XJENZA ONLINE

VOLUME 12 ISSUE 2, 2024

www.xjenza.org

The University of Malta Research, Innovation & Development Trust

MALTA CHAMBER OF SCIENTISTS

Science Journal of the Malta Chamber of Scientists

Editor-in-Chief: Cristiana Sebu

Xjenza Online: Science Journal of the Malta Chamber of Scientists
www.xjenza.org

Editorial Board

Xjenza Online: Science Journal of the Malta Chamber of Scientists
www.xjenza.org

Chronological List of Past and Present Editors of Xjenza
The Journal of the Malta Chamber of Scientists

2023 –
Editor: Cristiana Sebu
Associate Editors: *Ian Cassar, Alexandra Bonnici, Joseph Galea, Lourdes Farrugia, Godfrey Baldacchino, Liberato Camilleri*
Xjenza Online Vol. 12 Iss. 2 (2024)
Xjenza Online Vol. 12 Iss. 1 (2024)
Xjenza Online Vol. 12 Special Iss. (2024)
Xjenza Online Vol. 11 Special Iss. (2023)
Xjenza Online Vol. 11 Iss. 1 and 2 (2023)

2018 –2022
Editor: Cristiana Sebu
Senior Editors: *Sebastiano D'Amico, David Magri*
Associate Editors: *Sandro Lanfranco, Ian Thornton, Gianluca Valentino, Ian Cassar, Alexandra Bonnici, Joseph Galea, Pierre Vella, Lourdes Farrugia, Godfrey Baldacchino, Liberato Camilleri*
Xjenza Online Vol. 10 Iss. 2 (2022)
Xjenza Online Vol. 10 Iss. 1 (2022)
Xjenza Online Vol. 10 Special Iss. MNS Proceedings (2022)
Xjenza Online Vol. 9 Special Iss. (2021)
Xjenza Online Vol. 9 Iss. 2 (2021)
Xjenza Online Vol. 9 Iss. 1 (2021)
Xjenza Online Vol. 8 Iss. 2 (2020)
Xjenza Online Vol. 8 Iss. 1 (2020)
Xjenza Online Vol. 7 Iss. 2 (2019)
Xjenza Online Vol. 7 Iss. 1 (2019)
Xjenza Online Vol. 6 Iss. 2 (2018)
Xjenza Online Vol. 6 Iss. 1 (2018)

2013 – 2017
Editor: Giuseppe Di Giovanni
Associate Editors: *David Magri, Ian Thornton, Ian Cassar, Philip Farrugia, Sebastiano D'Amico, Nicholas Sammut, David Mifsud, Godfrey Baldacchino, Liberato Camilleri, Carmel Cefai*
Xjenza Online Vol. 5 Iss. 2 (2017)
Xjenza Online Vol. 5 SI MNS Proceedings (2017)
Xjenza Online Vol. 5 Iss. 1 (2017)
Xjenza Online Vol. 5 Virtual Issue COST (2017)
Xjenza Online Vol. 4 Iss. 2 (2016)
Xjenza Online Vol. 4 Iss. 1 (2016)
Xjenza Online Vol. 3 Iss. 2 (2015)
Associate Editors: *David Magri, Ian Thornton, Ian Cassar, Philip Farrugia, Sebastiano D'Amico, Nicholas Sammut, Joseph Galea, David Mifsud, Sandro Lanfranco, Mario Valentino, Godfrey Baldacchino, Liberato Camilleri*
Xjenza Online Vol. 3 Iss. 1 (2015)
Xjenza Online Vol. 2 Iss. 2 (2014)
Xjenza Online Vol. 2 Iss. 1 (2014)
Xjenza Online Vol. 1 Iss. 2 (2013)
Xjenza Online Vol. 1 Iss. 1 (2013)

2003 – 2007
Editors: Joseph N. Grima and Richard Muscat
Xjenza Vol. 12 (2007)
Xjenza Vol. 11 (2006)
Xjenza Vol. 10 (2005)
Xjenza Vol. 9 (2004)
Xjenza Vol. 8 (2003)

1996 – 2002
Editor: Angela Xuereb
Associate Editor: *Richard Muscat*
Xjenza Vol. 7 (2002)
Xjenza Vol. 6 (2001)
Associate Editors: *Martin Ebejer and Richard Muscat*
Xjenza Vol. 5 (2000)
Xjenza Vol. 4 Iss. 2 (1999)
Xjenza Vol. 4 Iss. 1 (1999)

Scope of Journal

Xjenza Online is the Science Journal of the Malta Chamber of Scientists and is published in an electronic format. Xjenza Online is a peer-reviewed, open access international journal. The scope of the journal encompasses research articles, original research reports, reviews, short communications and scientific commentaries in the fields of: mathematics, statistics, geology, engineering, computer science, social sciences, natural and earth sciences, technological sciences, linguistics, industrial, nanotechnology, biology, chemistry, physics, zoology, medical studies, electronics and all other applied and theoretical aspect of science.

The first printed issue of the journal was published in 1996 and the last (Vol. 12) in 2007. The publication of Xjenza was then ceased until 2013 when a new editorial board was formed with internationally recognised scientists, and Xjenza was relaunched as an online journal, with two issues being produced every year. One of the aims of Xjenza, besides highlighting the exciting research being performed nationally and internationally by Maltese scholars, is to provide a launching platform into scientific publishing for a wide scope of potential authors, including students and young researchers, into scientific publishing in a peer-reviewed environment.

Instructions for Authors

Xjenza is the Science Journal of the Malta Chamber of Scientists and is published by the Chamber in electronic format on the website: https://www.xjenza.org/. Xjenza will consider manuscripts for publication on a wide variety of scientific topics in the following categories

1. Research Articles
2. Communications
3. Review Articles
4. Notes
5. Research Reports
6. Commentaries
7. News and Views
8. Invited Articles and Special Issues
9. Errata

Research Articles form the main category of scientific papers submitted to Xjenza. The same standards of scientific content and quality that applies to Communications also apply to Research Articles.

Communications are short peer-reviewed research articles (limited to three journal pages) that describe new important results meriting urgent publication. These are often followed by a full Research Article.

Review Articles describe work of interest to the wide community of readers of Xjenza. They should provide an in-depth understanding of significant topics in the sciences and a critical discussion of the existing state of knowledge on a topic based on primary literature sources. Review Articles should not normally exceed 6000 words.Authors are strongly advised to contact the Editorial Board before writing a Review.

Notes are fully referenced, peer-reviewed short articles limited to three journal pages that describe new theories, concepts and developments made by the authors in any branch of science and technology. Notes need not contain results from experimental or simulation work.

Research Reports are extended reports describing research of interest to a wide scientific audience characteristic of Xjenza. Please contact the editor to discuss the suitability of topics for Research Reports.

Commentaries Upon Editor's invitation, commentaries discuss a paper published in a specific issue and should set the problems addressed by the paper in the wider context of the field. Proposals for Commentaries may be submitted; however, in this case authors should only send an outline of the proposed paper for initial consideration. The contents of the commentaries should follow the following set of rules: 3000 words maximum, title 20 words maximum, references 10 maximum (including the article discussed) and figures/tables 2 maximum.

News and Views The News section provides a space for articles up to three journal pages in length describing leading developments in any field of science and technology or for reporting items such as conference reports. The Editor reserves the right to modify or reject articles for consideration as News.

Invited Articles and Special Issues Xjenza regularly publishes Invited Articles and Special Issues that consist of articles written at the invitation of the Editor or another member of the editorial board.

Errata Xjenza also publishes errata, in which authors correct significant errors of substance in their published manuscripts. The title should read: Erratum: "Original title" by ***, Xjenza, vol. *** (year). Errata should be short and consistent for clarity.

Submission of Manuscripts

Manuscripts should be sent according to the guidelines given hereafter to xjenza@mcs.org.mt.

Referees All manuscripts submitted to Xjenza are peer reviewed. Authors are requested to submit with their manuscript the names and addresses of three referees, preferably from overseas. Every effort will be made to use the recommended reviewers; however the editor reserves the right to also consult other competent reviewers.

Conflict of Interest Authors are expected to disclose any commercial or other types of associations that may pose a conflict of interest in connection to with the submitted manuscript. All funding sources supporting the work, and institutional or corporate affiliations of the authors, should be acknowledged on the title page or at the end of the article.

Policy and Ethics The work presented in the submitted manuscript must have been carried out in compliance with The Code of Ethics of the World Medical Association (Declaration of Helsinki) for experiments involving humans (https://www.wma.net/policies-post/wma-declaration-of-helsinki-ethical-principles-for-medical-research-involving-human-subjects/); EU Directive 2010/63/EU for animal experiments (http://ec.europa.eu/environment/chemicals/lab_animals/legislation_en.htm); Uniform Requirements for manuscripts submitted to Biomedical journals (http://www.icmje.org). This must be stated at an appropriate point in the article.

Submission, Declaration and Verification Author(s) must only submit work that has not been published previously (except in the form of an abstract or as part of a published lecture or academic thesis), that is not under consideration for publication elsewhere, that has been approved for publication by all authors, and tacitly or explicitly, by the responsible authorities where the work was carried out, and that, if accepted, will not be published elsewhere in the same form, in English or in any other language, including electronically, without the written consent of the copyright-holder.

Permissions It is the responsibility of the corresponding author of a manuscript to ensure that there is no infringement of copyright when submitting material to Xjenza. In particular, when material is copied from other sources, a written statement is required from

both the author and/or publisher giving permission for reproduction. Manuscripts in press, unpublished data and personal communications are discouraged; however, corresponding authors are expected to obtain permission in writing from at least one author of such materials.

Preparation of Manuscripts

Xjenza accepts submissions in MS Word, Libre Office Writer and LaTeX, the latter being the preferred option. Anyone submitting in LaTeX should use the journal template, the latest version of which can be found at https://www.overleaf.com/latex/templates/xjenza-article/ktbfsjgqqcpw. All the necessary files to run the LaTeX document should be supplied together with the rendered PDF.

If a word processor is used the styling should be kept to a minimum. Bold face and italic fonts, as well as subscript and superscript text may be used as required by the context. Text should be in single-column format and the word processor options should not be used in order to justify text or hyphenate words. Alongside the native format of the word processer, a PDF file, generated by the word processor, must be provided. Furthermore, artwork should be in accordance with the artwork guidelines given below and must be submitted separately from the word processor file. Similarly, the bibliographic data of the cited material should be submitted separately as an Endnote (*.xml), Research Information Systems (*.ris), Zotero Library (zotero.splite) or a BibTeX (*.bib) file.

Article Structure

A manuscript for publication in Xjenza will typicall have the following components: Title page, Abstract, Keywords, Abbreviations, Introduction, Materials and Methods, Results, Discussion, Conclusions, Appendices and References.

The manuscript will be divided into clearly defined and numbered sections. Each numbered subsection should have a brief heading. Each heading should appear on its own separate line. Subsections should be used as much as possible when cross-referencing text, i.e. refer to the subsection by the section number.

Title page

- The title should be concise yet informative. Titles are often used in information-retrieval systems. Avoid abbreviations and formulae where possible.
- Author names and affiliations. Indicate the authors' affiliation addresses (where the actual work was done) below the names. Indicate all affiliations with a lower-case superscript number immediately after each author's name and in front of the appropriate address. Provide the full postal address of each affiliation, including the country name and, if available, the e-mail address.
- Corresponding author. Clearly indicate who will handle correspondence at all stages of refereeing and publication, including post-publication. Ensure that telephone and fax numbers (with country and area code) are provided in addition to the e-mail address and complete postal address. Contact details must be kept up to date by the corresponding author.
- Present/permanent address. If an author has changed the address since the work described, this can be indicated as a footnote to the author's name. The address at which the author actually did the work must be retained as the main, affiliation address. Superscript Arabic numerals are used for such footnotes.

Abstract A concise and factual abstract is required of up to about 250 words. The abstract should state briefly the background and purpose of the research, the principal results and major conclusions. An abstract is often presented separately from the article, so it must be able to stand alone. For this reason, references and non-standard abbreviations should be avoided. If essential, these must be defined at first mention in the abstract itself.

Abbreviations Define abbreviations that are not standard in this field in a footnote to be placed on the first page of the article. Such abbreviations that are unavoidable in the abstract must be defined at their first mention as well as in the footnote and should be used consistently throughout the text.

Introduction State the objectives of the work and provide an adequate background, avoid a detailed literature survey or a summary of the results.

