processing Tools and using the LAS tools, the Las Ground function was used to create a file concentrating on the ground features. From LAS tools - File – Processing Points – lasground, a ground.las file was created and saved.

A Digital Elevation Model (DEM) file was generated from LAS tools. The DEM was then added as a raster layer into QGIS. It was noted that there was a displacement between the DEM and the Acad drawing, due to the improper coordinate conversion parameters. This was corrected using georeferencing from Raster, georeferencer plugin, to match the DEM to the survey as per Acad drawing (Figure 3).

Figure 3: Superimposition of the road layout onto the DEM generated from LiDAR



Source: QGIS

A hillshade was generated from the DEM. One could notice the objects at different heights according to the shade intensity. This confirmed that there were objects captured by the LiDAR covering some road levels.

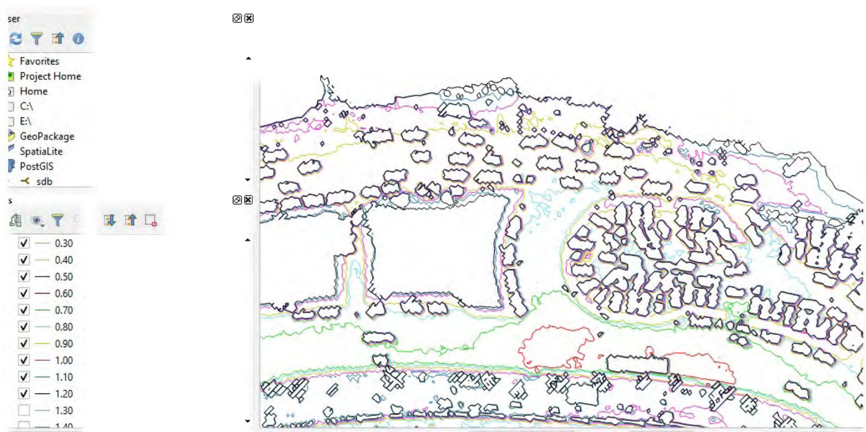
In preparation to generate the contours a text file of the points from LiDAR was created from Processing Tools - LAS tools - File conversion - Las2text. The 'ground.las' file was imported and an output file in .txt format was created. A text file was created and added in QGIS from Layer - Add Layer - Add Delimited Text Layer. The text file was used, the Encoding set as UTF8, entered the 'X' and 'Y' fields and ensured that the Geometry CRS was the same as that of the project and 'Add'. Using the LiDAR data and LAS tools, the contour lines were generated to analyse the tide levels and identify the inundated areas in the low-lying ground along Sliema Ferries. It was decided to use 0.10m intervals since we had already seen that the inundation due to tides varied from 0.50m MSL to 0.70m MSL in the most common cases.

In the 'Point Layer' the text file that was created previously was selected. In the 'Data Value' entered heights or levels. 'Remove duplicate' was checked and for 'Method' used Fixed contour interval for 0.10m to create contours at 0.10m intervals.

Discussion

When analysing the contours it was noticed that there were a lot of obstacles such as vehicles on the road, parked cars in the parking area, kiosks, tents and trees which generated contour lines at levels higher the road level (Figure 4). Hence it was decided to use the Autocad drawing which was an accurate representation of the street and nearby features to confirm that the contour levels were realistic. The Hydrographic Office of the Ports and Yachting Directorate within Transport Malta holds digital tide data which is currently stationed in Marsaxlokk port.

Figure 4: Resultant mapping of the flooding areas along Triq ix-Xatt Sliema



Source: QGIS

A set of water level measurements on site were taken to confirm that the vertical LiDAR data datum was referenced to the same water level datum. From the observations taken it was noted that there was only a 0.01m difference overall. Hence from these observations we concluded that the vertical datum of the tide data was an almost exact match with the LIDAR vertical datum and so the tide readings of Marsaxlokk could be safely used for this area as well.

To study the seiches effect better, digital data from the tide gauge at Marsaxlokk was downloaded. The vertical reference datum for this site is Least Astronomical Tide (LAT) which is 0.45m below MSL as per information provided by the Malta Hydrographic Office. Data was downloaded for the 3-year period under study that is from 2017 to 2019, as a sample for analysis. All the data had to be converted to MSL to be equivalent to the LIDAR data.

During the site inspection the outfalls were checked to ensure that they were still in place and that they link to the sea directly from the road. It was noted that storm water collection culverts on the building side are connected to the sea outfalls. A number of pedestrian crossings existing along the road with a refuge at road level between the opposite carriageways presented openings in the central strip that would allow water to pass from one carriageway to the other.

With respect to modelling, a polygon for the coastal road zone under study was created. Consequently, from research carried out various methods were identified and tested in QGIS to model the potential flooding zones.

The first method involved identifying the areas flooding at certain levels. The first level to be modelled was 0.6m. Raster calculator was used to polygonise the interested area, in this case using the expressions: DEM ≤ 0.60, then vectorised the areas, used select by location to locate the areas within the road zone under study and saved as a separate layer. This resulted in areas showing water flooding up to 0.60m level within the road zone. The areas were in the carriageway where the vehicles and buses pass. However, it was noted that the areas identified were possibly not realistic because of the LiDAR data captured. From the contours generated it was noted that the contours were showing the individual cars parked or travelling in the road captured in the position at the moment of data capture. Any structure in the field of view of the LiDAR was captured and hence such objects were blocking the actual levels of the road. This happened not just with cars but also landscaping features such as tree canopies, kiosks, street furniture on the footpaths, tented structures and the like under which water can pass and hence flood the area.

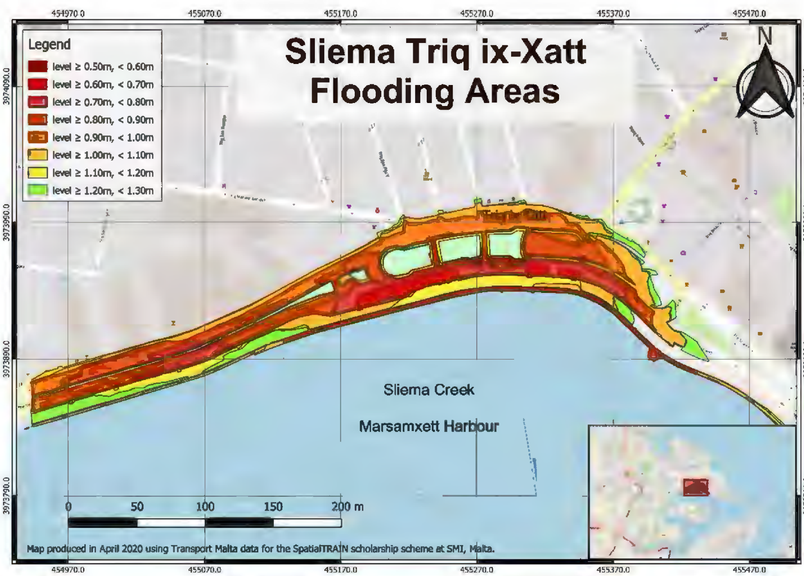
A second method used the r.lake tool which selected the areas within the 0.60m elevation, shown in yellow. Also tried to continue the 0.70m and other levels but the analysis was not successful possibly because there were no closed polygons in the contours. Hence following several attempts with different methods, it was decided to manually digitise the contours using the Autocad drawing as a guide with respect to the kerb alignments and the general layout of the area. The contours previously generated at 0.10m intervals were used. As explained earlier contours around kiosks, trees, cars, canopies etc were created hence using the Autocad as base and noting any contour level in between meant that this was to be included as well. Hence, this way objects which were temporarily in the way where ignored.

Polygons were digitised from levels ≥ 0.50m up to < 1.3m from MSL. Having completed all the contours then the overlaps were to be checked and thus by switching on editing and using the nodes tool the overlaps were removed. In some instances, it was noticed that the Lidar data did not extend up to the building but there was missing data, possibly because of balconies or canopies. Hence, the polygons had to be edited to extend to the actual building by moving the nodes. This was confirmed using google images and photos as reference.

With all the above methods, one would need to be careful as anything falling within the level under study would result in a polygon such as construction sites. Such areas were then deleted from the attribute table by selecting the polygon representing that zone and deleting its row from the table. Maps were generated for the different water levels under study and analysed.

From the maps generated one could see which areas would be flooded for each different level, and the extent of the impact (Figure 5). The higher the water level, the larger the area impacted and the closer to the buildings. Such inundations would have an adverse effect on the road users and in extreme conditions this may also cause traffic congestions in the area or a total road closure.

Figure 5: Areas would be flooded for each different level, and the extent of the impact



Results

Key results of this project were:

- From level 0.60m and above, the road level was affected by sea water inundation, on the seaside. In the level 0.70-0.80m the carriageway on the built-up side started being affected as well.
- From level 0.70m and above the road level was affected by sea water inundation, on the seaside for a continuous stretch of about 210m. At levels 0.80-0.90 m the carriageway on the built-up side was also affected for approximately 160m in length. The parking area started being flooded as well. At levels 0.90-1.0m, both carriageways were affected for the entire width for 400m.
- From level ≥ 0.90m, almost all the zone was covered - both carriageways and both directions of traffic and as well as most of the parking area.
- The most prone levels in the mid and long term were between 0.60m – 0.90m.
- From the data analysed it resulted that the level between 0.60m and 0.70m was the most prone to flooding in the road even without seiches. This resulted in an area of 889.66m2 using the Group Stats plugin which is used to calculate statistics for vector layers. (Figure 4).

Recommendations

Key recommendations of this study are:

- Any new cycle lanes in the area will get flooded from time to time if designed at road level along the seaside carriageway, so it is better to integrate such activity on the promenade which is at a higher level.
- Bicycle Racks. These are not recommendable in the lowest areas as they will not be safely accessible by users.
- Permanent structures like kiosks, tourist information office, public convenience within such areas. Their location is to be analysed in detail to avoid flooding and damages.
- Pedestrians crossing near the bus stops along the seaside may end up in a flooded road. One may consider shifting the bus stop bays locations, as long as this does not disrupt the routing of the buses. Alternatively, pedestrians may be advised through Variable Message Signs to avoid crossings located within the flooding zone and they may cross the road from other crossings located outside the flooded zone. The footpath levels may be altered as well.
- The installation of Electronic Variable Message Signs along the roadside as a safety precaution to alert drivers of flooding and to drive with caution.
- The same study may be conducted at other low-lying coastal zones around the Maltese Islands, such as Birżebbuġa, Marsaxlokk, Marsaskala and Msida to analyse and predict the potential impacts of sea water inundation.

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CHAPTER 34

Detecting volumetric alterations from drone & LIDAR data

Kevin Ciantar

Keywords

DTM, UAV, Photogrammetry, Volumetric computation, Land use, Illegality monitoring

Project Aim

This project aimed to: (1) detect the intensification of illegal activity in the form of excavation and deposition of granular material; (2) quantify the volumes as proof of such intensification; and (3) provide a supporting tool to the PA's Planning Enforcement Officers.

Introduction

Quantification of intensification of illegal activity remains difficult. The project used data from UAV flights and compared it to the 2018 DSM, as sourced from the Planning Authority. Similar studies applied photogrammetry to UAV captured data and compared the resulting model to a previous model built from LIDAR data (Colica et al., 2017). The study considered the coastal evolution and changes in the sand dune system of Ramla, Gozo. The concept of using UAV acquired data is not novel and documentation exists in the evolution of drone usage in photogrammetry applications (Colomina & Molina, 2014).

The area of this project is located outside the urban fabric of the village of Rabat, Malta, delineated by the bounding coordinates (in EPSG 32633): Min: 444455.62, 3969962.10, Max: 444840.65, 3970361.43. Site covers an area of 73,950 m2 and consists of an active hardstone quarry. The rock strata at the study area, forms part of the Upper Coralline Limestone formation, Mtarfa member (Geological Map of the Maltese Islands, 2016). Part of the site is used for the deposition of material (gravel and sand). Although licensed, the quarrying activity extends beyond its permitted boundaries and stockpiled material is beyond permitted and dumped (extraneous material) in the quarry. The study area is particularly sensitive due to the direct adjacency to a site protected as a special area of conservation. This Natura 2000 site consists of a cave system, known as "l-Għar tal-Iburdan" (Epsilon International S.A. & Adi Associates Environmental Consultants Ltd, 2014) that was reserved for its Archaeological Importance in Government Gazette Notice 1225 (2010).

Methodology

Data was captured with a DJI Inspire-2™ drone with a Zenmuse X5S™ camera (payload). Dataset comprises 766 images captured at regular intervals from an altitude of 45 m. Drone mission was pre-planned in Drone Deploy on 26/04/2019. The mission (survey) considered the quarry where inert material was being accumulated, but also the surrounding fields and access roads. The data was originally collected as part of the monitoring process by the Enforcement Directorate (PA) but was re-purposed for this project.

Processing drone Captured Data

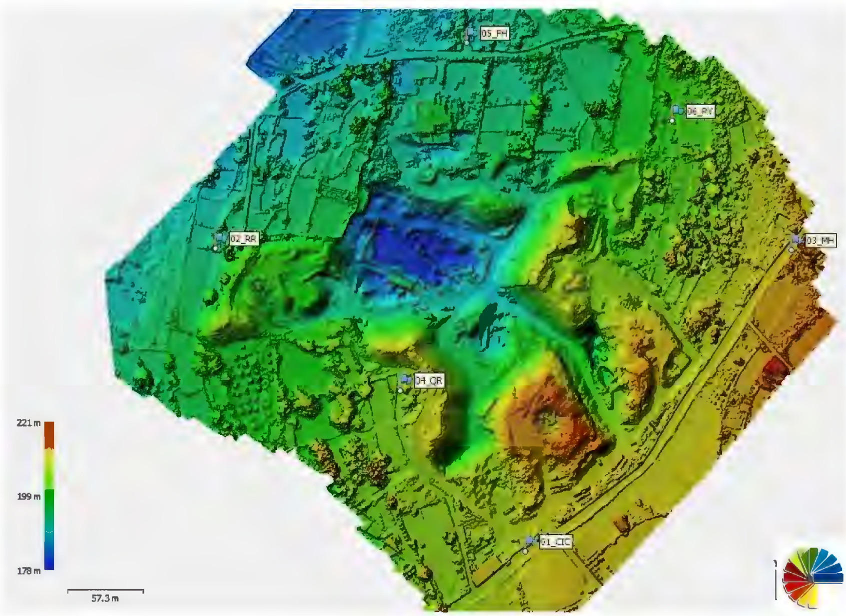
The dataset was uploaded to Agisoft PhotoScan Professional™ and aligned, based on the parameters stored by the sensor in each image, using the "Reference Preselection" parameter. The output of this initial process was a 3D sparse point cloud. The drone survey was carried out, with no ground control points, which are necessary to perform the absolute orientation of the site. To remedy this six features sparsely distributed around the study area were identified, where no change was detected. Their position was located on several photos. Longitude and Latitude were extracted from a Google satellite base map, loaded on QGIS™ with the QuickMapServices™ plugin. Elevation data for these points was extracted from a previous DTM overlaid on the project's QGIS.

Consequently, the values were inserted as parameters for the markers in PhotoScan™. The camera alignment was optimized, based on the ground control points. The building of the dense point cloud (Figure 1) was one of the most time -consuming processes in the project (over 20 hours). Given the number of photos and considering the accuracy of the comparative dataset, a "medium" setting was chosen for the quality and a "moderate" setting was chosen for the depth filtering. The DSM was built in PhotoScan (Figure 2) out of the dense point cloud. Some outlier points, that were evidently higher or lower than they should be, were assigned to a low (noise) or high (noise) class respectively. These points were erroneous, so both noise classes were excluded from data points used for building the DSM. The projection EPSG 32633 (i.e. WGS 84 / UTM zone 33N) was used for the DSM, in view that the other datasets, this model will be compared to, for use of this CRS. The produced DSM was exported (for use in QGIS) with a pixel resolution of 0.15 mm, which is the same resolution as that of the 2018 DSM dataset.

Figure 1: Dense Point Cloud (with GCPs)

Screen shot from Agisoft Photoscan

Figure 2: Digital Surface Model

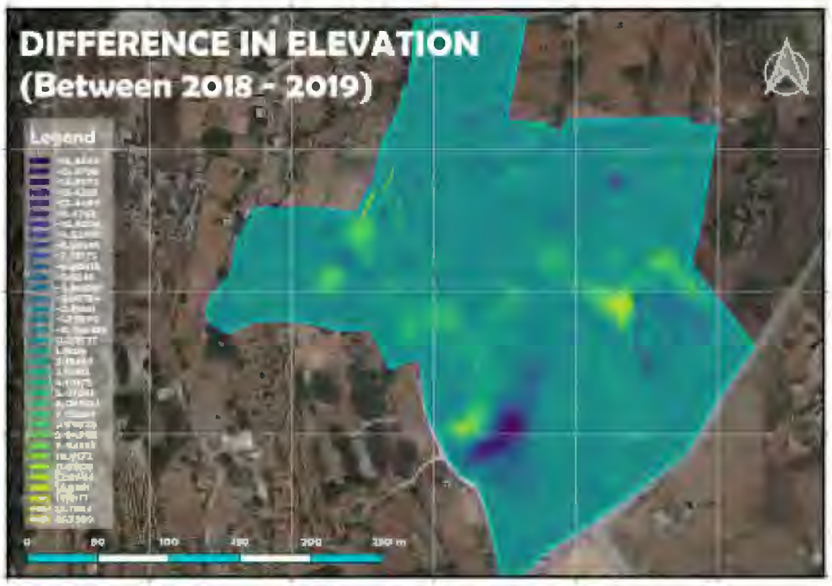


Screen shot from Agisoft Photoscan

The 2018 DSM of the Planning Authority encompassed the Maltese islands. The DSM was cropped to capture the study area, by using the tool "clip raster by mask layer". The clipping vector was a 200 mm buffer bounding box outside the study area vector polygon.

To calculate the change in volume, two surfaces are required. The difference in elevation was computed with the "raster calculator"" using the expression "PhotoScan_DSM@1-Clip2018DSM@1". The resulting raster showed positive changes from 2018 (i.e. deposition of material) in a light -tones, while negative changes (i.e. excavation) in dark tones. This layer was clipped, using the study area polygon as a mask layer (Figure 3). To evaluate only significant changes in elevation, differences less than +/- 3 mm were filtered out by the raster calculator with the equation "diff_DSM_clip@1 < -3 OR diff_DSM_clip@1 > 3". A value of 3 mm was selected to eliminate changes from vehicles or vegetation. The resulting binary raster was converted to vector form, with the GDAL "Poligonize" tool, with the default 4-connectedness, i.e., diagonal pixels not included. The tool "fix geometries" was applied to correct incorrectly converted vectors. Insignificant areas were eliminated by the tool "extract by expression" using the equation: "DN" = 1 AND $area > 40. Holes inside the resulting polygons were removed with the "Delete holes" tool.

Figure 3: Difference in Elevation (2018 – 2019)



Basemap Source: Google Satellite

Volumetric Calculation

The calculation of irregular volumes needs to be broken down into smaller / simpler geometrical shapes for which mathematical equations can be applied. Different methods for accurately calculating volumes are described in the literature (Tucci et al., 2019, Labant et al., 2013)) which include: equidistant horizontal sections (contours); vertical cross-sections of the formation; from surface grid levelling results; prisms between two surfaces. However, the aim of the project was to have proof on a change in the volume of material occurred. Thus, a close approximation method of calculating volume was adopted (Raeva et al., 2016). Therein the authors exploited the properties of the raster model, by breaking down the stockpile volume into a number of cuboids, the cross-section of which is the pixel area, and the height is given by the elevation value stored in said pixel. Since the area of the pixel is a constant, the volume is given by: $Vpol = PxA * \sum hi$, where: Vpol is the volume of material (change) enclosed by the polygon; PxA is the area of 1 pixel. (i.e., 0.15m*0.15m = 0.0225m2) and hi is the value stored in each pixel (ie. difference in elevation). It must be noted that the vector polygons (piles) created from the raster were not smoothed, which implies that a polygon contained only whole pixels.