Materials and Methods Provide sufficient detail to allow the work to be reproduced. Methods already published should be indicated by a reference: only relevant modifications should be described.

Results Results should be clear and concise. Numbered/tabulated information and/or figures should also be included.

Discussion This should explore the significance of the results of the work, yet not repeat them. Avoid extensive citations and discussion of published literature. A combined section of Results and Discussion is often appropriate.

Conclusions The main conclusions based on results of the study may be presented in a short Conclusions section. This may stand alone or form a subsection of a Discussion or Results and Discussion section.

Appendices Formulae and equations in appendices should be given separate numbering: Eq. (A.1), Eq. (A.2), etc.; in a subsequent appendix, Eq. (B.1) and so on. Similarly for tables and figures: Table A.1; Fig. A.1, etc.

Acknowledgements Collate acknowledgements in a separate section at the end of the article before the references. Do not include them on the title page, as a footnote to the title or otherwise. List here those individuals who provided assistance during the research (e.g., providing language help, writing assistance or proof reading the article, etc.).

Units Follow internationally accepted rules and conventions: use the international system of units (SI). If other units are mentioned, please give their equivalent in SI. Anyone using LaTeX should use the package siunitx in all cases.

Footnotes Footnotes should be used sparingly. Number them consecutively throughout the article, using superscript Arabic numbers. Many word processors build footnotes into the text, and this feature may be used. Should this not be the case, indicate the position of footnotes by a superscript number in the text and list the footnotes separately at the end of the article. Do not include footnotes in the Reference list.

Table Footnotes Indicate each footnote in a table with a superscript lower case letter.

Artwork Electronic artwork general instructions:

- Make sure you use uniform lettering and sizing of your original artwork.
- Save text in illustrations as 'graphics' or enclose the font.
- Only use the following fonts in your illustrations: Arial, Courier, Times, Symbol or Computer Modern Roman, the latter is preferred.
- Number the illustrations according to their sequence in the text.
- Name your artwork files as 'fig$x$' or 'tab$x$' where x corresponds to the sequence number in your document.

- Provide captions to illustrations separately.
- Produce images near to the desired size of the printed version or grater.
- Make sure that the artwork has no margins and borders.
- Submit each figure as a separate file.

Formats Regardless of the application used, when your electronic artwork is finalised its file format should be one of the following (note the resolution requirements for line drawings, halftones, and line/halftone combinations given below):

- PDF or SVG: Vector drawings. Embed the font or save the text as 'graphics'.
- JPEG or PNG: Color or grayscale photographs (halftones): always use a minimum of 300 dpi.
- JPEG or PNG: Bitmapped line drawings: use a minimum of 1000 dpi.
- JPEG or PNG: Combinations bitmapped line/half-tone (color or grayscale): a minimum of 500 dpi is required.

Where possible use a vector format for your artwork (PDF or SVG). If this is not possible, supply files that have and adequate resolution.

Colour Artwork Make sure that color artwork files are in an acceptable format (JPEG, PNG, PDF or SVG) and have the correct resolution.

Figure Captions Ensure that each illustration has a caption. Supply captions separately, not attached to the figure. A caption should comprise a brief title (not on the figure itself) and a description of the illustration. Keep text in the illustrations themselves to a minimum, but explain all symbols and abbreviations used.

Tables Number tables consecutively in accordance with their appearance in the text. Place footnotes to tables below the table body and indicate them with superscript lowercase letters. Avoid vertical rules. Be moderate with the use of tables and ensure that the data presented in tables do not duplicate results described elsewhere in the article. Large tables should be submitted in CSV format.

Citations and References Reference and citation styles for manuscripts submitted to Xjenza should be in accordance to the APA v6 style.

Citation in text References to cited literature in the text should be given in the form of an author's surname and the year of publication of the paper with the addition of a letter for references to several publications of the author in the same year. For further information regarding multiple authors consult the APA v6 guidelines. Citations may be made directly

Kramer et al. (2010) have recently shown . . .

or parenthetically

as demonstrated (Allan, 2000a, 2000b, 1999; Allan and Jones, 1999).

Groups of references should be listed first alphabetically, then chronologically. When writing in LaTeX use `\textcite{}` and `\parencite{}` for the respective cases mentioned.

The reference section Every reference cited in the text should also be present in the reference list (and vice versa). The reference list should also be supplied as an Endnote (*.xml), Research Information Systems (*.ris), Zotero Library (zotero.splite) or a BiBTeX (*.bib) file. Unpublished results and personal communications are not recommended in the reference list, but may be mentioned in the text. If these references are included in the reference list they should follow the standard reference style of the journal and should include a substitution of the publication date with either 'Unpublished results' or 'Personal communication'. Citation of a reference as 'in press' implies that the item has been accepted for publication.

References should be arranged first alphabetically and then further sorted chronologically if necessary. More than one reference from the same author(s) in the same year must be identified by the letters 'a', 'b', 'c', etc., placed after the year of publication. Consult the APA v6 guidelines for multiple authors. Below are some examples of referencing different bibliographic material.

Reference to a Journal Publication

Agree, E. M. and Freedman, V. A. (2011). A Quality-of-Life Scale for Assistive Technology: Results of a Pilot Study of Aging and Technology. *Phys. Ther.*, 91(12):1780–1788.

McCreadie, C. and Tinker, A. (2005). The acceptability of assistive technology to older people. *Ageing Soc.*, 25(1):91–110.

Reference to a Book

Brownsell, B. (2003). *Assistive Technology and Telecare: Forging Solutions for Independent Living*. Policy Press, Bristol.

Fisk, M. J. (2003). *Social Alarms to Telecare: Older People's Services in Transition*. Policy Press, Bristol, 1st edition.

Reference to a Chapter in an Edited Book

Brownsell, S. and Bradley, D. (2003). New Generations of Telecare Equipment. In *Assist. Technol. Telecare Forg. Solut. Indep. Living*, pages 39–50.

Web references The full URL should be given together with the date the reference was last accessed. Any further information, if known (DOI, author names, dates, reference to a source publication, etc.), should also be given. Web references can be listed separately or can be included in the reference list.

References in a Special Issue Please ensure that the words 'this issue' are added to any references in the list (and any citations in the text) to other articles in the same Special Issue.

Journal Abbreviations Journal names should be abbreviated according to:

-Index Medicus journal abbreviations: https://www.ncbi.nlm.nih.gov/nlmcatalog/journals/;

-List of title word abbreviations: http://www.issn.org/2-22661-LTWA-online.php;

-CAS (Chemical Abstracts Service): http://www.cas.org/sent.html.

Video data Xjenza accepts video material and animation sequences to support and enhance the presentation of the scientific research. Authors who have video or animation files that they wish to submit with their article should send them as a separate file. Reference to the video material should be clearly made in text. This will the modified into a linked to the paper's supplementary information page. All submitted files should be properly labelled so that they directly relate to the video files content. This should be within a maximum size of 50 MB.

Submission check list

The following list will be useful during the final checking of a manuscript prior to sending it to the journal for review. Please consult the Author Guidelines for further details of any item.

- One author has been designated as the corresponding author with contact details:
  - E-mail address.
  - Full postal address.
  - Telephone and fax numbers.
- All necessary files have been sent, and contain:
  - All figures are given separately in PDF, SVG, JPEG of PNG format.
  - Caption for figures is included at the end of the text.

  - All tables (including title, description, footnotes) are included in the text and large tables have been given separately as CSV.
  - The reference list has been given in XML, RIS, zotero.splite or BIB file format.
- Further considerations
  - Abstract does not exceed about 250 words.
  - Manuscript has been 'spell-checked' and 'grammar-checked'.
  - References are in the required format.
  - All references mentioned in the reference list are cited in the text, and vice versa.
  - Bibliographic data for all cited material has been provided.
  - Permission has been obtained for use of copyrighted material from other sources (including the Web).
  - A PDF document generated from the word processor used is submitted.

After Acceptance

Use of the Digital Object Identifier The Digital Object Identifier (DOI) may be used to cite and link to electronic documents. The DOI consists of a unique alpha-numeric character string which is assigned to a document by the publisher upon the initial electronic publication. The assigned DOI never changes. Therefore, it is an ideal medium for citing a document, particularly 'Articles in press' because they have not yet received their full bibliographic information. When you use a DOI to create links to documents on the web, the DOIs are guaranteed never to change.

Proofs, Reprints and Copyright The corresponding author will receive an electronic proof of the article and have an opportunity to review editorial changes and to double-check accuracy of content, tables, and statistics before publication. A list of any necessary corrections should be sent by email to the managing editor within a week of proof receipt to avoid unnecessary delays in the publication of the article. Alterations, other than essential corrections to the text of the article, should not be made at this stage. Manuscripts are accepted for publication on the understanding that exclusive copyright is assigned to Xjenza. However, this does not limit the freedom of the author(s) to use material in the articles in any other published works.

Publisher's note

All claims expressed in the editorial and articles of this Xjenza Online issue are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the MCS publisher, the editors and the reviewers.

Sebu, C. (2024). *Xjenza Online*, 12(2):88.

Xjenza Online: Science Journal of the Malta Chamber of Scientists
www.xjenza.org

Editorial

Concluding a successful year

Cristiana Sebu[*1]
[1]*Department of Mathematics, University of Malta, Msida, Malta*

Dear readers and authors of Xjenza Online, as Editor in Chief, I am pleased to announce the release of the second regular issue of the 12th volume of Xjenza Online concluding a very successful year for the journal. In 2024, Xjenza Online released two regular issues and a special issue on Economics and Finance and this would not have been possible without the valuable input of our current Copy Editor, Dr Karl Pelka.

As always, I am excited to share with you the journal's latest free open access publications.

The issue opens with the manuscript by Baldacchino et al. on the differential exposure to English language in the fields of chemistry and sociology based on a survey conducted in eight universities part of the "European University of the Seas' (SEA-EU) where the language of instruction is not mainly English.

Next, Ferranti and Fiorini report on the state of occupational health and safety in the Maltese construction industry, one of the most dangerous working sector locally including lacks of safety standards and of training for construction workers, and precarious working conditions for migrant workers. Strategies for improving the standards are suggested such as increased enforcement, alternative penalties, better resources for the involved inspectorate, adequate training, the licensing of contractors, and construction standards development.

Scicluna et al. present then a study on the identification of candidate sites for an offshore green Hydrogen production plant concept with integrated Floating Liquid Piston Accumulator using Seawater under Compression energy storage in Malta's Exclusive Economic Zone.

The following paper by Sultana discusses the land use in the Maltese Islands and follows the changes occurred during a period of 14 years (1998-2012). The research highlights a misalignment between the intended objectives of land use policies and the actual land use changes and underscores the importance of acquiring detailed spatial and temporal data to inform national land use and resource management policies aimed at promoting sustainable land use.

Then, Grech et al. review the influence of migration on Malta's demographic transition. The conclusions of the study are worrying in the sense that currently in Malta, domestic labour supply cannot keep up with an influx of foreign workers, weathering its demographic transition at the expense of a rapidly expanding population but the long-term results are of significant concern as infrastructures may not cope and a substantial worker efflux for whatever reason could potentially precipitate a significant economic downturn.

The issue closes with two news articles. The first one by Bianchi introduces the reader to OiPub, a new web platform for researchers where all research papers and outputs are automatically organised into topic streams that you can either access directly, or easily combine into research communities following multiple topics to create a custom stream of information and discussion in any research niche area. The second one by Mifsud et al. highlights the outcomes of the 2024 Collisions Physics and Chemistry and their Applications (COPCA) Conference in Valletta.

To conclude, I am very pleased to witness the growing popularity of the journal not only among the local scientific community but also the press.

**Correspondence to*: Cristiana Sebu (cristiana.sebu@um.edu.mt)

Baldacchino, G. et al. (2024). *Xjenza Online*, 12(2):89–104.

Xjenza Online: Science Journal of the Malta Chamber of Scientists
www.xjenza.org
DOI: 10.7423/XJENZA.2024.3.01

Research Article

Differential exposure to the English Language? Assessing English language use among chemistry and sociology academics in European universities.