The tool “Zonal Statistics” for the Raster Analysis was used for the difference in elevation raster, with the extracted polygons as the containment zone. The statistical attributes “count”, “sum” and “mean” were added to the attribute table of the polygon layer. The term “sum” was defined as the total sum of the values of the pixels within a particular polygon (QGIS Documentation, 2019) which effectively is $\sum hi$. The, “sum” had a negative value, which denotes that the material was deducted, from the 2018_DSM.

The attribute table in the extracted polygon layer was modified through the “field calculator” to include an additional field “volume” with attribute of: “_sum” * 0.0225. To classify the polygons by excavation or demolition, an additional field “matching”, was also created with the expression: if (“Volume” > 0, ‘Dumping’, ‘Excavation’), i.e., if the value of the volume was negative, it classified the change in volume as “Excavation”, and as Dumping if volume value was positive. Quantified and classified changes in volume area displayed in Figure 4.

Figure 4: Change in Volume

Basemap Source: Google Satellite
N.B. Basemap at the study area is an orthophoto mosaic, produced in PhotoScan and clipped to mask, with study area polygon

Net Volume Total

The net volume of all polygons involved was provided by the vector analysis tool "Basic statistics for fields" using the extracted polygon layer as input and the attribute "volume" to calculate the statistics on. Out of the various statistics provided by this tool, the "sum" provided the net volume, which resulted in a net deposition of material of 17,587.37 m3. An alternative method for estimating the total net volume, involved clipping the difference in elevation raster by the extracted polygons so that a calculation can be done directly on the raster. Using the raster analysis tool "Raster surface volume" and selecting the clipped raster difference as input, base level 0.00 and 'Subtract volumes below base level' as method, the resulting volume (net) was verified at 17,587.37 m3.

Results

Key results of this project are:

Drone imagery was successfully transformed into a Digital Surface Model and an orthophoto mosaic, despite the lack of ground control points from the survey. In order to enable such for future studies, the LiDAR2018 could be used to anchor your data as that would serve as a basis for GCPs since the 2018 run was anchored on a large set of GCPs.

- Proof of intensification of illegal activity was clearly established when areas with significant change in material was detected. The changes can be displayed in image format on a map, for clarity and ease of understanding.
- The process to quantify changes and calculating volumes was relatively expedient, however not optimized for everyday use. This process should be reserved for complex cases or when it is difficult to provide clearer proof in court.
- Compromises were made to reduce noise, which impinged on getting the exact volume of material.

Recommendations

Key recommendations are:

- Ground control points should be established at an early stage of the process. For sites that need to be monitored on a regular basis, permanent GCPs should be considered.
- Sites as the study area change rapidly. Regular surveys are suggested to model the site progressively, thus providing an understanding of the dynamics of the area subject to illegal action, enabling the construction of solid case data and possibly leading to ways to stop further illegal propagation of the activity.
- Examine the possibility to produce a DTM, wherein the process would not be as time consuming. Having had to use a DSM, meant that to eliminate noise from the resulting difference raster, the values had to be filtered at +/- 3m. This also meant that between the 0 - 3m level, some material along the perimeter of the detected polygon was omitted from the calculation.

Discussion

- The objective of the project was obtained, in that the drone imagery was transformed into a digital surface model (DSM) and an orthophoto mosaic, despite the lack of ground control points for the survey. It must be pointed, that a systematic error was noticed between the extracted DSM (2019) and the 2018_DSM of the Planning Authority, when data was imported into QGIS.
- It was noticed that the 2018_DSM supplied by the Planning Authority, does not represent a continuous field, but data is staggered in 1m integer valued "steps". In this manner it functioned as a 1m contour representation. This had an impact on the difference in elevation raster as it produced artificial, ripple like anomalies in the vector polygons, instead of the more organic rounded shapes, that would be expected from a comparison of two continuous raster fields.

- As for the provision of proof of intensification and the quantification thereof, the project aim was satisfactorily achieved. The aim was not to have an accurate survey of the material, for which this project is not adequate to conclude because of GIS based compromises to reduce noise data that diminish the accuracy of the volume calculation.

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CHAPTER 35

A Safe Cycling Route for Bicycles and e-bikes between Paola and the historic South Harbours

Mark Anthony Scotto

Keywords

Cycling, Routes, Navigation, GIS, Safety

Project Aim

The aim of the project is to create a safe cycling route for cyclists without significant cycling experience. The route must be safe, without significant hills and can be covered in less than 3 hours. The route will also allow one to appreciate Maltese built Cultural Heritage.

Introduction

The Global Positioning System or GPS was developed in the 1970's by the United States Department of Defence. (Sullivan, 2012). At the time GPS units were large and expensive. Although the system was freely available, it was purposefully degraded and so only an inaccurate version was available for public use. In 2000, the system became freely available without degradation and so GPS units became more freely available, smaller and cheaper (McDuffie, 2017; Sullivan, 2012).

In 2003 GPS based computers began making their way into sport. GPS gave an accurate location. From the time it took to move from one point to another, speed and acceleration could be calculated while sensors worn by the athlete, particularly the heart rate monitor gave a very good indication of the athlete's performance and changes to improve this performance could be made more accurately (Garmin Products, 2021, Tom Tom, 2021; Wahoo, 2021).

As the GPS units got lighter and smaller these trickled down to performance cycling at around 2005 and were soon available at an affordable price for everyone. The early units only stored the data which could then be uploaded to a PC for interpretation by a dedicated App, however this cycling GPS computer was soon able to act as a portable map. It is here that GPS and GIS began to merge and integrate (Garmin, 2021, TomTom, 2021).

Route Plotting and Mapping

Route mapping for cyclists is a very important tool. This is especially if it is to be carried out in a place the cyclist is unfamiliar with. Route plotting can be done by using an App such as Ride with GPS (Ride with GPS, n.d.), Kamoot (n.d.) or Garmin Connect (Garmin Connect, n.d.), amongst others. All these give one the facility to create a route and even view the elevation profile, however all have limitations. The main limitations are the base map. Depending on the App these generally come from Open Street Map (Open Street Map, n.d.), Google Maps (Google Maps, n.d.) or Microsoft Bing (Microsoft Bing Maps, n.d.). The user has no choice and must use what is available within the App. This means that if better base maps or imagery is available to the user, these cannot be uploaded in the App.

Another limitation is the inbuilt automatic route finder. This feature will automatically plot the route being drawn on pre-programmed known roads. Therefore, it difficult to create a route that goes through paths that the system does not recognise (Ride with GPS n.d., Kamoot (n.d.), Garmin Connect (n.d.)).

Other issues are also associated with routes that go under tunnels. In most cases the App will ignore the existence of this tunnel and will try to guide the route to existing roads above it as it is programmed to follow defined routes as available on the basemap (Ride with GPS, n.d.; Kamoot, n.d.; Garmin Connect, n.d.).

The use of GIS for plotting routes avoids this. There are plenty of tools that can be used as aid, however most importantly using GIS allows one to create routes using:

1. Any base map available. GIS uses are not limited to the freely available maps but one can acquire more accurate Ordinance Survey sheets. Basemaps from Google, Bing and OpenStreetMap can be inserted in QGIS using the openlayers plugin (QGIS, n.d.) while Ordinance Survey Sheets can be inserted as a standarard shape file;
2. Any suitable Aerial photos available as help in locating the correct route. If Aerial photos are available these can easily be used; and
3. Routes that have already been identified. Some cycling clubs publish on the web suggested routes. These can be included in the planned route. If available only as a picture, one can upload it in GIS (QGIS) (Welcome) to the QGIS project, 2021) using the Georeferencer GDAL plugin or a similar tool if another GIS program is used.

When deciding on a cycling route one normally looks at the following:

1. The gradients that need to be climbed;
2. Are the gradients steep?

3. Are the gradients long? One does not necessarily try to avoid them as it depends on the type of route desired. Some cyclists seek hills;
4. The length of the route. This is important since from it, together with the ascent one can calculate the approximate journey time; and
5. The terrain. This is necessary since not all bicycles can go everywhere. The requirements differ as these depend on the type of bicycle that will be used and on the scope of the cycling route.

Location

An aspect in the choice of location of the trail is the historical surroundings. The location chosen is the Southern Harbour region of Malta, which is an area full of Cultural Heritage, dating from the late 1600s, during which time Malta was occupied by Knights of the Order of St John to the mid-20th Century World War 2 defences built by the British forces who occupied Malta at the time. In the Southern Harbour region one finds historic cities which are known as The Three Cities of Isla, Birgu and Bormla. These are some of the oldest cities in Malta and were also the initial location where the Knights of the Order of St John settled in Malta. The Knights were responsible for the construction of the historic fortifications and the new capital city Valletta (The Grand Harbour, 2021)

Methodology

The type of cycling route chosen for this exercise is aimed at the relative inexperienced cyclist with little to no knowledge of the area. The route had to be relatively safe for cyclists who are not too experienced cycling in traffic. So major roads were avoided. It was also intended for mountain bikes or e-mountain bikes, which are easily available for hire, here in Malta (EcoBikes Malta, 2021, MelaBikes Malta, 2021). Rough terrain was limited to unpaved roads and paths that do not require any particular off-road skill. The exact location obtained from GPS and combined with data from sensors carried by the cyclist, such as the heart rate monitor, speed sensor, cadence sensor and others, and this data is captured by the cycling computer, allows one to monitor real time the performance. When this data is uploaded to a GIS based App like Strava (Strava, n.d.), Ride with GPS (Ride with GPS, n.d.) or Garmin Connect (Garmin Connect, n.d.), an analysis of the performance based on the data acquired by the GPS unit or App and on the settings a user sets in the GIS based App can be obtained.

The cycling computer also functions as a GPS and one can use it to follow preprogramed courses or tracks. These courses should not only show the route but also the elevation at any particular section of the trail. One can also view a course and elevation graph on the cycling computer or App. One should note that smartphones are fast replacing the cycling computer and some Apps like Ride with GPS can perform almost all the functions of a cycling computer. Smartphone compatible sensors (Bluetooth) can also be purchased.

The intention of this exercise was for a safe path in the Southern Harbour Region. For this exercise QGIS was employed as the GIS software. Basemaps from Open Street Map and Satellite images from Google satellite were also used. The route was determined from the maps whilst the Planning Authority's Geoserver was used as an additional visual aid. Part of the route could not be completely determined on the desktop since high resolution aerial photos, were required. As these were unavailable, the route was accurately plotted on the ground with a cycling computer, a Garmin Edge 1000 and downloaded and inserted in QGIS.

The elevation profile of the route was plotted using the QGIS Profile Tool plugin. Moreover, the profile was also visually interpreted by the DEM viewed in pseudocolour and through the superimposition of contour lines created from the DEM as in Figure 1. The length was calculated using the QGIS field calculator and was found to be 22.266km. Therefore a beginner cyclist cycling at an average speed of 16km/h could do the route in under 1.5 hours without stops.

The location of the historic sites were determined from Spiteri's book and confirmed on site (Spiteri, 2017).

Creating the Route

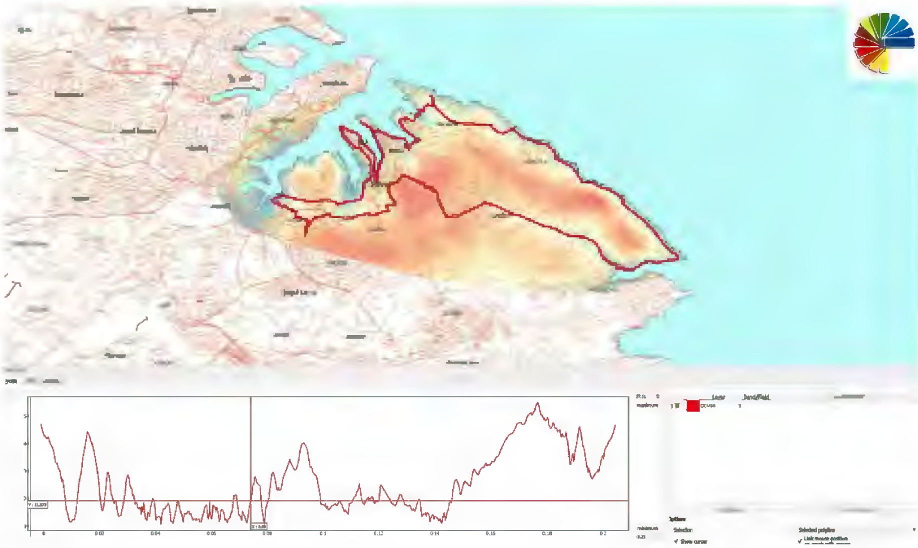
An initial route was created on the desktop as follows:

The first stage involved the identification on a map of the general area of the proposed route.

A DEM of the area was then created. This was done by creating a path in Google Earth and exporting it as a KMZ file. This file was then uploaded on the website GPS Visualizer and converted into a comma delimited text file and imported into QGIS though the folder Layer – Add Layer – Add Delimited Text Layer. SAGA Natural Neighbor was applied, and the DEM was created.

The band rendering was then changed to pseudocolor and the result in Figure 1 was obtained. Once the DEM was created, a contour map was also created so that the elevation changes could be noted while the route was plotted. Open Street Map and Google Satellite were then used for the identification of the route. The Planning Authority Geoserver was also used as a visual aid.

Figure 1: Screenshot showing the DEM overlaid on Roads



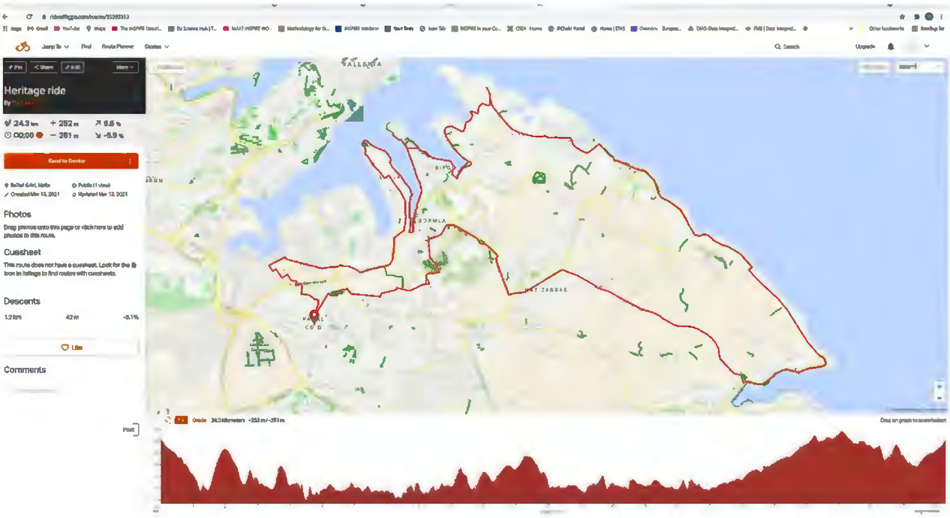
Source: Malta Inspire Geoportal (https://msdi.data.gov.mt/download.html)

Discussion

Analysis of the created route

Once the initial route was plotted, the elevation and slope were analysed using the Profile Tool plugin. Part of the route does not use a road or mapped path and the area was modified rather recently so Google satellite was outdated. This part of the route, between Xgħajra (near Smart City) and Marsascala (Zonqor Point) was recorded on-site using the Bike computer as a GPS The final route was then plotted (Figure 4). The route was then test ridden. The route and photos were uploaded on the App Relive so that better visualization of the route could be made. The route was also converted to GPX so that it can be uploaded in GPS Devices, PC and mobile phone Apps like Ride with GPS and Garmin Connect. Both elevation and the route can be visualised within the Apps (Figure 2). This allows one to visually analyse the elevations that would need to be cycled.

Figure 2: Screenshot from Ride with GPS App



Following the exercise, the importance power and versatility of GIS like QGIS for the plotting of a route over apps dedicated to such use was evident. Moreover, the control over the data used for the creation of the route was not limited to what is available in the App. Strava (Strava, n.d.), Ride with GPS (Ride with GPS, n.d.) or Garmin Connect (Garmin Connect, n.d.), which themselves do not provide the user with any choice of basemaps or choice satellite/ aerial imagery. GIS, however, is versatile in the choice of base maps, satellite imagery and DEM which then enabled the addition of elevation to the route for which the choice is only limited to what is available to the creator of the route.

The exercise also provided an insight into problems that may be encountered when planning a similar route for an unknown area. The lower resolution photos from Google Satellite and the limited detail of the base map by Open Street map were a problem in the section of the route that necessitated onsite plotting using a GPS. Better resolution aerial photography and if possible, a better base map or ordinance survey sheets would have avoided such a necessity and are required for more unfamiliar territory.

Results

Key results of this project:

- A safe route for relative inexperienced cyclists was created. The route avoided Major Road Arteries, steep inclined roads, long inclined roads and was of a reasonable length.

- The route passed through the historic areas of the Southern Harbour Area of Malta and allows one to appreciate the rich Cultural Heritage of the area while cycling.
- The route is available in GPX format for use in GPS cycling computers and/or Mobile Phone and PC dedicated Apps.
- A physical map indicating cultural heritage sites allows cycling users to appreciate such areas along the route and helps to provide additional interest to those cycling the route (Figures 3 and 4).
- The exercise and the use of GIS software (QGIS), plugins and other software gave a clear insight for the creation of such routes.

Figure 3: Route with samples of Historic Interest

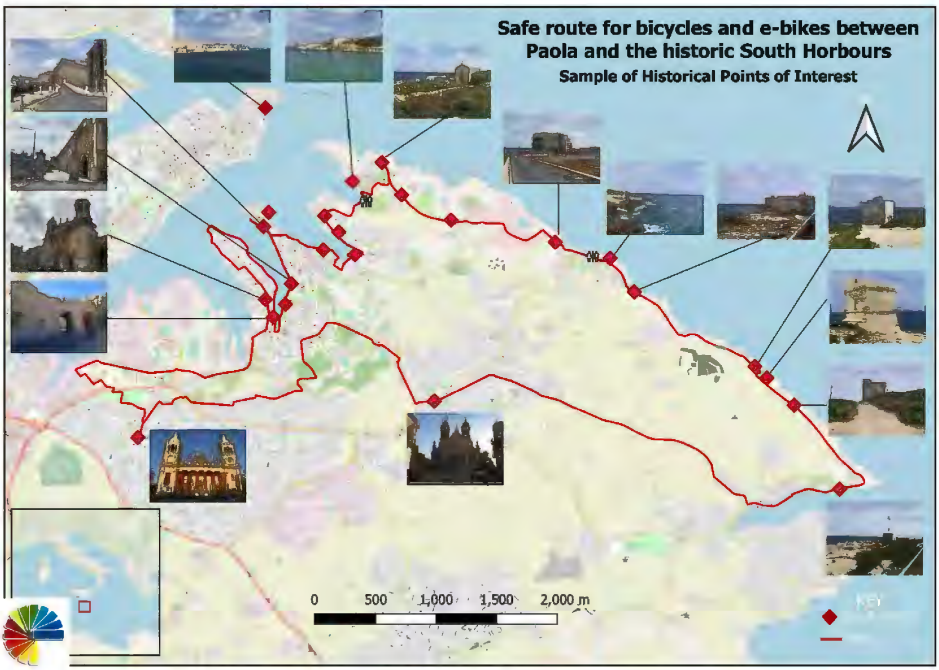
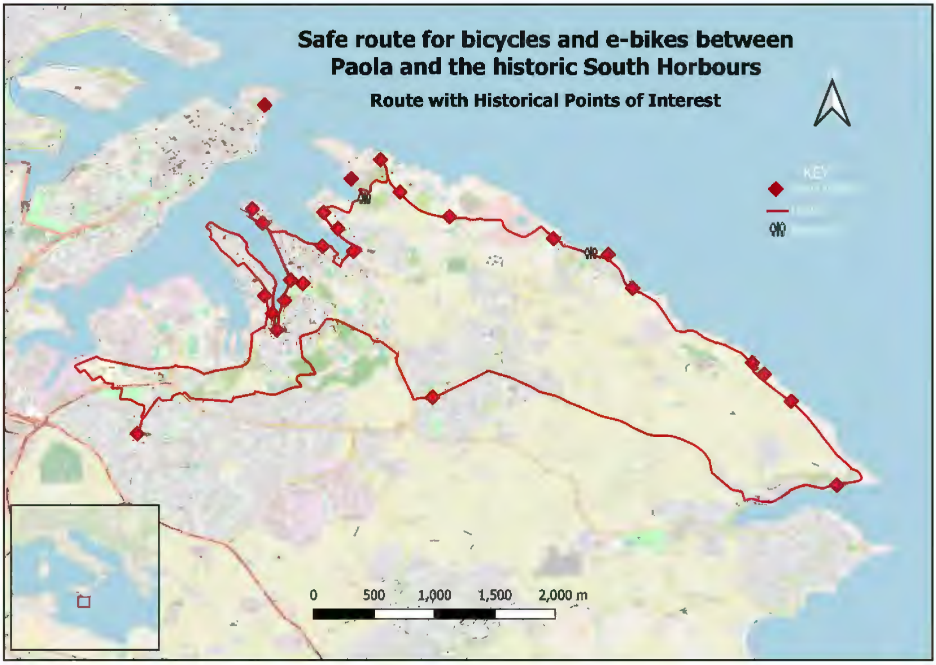


Figure 4: Route as designed



Recommendations

Key recommendations of the effort are:

- GIS software especially if combined with appropriate tools is an extremely versatile tool for mapping of cycle routes.
- Although an app may exist for an inexperienced user, such as the route plotting Apps mentioned in this exercise, using GIS directly is more versatile, accurate and flexible.
- Further cycling route courses such as the one created for this exercise are needed.

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CHAPTER 36

Exploring the integration of spatial data from drone's imagery and its use in the aviation sector

Massimo Caruana

Keywords

Drone, Aerial Imagery, GIS software, Digital Models, Aviation, Obstacles, Elevation, Safety, Aircrafts, Digital representation

Project Aim

The aim of this project has been to analyse the exploitation of drones' vulnerabilities within the extraction of spatial data related to terrain and obstacles and show how this can be used towards benefits for aircrafts and to present a detailed review on the drone/UAV usage in multiple domains (i.e. civilian, military, aviation) and for different purposes.

Introduction

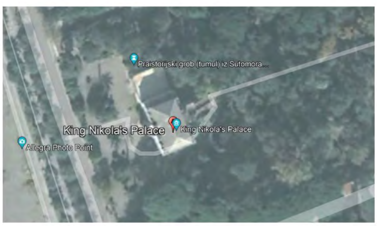
The drone (Unmanned Aerial Vehicle - UAV) has been used in various applications such as mapping applications (e.g. Map revision, archaeology, wildlife environment, forestry), in industrial applications (e.g. Engineering, aviation sector, crash accident) and in GIS applications. The procedure in conventional aerial photogrammetry involves many stages including production of flight map, acquisition of digital aerial imagery, establishment of ground control point and lengthy image processing procedure (Tate, 2018).

Within this project, 'Elevation' shall be defined as the vertical distance of a level, a point, or an object considered as a point, measured from a specified datum above ground level (AGL). The most restrictive requirement needed for obstacle acquisition by photogrammetry is the minimum size of the obstacles which must be captured. To capture very thin objects (e.g., antennae, streetlamps, etc.), the image scale has to be bigger than with traditional survey flights. This requires a lower flight height. With regards to terrain and obstacle data, photogrammetry can be used for the tasks of Terrain and Obstacle mapping (Lasnier, 2003). According to the International Civil Aviation Organisation's (ICAO) new requirement in Appendix 15, all ICAO participating states are to ensure the availability of terrain and obstacle data in electronic format. Malta, being part of this organisation, must adhere to these requirements and is continuously updating its data through the national AIP (Aeronautical Information Publication).

Methodology

The initial stages of the research involved the selection of the topic of discussion and the collection of the images. The second phase of the study involved the processing of images through Pix4D Software. The images consisted of an aerial survey of King Nikola's Palace using UAV flowing 3000sqm over the locality of Bar in Montenegro (Figures 1 & 2). The aerial images used in this project were captured by UAV Phantom 4 Pro camera FC6310_8.8_5472x3648 (RGB). Its goal was to collect up-to-date images for the mentioned area (Figure 3). Throughout the area of interest approximately forty (40) images were acquired. Generally, the final goal of photograph processing using photogrammetry software is to build a Digital Elevation Model (DEM) or a Digital Terrain Model (DTM).

Figure 1: Aerial view of King Nicola's Palace

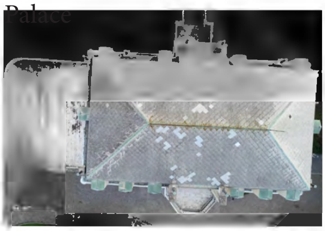


Source: Google Earth Pro

Figure 2: Image of King Nicola's Palace in Bar, Montenegro

Source: Google Maps

Figure 3: Drone Image of the King Nicola's Palace



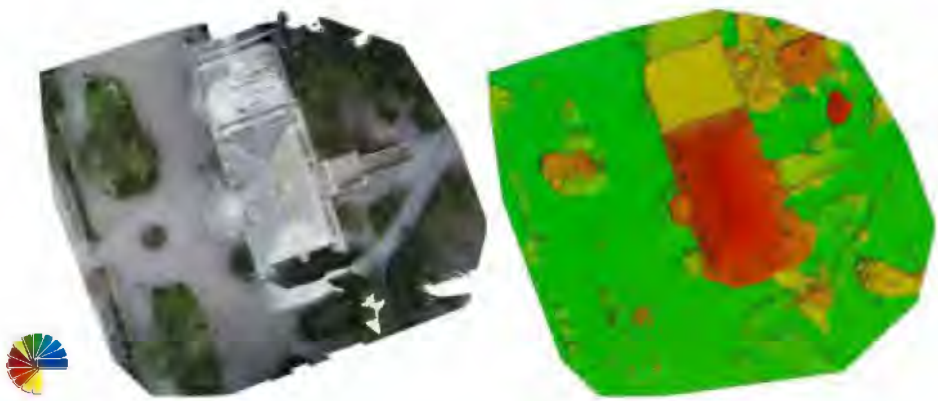
Source: Kovacevic, 2020

Digital Models and Contouring

An additional process on the above-mentioned area was carried out using QGIS. Such software has numerous applications for storing, analysing and processing spatial data. What Pix4D software does is to provide the input for the spatial analysis. QGIS, however, needs input from for example, point cloud, Digital Surface Model (DSM) and orthomosaic in order to analyse data. QGIS does not do image processing in order to acquire the input source. Although Pix4D cloud, has several useful GIS functions it still does not replace the full functionalities of a GIS software. While Pix4D uses drone imagery, GIS Software uses input from other sources as well.

In this phase, Google Earth Pro was used to create the input source for QGIS. This was done by adding a path on the area concerned whereby a point cloud was created and then saved as '.kml' file. This, in order to display geographic data, pinpoint locations and add image overlays. The .kml file was then converted into .txt format through GPS visualizer software. Data can be imported from text files, providing some additional details about how the geometry information is stored in text. Finally, the .txt file was imported in QGIS 3.10.8 and SAGA tools were used to generate a Digital Elevation Model (DEM) and Contour lines. A Digital Elevation Model was used as it is a digital representation of elevation data to represent terrain of the targeted building in Bar, Montenegro. Using contour lines, elevation and shape of the terrain was shown. Contour lines show the topography of the land surface on a map. Elevation would remain constant, if physically, a contour line is followed.

Figure 4: Preview of Orthomosaic



Discussion and Results

These GIS systems allow geographical data to be analysed.

In Figure 4 a preview of the Orthomosaic, can be seen along with the corresponding sparse Digital Surface Model (DSM) before densification. Figure 5 then shows a number of overlapping images computed for each pixel of the orthomosaic. The red and yellow areas indicate low overlap for which poor results were generated. The green areas indicate an overlap of over 5 images for every pixel. By using reality-based images through Pix4D, it was possible to derive digital representations for several kinds of investigations such as the Digital Surface Model as shown in Figure 6.

Another feature applied was the projection of an orthomosaic map. The orthomosaic is a 2D map where each point contains X, Y and colour information. The orthomosaic in Figure 7 has a uniform scale and can be used for 2D measurements of distance and surface. An orthomosaic is generated on the DSM that is created from the Densified Point Cloud. As a result, any errors and noise present in the Densified Point Cloud will be reflected in the orthomosaic (Pix4D, 2021). Such errors appear often at building edges or on small details like trees as shown in our project. Figure 8 shows a combination of both DSM and Orthomosaic. The Elevation bar indicates elevation in meters.

Figure 5: Overlapping Images

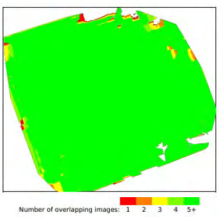


Figure 6: DSM

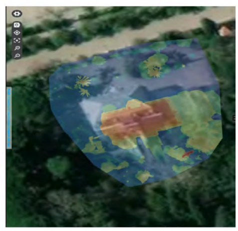


Figure 7: Preview of Orthomosaic

Figure 8: DSM and Orthomosaic

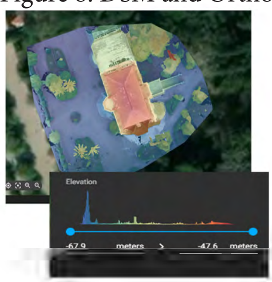


Figure 9: 3D Textured Mesh

Figure 10: 3D Point Cloud

Through the use of Point Cloud, the 3D Textured Mesh was generated. This is a surface composed of triangles. During the process of the 3D Textured Mesh generation, the vertices of the triangles were defined to minimise the distance between some points of the Point Cloud and the surface as to be observed in Figure 9. In Figure 10, a point cloud was represented. This is a set of data points in space. As can be observed, the points represent a 3D shape where each point has its set of X, Y and Z coordinates. These point clouds are generally produced by photogrammetry software, which measure many points on the external surfaces of objects around them. The 3D Point Cloud again was presented through Pix4D.

During this project, one of the aims was to develop a Digital Terrain Model (DTM). This was done through QGIS software. To accomplish this, various test methods and techniques known in the GIS world were used. King Nikolas Palace was used in QGIS to analyse some features or characteristics of terrain in the created DTM (Maliqi, 2017). The Inverse Distance Weighted (IDW) is the Interpolation method used, as shown in Figure 11. This method of interpolation estimates cell values by averaging the values of sample data points in the neighbourhood of each processing cell. It gives more influence to the points that are farther away, resulting in a smoother surface as represented below.

Digital Elevation Models in QGIS are files that contain either points (vector) or pixels (raster), with each point or pixel having an elevation value. They come in a variety of file formats, from .csv to .dem to .txt. In our case .txt was used and lots of information, like contours or 3D surface models were derived as per Figure 12. The digital surface based on hillshade technique was also performed for King Nikola's Palace area. The Hillshading technique is based on a specialised azimuth and altitude of the sun (light). The given elements of hillshading in QGIS software are: azimuth of light and altitude of the light. Different values of azimuth and altitude of light were used to see this technique of visualisation in the best way and finally an evaluation of the created hillshading was done to confirm the quality. The below Figure 13 represents the process performed in order to get this result.

QGIS software also supports methods and techniques of generating a Digital Terrain Model. In this report the DTM is represented in Figure 14. The DTM for the Palace can be taken as an example and the same concepts applied for the aviation sector (Maliqi, 2017). Contour lines were used for representing the elevation of the terrain near the area of the Palace. This method was used for displaying relief. A disadvantage of this form is that it cannot not show a perspective view of the terrain. Figure 15 shows a representation of contour lines.

Figure 11: IDW Interpolation DEM

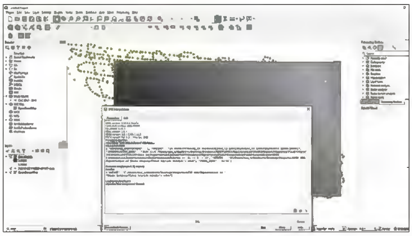


Figure 12: King Nikola's Palace

Figure 13: Hillshading – King Nikola's Palace

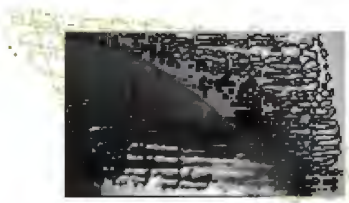


Figure 14: DTM – King Nikola's Palace

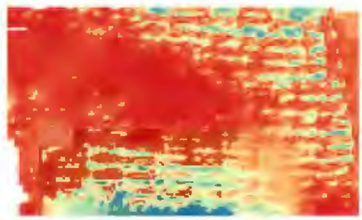
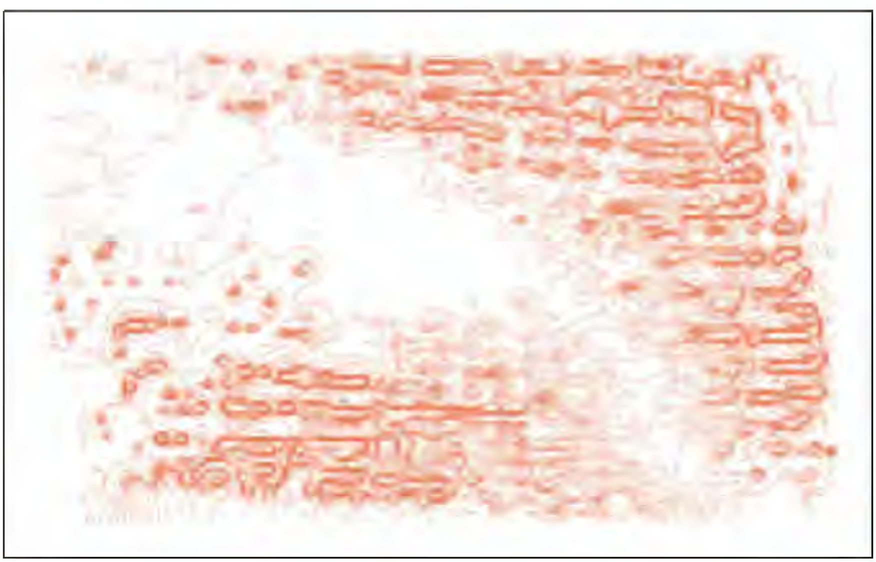


Figure 15: Contour Lines – King Nikola's Palace



To meet ICAOs requirements, ESRI Aeronuatical Solution implemented the Electronic Terrain & Obstacle Data (eTOD) in the AIM Data Model (PSTAviation, 2017). The eTOD solution is a service that provides terrain and obstacle data using one of the world-leading high-resolution satellite images. Rather than using aerial imagery, eTOD uses satellite images so its impact on the normal flight operations is kept minimal. The Aviation sector considers safety as its overriding responsibility and consequently this factor is accorded the highest priority on any commercial, financial, operational and social pressures and constraints, according to ISO 9001 2015.

While the eTOD system provides accurate terrain & obstacle data, and facilitates the safe operation of the aircraft, GIS software and drone imagery can be used in other fields pertaining to aviation such as the development of aeronautical infrastructure, route planning and territory scanning.

Recommendations

This project delivered various digital models like; Digital Surface Model, Orthomosaic, 3D Textured Mesh, 3D Point Cloud, IDW Interpolation, Digital Elevation Model, Hillshade, Digital Terrain Model and Contour Lines. Based on the results obtained, it can be concluded that GI software is an appropriate software for creating, analysing, interpreting and visualising geo-spatial data through aerial images.

Terrain may be depicted on a grid of elevations at regular intervals. The result is a Digital Elevation model (DEM) (ICAO, 2003). Reliable and precise obstacle and terrain data for in-flight and ground-based applications can provide significant safety benefits for international civil aviation. Ideally the data should be presented in a geographical information format to readily permit evaluation and presentation to users. As stated in the literature, through this case study, it has been shown that GIS software can assist in the analysis of terrain in the field of aviation and that such process can secure safety in the aviation sector.

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CHAPTER 37

Implementation of an Electronic Terrain and Obstacle Database for Malta (eTOD.MT)

Naomi Galea

Keywords
Aviation, DEM, eTOD, GIS, ICAO, LIDAR, Malta, Obstacle Database

Project Aim

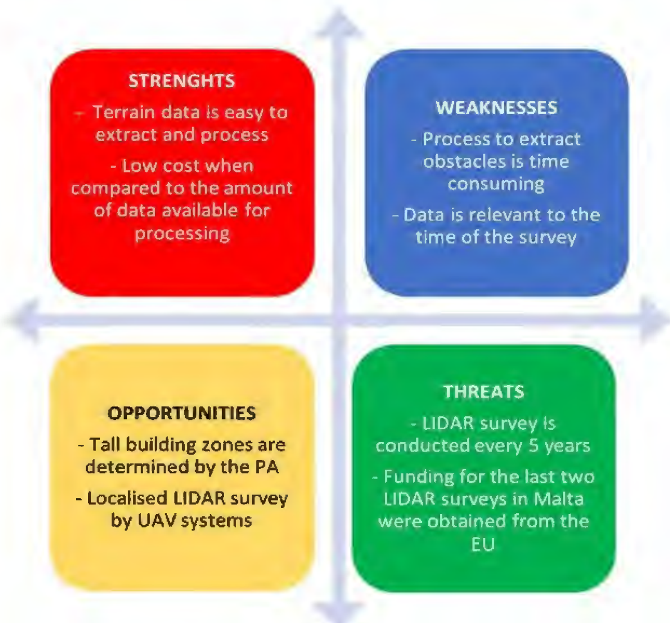
The aim of the project was to: (1) address the requirements of an eTOD policy, (2) create a Digital Elevation Model, (3) process LAS files and separate the buildings from the terrain, and (4) apply eTOD (Eurocontrol Terrain and Obstacle Data Manual Edition) parameters to identify buildings deemed as obstacles, next to antennas and other.

Introduction

In the early days of aviation, pilots used a compass and navigation was done visually. Today the compass has been replaced by a Flight Management System (FMS) attributed to the 'brain' of the aircraft's navigation system, that automates most of the pilot's tasks. The FMS is equipped with GPS receivers and an Inertial Navigation System (INS) for the aircraft's positioning. With a flight plan, the aircraft navigates following "waypoints" identified via WGS-84 coordinates. Sensors enable the aircraft to operate on autopilot, whilst data fed into the FMS is critical to the safety of the flight, one set of data being the Electronic Terrain and Obstacle Data (eTOD).