G. Baldacchino[*1], S. Karimi-Aghdam[2], L. Abbamonte[3], N. Costa[4], A. Dulska[5], J. Durgadoo[6], J. Granić[7], G. Le Gall[8], P. López-Zurita[9], M. Wawrzyniak-Śliwska[5]

[1] *Department of Sociology, University of Malta, Malta*
[2] *Faculty of Education and Arts, Nord University, Levanger, Norway*
[3] *Department of Law, Parthenope University Naples, Italy*
[4] *Department of Arts and Humanities, University of Algarve, Portugal*
[5] *Foreign Languages Centre, University of Gdańsk, Poland*
[6] *International Center, Kiel University, Kiel, Germany*
[7] *Department of Croatian Language and Literature, University of Split, Croatia*
[8] *Pôle Langues - Language Center, University of Western Brittany, Brest, France*
[9] *Department of French and English Philology, University of Cádiz, Spain*
[10] *Department of Glottodidactics and Natural Language Processing, University of Gdańsk, Poland*

Abstract. In universities where the language of instruction is not (mainly) English (EN), academic members of staff from different disciplines are exposed to EN to varying extents and may thus be expected to demonstrate different degrees of EN competence. We hypothesise that, generally speaking, university professors and lecturers of national literature, national language, linguistics and local social studies may be the least obliged to use EN, while those in, or dealing with, the hard sciences have a greater need and obligation to engage with technical EN. In December 2023, a survey based on self-reporting was organised amongst the academic, administrative and student community of the nine universities that now constitute the 'European University' Alliance: the 'European University of the Seas' (SEA-EU). Amongst various other themes, this survey explored the self-declared English Language competences of lecturers and professors of sociology ($N = 23$) as well as lecturers and professors of chemistry ($N = 88$) in eight out of these universities. The results, while only indicative, support the claim that academics in the field of sociology, working in largely non-EN teaching universities, may not need a strong level of EN competence as much as chemistry lecturers and professors. Thus, one can argue that chemistry academics are generally under greater pressure to improve their level of English in all areas of language reception and production (reading, writing, listening, speaking alone or in a conversation, delivering formal lectures, preparing notes, slides and examinations, etc.) than sociology academics. These results provide valuable nuance to the use of the English language in the European academic community.

Keywords: English language competence, European universities, sociology, chemistry, SEA-EU Alliance

1 Introduction

SEA-EU, or the European University of the Seas, is a 'European University' Alliance set up and launched with the first wave of such bodies, in January 2020. Initially with six members, it now has nine partner universities, namely: the University of Cadiz (UCA), Spain; University of Western Brittany (UBO), Brest, France; Kiel University (CAU), Germany; University of Gdańsk (UG), Poland; University of Split (UNIST), Croatia; University of Malta (UM), Msida, Malta; Parthenope University of Naples (UPN), Italy; University of Algarve (UAlg), Portugal and Nord University (Nord), Norway. (www.sea-eu.org). One of the tasks that fall within the purview of SEA-EU deals with promoting multilingualism, building English language competence, and setting up a common SEA-EU language

Correspondence to: G. Baldacchino (godfrey.baldacchino@um.edu.mt)

policy.

"Multilingualism as a social phenomenon is not a specialty of this age, since many pre-modern societies were multicultural and multilingual" (Granić, 2012, p. 85), it is "an everyday reality for the majority of the world's inhabitants" (Phillipson, 2003, p. 3), and its rise and ramifications are not difficult to understand (Edwards, 2012). Being "frequently prised as one of our age's major progressive paradigm shifts in curriculum, research, and civil society" (Gramling, 2021, pp. 11, 65), multilingualism is a practice under pressure. Considering language as "a bridge between persons and a vehicle for members of a community to feel close to each other" (Metsola, 2023, p. 126), multilingualism requires ongoing attention. Language diversity in the EU, particularly in public communication, and including academic discourse, "has remained an unfulfilled ideal, inasmuch as 'we have to shift to English to be heard'" (Granić, 2017, p.104). The SEA-EU Alliance is called upon to establish a common language policy by promoting English as a global language and to implement multilingualism in its own practice (cf. Blackwood & Dunlevy, 2021; Horner & Dailey-O'Cain, 2020; Mary et al., 2021).

One of the core goals of this task is to ensure an effective use of English as a means of communication, scholarship, teaching and learning within the SEA-EU Alliance and beyond. After all, the globalisation and consequent internationalisation of higher education have "taken the form, in non-English speaking countries, of an increasing role for the English language" (Zanola, 2024). In much of Europe and beyond, competence in English is becoming a prerequisite for access to higher education and employment.

2 Objectives: A comparison between two disciplines

In most cases, where such studies are carried out, the analysis proceeds with an inquiry based on a comparative analysis of data across universities and countries. In this paper, we focus however on an inter-disciplinary comparison. Indeed, the survey instrument intentionally targeted two mutually exclusive sets of academics: those who report being chemistry lecturers / professors ($N = 88$) and those who self-report as sociology lecturers/professors ($N = 23$), with a comparative exercise in mind.

The adoption of English as a Medium of Instruction (EMI) has been sweeping across the higher education landscape worldwide for a while (e.g. Coleman, 2006; Crystal, 2004). Under the guise of internationalisation, formal teaching and research are often becoming monolingual, gravitating towards the use of English as a single lingua franca, or lingua academica (Grin et al., 2018). Phillipson (2007, p. 78) however argues that lingua franca is a slippery concept, suggesting other signifiers such as: lingua economica (the globalisation imperative); lingua cultura (needing exploration in foreign language teaching); lingua academica (for international collaboration in higher education); lingua emotiva (where grassroots identification with English ties in with top-down promotion of the language); lingua tyrannosaura (the language that gobbles others); and lingua belica (the language of war and military contexts).

With the ongoing globalisation of higher education and the internationalisation drive of most universities, academics find themselves in environments where engagement with the English language (EN) is almost inevitable: for keeping in touch with their research field, for publishing their work, for attending and presenting at international conferences, for lecturing and assessing student work, for successfully applying to collaborative research projects, and for maximising citations and deepening impact (Di Bitetti & Ferreras, 2017; Liang et al., 2013). It is all the more so if such academics find themselves teaching study units that are specifically earmarked as EN-language units, in order to appeal to and attract international students as well as Erasmus mobility students from other universities. Nevertheless, this level of engagement is not necessarily the same in all disciplines. In this paper, we hypothesise that certain academic disciplines are more or less obliged to be fully competent in the English language than others.

The basis for proposing this hypothesis is summed up here. In language, linguistics and some social science, university academics may have secured their academic qualifications from home universities; they are obliged and expected to teach, research and critique the local corpus, which would be primarily written in the local language (or dialect); they may be obliged and expected to comment and deliver presentations on such material again in the local language; the obligation to engage with non-locals on such material is less inevitable than in the case of academics in the hard sciences – physics, chemistry, mathematics, et cetera. Indeed, to achieve credibility, visibility and inclusion in the international hard science community, the use of EN has become inevitable.

For this exercise, we will exclude the academic representatives of the University of Malta (UM). The language of instruction of this university is English; so, naturally, all academic members from every department are expected to have a very good or excellent command of this language, and in the full repertoire of associated skills. This is indeed the case, as self-reported by respondents: for example, in the case of EN reading skills, out of eight UM academics, seven reported an excellent command of EN; and one a very good command. The situation re-

peats itself with respect to the other three sets of EN-related skills. The situation is quite different where the other eight universities are involved. The local, vernacular language is the default language of instruction and assessment in these institutions: Croatian, French, German, Italian, Norwegian, Polish, Portuguese and Spanish respectively. However, there are demands being (recently and increasingly) placed on these academics to also teach in English, as shall be discussed below.

Five different sets of questions were asked, dealing with different types of EN competence: reading (work related material, and more broadly), listening, writing, speaking alone (as in a presentation) and speaking with others (as in a dialogue). For each set of questions, respondents were asked about their self-perceived level of competence and whether they were interested in taking initiatives to improve their competence. The responses are reviewed in turn below.

3 Methodology

To undertake this task more effectively, and better align initiatives with needs, a 'needs assessment' (Long, 2010; Piquer-Píriz & Castellano-Risco, 2021) exercise of the language situation within each partner university was undertaken by means of an on-line survey in December 2023. This survey targeted five representative sectors of the campus community: namely, academics who teach either Chemistry or Sociology, Library Staff, the Staff of the Central Administration (Office of the Rector or President; Offices of the Vice-Rectors), and the Student Union or Central Student Association(s). The objective of this survey was to determine how to best enhance and deepen English language competence in our campuses. The survey was circulated both in English as well as in the respective national languages of the SEA-EU partner universities. Completed survey responses were accepted until December 15, 2023 (just before the Christmas recess). A total of 654 valid submissions were received within that time frame.

Methodological caveats There are some methodological issues that need to be discussed before a discussion is proposed. Survey questionnaires were available in the nine languages of the Alliance – Croatian, French, German, Italian, Maltese, Norwegian, Polish, Portuguese, Spanish – plus in English, and there may have been slight differences in meaning between different questionnaire versions. Respondents who chose to answer using the EN-version of the survey instrument, and who may not have a full level of competence in the language, may have somewhat misinterpreted the questions, and so possibly provided unintended answers. And, of course, all answers are based on self-reporting: they are subjective judgement calls on a range of skills related to English-language competence. Such answers would need to be compared to the results of objective language competence tests in order to determine their veracity, validity, and accuracy. Moreover, no chemistry or sociology professors from Nord answered the survey, or self-identified as such; there were also no chemistry academics from CAU; and no sociology academics from UAlg. This somewhat distorts the compatibility of the two datasets. Finally, the number of respondents who self-identify as chemistry lecturers/ professors ($N = 88$; N less UM=84) is much larger than those who identify themselves as sociology lecturers/ professors ($N = 23$; N less UM=17). This creates some difficulties in drawing conclusions from small numbers, which is why the analysis here is mainly pursued by looking at aggregate figures.

However, with all these caveats, we consider the methodology to be, in principle, sound enough to permit indicative comparisons between chemistry and sociology professors at the universities that are members of the SEA-EU Alliance, hailing from eight different European countries. Further research would be able to confirm or refute whether these initial observations are tenable.

4 Results

4.1 Assessment and Interest in Improvement

4.1.1 English Language Reading Skills

Chemistry academics ($N = 84$): The EN reading skills of most chemistry lecturers or professors in UAlg and UNIST are self-reported as excellent; and most of those at UG as very good. In UPN, reading skills are reported as both very good and good; and in UBO and UCA, EN reading skills are self-noted as being good. 23 respondents (27%) reported their EN reading skills as excellent. Just four respondents indicated basic EN reading skills (the lowest category available for selection). When asked if they wished to improve their EN reading skills, most chemistry academics responding from UNIST, UCA, UG and UPN (but not UBO) declared that they would. There were no submissions from CAU and Nord. (See Figures 1 and 3).

Sociology academics (N=17): The EN reading skills of the majority in CAU, UCA and UNIST are self-reported as excellent. The single respondent from UG self-reports as very good, the majority in UPN are self-noted as good and the majority in UBO are self-indicated as basic. Six respondents (35%) reported their EN reading skills as excellent. Despite much lower numbers of respondents compared to the chemistry sub-sample, an equal number of respondents – four – indicated having just basic EN reading skills. When asked if they wished to improve their EN reading skills, most sociology academics responding from UBO, UCA and UPN declared that they would. There

were no submissions from Nord and UAlg. (See Figures 2 and 4).

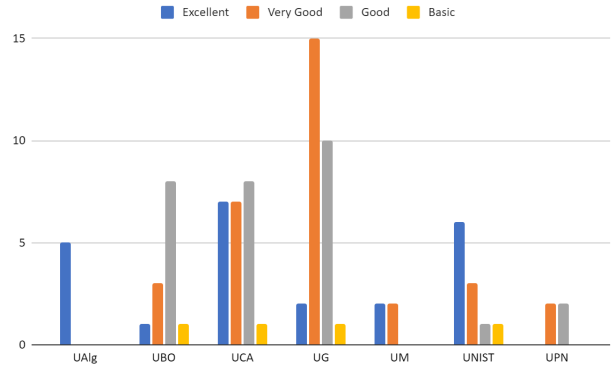

Figure 1: EN reading skills assessment – Chemistry Academics

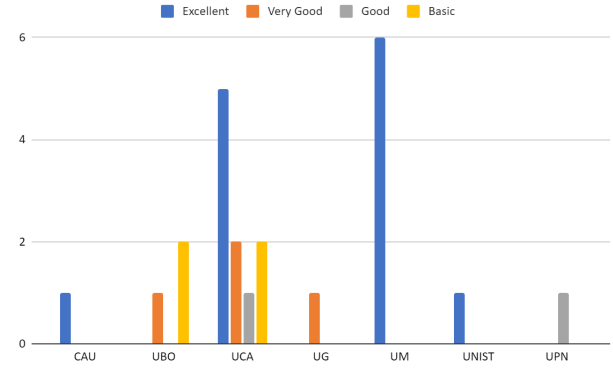

Figure 2: EN reading skills assessment – Sociology Academics

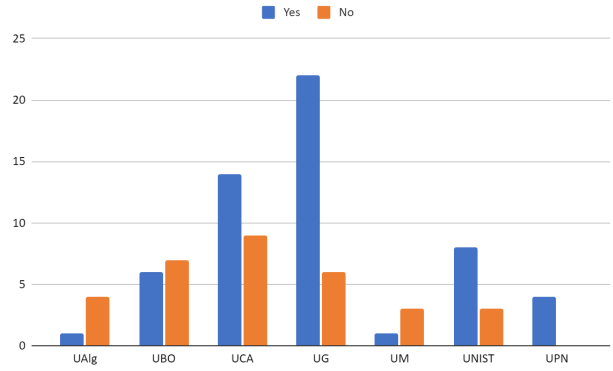

Figure 3: EN reading skills improvement – Chemistry Academics

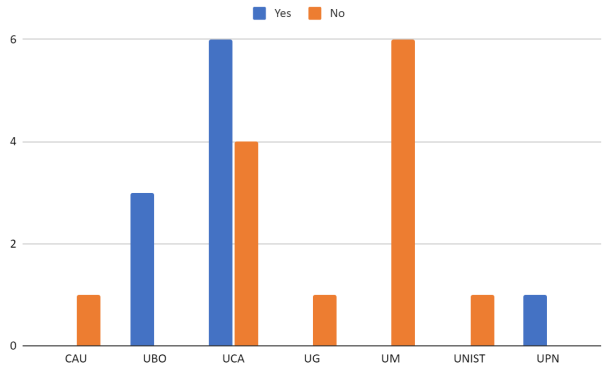

Figure 4: EN reading skills improvement – Sociology Academics

4.1.2 English Language Listening Skills

Chemistry academics ($N = 84$): This time, only the five chemistry respondents at UAlg *all* claim to have excellent English listening skills. In all, twelve respondents (14%) claim excellent skills (UM excluded). Most respondents from UNIST claim to have very good English listening skills; and the majority from UG reported good skills. Most respondents from UCA, UPN and UBO self-report basic EN listening skills. No single respondent from UCA or UPN self-identified as having excellent EN listening skills. 62 of the respondents (74%) indicate a willingness to improve in this skill. There were no submissions from CAU (See Figures 5 and 7).

Sociology academics ($N = 17$): The two sociology respondents from CAU and UNIST reported excellent listening skills; while the single UPN respondent self-reported good skills. Excluding UM, four respondents (24%) declared excellent English language listening skills. Most respondents from UCA reported basic level skills. Two respondents (both from UCA) self-rated their EN listening skills as very poor. Eleven respondents (65%) self-reported a readiness to improve these range of skills. There were no submissions from UAlg (See Figures 6 and 8).

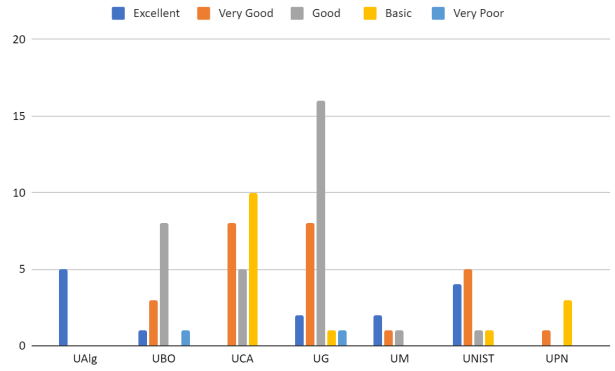

Figure 5: EN listening skills assessment – Chemistry Academics

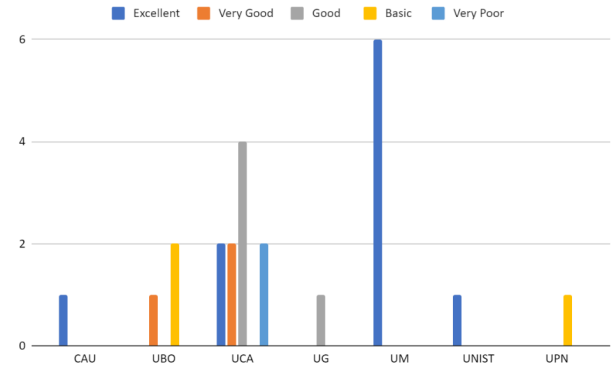

Figure 6: EN listening skills assessment – Sociology Academics

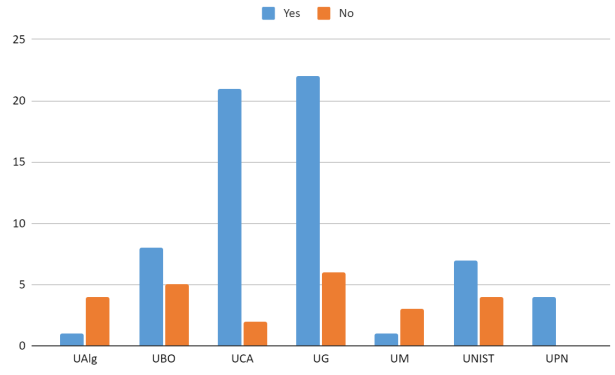

Figure 7: EN listening skills improvement – Chemistry Academics

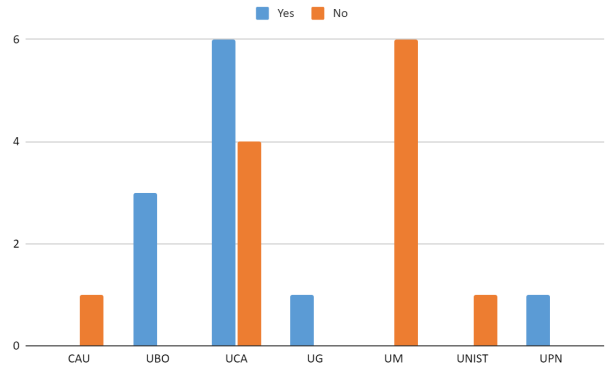

Figure 8: EN listening skills improvement – Sociology Academics

4.1.3 English Language Writing Skills

Chemistry academics ($N = 84$): The majority in UAlg self-reported their EN writing skills as excellent and the majority at UPN self-reported as very good. Most respondents from UBO, UCA, UG and UNIST claimed their writing skills to be good. Three respondents self-reported as having very poor EN writing skills. (Always excluding UM), only UAlg has a slight majority of respondents who are not interested in improving their EN writing skills. There were no submissions from CAU and Nord (See Figures 9 and 11).

Sociology academics ($N = 17$): Most respondents from CAU and UNIST self-noted their writing skills as excellent; at UCA, writing skills are largely self-reported as very good; in UG writing skills are largely self-reported as good; and in UPN writing skills are largely self-reported as very poor. UBO claimed their writing skills as equally very good, basic, and very poor. Three sociology respondents self-reported as having very poor EN writing skills. Despite this result, five of the respondents do not feel the need to improve their EN writing skills. There were no submissions from UAlg (See Figures 10 and 12).

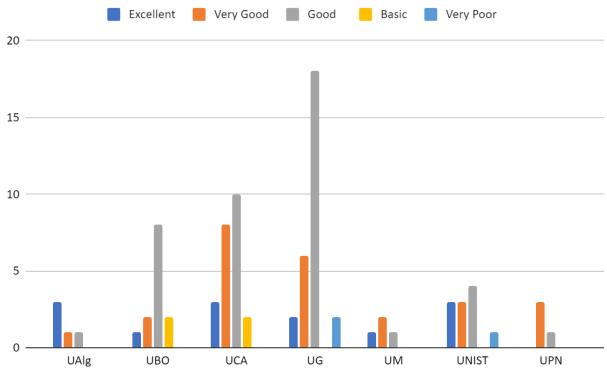

Figure 9: EN writing skills assessment – Chemistry Academics

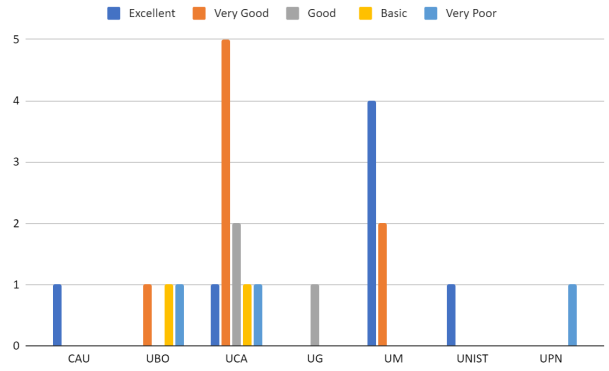

Figure 10: EN writing skills assessment – Sociology Academics

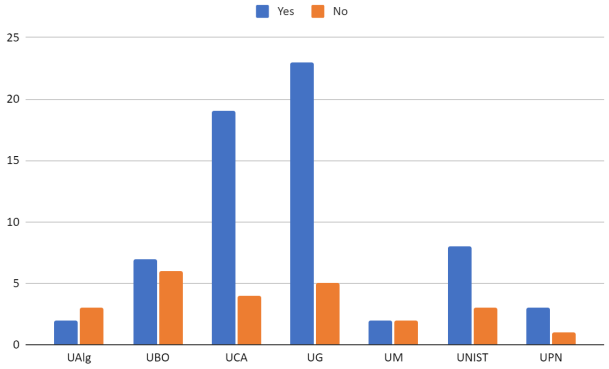

Figure 11: EN writing skills improvement – Chemistry Academics

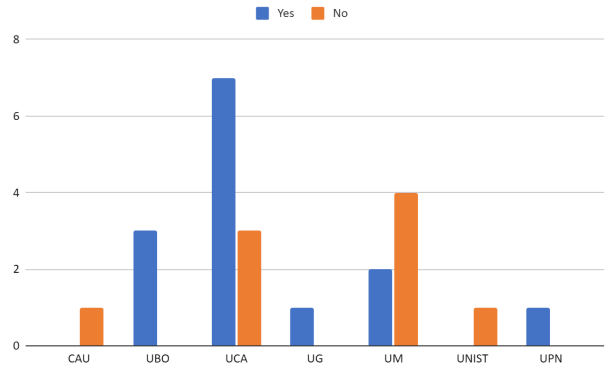

Figure 12: EN writing skills improvement – Sociology Academics

4.1.4 English Language Speaking Skills

A) while speaking alone, such as when delivering a speech or presentation *Chemistry academics* (N = 84): Only a majority of chemistry respondents from UAlg self-reported their speaking skills as excellent. The majority in UNIST self-claimed to have very good skills. The majority from UBO, UCA and UG reported their speaking skills as good; and in UPN, speaking skills are self-reported as basic. Excluding UM, just seven respondents self-indicated excellent EN speaking skills, while three admit very poor skills. Excluding UM, all universities except UAlg have a majority of respondents who are keen – some very keen – to improve their EN speaking skills, although the level of keenness at UBO is quite lukewarm. There were no submissions from CAU (Figures 13 and 15).

Sociology academics (N = 17): Respondents from CAU and UNIST self-reported their speaking skills as excellent. Most sociology respondents from UG self-reported their speaking skills as very good; the majority in UCA self-reported as good; and the majority from UBO and UPN reported their speaking skills as basic. Excluding UM, just seven respondents self-indicated excellent EN speaking skills; and two admit having very poor skills. Sociology respondents from UBO, UCA, UG and UPN favour improving their EN speaking skills. There were no submissions from UAlg (Figures 14 and 16).