The eTOD policy is set by the International Civil Aviation Organisation (ICAO) and obligations and requirements of the Member States are included in the "European Single Sky" Implementation Plan (ESSIP). The eTOD requirements include a strict process for data acquisition, the implementation of a monitoring process together with a period review prerequisite, currently set at 5 years. Although Malta has not an established eTOD policy, the process to identify obstacles and conduct assessments is in place with critical obstacles, which are ground surveyed, and results are published in the Malta Aeronautical Information Publication (AIP). Prior to launching the eTOD, a SWOT (Strengths, Weaknesses, Opportunities, and Threats) analysis was conducted to determine the feasibility of LIDAR data use. The SWOT analysis has been applied at the planning phase to determine the feasibility of the project (Figure 1). Strengths identified included facts such as the terrain data is easily extractable and LIDAR data acquisition is comparatively low in cost when compared to the large volume of data produced. Weakness has been the time required to extract obstacles and the fact that data was only relevant to time of the study. Opportunities and Threats arise in the external environment. External opportunities for obstacle assessment would be to assume LIDAR runs in localised areas with the use of a UAV. A possible threat in the future would be financing, as LIDAR runs were funded through EU Structural Funds.

Figure 1: SWOT Analysis

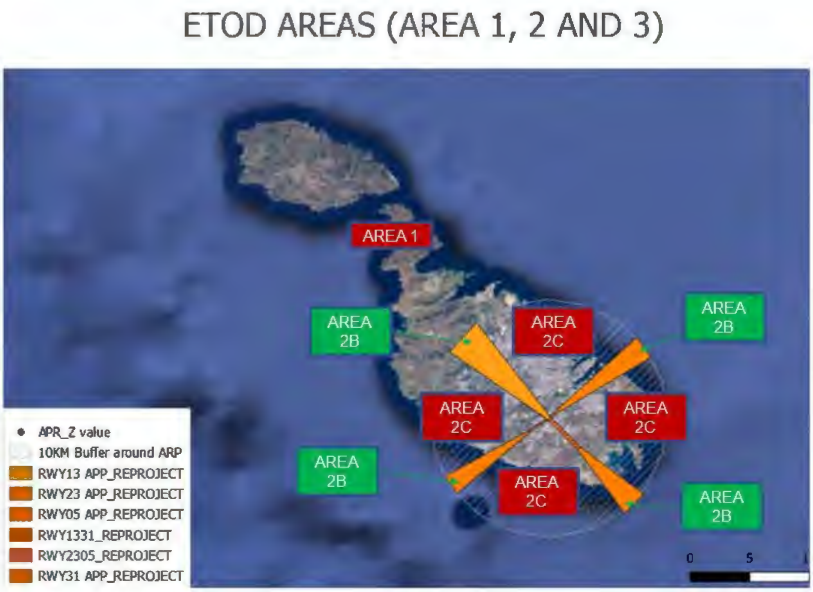


The eTOD policy establishes four coverage areas with different data requirements applicable for terrain and obstacle data.

- Area 1: Refers to the entire State: Data Requirements: An electronic terrain data set is to be provided for the entire State. The terrain data established for Area 1 is mainly used for enroute applications specifically for aircraft overflying mountainous terrain. The standard allows such data to be extracted from a Shuttle

Radar Topography Mission (SRTM) data, and ASTER Global Digital Elevation Map data, meeting the vertical accuracy of 30m and post spacing of 3 arc seconds (Figure 2). In Area 1, obstacle data shall be provided for obstacles of height 100m or higher above ground.

Figure 2: eTOD Coverage Areas



- Area 2: Is defined as the area extending with a 10 km radius from the Airfield Reference Point (ARP) and beyond the 10 km radius where obstacles stand at 120m above the lowest runway elevation. It is the most critical in terms of procedure design because it contains the "take off and approach" surfaces. Data Requirements: In addition to the terrain data required for Area 1, the obstacle data requirements to be collected in Area 2 are: (1) Obstacles of 3m above ground shall be recorded in the flight path areas, (2) Obstacles of 15m above ground shall be recorded in the areas outside the flight paths.

- Area 3: Is defined as the area bordering an aerodrome movement area that extends horizontally from the edge of a runway to 90m from the runway centreline and 50m from the edge of all other parts of the aerodrome movement area. Data

Requirements: Area is contained within the parameters of the airfield and shall be free from infrangible obstacles as much as possible.

- Area 4: Is specifically designed for precision runways with Category-II (CAT II) and CAT III landing systems. Since the landing capabilities for Malta International Airport are CAT-I, this area is not defined and was not considered for the scope of the study.

Methodology

The LIDAR data of 2018 was used as the basis of this study. Research suggests that LIDAR-based surface models are considered accurate for visibility analyses (Lagner et al. 2018). Furthermore, 'using LIDAR for Digital Elevation Modelling (DEM) and contour generation is faster than using conventional photogrammetric techniques and less susceptible to data collection problems as data can be collected at any time of day' (Lansier, G.). A study conducted by Lansier (n.d) states that when comparing aerial laser scanning to other surveying techniques, although expensive, airborne laser scanning is efficient for the creation of DEMs/DSMs. This is because the acquisition of terrain data is performed almost at no extra cost when combined with obstacle mapping, and data can be extracted almost automatically.

Airborne laser scanners (ALS) directly measure objects in 3D-dimensions and results are recorded in a point cloud file in LAS format. Point clouds are classified with codes to represent objects such as terrain (ground), vegetation (low, medium, high), building, and other objects which classify as terrain and off-terrain. As stated by Yastikli & Cetin (2016), LIDAR point clouds are generally used for "object extraction, Digital Terrain Model (DTM) generation, 3D building modelling, and change detection applications".

The LIDAR data for Malta was provided in LAS format at 1km x 1km resolution. A Digital Elevation Model was created using the open-source software: Cloud Compare, Lastool and QGIS, and (1) In Cloud Compare, each LAS file was filtered with classification 2 (bare earth) and restricted to a point cloud of 1 million points or less, (2) In QGIS, through LAStools (available via plugin) delimited text files were processed with the Las2DEM function. Each file was saved as a GEOTIFF file, results are provided in Figure 3.

For the extraction of obstacle data, each LAS file was individually processed. A similar process to the one mentioned was conducted to extract a point cloud with the building data (objects classified with classification 6). The LAS files were processed on open software Fugroviewer (Figure 4). The LAS file was uploaded in the software that delivered an ASCII file of a point cloud of objects classified as buildings with x, y, and z values. This process was applied to each LIDAR tile. Uploading of the files (as delimited text files) in QGIS resulted in a large volume of vector point files that defined the actual buildings (Figure 5).

Figure 3: LIDAR classification list [Source: ArcGIS] Lidar point classification—Help | ArcGIS Desktop

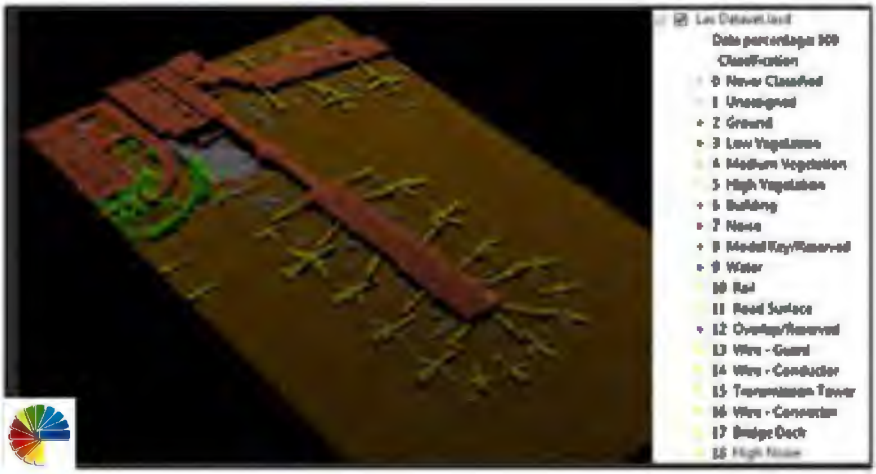


Figure 4: Fugroviewer

Table 1. ASPRS Standard LIDAR Point Classes

Classification Value (bits 0:4)	Meaning
0	Created, never classified
1	Unclassified
2	Ground
3	Low Vegetation
4	Medium Vegetation
5	High Vegetation
6	Building
7	Low Point (noise)
8	Model Key-point (mass point)
9	Water
10	Reserved for ASPRS Definition
11	Reserved for ASPRS Definition
12	Overlap Points
13-31	Reserved for ASPRS Definition

Figure 5: Zejtun vector points

The eTOD policy states that obstacles which require evaluation should be 120m higher than the lowest runway elevation. At Malta International Airport the lowest runway elevation is that of RWY.31 which measures 231ft above mean sea level (equivalent to 70.41m). The sum of 120m and 70.41m (runway elevation) indicates that obstacles above 190.41m from mean sea level do fall under eTOD criteria.

QGIS does not provide a straightforward approach to assessing building heights over the terrain model, therefore, the following calculations were applied: (1) To determine which of the buildings need to be listed as obstacles in the eTDO database, the lowest and highest elevations need to be considered. (2) The lowest and highest elevations were extracted from the DEM and these were added with the lowest and the highest point of the building file.

Figure 6 shows an example when using the tile for Rabat / Mdina. The lowest elevation extracted from the DEM is 113.962m and the highest 198.55m. The DEM was layered on Google Maps for reference and the ASCII building file was layered on the DEM. To obtain a better understanding of the different building elevations, the symbology of the point vector file was filtered with a graduated function for ease of reference. Secondly, points were digitised manually, and polygons were drawn around points of the same colour (meaning same elevation) as depicted in Figure 7.

The symbology for the polygons were set to represent the elevation and a centroid was introduced for each polygon. The CENTROID (Vector > Geometry Tools in QGIS) coordinates are recorded as the obstacle and the elevation would be extracted for the Electronic Terrain and Obstacle database. The approach indicated that LIDAR data is well suitable for the implementation of Electronic Terrain and Obstacle Data. LIDAR data covers all eTOD Areas 1, 2, 3, hence the need to obtain satellite imagery has not been explored (Figure 8).

Figure 6: Mdina

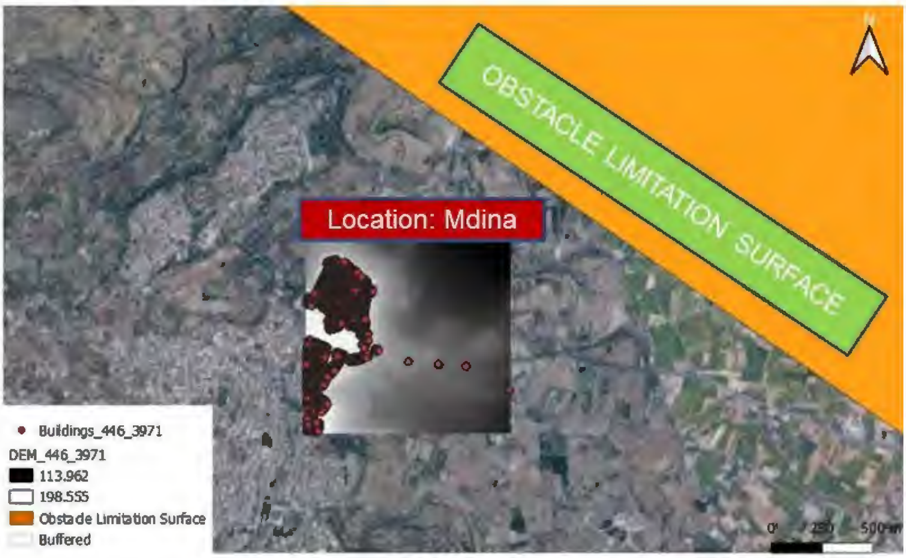


Figure 7: QGIS Image

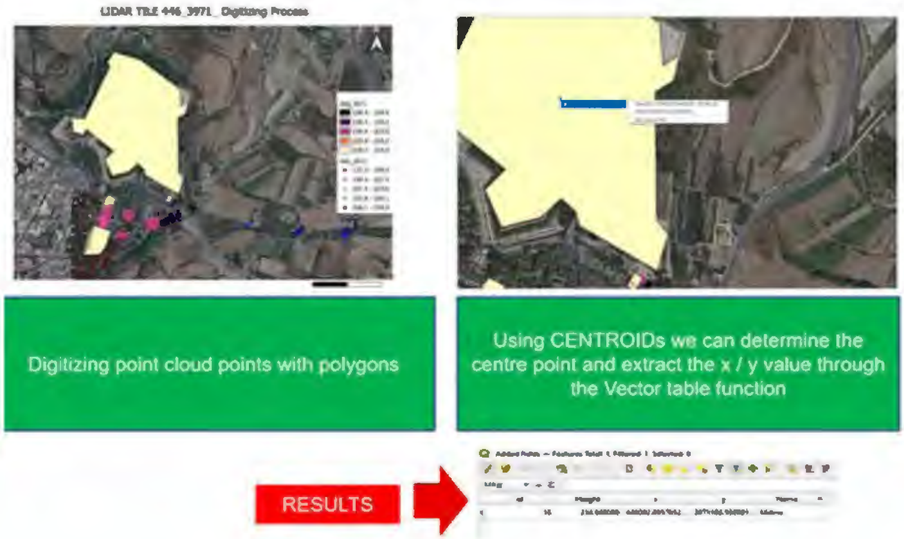
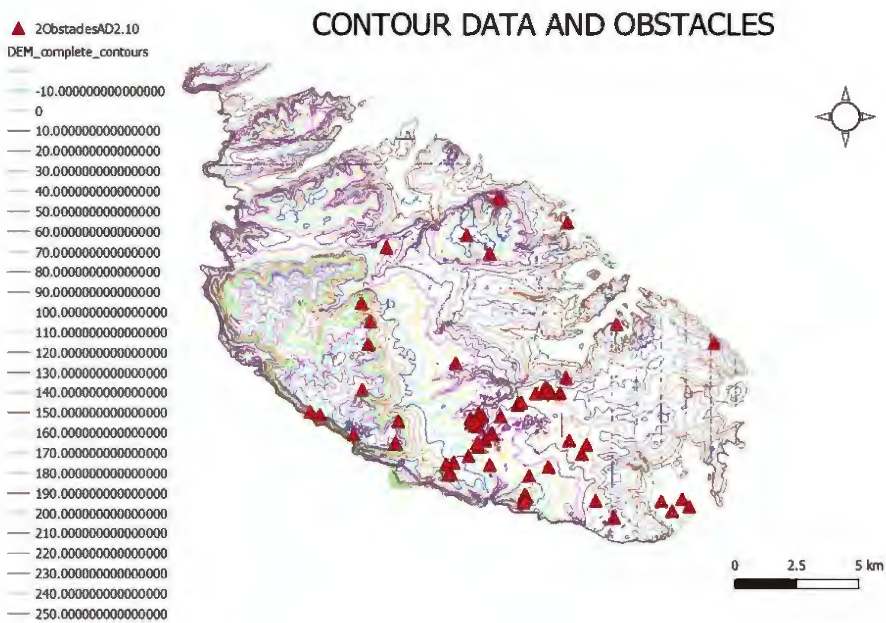


Figure 8: Contour Data



Due to the large volume of LAS files, the processing of a Digital Elevation Model was time consuming but straightforward. The GEOTIFF files DEM model was used for the creation of a contour file used to determine high terrain profiles.

Discussion

The creation of an obstacle database extractable from LIDAR was challenging with each building block being digitised with the creation of a polygon manually drawn. The QGIS plugin Convex Hull was considered, however, after several unsuccessful trials, manual digitization was assumed. Digitising is simple but time consuming. Introducing a centroid in the middle of the polygon deemed as a suitable reference point for the identification of an obstacle. The centroid coordinate, elevation and an identification reference code would define the obstacles in the eTOD database.

LIDAR data contains all the information required for the establishment of an eTOD policy for Malta. A LIDAR run gives a representation of the Digital Elevation Model and Digital Surface Model at the time of the survey. This means that in between LIDAR runs, a process needs to be established to include new obstacles in the eTOD database. The Planning Authority has documentation which indicates designated areas for tall buildings (which would be a concern for air navigation). However, the plan, although still valid, dates to 2014. Moreover, areas for tall buildings, such as the upcoming Quad Towers located in Mrieħel, are not included in this effort.

Another issue would be the building permit duration. In Malta a building permit is valid for 5 years. Although the aviation authorities do receive building permits for review and approval, the time between the approval of the permit and the construction phase is excessive. Furthermore, there is currently no process in place to advise external parties that the buildings have been physically established.

Malta has two sets of LIDAR data sets dating to 2012 and 2018 and the eTOD policy stipulating that data needs to be reviewed every 5 years. Therefore, local authorities need to plan the next LIDAR survey early.

Results

Project Results:

- LIDAR data is a suitable source for the establishment of an electronic terrain database and obstacle data. However, obstacle data will only reflect obstacles at the time of the survey.
- Whilst terrain data does not tend to change drastically between LIDAR runs,

changes in obstacle data, especially in Malta where the island experienced a boom in construction between LIDAR runs (increase in buildings building heights and trees) can be observed.

- Data contained in the LAS files are easy to process once the right software is available. During the study, it was observed that not all open-source software can give you the desired results – it took a lot of trial and error before the open-source software Fugroviewer was selected.
- Clustering the buildings (classification 6 of the LAS files) is most challenging. QGIS is a powerful tool for geospatial data extraction however a setback was noted when uploading data files for buildings. The buildings file was displayed in individual points which originated from each LIDAR drop. Following the categorisation of the points with similar heights, it was then easy to view the buildings and their heights. At the time of this study, QGIS did not have a feature which collates points of similar height and incorporates them into a polygon. This part had to be done manually.
- QGIS provides the necessary tools for obstacle evaluation. Once the centroid is determined for each building then other features, such as the hillshade tool, make the study more straight forward.
- Although requests for building permits are received for consultation purposes, little information is received with respect to the building approval / refusal. At the time of writing the policy is that once a building permit is approved by the authorities, the applicant has 5 years to execute the building permit. For the ETOD database to be effective, there must be a distinction between what is being evaluated at permit level vis-à-vis the actual building (physical obstacle) once complete. A process must be introduced once the building project is complete, a communication is exchanged between interested parties and a survey of the physical obstacle is presented and uploaded on the database.

Recommendations

Key Recommendations

- The eTOD database is a requirement of the State and a database including an electronic terrain database and more importantly an obstacle database needs to be implemented and included in the Malta AIP.
- Following the setup of an eTOD policy, a combined effort needs to be applied between Government Entities to keep the Obstacle database updated.
- Awareness needed for the personnel responsible for Permits, on the implication of high buildings on aircraft approach and landing paths.
- For a national eTOD policy to be effective, there needs to be an audit trail which

would state the progress of the building (obstacle) from permit approval. This would include the centre coordinates together with the height above terrain, until the building would have reached its completion.

- This audit trail would have to be made available to different entities including MATS, TM CAD, and MIA, which should have all means to conduct an obstacle assessment for an updated database.

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CHAPTER 38

Development of a centrality index for regional transport network analysis in Malta

Patrick Cachia Marsh

Keywords

Transport planning; network analysis; centrality analysis; graph theory

Project Aim

Through the analysis of prime centrality indices, the development a new centrality index which can identify nodes which that exert the most influence on the rest of the network. Secondary aim: To use the developed index to identify optimal locations for transport hubs within a regional transport network.

Introduction

Centrality analysis is an often-neglected part of the transport planning process. As Lange (2011, p. 3) states, there is a strong relationship between centrality and various network performance KPIs. Indeed, the author argues that ensuring that transport hubs are located at nodes with high centrality should be seen as a KPI in itself: "Network centrality should be seen as a core KPI for transportation networks, but is currently not perceived as such, neither in academic transportation network design, nor in decision-making on transportation networks in the logistics sector".

So far, centrality analysis has not been directly utilized within the transport modelling process within the local context of Malta. This research is therefore not only relevant from a scientific point of view, but also represents a novel approach to improve the transport planning process locally. Several GIS tools were utlised in the process of this research. Table 1 lists the main software applications used, and their respective plugins and modules.

Table 1: Main software applications used

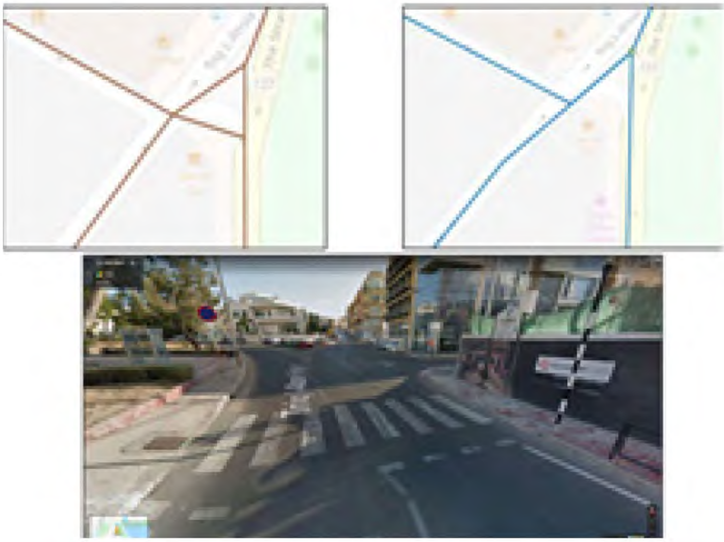
Tool	Process	**Plugin/module**
QGIS	Network preparation	Core plugins
	Network analysis	Core plugins
	Clustering analysis	ORS Tools; Attribute-based clustering
GRASS	Creation of network graph	v.net
	Centrality operation (prime indices)	v.net.centrality

Methodology

The network utilised for this research was Malta's National Transport Model (NTM). The NTM is a mathematical macro model developed by the Authority for Transport which simulates network conditions over the national road network of the country of Malta during the morning and evening peak hours (Transport Malta, 2016). The NTM was developed using the modelling software Cube, however it allows export of various features into shapefile format using its GIS engine. Despite being at a national scale, the network the NTM utilises is detailed, with roads being split into links that represent stretches that are only few meters in length. While this level of detail is ideal for a link-based model, this is not the case for network analysis which requires focus on node relationships.

Therefore, an extensive cleaning and network preparation process was undertaken in QGIS™. Firstly, the regional network pertaining to the area of interest was extracted. Following this, several cleaning and simplification procedures were undertaken. For example, roads represented by multiple separate line features were converted into a single polyline feature. Various junctions were also simplified. For example, roundabouts were converted from circular multiple node intersections to single nodes. Similarly, complex and irregular junctions were also simplified, particularly if nodes were located within a few meters of each other (Figure 1).

Figure 1: Junction simplification to single node via use of polylines and vertices



Source: QGIS/Google Maps Streetview

Since transport networks represent tangible physical infrastructure, it was decided the network to be a weighted directed graph. The next step of the research process was to develop a cost function (i.e. weight) to represent physical network morphology. This cost function was primarily based upon time travelled, taking into consideration various link attributes from the NTM network:

$$a = log_b(t)$$

where a = cost factor
b = link capacity (after adjustments)
t = time (link length/link speed limit after adjustments)

A logarithmic function was used above with the base of the function being the link capacity. The assumption behind this choice is based upon the fact that the network was small with only two types of road classes. Since the higher class of road had substantially higher capacities, this design choice was made to dampen this contrast. The adjustments to both link capacity and speed refer to friction factors derived from the NTM that have been applied to maximum theoretical capacities and maximum theoretical speeds of roads. These adjustments reflect, for example, the presence of parked cars or roads in urban conservation areas.

Furthermore, the following assumptions are also made in relation to the network:

1) This analysis is based upon free flow conditions (i.e. speeds to do not take into consideration peak hour flows which may be affected by traffic congestion).

2) Every node in the network is of equal importance, whereas, nodes may be located near places of interest/entertainment.

Following cleaning, the GRASS™ v.net module was used to convert a shapefile into a network graph. In particular, the nodes operation was used to assign nodes to both line ends and intersections. The network file created with v.net has a unique data structure ideal for graph and network analysis, with a layer each being created for 1) arcs 2) nodes 3) turntable costs and 4) turntable categories. The v.net.centrality module utilised later in this methodology does not consider turntable costs, so this was not created. However, it is a useful layer when conducting route optimisation analysis. The developed network graph has arcs that are both bidirectional and unidirectional (i.e. one-way streets). This was done by creating attribute columns for forward and reverse costs. Two-way streets had equal forward and reverse costs, whereas one-way streets had a negative cost (GRASS v.net modules do not normally consider negative costs).

As the network preparation procedures were finalised, the next step of the process was the calculation of prime centrality indices using v.net.centrality and development of the novel centrality index (i.e. the prime objective of this research). As a theoretical background, various indices have been developed to determine centrality, all are ultimately derived from the prime centrality indices developed in the middle of the 20th century: degree centrality, eigenvector centrality, closeness centrality and betweenness centrality. Indeed, the above indices are representative of three distinct classes of indices which either base their computation upon neighbours, distance, or shortest paths. (Tsiotas & Polyzos, 2015, p. 94; Valente, et al., 2008, p. 16). These prime indices were then evaluated considering the development of an index which best represents the ideal location for transport hubs, the results of which can be seen in Table 2.

Table 2: Ideal location for transport hubs

Centrality	**Description**	**Evaluation**
Degree	Measures its importance by number of edges connected to each vertex	A useful metric, but well-connected nodes in the periphery of an area might not be of high importance.
Closeness	Measures its importance by identifying the node with the shortest distance to all other nodes	Although closeness centrality is a useful metric, it has little importance in periphery areas.
Betweenness	Measures its importance by number of times the vertex lies within the shortest paths between two vertices	High relevance, as it indicates nodes which have high potential for mobility.
Eigenvector	Measures its importance by assigning weights to their nodes based upon the number of connections to other nodes (i.e. degree centrality)	A useful metric, as it identifies nodes along the network which allow ease of connectivity.

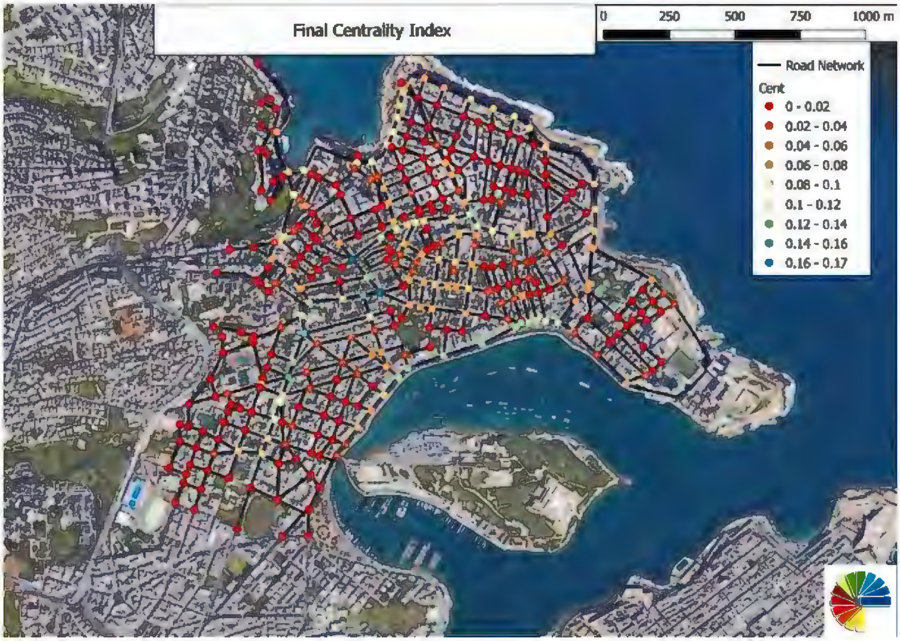
Betweenness and eigenvector indices were seen as the most useful to develop the new centrality index. However, since eigenvector values were seen to be extremely high in the centre of the network, it was decided to use a weighted mean to develop this index.

$$C^n = 0.5 \times \left((0.9 \times C^b) + (0.1 \times C^e)\right)$$

where = new centrality index
= normalized betweenness centrality
= normalized eigenvector centrality

A map showing the output of this index can be seen in Figure 2. Here, higher values denote a stronger index.

Figure 2: Final centrality index applied to network nodes



Source: Map developed in QGIS

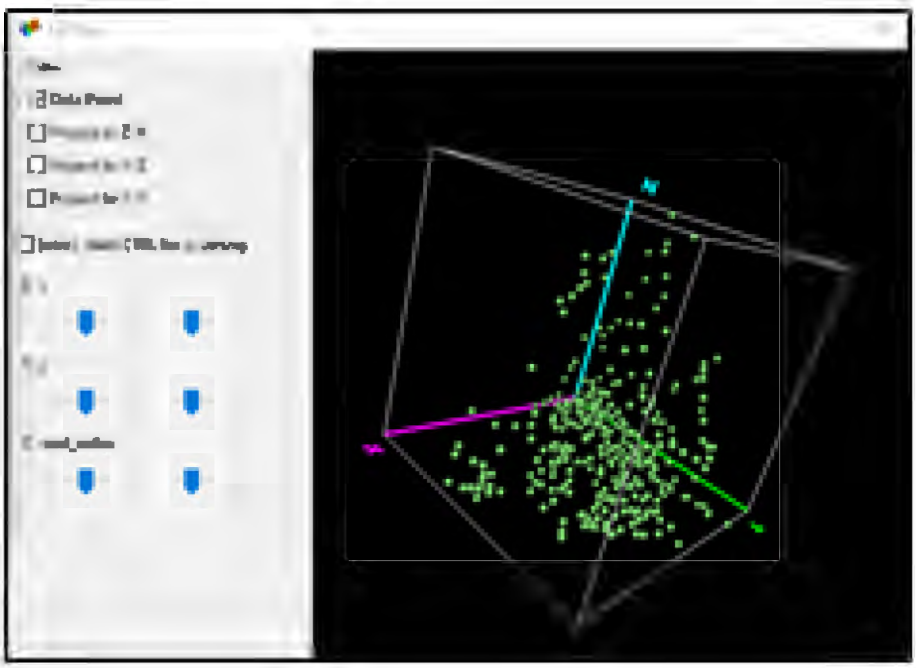
Discussion

After the methodology for the first objective was completed, the next stage of the project focussed on the secondary objective. The network was seen to have a high-density of nodes, with certain areas having a high concentration of nodes with similar centrality values. However, while it was noted that optimal transport hubs should have high centrality values, they should also be geographically spread out. This was seen to ensure that the network is completely well-serviced by the hubs' combined catchment area. It was therefore clear that a location-based clustering and filtering mechanism had to be utilised to determine ideal transport hubs within their associated area of influence.

A clustering analysis was therefore performed with QGIS. The plugin Attribute-based clustering was used to perform a K-means clustering taking into consideration 3 dimensions: 1) X coordinate of the hub 2) Y coordinate of the hub 3) new centrality index. A 3D visualization of this can be seen in Figure 3, created using the spatial data analysis program Geoda. The data was then organized into 26 hierarchical clusters based upon the above procedure. This clustering ensured that nodes were grouped according to their proximity and similar centrality values.

The filtering procedure was then initiated, with any hubs situated on links with a capacity lower than 400 being removed. The rationale behind this was that they could not physically accommodate a hub. Following this, 350m isochrones were created over each node utilizing the ORS Tools™ plugin. The decision for this distance is based upon the fact that 350-400m was the maximum walking distance threshold. The next stage of the filtering involved nodes being removed cluster-by-cluster until it was ensured those that remained had the highest centrality index within their 350m isochrone. These remaining nodes were the final transport hubs. The final transport hubs, and accomplishment of the secondary aim of this project, are visualised in Figure 4, along with their respective isochrones.

Figure 3: 3D Plot of K-Means



Source: Visualisation produced in Geoda

Figure 4: Final transport hubs and isochrones

Source: Map developed in QGIS

Results

Key results of this project are:

- Development of a new centrality index, and its use to identify influential network nodes of the Gżira -Sliema regional transport network.
- Determination of strategic locations for the implementation of transport hubs within Gżira -Sliema.
- Demonstration of the use of centrality analysis in the local transport planning framework and process.

Recommendations

Key recommendations of the effort are:

- Sensitivity tests to ensure the veracity of the cost function developed for the centrality index.
- Modelling the implementation of the proposed transport hubs to determine the

validity of the centrality index. This can be performed by the modelling of new and existing transport services utilizing these hubs.

- Application of the defined methodology to other regional transport networks in Malta.
- Consideration of the approach developed within this research project to be formally incorporated within the local transport planning and transport modelling process.

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A Word in Space

Wied Merill – San Lawrenz
Easting: 427344.660, Northing: 3990580.380

Beauty and Danger: the Għar Lapsi case for spatial information integration

Saviour Formosa

Keywords

Erosion, Unmanned aerial vehicle (UAV), Terrestrial laser scanner (TLS), Backpack scanner, Caves, Tunnel, Data integration, WebGL, Cloudisle.org

Note

Acknowledgments are due to Ing Ray Farrugia, Perit Mario Ellul, Dr George Buhagiar and their teams from the Marine and Storm Water Unit of the Public Works Department within the Ministry for Public Works and Planning and Mr Christopher Cutajar who enabled this process to start off following a mission to Cyprus as well as championing the SIntegraM and SpatialTrain projects.

Introduction

Spatial data integration across diverse technologies, methods and analytics is gaining ground through enhanced research functionality throughout the data cycle. Projects employing the entire data cycle in conjunction with readily available tools both open-source and proprietary, have become common place across the domains, as evidenced in this publication. The terrestrial, bathymetric, aerial and underground domains spanning the physical, natural and social environments have reached fulfillment in delivering useful outputs that are fundamentally spatial based. Spatial information has reached the desks of policy makers and decision takers, such that it is becoming increasingly difficult for the makers and takers to push forward an outcome when faced by an informed public and significant others who posit their feedback and consultations on an informed based: a spatial baseline. This case study depicts an exploration into the integration of various methods and technologies to aid decision-makers to preserve a beautiful but also a dangerous site. Use of a drone (UAV), a terrestrial laser scanner and a backpack laser scanner, enable the creation of an integrated dataset that depicted the structural status of the area, interesting findings and a case for intervention.

Technological imperatives in integrating data

Capturing reality through scanning devices or photogrammetric processes delivers 3D outputs for the former and 2D/3D outputs when the latter is used. Integrating both data acquisition outputs would generate more accurate data. Aerial data capture using unmanned aerial vehicles, commonly referred to as drones delivers highly accurate 2d and 3D outputs as delivered through photogrammetric processing (Adnan et al, 2019), whilst terrestrial laser scanners (TLS) are instrumental in capturing 3D point clouds (Fabbri et al, 2016) as are backpack laser scanners (Erdal et al, 2021).

Whilst the UAV method seeks reality capture from an elevated position, it may be limited in capturing low or underhanging areas such as cave beneath overhangs or door beneath balconies. At the other end TLS captures data from the ground up and acquires those areas not captured by UAV technologies. The TLS, however fails to capture the elements above those areas which are being scanned such as roofs and treetops unless access is sought. Laser scanners borne by UAVs are an option to overcome these lacunae, whilst videos and imagery acquire at ground level counter the UAV image capture loss. Integrating the data implies a need to use the same coordinate system, in this case UTM WGS84, adjusting heights of the captured data since both UAVs and TLS acquire z-values that requires anchoring to pre-captured Ground Control Points (GCPs) (Cunha et al, 2021).

The study of the evolving importance of these capture systems, which whilst recently available to researchers and operational entities in more accessible relative-inexpensive technologies has focused on UAV-dedicated photogrammetric processing (Jaud et al, 2019), multi-platform UAVs (rotor and fixed wing) (Gutiérrez et al, 2020), TLS-dedicated measurements (Eltner et al, 2013) in combination with targets placement (Abdulrahman et al, 2014). The availability of mobile backpack laser scanners has enabled studies to be carried out in rapid capture through walking modes or Segway-assisted devices in an urban environment (Formosa, 2019), whilst (Erdal et al, 2021) mapped historical buildings, forestry (Ko et al, 2021; Xie et al, 2022). Integrating these different technologies and methods results in multi-scalar outputs as exemplified by Jaillet et al (2017) through the use of photogrammetry and TLS to study rock art (increasing capture iterations from micro areas to entire landscapes.

Various studies have been carried out that investigate the data capture process and how it is employed in the study of urban and rural structure, notably on beach topography (Zimmerman et al, (2020), sand dunes (Pintado et al, 2018), cliff monitoring (Kersten et al, 2020; Jaud et al, 2019), its erosion (Letortu et al, 2017) and collapse Dewez et al, 2016.

Other studies focused on coastal monitoring (Zimmerman et al, (2020), sedimentology (Kordic et al, 2019), volume measurement through erosion (Hayakawa et al, 2020; Obanawa et al, 2018) and through mining (Correia, 2020; Jaroslaw et al, 2021), landslides (Garnica, 2021), and forensic engineering that studied accidents sites (Cappelletti et al, 2019; Urbanová, 2017). In terms of the scanning of underground areas inclusive of caves, Walters et al (2020) and Fabbri et al (2016) investigate issues emanating from TLS scanning of large natural caves, taken further through its analysis through visualisation by Buchroithner (2015).

Study Scope

This paper covers a study designed to investigate the coastal landform in the Maltese island areas called Għar Lapsi, an area exposed to significant wave and wind erosion (Figure 1). The paper does not delve into the study of coastal erosion which is being investigated in another research activity but focuses on the methods used to capture the data, the technologies employed, the analysis taken up and the eventual outputs.

This document reports the findings pertaining to the spatial analysis of the site under study as related to erosion indication by the Erosion Unit within the Public Works department. The spatial analysis reviews the points of interest identified by this Unit and creates a 3D model of the area. The latter was particularly crucial since the area is deemed as a potentially dangerous structure or is inaccessible due to sheer cliff-faces or underwater cavities. This renders any filming and in-situ analysis as difficult or impossible to access. The use of remote technology and 3D generation helps the investigators to revisit the site in a digital immersive format.

The scope of the analysis was to carry out baseline data capture as well as build a 3D model of the zone for operational implementation, an output that could be measured online through a normal web-browser that pushes spatial data towards the general public and academics, away from those with proprietary tools and access rights. This process ensures that the output leads to a democratisation of spatial data whilst ensuring that analysts from multiple domains can contribute to the safety and security of the zone as well as furthering the study to include predications of structural change (Garnica, 2021).