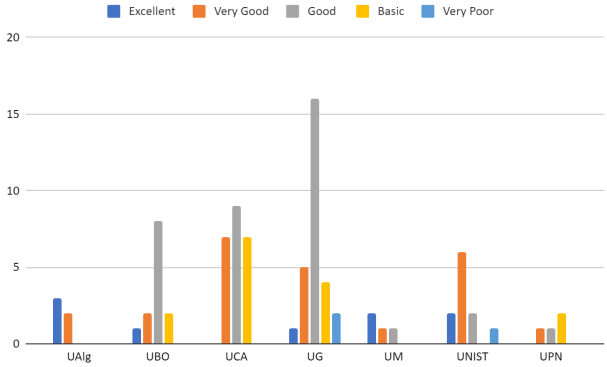

Figure 13: EN speaking (presentation) skills assessment – Chemistry Academics

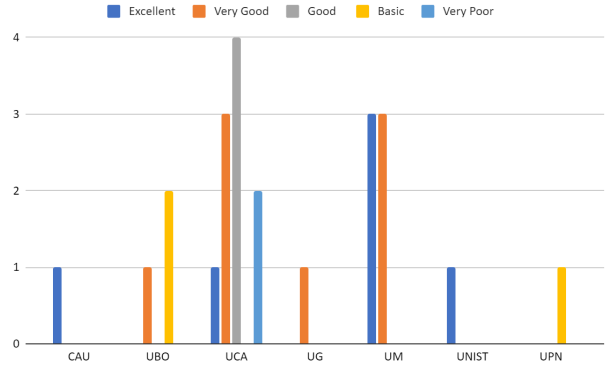

Figure 14: EN speaking (presentation) skills assessment – Sociology Academics

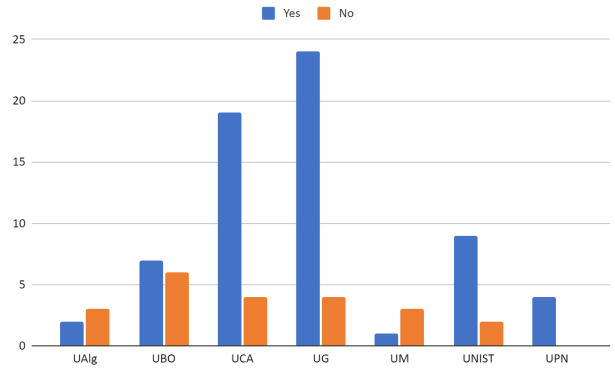

Figure 15: EN speaking (presentation) skills improvement – Chemistry Academics

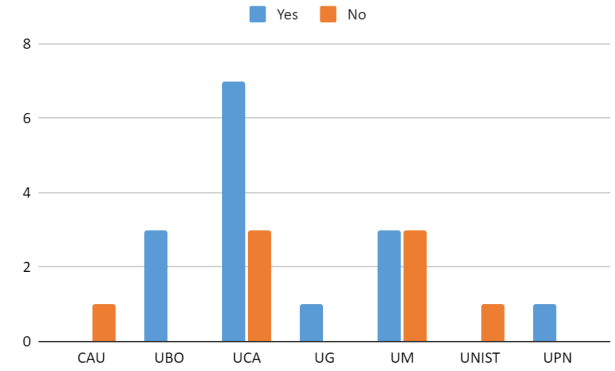

Figure 16: EN speaking (presentation) skills improvement – Sociology Academics

B) while speaking with others, in a conversation or dialogue The deterioration in the general competence levels in the English language reported by the respondents continues; it hits the lowest scores for this fifth and final category of EN skills.

Chemistry academics ($N = 84$): Only the majority of chemistry academics at UAlg self-reported their EN speaking skills as excellent (and, as usual, excluding UM). Most respondents from UNIST self-noted their speaking skills as very good and the majority in UBO and UG self-reported as good. The majority in UCA and UPN self-reported their EN speaking skills as basic. Excluding UM, only nine respondents self-declared excellent skills in this area. All universities except UAlg declared that they wish to improve their speaking skills. There were no submissions from CAU (See Figures 17 and 19).

Sociology academics ($N = 17$): The majority of sociology respondents from CAU and UNIST self-reported excellent speaking skills; while the majority from UCA and UG self-reported very good skills. Sociology academics from UBO self-reported a range of very good, basic and very poor skills, while the UPN respondent self-reported basic skill level. Just three academics declare excellent skills here. Yet, most respondents from CAU, UG and UNIST do not want to improve their competence in this area. There were no submissions from UAlg (See Figures 18 and 20).

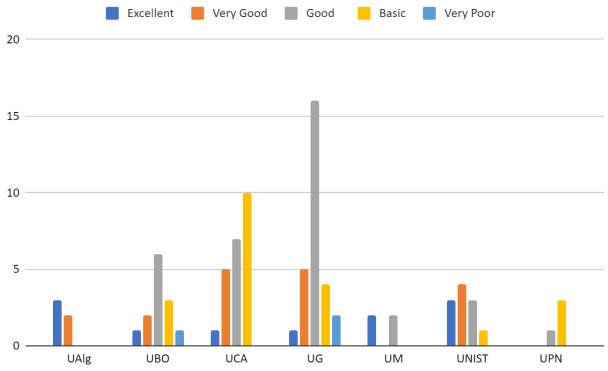

Figure 17: EN speaking (dialogue) skills assessment – Chemistry Academics

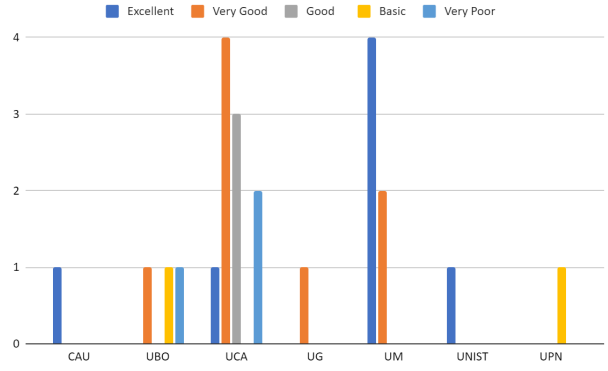

Figure 18: EN speaking (dialogue) skills assessment – Sociology Academics

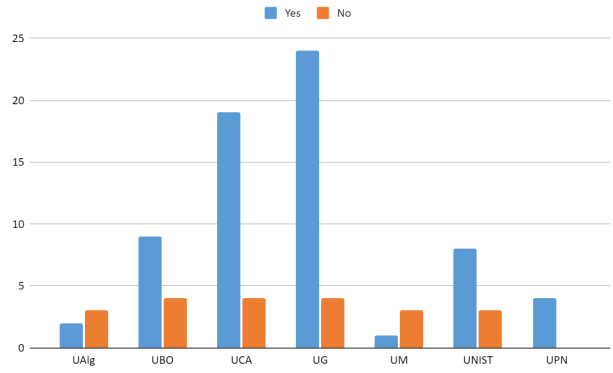

Figure 19: EN speaking (dialogue) skills improvement – Chemistry Academics

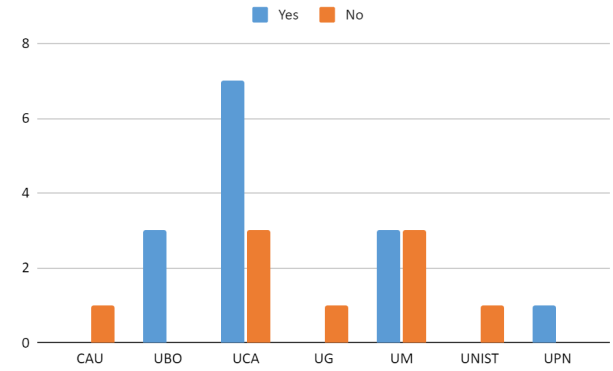

Figure 20: EN speaking (dialogue) skills improvement – Sociology Academics

4.2 Tasks performed

4.2.1 Sending Emails In English (Frequency In Last Month)

The volume of email messages sent or received in the English language is another indicator of the internationalisation of the particular discipline. *Chemistry academics* ($N = 84$): 36 (43%) of the chemistry academics self-reported never having sent an email message in English in the previous month. This is the majoritarian response across the board (with UM as the single exception). Excluding UM, eight chemistry academics self-report sending email messages in EN over 75% of the time. There were no submissions from CAU (See Figure 21).

Sociology academics ($N = 17$): 4 (23%) of the sociology academics self-reported never having sent an email message in English in the previous month. Excluding UM, no sociology academics self-report sending email messages in EN over 75% of the time. There were no submissions from UAlg (See Figure 22).

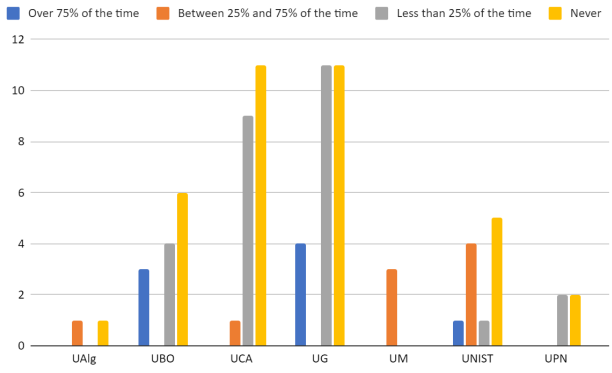

Figure 21: Sending emails in EN – Chemistry Academics

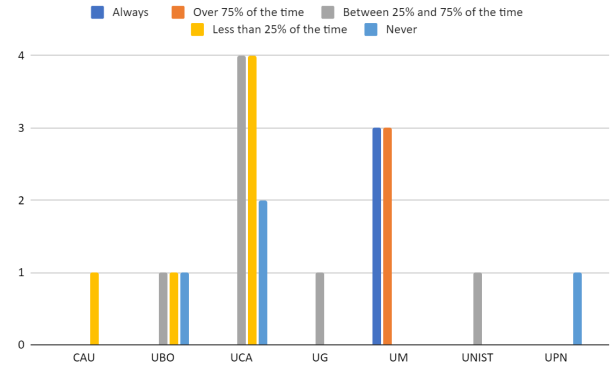

Figure 22: Sending emails in EN – Sociology Academics

4.2.2 Receiving Emails In English (Frequency In Last Month)

Chemistry academics ($N = 84$): only a majority of chemistry respondents from UAlg self-reported receiving emails in EN over 75% of the time during the previous month. Most respondents from UBO, UCA, UG and UPN self-reported emails in EN between 25% and 75% of the time; and the majority from UNIST reported emails in EN less than 25% of the time. Just four chemistry academics self-declared not having received a single email message in EN during the previous month; while nine declared that they received email messages in EN all the time. There were no submissions from CAU (See Figure 23).

Sociology academics ($N = 17$): UPN self-reported that they did not receive emails in EN during the previous month. Three respondents self-declared receiving no single email message in EN during the previous month. Excluding UM, only one respondent (from UCA) self-declared receiving emails in EN over 75% of the time. No one declared receiving email messages in EN all the time There were no submissions from UAlg (See Figure 24).

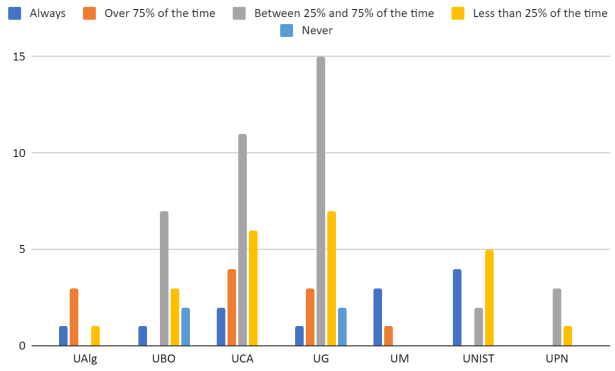

Figure 23: Receiving emails in EN – Chemistry Academics

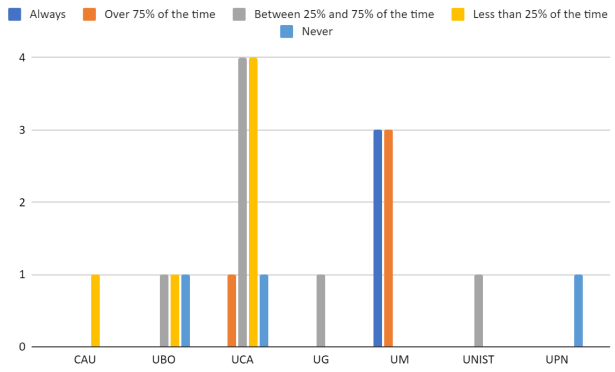

Figure 24: Receiving emails in EN – Sociology Academics

4.2.3 Reading Work Related Material In English During The Previous Month

Chemistry academics ($N = 84$): 27 respondents self-declare that they have always read work-related material in EN during the previous month. Only three respondents admit that they have read work-related material in EN less than 25% of the time. There were no submissions from CAU (See Figure 25).

Sociology academics ($N = 17$): Excluding UM, only one sociology respondent (from UCA) has always read work-related material in EN during the previous month. Meanwhile, one respondent (from UBO) has not read any work-related material in EN during the previous month. Five respondents admit that they have read work-related material in EN less than 25% of the time. There were no submissions from UAlg (See Figure 26).