Figure 1: Għar Lapsi - Scene Location

Figure 1a: Għar Lapsi location in Siggiewi Local Council

Source: Topographic Data

Figure 1b: Scene Zone LiDAR colour map: GridCell: 447_3965 and 448_3965

Source: LiDAR data: SIntegraM, 2018

Figure 1c: Għar Lapsi West Zone

Figure 1d: Għar Lapsi East Zone

Figure 1e: Għar Lapsi West Zone Erosion

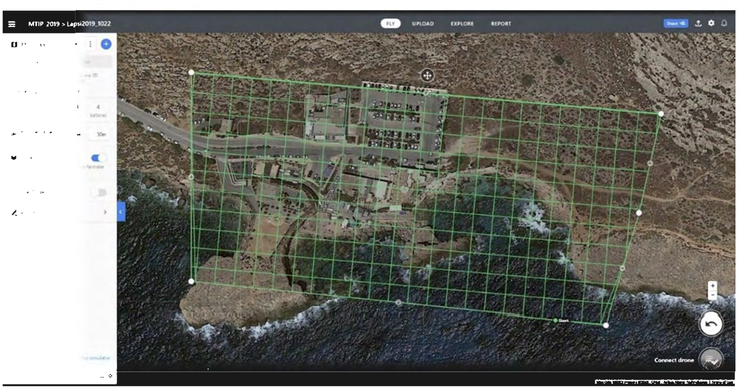
Figure 1d: Għar Lapsi East Zone Erosion

Capture Considerations

Whilst Cunha et al's (2021) indicated UAV capture at 20m and 40m distance, the Għar Lapsi study focused on heights of 30m, 60m and 100m, thus ensuring less data loss through oblique (65deg within the grid and 45deg at the perimeter) and nadir capture. This was carried out in conjunction with GCPs acquired through a previous national LiDAR scan (SIntegraM, 2018), and a set of image-based targets set in visual sight of each other to ensure capture in areas where GPS is in accessible (Abdulrahman et al, 2014). The process to capture same data through the Backpack scanner that employs SLAM technologies and GNSS enables a better capture (Xie et al, 2022).

The Għar Lapsi data capture was carried out in grid format to ensure cross-shore and along-shore capture in both directions (Figure 2 - Drone deploy). Whilst aerial laser scanners are best suited for the study of zones as is the Għar Lapsi area, digital photogrammetry is recognised as a viable method to survey sea-cliffs and areas that are difficult to observe from the land sides, particularly in areas liable to collapse and safety issues. Obanawa et. al (2014) state that the method lowers the cost and enables frequent measurements particularly through the need to scan multiple times due to the erosive impact of sea waves on cliff sides (Obinawa et al, 2018), is the case in Għar Lapsi. The indicated non-contact surveying method that UAVs offer enable cost and capacity reduction as well as enable multiple runs to aid the spatio-temporal analysis of cliff face, cave and environmental movements (Kordic et al, 2019). The method however may be subject to changing weather conditions that may hamper capture (Letortu et al, 2017), mainly temperature, wind and rain. Human factors such as operator and pilot adherence to IMSAFE regulations may also hamper capture, however such still result in quicker data capture than traditional means using land-based and sea-based measurements.

Figure 2: Drone Deploy: Planning the flights



Technologies Employed

Technologies employed for this study were dual in nature, based on UAV (Unmanned Aerial Vehicle) and Laser Scanning, the latter on TLS (Terrestrial Laser Scanner). The technologies employed included a DJI Mavic Pro 2 AUV, a RiEGL VZ400i Terrestrial Laser Scanner and a GreenValley LiBackpack50. Software used in the study included Agissoft Metashape, Pix4D, Lidar360 and RiScanPro. Additional output software that was used for immersion analysis include Unity 3D and the MagicLeap applications, whilst the WebGL outputs were published using LasPublish as published on www.cloudisle.org.

Methodology

This study involved a main method of data acquisition that aided the creation of the 3D scene reconstruction:

An Image-based data capture process. This process employed the main method using drone technology taken from a gridded mission at 60m height; (Figure 2)

A Terrestrial LiDAR scan rendered at 50,000 points per sec transmission; and

A Backpack LiDAR scan rendered at 200,000 points per sec transmission.

The site was generated using multiple technologies where, the 3D model was created through the implementation of LIDAR (Light Detection and Ranging) data acquired through the SIntegraM project that delivered point data at a 40-120 points per meter squared resolution, which allowed for the generation of a triangulated image that enables 3D extrusion of the base map for easier visualisation. Further data analysis enabled the integration of the aerial photos and the 3D data to deliver a virtual replication of the study site.

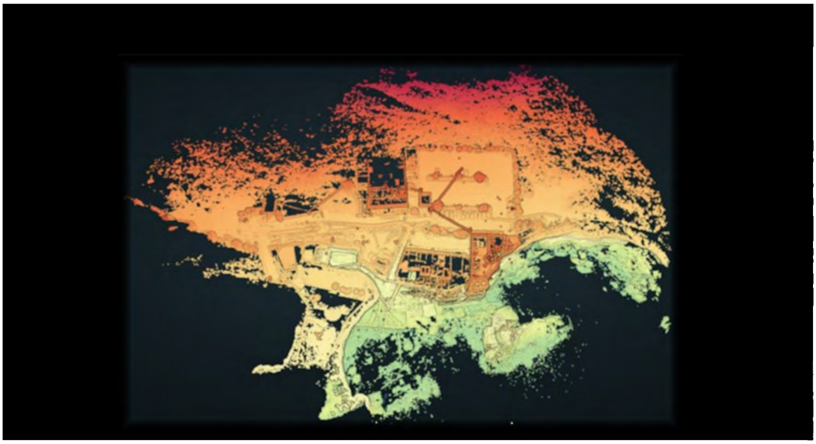
- The video-to-image-to-pointcloud generation was based on a 4k image-based approach that allowed for the generation of a 3D interactive model that allows the user to rotate and view the model from different perspectives which allowing for visual analysis of the Għar Lapsi scene, particularly as it offers the users a tool through which to one can revisit the scene digitally (Figure 3).
- The Terrestrial Laser Scanner enabled the direct pointcloud capture through the generation of a 3D interactive model that can be exported to various formats for analysis as well as for export to a web-based light interactive tool as indicated in the video-image-pointclouds process (Figure 4).
- The Backpack Laser Scanner enabled the direct pointcloud capture through a walkthrough of the area which process captured a composite non-colour pointcloud using LiDAR and SLAM technologies (Figure 5).

- Additional videos and in-situ imagery were also employed in the real to virtual data conversion.

Figure 3: Photogrammetry aerial (lacks oblique capture)

Figure 4: TLS LiDAR terrestrial (lacks building roofs)

Figure 5: BackPack Laser scanner output



The process to investigate the area and identify scene dynamics required the generation of the area in 3D. The process entailed the following:

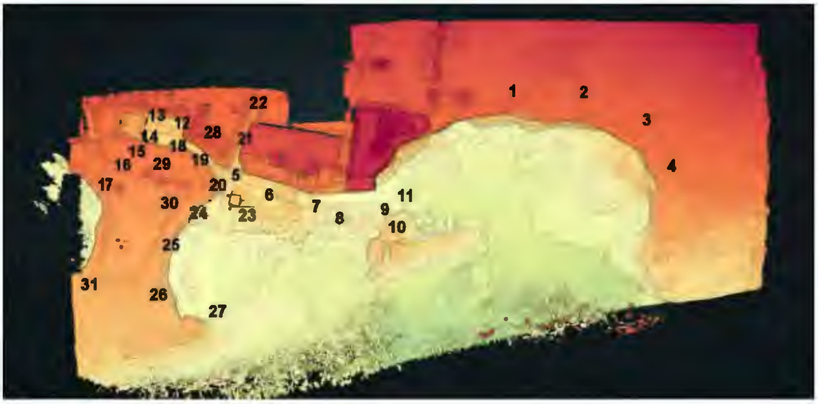
Phase A: Raw data and imagery acquisition

The data acquisition phase (Phase A) required a series of scene-related imagery and locational information which serves as the foundation for the generation of a 3D model (Phase B) and the later analysis in Phase C of the scene.

The process entailed the following steps:

- The acquisition of LiDAR data that included z-height (to determine the actual laser height of each point in the Għar Lapsi area. Source: SIntegraM 2018;
- The acquisition of aerial remote-acquisition imagery (to identify the coordinates and imagery of the points of interest). Source: SIntegraM 2018;
- The acquisition of drone imagery/videos taken during the Għar Lapsi scene investigation process; and
- The acquisition of terrestrial laser scans taken during the Għar Lapsi scene investigation process. Thirty one (31) scan positions were taken (Figure 6).

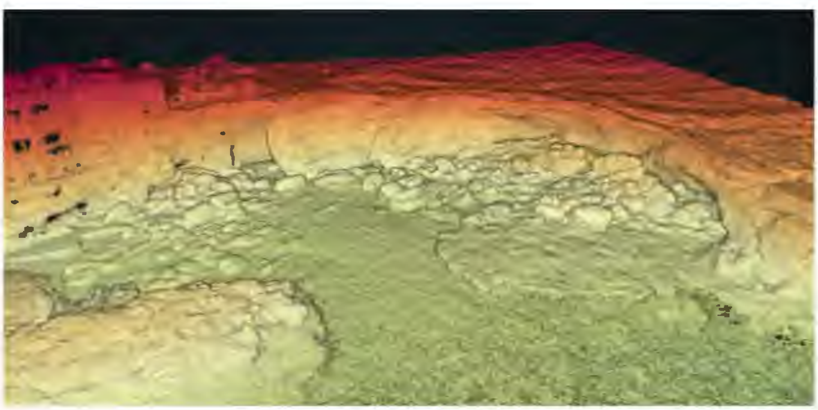
Figure 6: Scan Positions: 1 – 31



Phase B: Data extraction

The data extraction exercise employed various technologies and processes that converted the diverse Phase A technologies into pointcloud information which would allow analysis of the scene in a 3D virtual environment. The different imagery and data were integrated into a spatial information system using diverse data conversion technologies and a 3D model of the area was generated. The output was such that due to very clear waters at the moment of image capture (best taken just before sunrise which would cause thermals and in turn waves), a clear 3D scan of the seabed could be derived. The output as depicted in Figure 7, shows the bathymetric part clearly highlighting the rocky bottom.

Figure 7: 3D pointcloud Oblique Height Perspective – Facing NW



Phase C: Scene dynamics and analysis

The 3D virtual environment was used to visit the scene from various angles and perspectives as well as to allow the erosion experts to identify potential scene dynamics. The resultant model was available in different formats that included the 3D model as pointclouds and meshes.

Data was made available in various formats to allow users to employ the data in proprietary software and applications. The data captured from the different scans were initially rendered on their own, then integrated within one pointcloud. The results were then prepared for publishing through WebGL and uploaded to the links indicated in the text. Such does not need a powerful computer but a common web-browser. The LasPublish (potree) WebGL tool employed for this exercise allows for coordinate identification, measurements, 3D movement, profile generation and export. DEM, DSM and DTM outputs were resultant through the spatial analytics carried out through Pix4D and Global Mapper in conjunction with outputs from the proprietary TLS software (RiScanPro) and backpack (Lidar 360). In this study, error generation (Cunha et al, 2021) through data lacunae was reduced through the integration of data from the aerial imagery and terrestrial laser capture. The resultant DSM was employed to anchor the 3D data covering the caves, the erosion zones and the underground tunnel (Correia, 2020).

Scene Dynamics: Transacts

This section is based on the calculations pertaining to the scene under study. The area has a generic length of 30.8m with heights varying from contact with sea-level to 6.4m. The transacts indicate a length of 21.3m and a height of 4.2m for transact 1, a length of 20.1m and a height of 4.9m for transact 2, a length of 1.6m and a height of 3.4m for transact 1 (Figure 8).

Figure 8: Transacts

Figure 8a – Transacts Lines

Figure 8b – Transacts Buffers of 3m, 8m and 20m (accommodates the feature width)

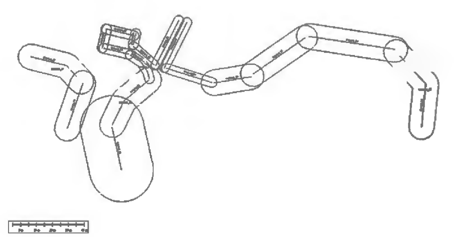


Figure 8c – LiDAR data in Transacts Buffers of 3m, 8m and 20m (accommodates the feature width)

Figure 8d – Area 1 Transact 14 Line and Buffer 8m plus TLS data

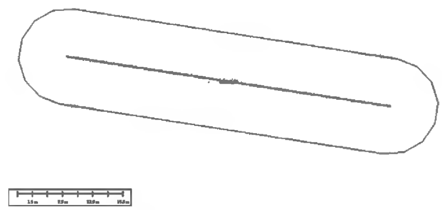
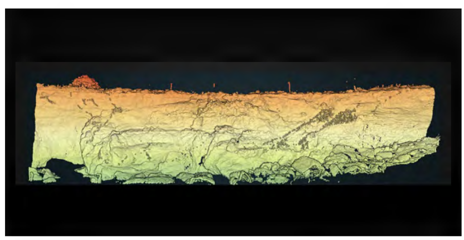


Figure 8e – Area 1 Transact 14 Data Face Frontal RGB

Figure 8f - Area 1 Transact 14 Data Face Frontal Elevation



Scene Dynamics: Erosion visuals

A quick measurement based on the point clouds from the extreme ends of the dataset indicate that the eroded areas vary in dimensions of 4.5m (depth) by 4.5m (width) by 1.5m (height) for Area 1, 6.4m (depth) by 7.4m (width) by 2.4m (height) for Area 2 and 4.97m (depth) by 2.2m (width) by 2.6m (height) for Area 3 (Figure 9). Note that these are based on random points that need extensive measurements through dedicated programmes.

Erosion prone spots can be analysed through a side visual as depicted through LasPublish output that allows for profile visuals and measurements.

Figure 9: Erosion Visuals

Figure 9a – Area 1 Intra-Rock (view from inside the rock) Oblique RGB Perspective – Facing N

Figure 9b - Area 1 Intra-Rock (view from inside the rock) Oblique Height Perspective – Facing N

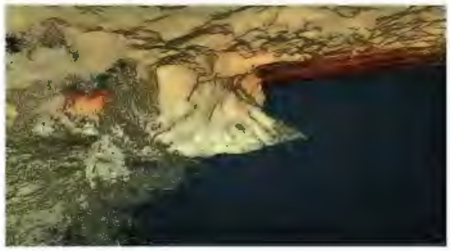


Figure 9c - Area 1 Exterior Oblique Height Perspective – Facing N

Figure 9d - Area 1 Exterior Oblique Height Perspective – Facing N

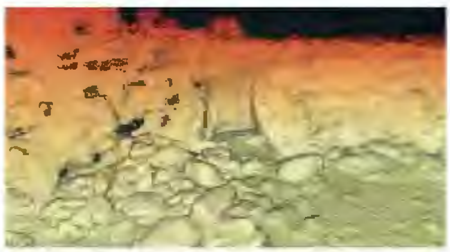


Figure 9e - Area 1 Intra-Rock (view from inside the rock) Nadir RGB Perspective – Facing E

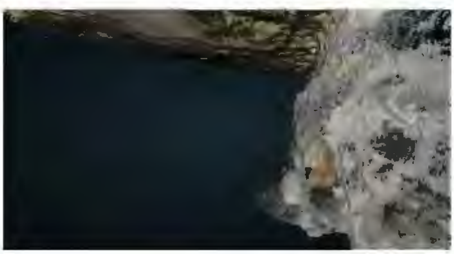


Figure 9f – Area 1 Intra-Rock (view from inside the rock) Nadir Height Perspective – Facing E

Comprehending the Spaces

In order to comprehend the spaces involved in the Għar Lapsi scene, the purpose of this study was aimed at recreating the scene in 3D which would allow the decision-makers to be able to revist the Għar Lapsi scene in an interactive 3D output. The process to create and eventually to render the scene of investigation is a laborious and intensive process requiring high-end computing power and tools that were necessary to allow investigators and the actors to acquire an accurate model of the scene under study.

The model, in conjunction with the GIS component allows the decision-makers to identify those areas that are depicted as potential areas serving as line of sight through scene rotation and immersion as well as a more detailed depiction of the scene (Refer to the Online Data Results and Resources section for an interactive data experience).

It is of importance to note that this exercise was verified through the use of the two methods (photogrammetry and laser scanning), which interestingly also enabled the rendering and measurement of caves (Figure 10), eroded spaces (Figure 11) and tunnels dug beneath the earth (Figure 12), one of which penetrated right through to the cliff, currently used as a boathouse (Figure 13).

Figure 10 depicts the main cave as being 30.48m in depth from the outermost jetty corner, 3.96m in height and 4.37m below street level, a cave that has been protected from erosion through netting installed in place by the Public Works Department.

Figure 10: Għar Lapsi main cave dimensions
TLS Area 2 Intra-Rock (view of Cave from inside the rock inclusive of surface underside)
Height Perspective – Facing N

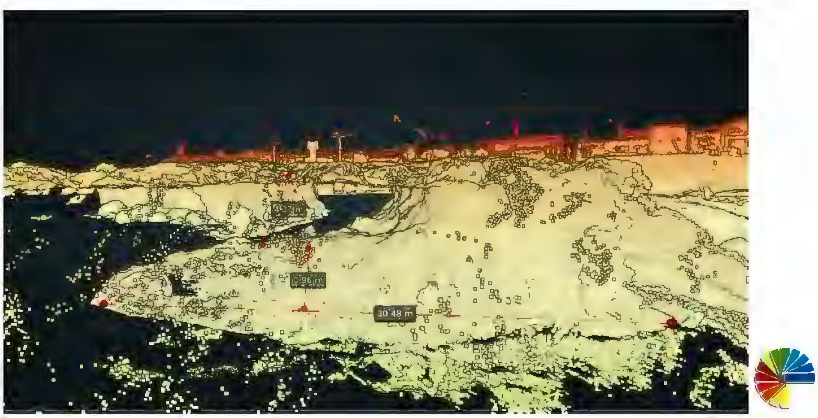


Figure 11 depicts the incursion of (Figure 9) wave action that eroded a section of the eastern bay cliff 5.66m in a horizontal direction beneath a 13.92m cliff face. Note that the eastern part of the bay shows an extensive collapse history.

Figure 11: Eroded areas (beneath cliffs) dimensions - Area 1 Profile 1

Figures 12 and 13 depict the western Bay that posits an old concrete cliff-face balcony which was traced to a boatyard in the hill that resulted in a 25.70m rock-cut tunnel of 1.86m height and located 3.26m beneath the yard floor. The Lapsi Area is littered with boathouse windows overlooking the sea, which would posit a need for future studies in order to map the entire zone and analyse the entire Lapsi area for its safety and security as well as danger potential. The technologies employed in this study could be complemented by Ground Penetrating Radar to enable the discovery of underground spaces, which output can be integrated within the model resultant from this study.