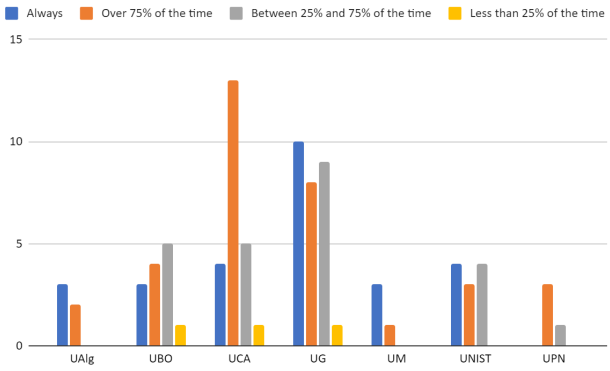

Figure 25: Reading work-related material in EN – Chemistry Academics

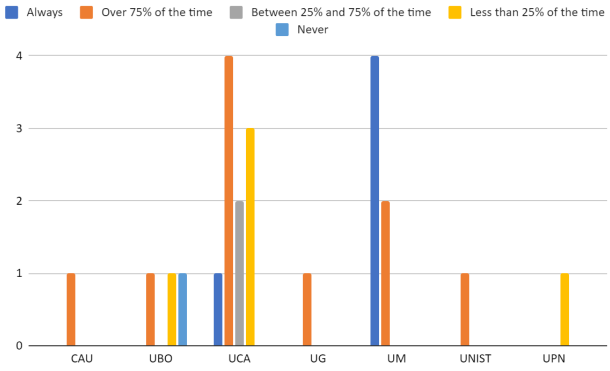

Figure 26: Reading work-related material in EN – Sociology Academics

4.2.4 Listening To Work Based Conversations In English (Frequency In Last Month)

Chemistry academics ($N = 84$): Excluding UM, most chemistry respondents from UAlg reported listening to work-related conversations in EN over 75% of the time during the previous month. The majority in UBO self-reported doing so between 25% and 75% of the time; while the UPN respondent and most respondents from UCA, UG and UNIST reported doing so less than 25% of the time. 14 respondents (17%) stated that they did not hear a single conversation in EN during the previous month at work. There were no submissions from CAU (See Figure 27).

Sociology academics ($N = 17$): Excluding UM, only one respondent (from UG) has self- reported listening to work-related conversations in EN over 75% of the time during the previous month. Four respondents (24%) stated that they did not hear a single conversation in EN during the previous month at work. There were no submissions from UAlg (See Figure 28).

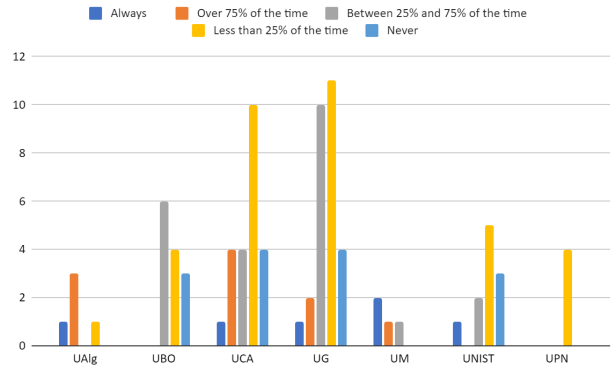

Figure 27: Listening to work-based conversations in EN – Chemistry Academics

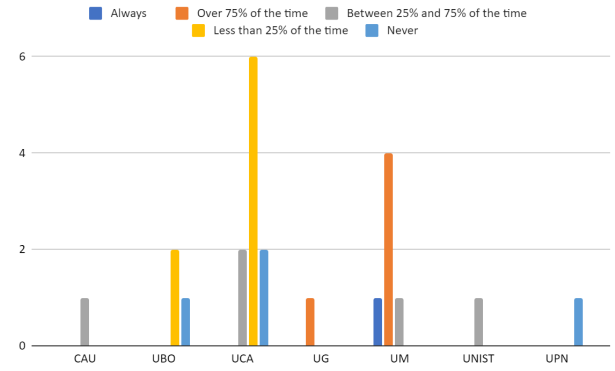

Figure 28: Listening to work-based conversations in EN – Sociology Academics

4.2.5 Speaking English At Work (Frequency In Last Month)

Chemistry academics ($N = 84$): Excluding UM, only most chemistry respondents from UAlg self-reported speaking EN between 25% and 75% of the time at work during the previous month. All four UPN respondents and most responses in UBO, UCA, UG and UNIST self-reported speaking EN at work less than 25% of the time. 15 respondents (18%) admitted not having spoken English at all at work during the previous month. There were no submissions from CAU (See Figure 29). *Sociology academics* ($N = 17$): Six respondents (35%) admitted not having spoken English at all at work during the previous month. When UM is excluded, none of the other 17 sociology respondents has spoken EN at work over 75% of the time during the previous month. There were no submissions from UAlg (See Figure 30).

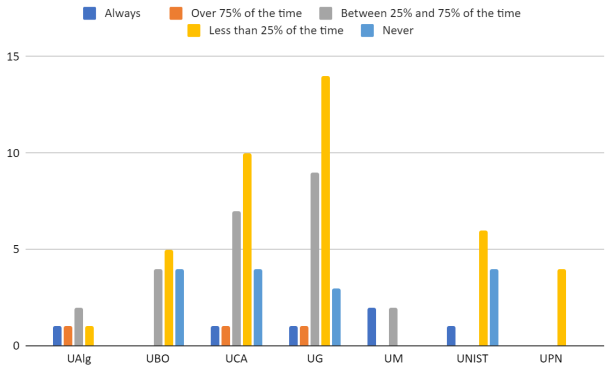

Figure 29: Speaking EN at work – Chemistry Academics

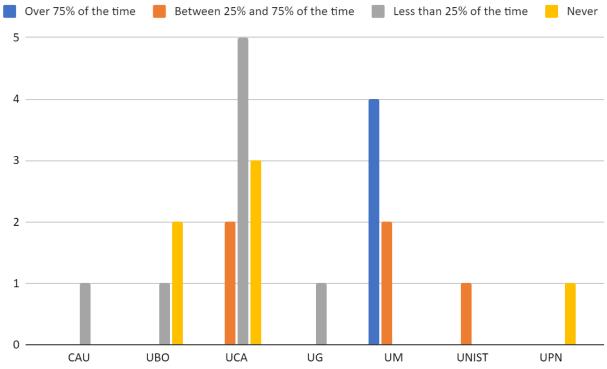

Figure 30: Speaking EN at work – Sociology Academics

4.2.6 Dealing With Written Material (Emails, Circulars, Media Releases, Social Media Posts, Documents, Publications) In English (Frequency In Last Month)

This question is similar to that discussed under 3.2.4 above, but goes beyond written material associated directly with work. The answers interrogate the respondents' wider engagement with the English language beyond strict, work-related requirements.

Chemistry academics ($N = 84$): After excluding UM, only most respondents from UAlg self-reported over 75% of written material in English during the previous month. The majority in UCA, UG and UPN self-reported dealing with such material between 25% and 75% of the time; and a majority from UNIST self-reported less than 25% of the time. Results from UBO were mixed. Only three respondents (4%) self-report not dealing with *any* material written in EN at work during the previous month. There were no submissions from CAU. (See Figure 31).

Sociology academics ($N = 17$): *Four* respondents (24%) self-report not dealing with any material written in EN at work during the previous month. Excluding UM,

just one sociology academic (from UCA) declared dealing with English language material over 75% of the time during the previous month. The sociologist from UPN self-declared dealing with no EN language material at all. There were no submissions from UAlg (See Figure 32).

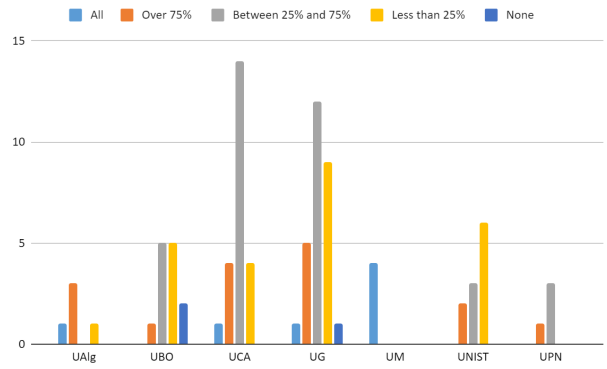

Figure 31: Percentage of written material in EN – Chemistry Academics

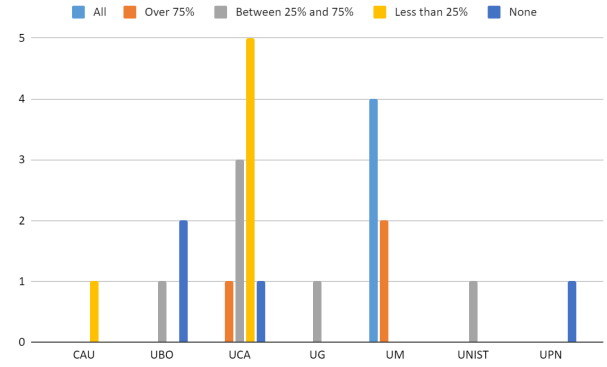

Figure 32: Percentage of written material in EN – Sociology Academics

4.2.7 Preparing Lecture Slides and Notes

Chemistry Academics ($N = 84$): Respondents from UAlg and a majority from UBO reported that they do not need to develop EN language skills when preparing lecture slides and notes. Meanwhile, most respondents from UCA, UG, UNIST and UPN selected a 'yes' answer. Overall, 43 chemistry respondents (51%) admitted that they would benefit from help to prepare their teaching slides and notes. There were no submissions from CAU (See Figure 33).

Sociology Academics ($N = 17$): Most respondents from CAU, UM, UNIST and UPN and the majority in UBO reported that they do not need to develop their EN language skills when preparing lecture slides and notes; while most UG respondents indicated that they did. UCA reported equal submissions of yes and no. Overall, seven sociology respondents (41%) admitted that they would benefit from help to prepare their teaching slides and notes. There were no submissions from UAlg (See Figure 34).

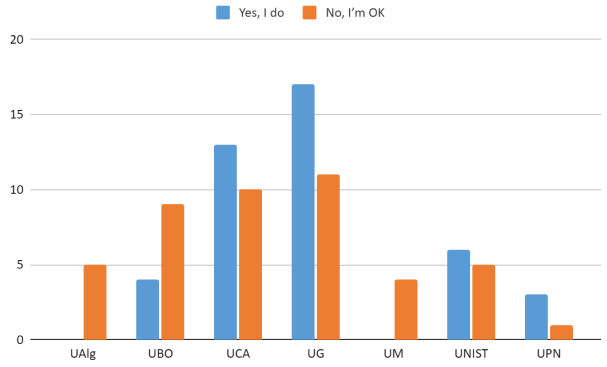

Figure 33: Do you need to develop your EN skills to better prepare lecture slides and notes? – Chemistry Academics

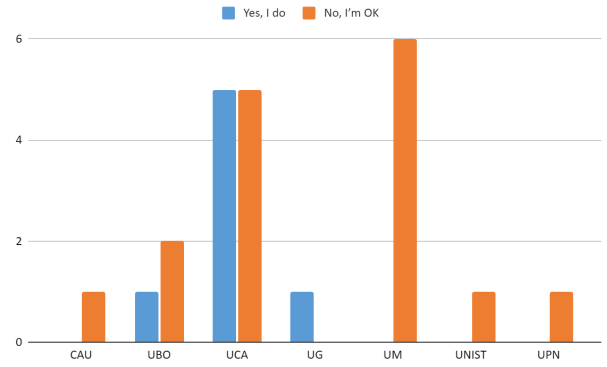

Figure 34: Do you need to develop your EN skills to better prepare lecture slides and notes? – Sociology Academics

4.2.8 Designing a Test or Exam

Chemistry Academics ($N = 84$): 35 respondents (42%) indicated a desire to improve their ability to design tests or exams in the English language. Except for UPN (which had a majority), and excluding UM, all universities had minorities of respondents that expressed an interest in coaching in this area. There were no submissions from CAU (See Figure 35).

Sociology Academics ($N = 17$): Seven respondents (41%) indicated a desire to improve their ability to design tests or exams in the English language. All responses from sociologists at CAU, UBO, UNIST and UPN – while excluding UM – indicated no desire for additional coaching in this area. There were no submissions from UAlg (See Figure 36).