Figure 12: Area 2 Measurements Tunnel/Boathouse

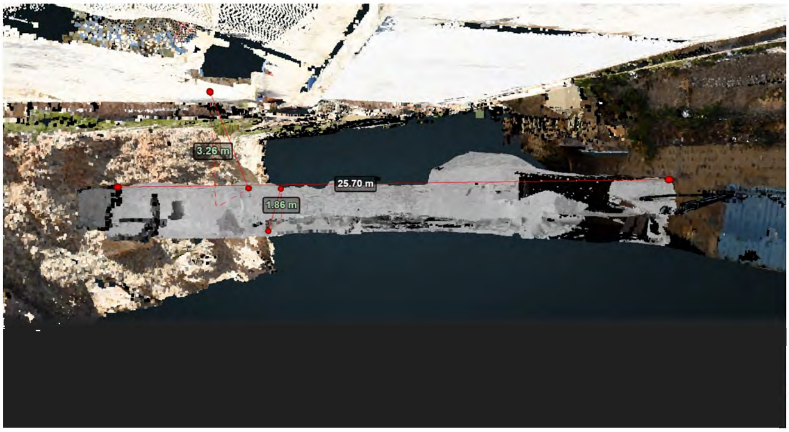


Figure 13a: Identification of tunnel exit through a cliff hanging balcony

Figure 13b: TLS Intra-Rock Tunnel linking Area 2 with Area 3 (view of tunnel from inside the rock inclusive of surface underside) RGB Perspective – Facing SE

Conclusions

Integrating diverse datasets for analytical purposes resulted in a comprehensive information system comprising aerial (top down), laser (Bottom up) and laser façade capture. The Għar Lapsi study enabled the researcher to analyse the dimensions of the entire zone, inclusive of the main cave, eroded areas that might point towards hazards such as cliff collapse, rock falls, amongst other safety and security issues. The process employed related to studies on cliff monitoring (Kersten et al, 2020; Jaud et al, 2019), the erosion in the western and eastern Lapsi areas (Letortu et al, 2017) and potential and real collapse in the eastern bay (Dewez et al, 2016). The study highlighted the technologies required to scan a large zone and the depiction of results that can be accessed through WebGL.

Online Data Results and Resources

HTML Links for online 3D datasets:

3D Lidar Point Clouds

- Imagery Source: UAV DroneDeploy Mission
https://www.um.edu.mt/projects/cloudisle/DATA1/MTIP/47p_lapsi_dji.html

- Imagery Source: UAV Manual Flight Capture (a Balcony area)
https://www.um.edu.mt/projects/cloudisle/DATA1/MTIP/gharlapsi_zone03_ul.html

- Imagery Source: TLS Laser Scanning
https://www.um.edu.mt/projects/cloudisle/DATA1/MTIP/gharlapsi_tls_comb.html

- Imagery Source: Backpack Laser Scanning
https://www.um.edu.mt/projects/cloudisle/DATA1/MTIP/gv_lapsi_2019_walk.html

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EPILOGUE

The SpatialTrain Scholarship Scheme Futures

Malcolm Borg

The rapid emergence of GI and its diverse applications

The use and spread of GI have evolved rapidly in the past decades. It evolved as a mapping data tool to integrate and dovetail other diverse applications making it one of the most powerful data gathering, assessing and strategic tools available for planners in various sectors. The offshoots from the implementation of this tool in planning have been expansive and diverse spreading from the then Planning Authority to other departments, agencies and the private sector. The SpatialTrain Scholarship Scheme is a valuable and vital project which increases the use, application and science of this ever-transforming platform. As Elaine Sciberras has highlighted in her introduction, "The SpatialTrain Scholarships Scheme project was a first major step at a local level to provide accreditation of the public sector within the field of geomatics." Accreditation and training are key to readily respond to the "rapid development in digital technology, particularly with the growing use of cloud technology, Artificial Intelligence, and higher resolution remote sensing from both UAVs and satellites." Apart from setting out current capacity-building needs, SpatialTrain has set benchmarks for future evolution and training.

The initial and humble beginnings with applications for the; National Protective Inventory, character appraisals, heritage management systems and visual connectivity with the grafting of 3D applications and web mapping are a far cry from the current GI applications. The 1990s gave the initial creative spark which led to the developments presented in this publication. The original applications flexed and extended the use of GIS (through Mapinfo), bringing various possibilities across various departments. At the outset, GIS was seen as a tool to; warehouse, analyse, and publish data in an integrated and user-friendly format. The significant initial and continuous investment in resources by the Planning Authority has left a legacy. In hindsight, this investment has rendered long-term and changed the view on data gathering and hoarding. GI has developed carrying the three established fundamental ideals: accessibility, integration, and sustainability.

Access

The SpatialTrain scholarship drives the principle of access. GI has opened up further the concept of space as a visual experience to all. At the click of a mouse or button, or swiftly via touchscreen, one may gain full access (or nearly) to the world's geography. It has made its way into our homes, our cars and most importantly, as a primary tool on our mobile phones. It may be adopted as a simple locator or a pathfinder, but it has also evolved with algorithms in the development of augmented reality, to name just one application.

Nevertheless, this access is limited in its form, and the possibility to view Google maps or search for a development or planning application is fundamental but now basic as a concept. Access in the context of training has moved from GIS. This scholarship has extended out promoting geomatics and the opportunity and the possibility to branch out in various fields and related disciplines. Both are Canadian in origin, but geomatics is relatively recent and harnesses modern or, more appropriately, evolving technology. It is targeted to deliver disciplines in surveying, photogrammetry, geodesy and hydrography. It encompasses various methods and tools, from data acquisition to distribution and related products or services, which provide for geographic data collection, integration, and management. Access to these disciplines has made "the science of geography and the geography of science" evolve at a phenomenal rate across various fields. The mathematics of the WHERE has driven geography from the spatial behaviour of people, concerns with spatial relationships and Earth sciences to where these are going – a physical and spatial bridge.

Integration

This corpus of papers shows the validity and success in providing access to these disciplines, related tools and adaptive use of relative applications. Saviour Formosa, considered a pioneer in this sector, has dedicated his professional and academic acumen to push GI and related uses. He stresses the need to become more knowledgeable in the field of geomatics as it proliferates with public entities as prime users who need to harness this technology and adapt it locally. EU-funded projects have spurred the spread of this knowledge and supported the training. The EU, through its diverse programmes, has supported research and development in the sector and the application in the various domains is a witness to its success. However, one must highlight that integrating domains or work across domains in the public administration and the private sector is crucial to increasing local capabilities and accelerating capacity-building and knowledge. The acquisition of high-end geomatic technology and the capability to collate spatial data strategically is a vital step in sharing resources.

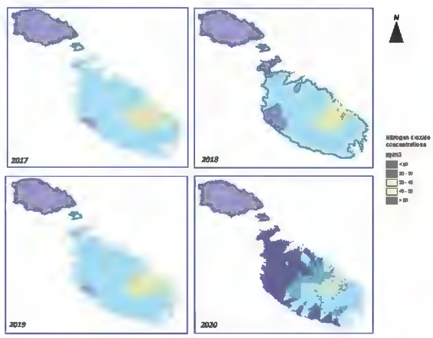
The future is interesting!

Malcolm Borg, Saviour Formosa and Denis Darmanin have locally taken the initial Heritage Management Systems to new levels. In just over two decades the digital web-mapping tool through advanced technology has made the application of Historic Building Information Modelling (HBIM) for local scenarios possible. This methodology in the Cultural Heritage domain is proving significant in reading, assessing and transmitting the characteristics and value of heritage buildings through the grafting and integration of GI, Lidar, CAD and 3D applications. These tools are vital for urban archaeology and the archaeology of building and truly justify the drive for further training and development in the sector. Again, as in 1999, these elements are encapsulated in the EU sustainable cities principle of ecosystems thinking. The SpatialTrain Scholarship Scheme project is not only a matter of statistics it is essentially the advancement of the science of geography.

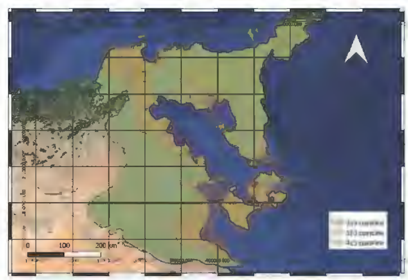
COLOUR IMAGERY

This section depicts colour versions of selected images from the chapters

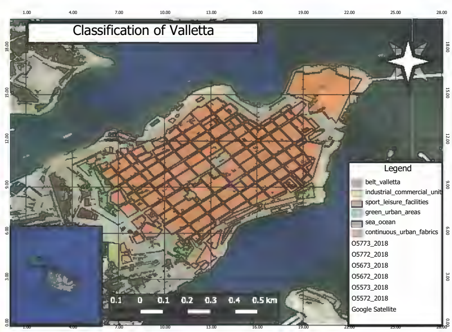
Chapter 1
Figure 2: Pollution maps using kriging interpolation for the years 2017 to 2020



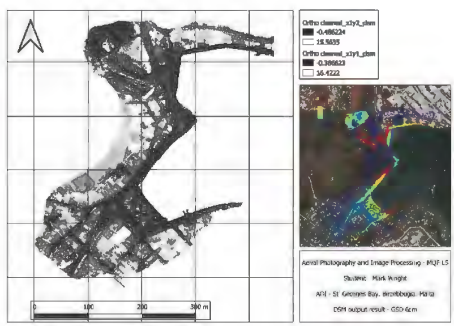
Chapter 3
Figure 7: three superimposed models at -200m, -300m, -400m



Chapter 2
Figure 2: Land Classification



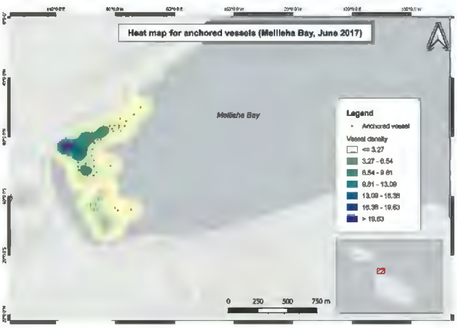
Chapter 4
Figure 3: AOI – St Georges Bay B'Bugia



Source: 3DF Zephyr Aerial

Chapter 5

Figure 2: Heat map for anchoring vessels in Mellieħa Bay based on the June 2017 scenario. Vessel positions are indicated in red points, whereas the heatmaps are shown in a blue gradient where the darker shades indicate higher boat densities



Chapter 6

Figure 6: Two vessels, one AIS point

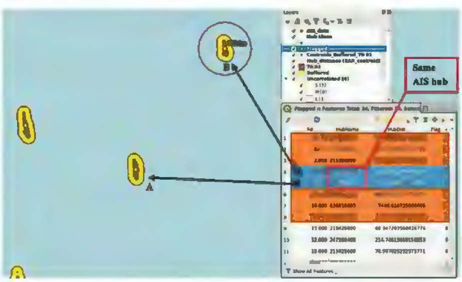


Figure 10: AIS heat map and AOI bathymetry

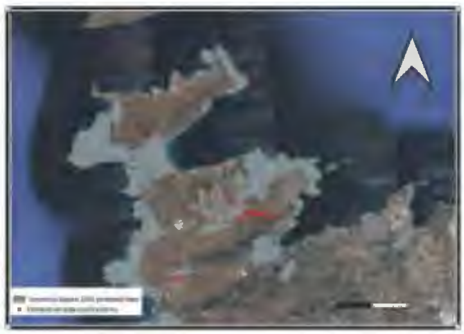
Chapter 7

Figure 4: Areas required to be closed off by cordoning to reduce trampling pressures on sand dune habitats identified and marked by Pix4D software

Source: Pix4D Support, 2021

Chapter 8

Figure 3: Pennisetum setaceum locations and terrestrial N2K sites in North Malta



Chapter 9

Figure 2: Percentage development applications approval rate per N2K site

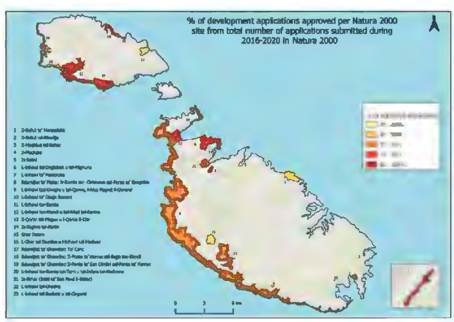
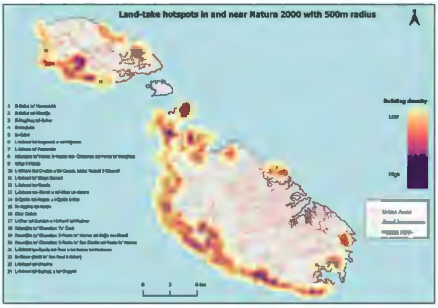
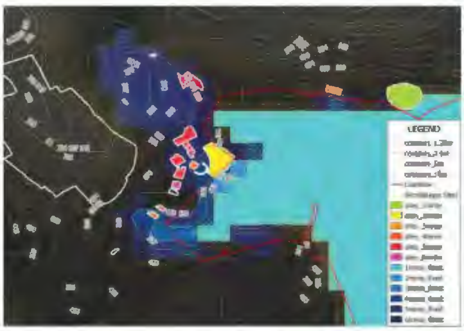


Figure 4: Heatmap: Buildings density within and around N2K sites



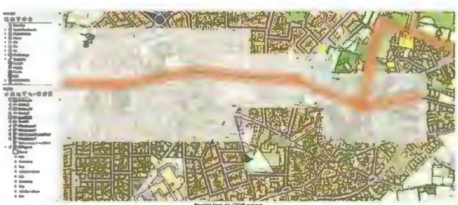
Chapter 10

Figure 1: Detail from overall canvas showing part of Birżebbuga, with projected 1 to 6 m SLR.



Chapter 11

Figure 5: Map output indicating significant tracts of the aqueduct from Rabat to Attard plotted on QGIS



Source: Superintendence of Cultural Heritage 2020

Chapter 12

Figure 1: Heatmap generated around post-2013 discoveries

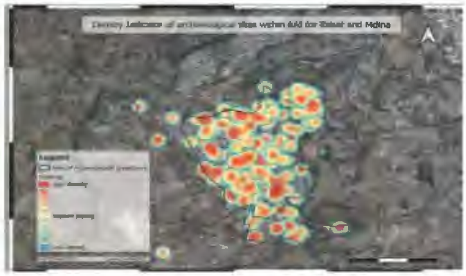
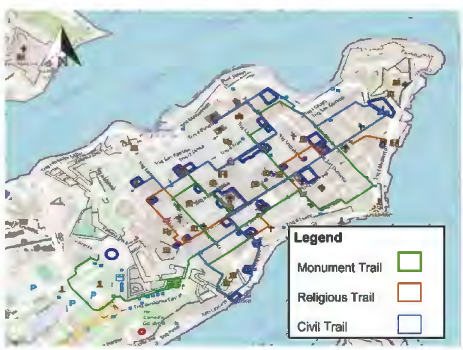


Figure 4: Archaeological discoveries resulting from development

Chapter 13

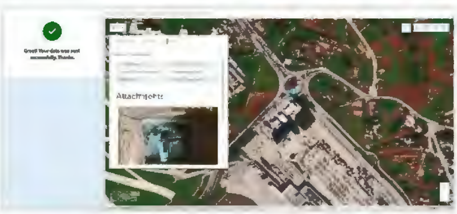
Figure 4: All the Trail Lines Formulated for this project



Chapter 14

Figure 3: Field Exercise

Figure 4: Published Questionnaire

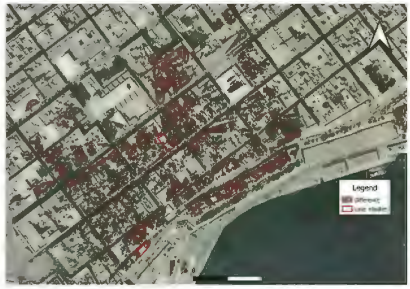


Chapter 15

Figure 1: Case study 1 viewshed overlayed on orthophoto

Source: Planning Authority, 2017

Figure 4: Case study 4 viewshed overlayed on orthophoto



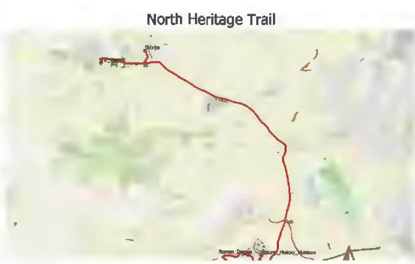
Source: Planning Authority, 2017

Chapter 16

Figure 2: The Prehistoric Heritage Trail Base map

Source: © OpenStreetMap contributors)

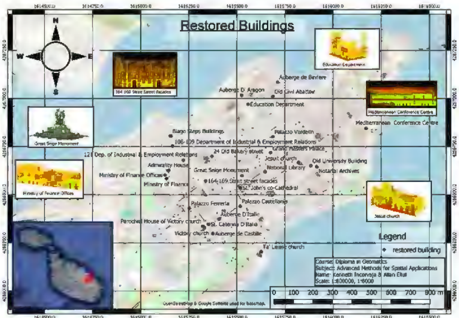
Figure 3: The 'North Heritage Trail' one of the spatially based trails produced.



Source: Base map: © OpenStreetMap contributors

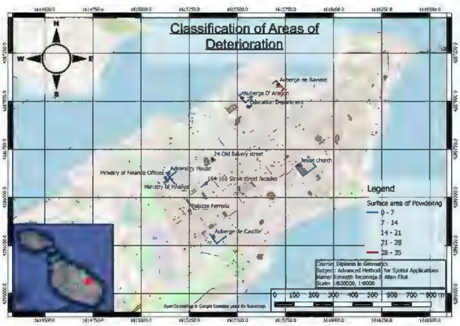
Chapter 17

Figure 1: General Layout indicating the restored historical buildings at Valletta



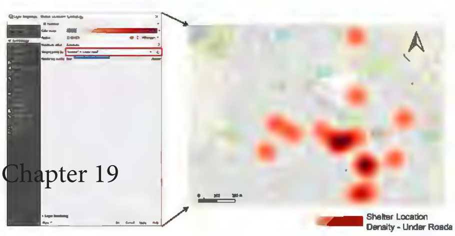
Source: Restoration Directorate

Figure 3: Highlighting the areas most affected by powdering on the restored buildings carried out by Restoration Directorate



Chapter 18

Figure 2: Heatmap Showing of Shelters Located Under Roads and their Location Density

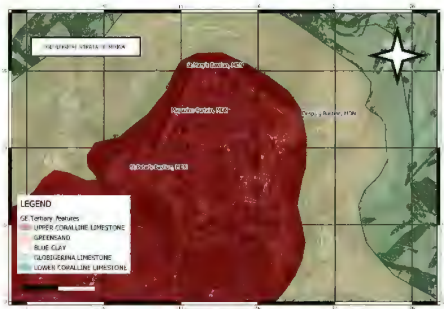


Chapter 19

Figure 4: Map showing all the selected fortification walls in Mdina, with the geological strata layer showing above this layer

Chapter 19

Figure 4: Map showing all the selected fortification walls in Mdina, with the geological strata layer showing above this layer



Chapter 20

Figure 2: Performing of Tie and Ground Control within the overlapped images, in order to create an internal orientation.

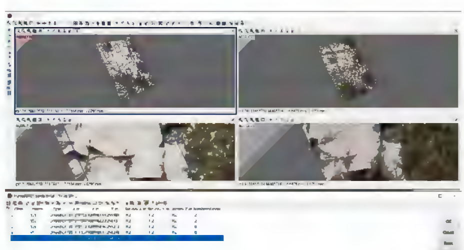
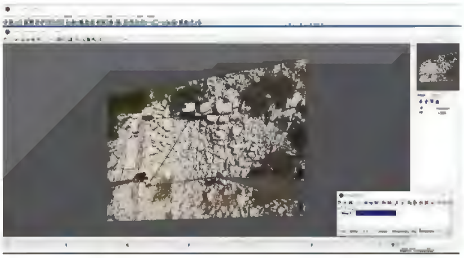


Figure 3: Outcome of the Ortho-mosaic, after performing internal and external orientation.