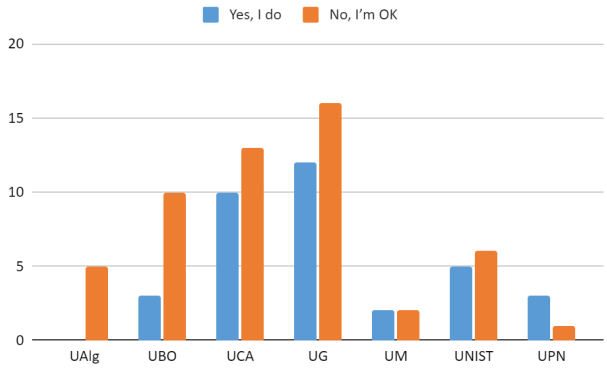

Figure 35: Do you need to develop your EN skills to better design a test or exam? – Chemistry Academics

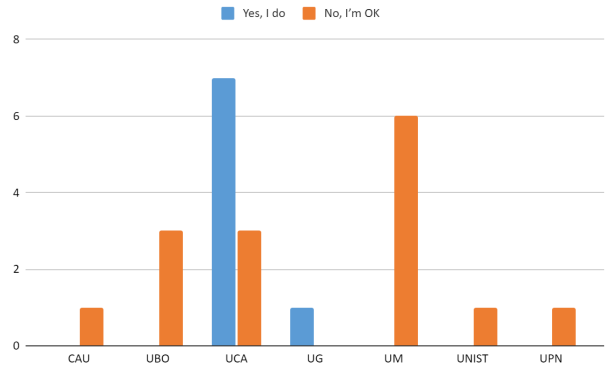

Figure 36: Do you need to develop your EN skills to better design a test or exam? – Sociology Academics

4.2.9 Lecturing or conducting Laboratory Sessions

Chemistry Academics ($N = 84$): The Majority of chemistry respondents from UCA, UG, UNIST and UPN self-declare that they would benefit from such coaching; but just a minority from UBO (as well as one respondent from UM). 45 chemistry respondents (54%) are interested in coaching to improve their skills in this area. There were no submissions from CAU (See Figure 37). *Sociology Academics* ($N = 17$): 10 sociology respondents (59%) are interested in coaching to improve their skills here. There were no submissions from UAlg (See Figure 38).

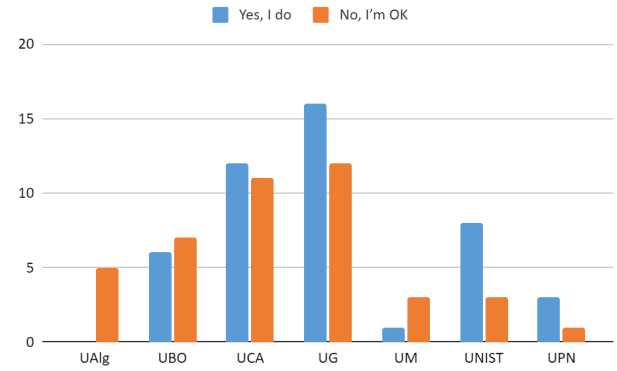

Figure 37: Do you need to improve your EN skills to better design lectures or laboratory sessions? – Chemistry Academics

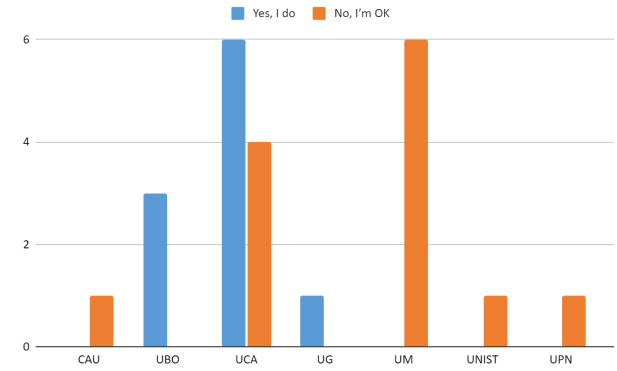

Figure 38: Do you need to improve your EN skills to better design lectures or laboratory sessions? – Sociology Academics

5 Discussion and analysis

An aggregate assessment of the data from the various tables presented suggests that chemistry professors are indeed more immersed in the English language world of international academia than their sociology counterparts. This conclusion results from the consistently greater extent to which chemistry professors indicate an exposure to English language in a wide variety of work-related tasks; and the consistently greater extent to which they are interested in requesting support or coaching in the skills related to such tasks. This observation is also supported by the statements of chemistry professors who declare that they are more obliged to deliver courses/study units in the English language than their sociology counterparts: again, this is to the exclusion of UM academics, who self-report that they are all exposed to English-language demands at work, always or at least 75% of the time. Only three sociology respondents – one from UBO, one from UCA, one from UG (18%) – report some English language course/ study unit delivery, and all for less than

25% of the time. The situation for chemistry academics is different, with almost half – 37 respondents (44%) – self-reporting that they deliver courses/ study units in English (See Figures 39 and 40).

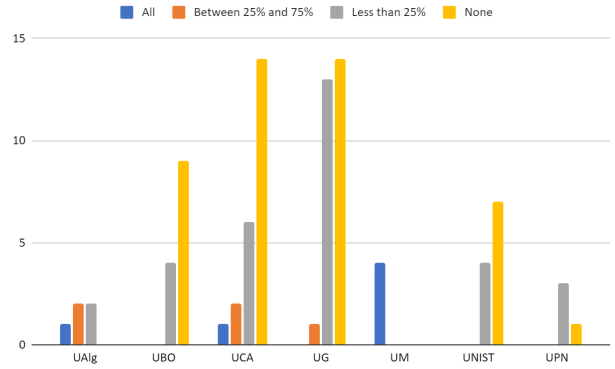

Figure 39: Percentage of lectures in courses/study units delivered in EN – Chemistry Academics

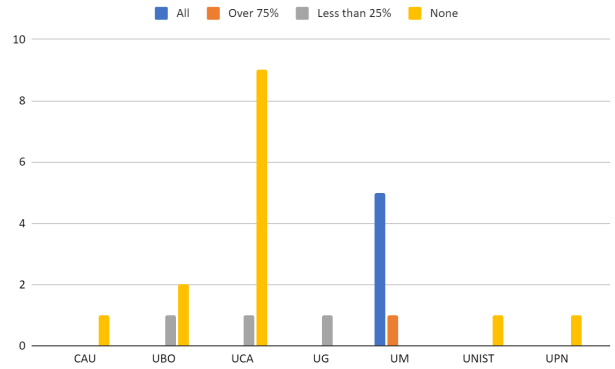

Figure 40: Percentage of lectures in courses/study units delivered in EN – Sociology Academics

A similar contrast is identified when the respondents were asked about the language of required readings for their courses/ study units. (UM stands on one extreme, with all recommended readings being in English, for both chemistry and sociology.) 25 chemistry respondents (30%) report no readings in English; as do 7 sociology respondents (41%). Excluding UM, 12 chemistry academics use English language material 75% of the time or more; in contrast, no sociology academic admits using such English language material so frequently (See Figures 41 and 42).

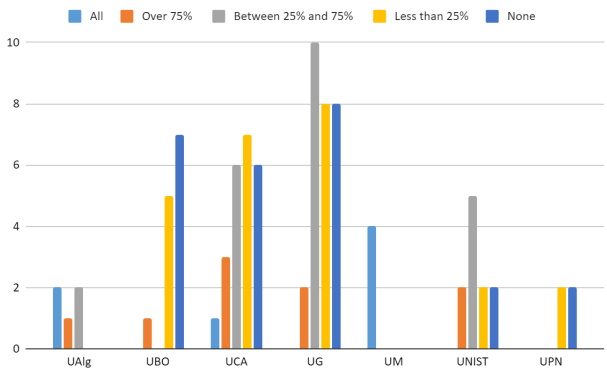

Figure 41: Percentage of required readings in EN – Chemistry Academics

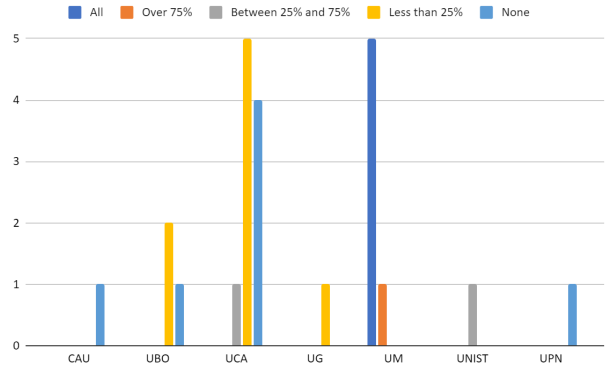

Figure 42: Percentage of required readings in EN – Sociology Academics

What about the proportion of slides and notes accompanying courses / study units? How many of these are in the English language? (For UM respondents, all slides and notes are self-reported as being in English.) For the chemistry respondents, only 23 respondents (27%) never used slides or notes in the English language. There were no submissions from CAU (See Figure 43). For the sociology respondents, just one non-UM academic (from UBO) reported using slides and notes in English during lectures for up to 75% of the time. All remaining 16 respondents (94%) indicated a low level of English language material usage: of 25% of the time, or less. There were no submissions from UAlg. (See Figure 44).

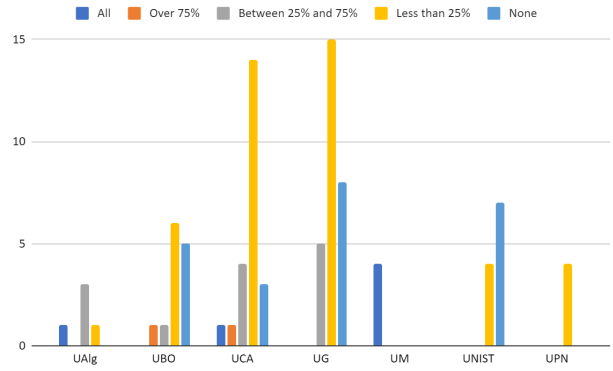

Figure 43: Percentage of slides and notes accompanying courses/study units in EN – Chemistry Academics

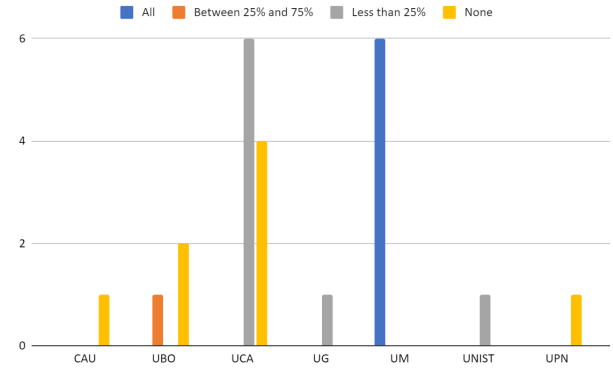

Figure 44: Percentage of slides and notes accompanying courses/study units in EN – Sociology Academics

Finally, even when it comes to methods of assessment – exams, tests, assignments, projects, etc. – the chemistry subset evidences a higher level of exposure to the English language than the sociology subset. (The methods of assessment for UM are all self-reported in English.) *Chemistry academics* ($N = 84$): 32 respondents (38%) report some percentage of English language methods of assessment. There were no submissions from CAU (See Figure 45).

Sociology academics ($N = 17$): With one exception (from UCA), all respondents claim no methods of assessment in English. There were no submissions from UAlg. (See Figure 46).