Chapter 21

Figure 2: Georeferenced Ordnance Sheets with superimposed Original Route and Features

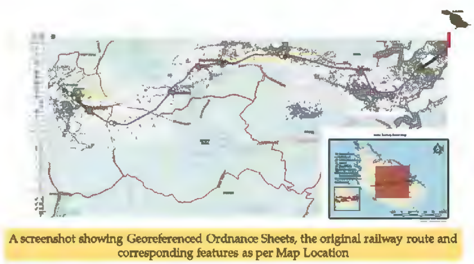
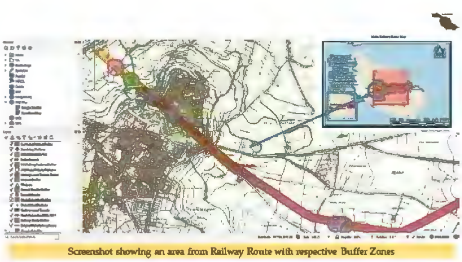


Figure 4: Detail showing Buffer Zones in Mdina Region



Chapter 22

Figure 3: Heatmap of the Accessibility Pavements

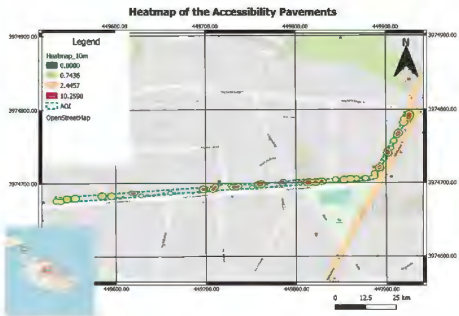
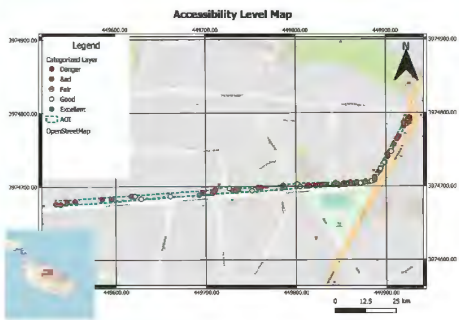


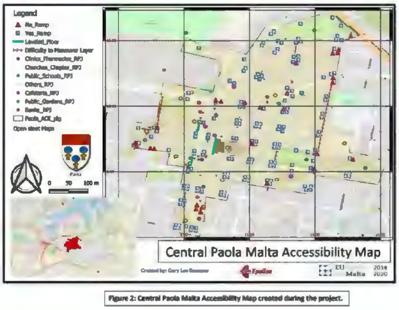
Figure 4: Accessibility Pavements' Map



Chapter 23

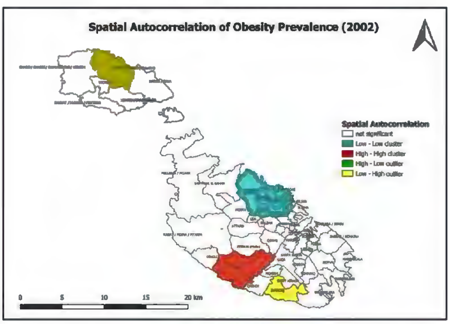
Figure 1: Qfield Mobile application Screenshots while gathering onsite data

Figure 2: Central Paola Malta Accessibility Map



Chapter 24

Figure 2: Statistically significant clusters and dispersed areas of obesity prevalence for 2002 (top) and 2014 (bottom)



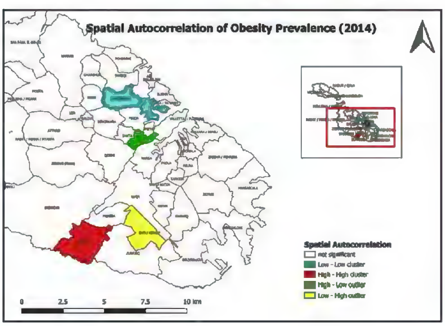


Figure 3: Choropleth thematic map showing the change in obesity prevalence between 2002 and 2014

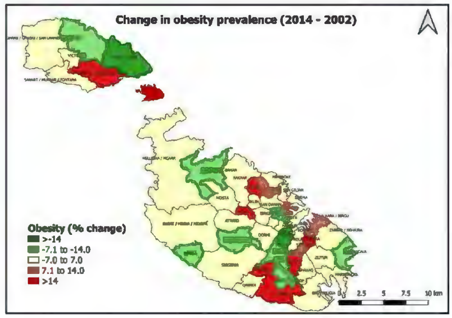


Figure 4: Heatmap showing the estimated number of obese residents living with obesity in 2014

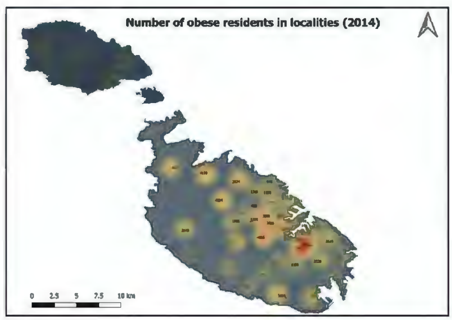


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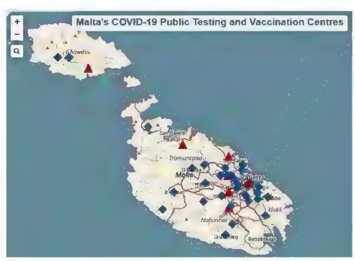
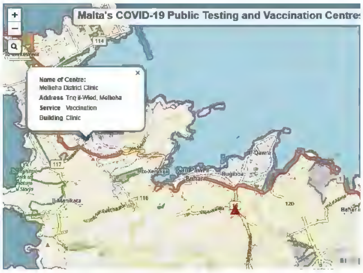
Figure 2: The output of the qgis2web plugin.



Source: qgis2web

Figure 3: Detail from the shareable map showing a popup with information about each centre.



Source: qgis2web

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Figure 2: Nadur Digital Elevation Model

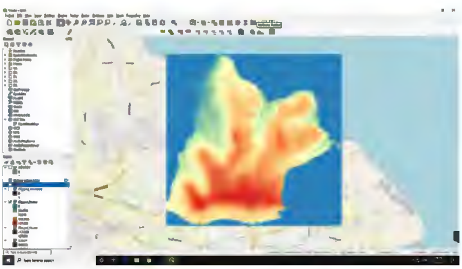
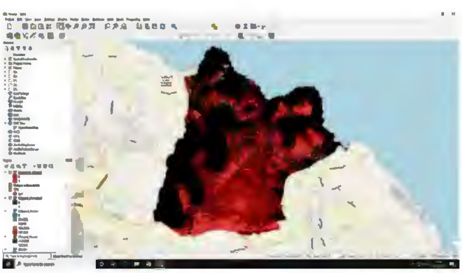


Figure 4: Viewshed (white shade) vs ITU-R P1812-5 (dark red) – Test Point 1. Light red represents areas covered by both test-points



Chapter 27

Figure 1: Malta's mobile network

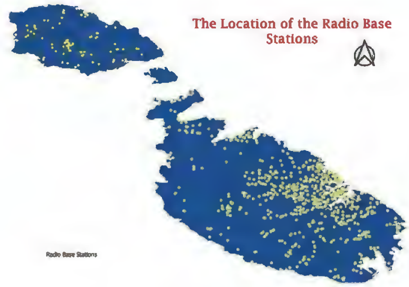


Figure 4: Complaints which fall within 200m from the Base Stations

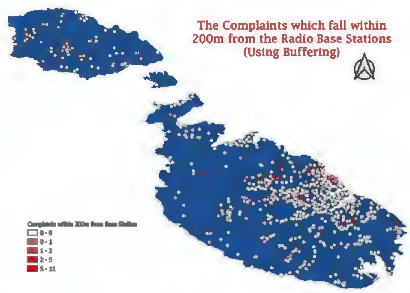


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Figure 3: E Field Exposure Level (V/m)

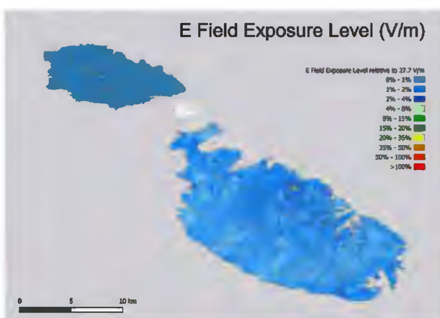

Figure 4: EMF Exposure in Ta' Qali National Park

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Figure 2: EMF measurements under analysis after being categorized according to the measured EMF exposure level.

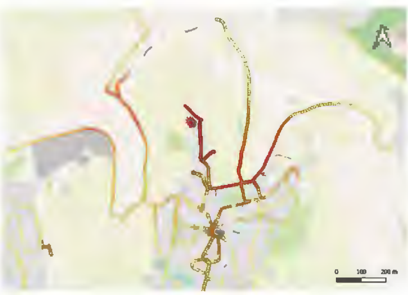
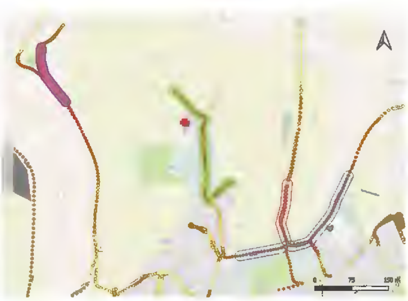


Figure 3: Buffer around the EMF data points which fall within the areas of maximum EMF exposure



Chapter 30

Figure 1: Centroids Urban Areas, Malta

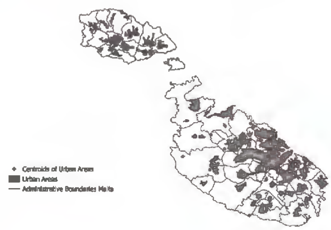


Figure 2: Urban Areas Identified for GI Projects

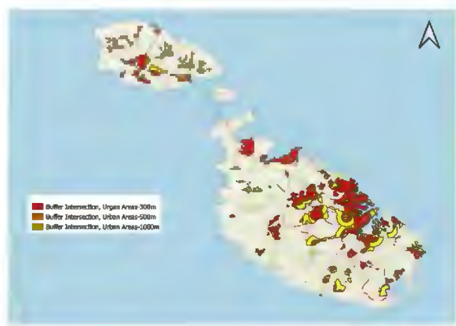


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Figure 1: Height raster shows the identified wall pixels

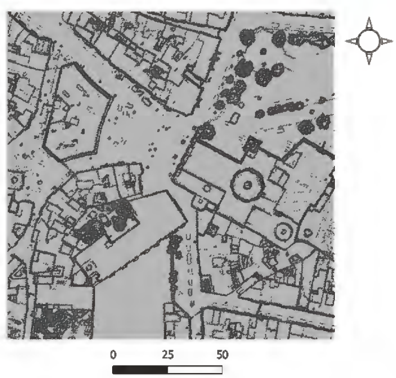

Figure 2: Aspect raster shows the compass direction of the walls and buildings

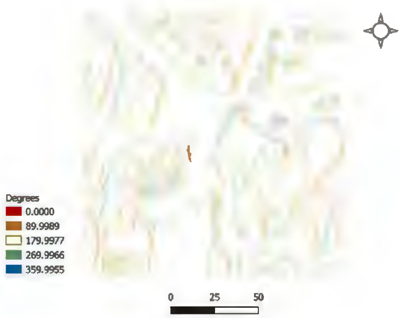

Figure 3: Raster showing the annual cumulative incident radiation per square meter for roofs

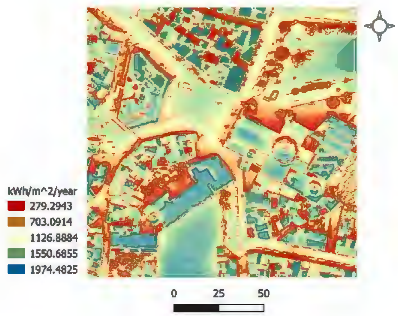

Figure 4: Raster showing only the pixels above 900kWh/m2/year

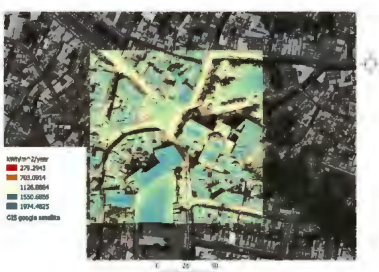

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Figure 3: ArcGIS Dashboard© for the door-to-door collection system of recyclables

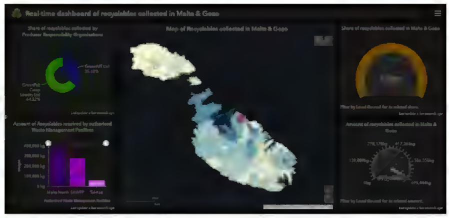
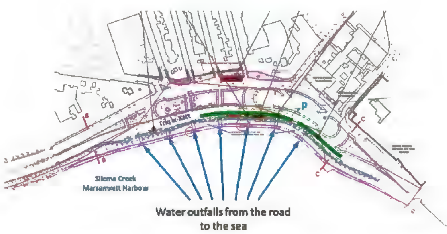


Figure 4: ArcGIS Dashboard© for the bring-in sites management system

Chapter 33

Figure 2: Triq ix-Xatt Sliema, general road layout and land uses



Source: Transport Malta archives (2012)

Figure 5: Areas would be flooded for each different level, and the extent of the impact

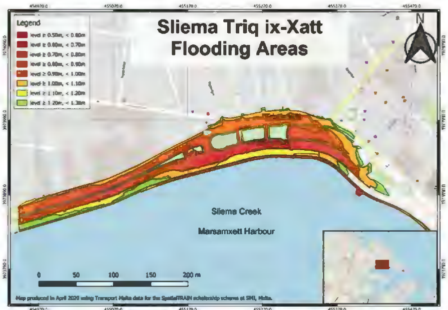


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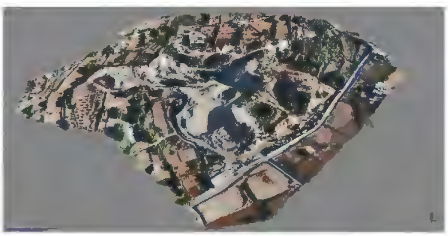
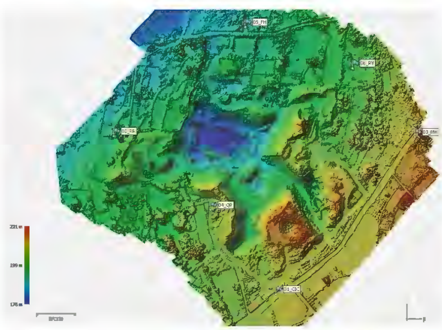
Figure 1: Dense Point Cloud (with GCPs)



Screen shot from Agisoft Photoscan

Figure 2: Digital Surface Model



Screen shot from Agisoft Photoscan

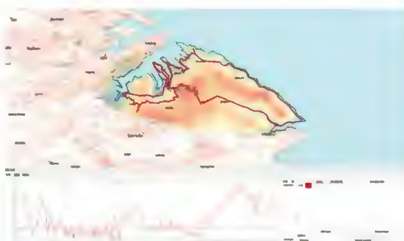
Figure 4: Change in Volume

Basemap Source: Google Satelite

N.B. Basemap at the study area is an orthophoto mosaic, produced in PhotoScan and clipped to mask, with study area polygon

Chapter 35

Figure 1: Screenshot showing the DEM overlaid on Roads



Source: Malta Inspire Geoportal (https://msdi.data.gov.mt/download.html)

Figure 3: Route with samples of Historic Interest

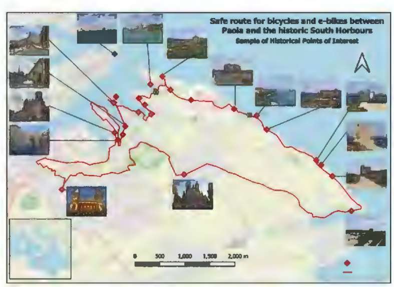


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Figure 4: Preview of Orthomosaic

Figure 15: Contour Lines – King Nikola's Palace

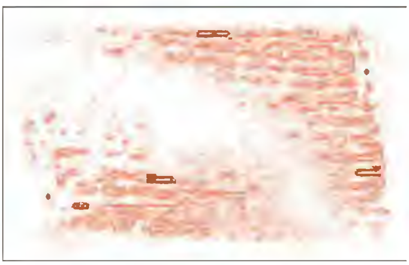

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Figure 3: LIDAR classification list [Source: ArcGIS] Lidar point classification—Help | ArcGIS Desktop

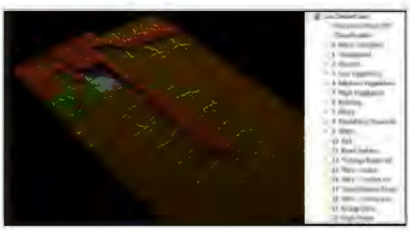
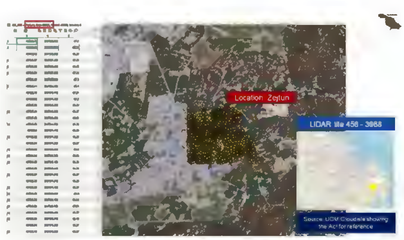


Figure 5: Zejtun vector points



Chapter 38

Figure 2: Final centrality index applied to network nodes

Source: Map developed in QGIS

Figure 4: Final transport hubs and isochrones

Source: Map developed in QGIS

A Word in Space

Figure 3: Photogrammetry aerial (lacks oblique capture)

Figure 4: TLS LiDAR terrestrial (lacks building roofs)

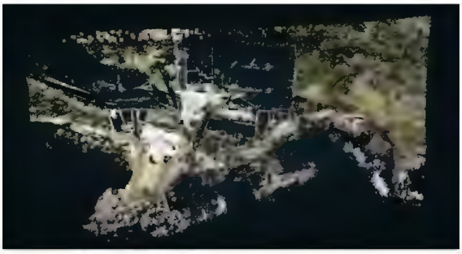


Figure 5: BackPack Laser scanner output

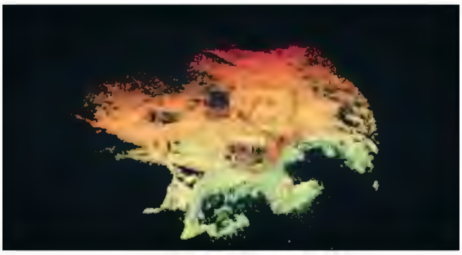


Figure 10: Għar Lapsi main cave dimensions TLS Area 2 Intra-Rock (view of Cave from inside the rock inclusive of surface underside) Height Perspective – Facing N

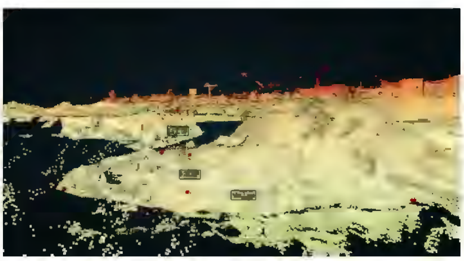


Figure 11: Eroded areas (beneath cliffs) dimensions - Area 1 Profile 1

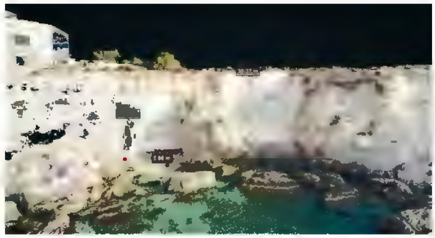


Figure 12: Area 2 Measurements Tunnel/ Boathouse

Pathways to Spatial Cognition
A Multi-Domain Approach - SpatialTrain I

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