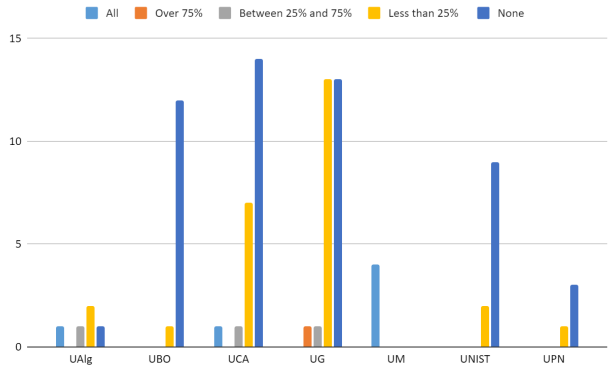

Figure 45: Percentage methods of assessment in courses/study units in EN – Chemistry Academics

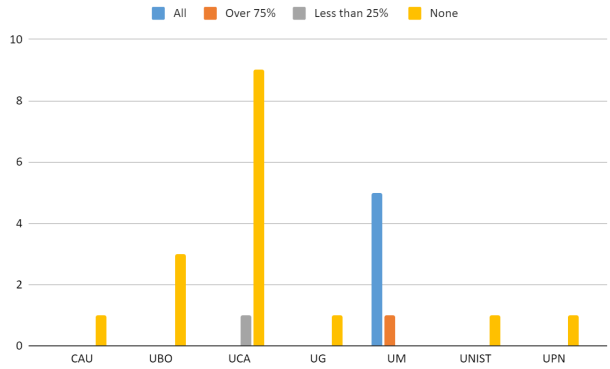

Figure 46: Percentage methods of assessment in courses/study units in EN – Sociology Academics

The data supports the initial hypothesis: chemistry professors in European universities represent a disciplinary category that is more exposed to the English language than sociology professors in the same universities. Such differential exposure covers all aspects of language engagement: reading, listening, writing, speaking alone (as in a presentation) and speaking with others (as in a dialogue), as well as preparing notes, slides, and tests for students. Although the data on which this conclusion is based is totally made up of self-reported assessments, they are consistent and regular enough to warrant such a statement.

What is the rationale behind the hypothesis? Some co-authors of this paper are sociologists; and some responded to the survey questionnaire. They admit that, in all universities covered by the December 2023 survey except UM, it is possible to run certain university classes, offer certain readings, and issue certain methods of assessments without the use of the English language. Nevertheless, incoming ERASMUS+ and/or international students are likely to be looking for classes that are taught in Eng-

lish; and they will vehemently protest if such classes drift into national language settings. Even in classes which are officially meant to be taught in the native language, non-native students may request that their professors provide them with materials, such as readings and assessment options, in English. It becomes a vicious cycle when such courses, laboratory sessions or assessments, being offered in the national language, do not attract international or Erasmus mobility visiting students, obviating the need to consider introducing some measure of English into the running of the activity. It is also more possible for sociologists to publish research in national journals, as national monographs, etc., which once again reduces, or perhaps eliminates, the need to produce scholarship in the English language. One must remember that most universities also have a responsibility to promote the national culture and language. UM is an exception here, since the language of instruction is not the national language: quite unique for a public university (University of Malta, 2021).

6 Conclusion

In a globalised world English is socially constructed as a language of development, emancipation, science, and technology as well as a language of unity and reconciliation (Mohanty, 2019). The linguistic landscape at the contemporary university is complex. The increasing prominence of the English language in this context is both key and contentious (Murray, 2016, p. 1). This paper set out to examine whether those teaching chemistry and sociology at nine European universities experience similar pressure and environment when it comes to the use of the English language at work. The results suggest that they are not. The implications of these results are worth some deep reflection. The wave of internationalisation that is impacting many universities – and encouraged by the drive to move up the global rankings – does not unfold evenly and uniformly on their campuses. We are not referring to pockets of indifference or resistance which are also bound to occur: some academics may refuse or avoid as much as possible lecturing in a foreign language; especially in situations where their own students may have an English language competence that is stronger than the academics' own. Research in EMI also suggests that teaching in a non-native language increases the level of difficulty for (local) students and slows down their pace of acquisition (Ozer, 2020; Xiao & Zou, 2020). Setting up professional development courses for lecturers, and supplementary English courses for domestic students to help them adapt to the English-language driven situations, may both be required (Aizawa & McKinley, 2020). This paper is suggesting that disciplines already face the threat, or promise, of English language competence from different starting points. The nature of a discipline, and how the craft gets practised, exposes academics to more or less of the English language. This situation, in turn, breeds varying leves of enthusiasm, motivation, urgency or willingness to improve one's skills in this language. We agree with Robichaud (2015, p. 175) that: "a substantial portion of the population [could be convinced] not to learn English, or at least not to use it in some contexts [...] especially in more formal contexts where the symbolic significance of political decisions can be very important." But, on the other hand, English speakers benefit from their English proficiency due to the dominance of English as a lingua franca in academic contexts. The proficiency gap between native and non-native English speakers could be problematic in some cases, "since native or very proficient speakers are likely to enjoy greater opportunities (for work, study, etc.) than less proficient speakers" (Mac Giolla Chríost & Bonotti, 2018, p. 69). Bubbles or pools of anti-internationalisation may exist in every higher education institution; but disciplinary allegiance, training and a sense of belonging to one's place of residence can either improve or worsen the prospects of isolation or exposure and openness to a wider dimension.

Acknowledgements

The authors thank Maria Grima Calleja (Manager) and Isabella Bianco, Fernanda Giraldo Guzman, Tamara Micallef, and Stefania Zdral from the SEA-EU Office at the University of Malta. They compiled the English language needs assessment report from which all the tables in this article are drawn (https://www.um.edu.mt/about/sea-eu/contact/). We also acknowledge the support of Saeed Karimi-Aghdam, Nord University, Norway, in organising the actual on-line survey using the Nettskjema platform developed by the University of Oslo, Norway (https://nettskjema.no/). Each of the SEA-EU partner universities was responsible for translating the master survey instrument into their own language and distributing it across the relevant categories of staff and students on their respective campuses.

Disclaimer

The authors report no conflicts of interest.

References

Aizawa, I., & McKinley, J. (2020). EMI challenges in Japan's internationalization of higher education. In H. Bowles & A. C. Murphy (Eds.), *English-medium instruction and the internationalization of universities* (pp. 27–48). Palgrave Macmillan.

Blackwood, R., & Dunlevy, D. A. (2021). *Multilingualism in public spaces: Empowering and transforming communities*. Bloomsbury Academic.

Coleman, J. A. (2006). English-medium teaching in European higher education [Online]. *Language Teaching*, *39*(1), 1–14.

Crystal, D. (2004). The past, present, and future of World English. In A. Gardt & B. Hüppauf (Eds.), *Globalization and the future of German* (pp. 27–45). De Gruyter.

Di Bitetti, M. S., & Ferreras, J. A. (2017). Publish (in English) or perish: The effect on citation rate of using languages other than English in scientific publications. *Ambio*, *46*(1), 121–127.

Edwards, J. (2012). *Multilingualism: Understanding linguistic diversity*. Continuum.

Gramling, D. (2021). *The invention of multilingualism*. Cambridge University Press.

Granić, J. (2012). Multilingual Reality vs. Monolingualist Ideology. In M. Jernej, J. Lah & A. Iveković Martinis (Eds.), *Multilingualism in the public sphere: Program and abstracts* (pp. 85–86). Institute for Anthropological Research; Croatian Anthropological Society.

Granić, J. (2017). The European identity crisis and the promotion of linguistic diversity. In S. Ureland & L. Sočanac (Eds.), *Glottogenesis and language conflicts in Europe* (pp. 91–109). Logos Verlag Berlin.

Grin, F., Conceição, M. C., Caruso, E., & Costa, N. (2018). What is the role of English in multilingual and multicultural learning spaces? In F. Grin, M. C. Conceição, P. A. Kraus, L. Marácz, Z. Ozolina, N. K. Pokorn & A. Pym (Eds.), *The MIME vademecum: Mobility and inclusion in multilingual Europe* (pp. 140–141). Artgraphic Cavin (for the European Commission).

Horner, K., & Dailey-O'Cain, J. (2020). *Multilingualism, (im)mobilities and spaces of belonging* (K. Horner & J. Dailey-O'Cain, Eds.). Multilingual Matters.

Liang, L., Rousseau, R., & Zhong, Z. (2013). Non-English journals and papers in physics and chemistry: Bias in citations? *Scientometrics*, *95*, 333–350.

Long, M. H. (2010). *Second language needs analysis*. Cambridge University Press.

Mac Giolla Chríost, D., & Bonotti, M. (2018). *Brexit, language policy and linguistic diversity*. Palgrave Macmillan.

Mary, L., Krüger, A.-B., & Young, A. S. (2021). *Migration, multilingualism and education: Critical perspectives on inclusion* (L. Mary, A.-B. Krüger & A. S. Young, Eds.). Multilingual Matters.

Metsola, R. (2023). Multilingualism: expressing unity through diversity. In C. de Toledo, S. Tafrov, J. Pascual et al. (Eds.), *Multilingual postcards* (pp. 125–128). Court of Justice of the European Union & Publications Office of the European Union.

Mohanty, A. K. (2019). *The multilingual reality: Living with languages*. Multilingual Matters.

Murray, N. (2016). *Standards of English in higher education: Issues, challenges and strategies*. Cambridge University Press.

Ozer, O. (2020). Lecturers' experiences with English-medium instruction in a state university in Turkey: Practices and challenges. *Issues in Educational Research*, *30*(2), 612–634.

Phillipson, R. (2003). *English-Only Europe?: Challenging language policy*. Routledge.

Phillipson, R. (2007). *English in Europe: Threat or promise?* (M. Nic Craith, Ed.).

Piquer-Píriz, A. M., & Castellano-Risco, I. O. (2021). Lecturers' training needs in EMI programmes: Beyond language competence. *Alicante Journal of English Studies RAEI*, *34*, 83–105.

Robichaud, D. (2015). Cooperative justice and English as a lingua franca: The tension between optimism and Anglophones free riding. *Critical Review of International Social and Political Philosophy*, *18*(2), 164–177.

University of Malta. (2021). *Comprehensive guidelines for the use of language at the University of Malta* (tech. rep.) (https://www.um.edu.mt/media/um/docs/languageuseguidelines.pdf). University of Malta.

Xiao, J., & Zou, X. (2020). Strategy use to overcome difficulties in EMI courses in higher education. *International Journal of Innovation and Research in Educational Sciences*, *7*(6), 503–519.

Zanola, M. T. (2024). Language policy in higher education. In M. Gazzola, F. Grin, L. Cardinal & K. Heugh (Eds.), *The Routledge handbook of language policy and planning* (pp. 483–496). Routledge.

Ferranti R. et al. (2024). *Xjenza Online*, 12(2):105–120.

Xjenza Online: Science Journal of the Malta Chamber of Scientists
www.xjenza.org
DOI: 10.7423/XJENZA.2024.3.02

Research Article

The State of Occupational Health and Safety in the Maltese Construction Industry and the Way Forward

R. Ferranti[1], **L. A. Fiorini**[*1]
[1] *Center for Labour Studies, University of Malta, Msida, Malta*

Abstract. Construction is the most dangerous sector in Malta. Most fatal accidents at work occur in this sector, while it also has the highest annual number of non-fatal accidents per capita. To date, no studies have analysed the state of this sector from the perspective of occupational health and safety practitioners working in the construction industry. This qualitative study aims to do this while identifying strategies to improve standards. Structured interviews were conducted with twelve qualified participants, all of whom worked in the construction industry. The resulting data was analysed thematically. All participants agreed that the state of health and safety on construction sites in Malta has improved over time. Participants identified several challenges, including unregulated developers who have no interest in health and safety, a lack of safety standards in the construction industry, friction between practitioners and the Occupational Health and Safety Authority, issues regarding enforcement, a lack of training for construction workers and precarious working conditions for migrant workers. In light of the findings, short-term and long-term solutions are suggested. These include increased enforcement, alternative penalties, better resources for the involved inspectorate, adequate training, the licensing of contractors, and construction standards development.

Keywords: Occupational Health and Safety, Construction Industry, Occupational Accidents, Enforcement, Standards, Inspectorate.

1 Introduction

In 2020, construction accounted for 21.5% of fatal accidents at work in the European Union (EU), followed by manufacturing (15.2%) (Eurostat, 2020). The situation is no different in Malta, where construction has the highest fatal accident rate per capita (Fiorini et al., 2024; National Audit Office [NAO], 2016, 2020). Locally, non-fatal injuries are most frequent in the manufacturing industry. Injuries in the manufacturing industry have decreased significantly over the years, most likely due to the decline in employment in the sector and an improvement in safety levels (Fiorini & La Ferla, 2021). However, per capita, non-fatal injuries are more common in construction as well as transport and storage (Fiorini et al., 2024; NAO, 2016, 2020), but here too accidents appear to be declining (Fiorini et al., 2024). Despite progress being made in non-fatal accidents in construction (Table 1), it should be noted that the statistics may not give a true picture of the sector. It has previously been claimed that over a 12-month period, 75% of occupational injuries and illnesses were not reported to the competent authorities (Occupational Health and Safety Authority, 2011).

Table 1 shows that 48 work-related deaths were reported in Malta between 2016 and 2022, of which 34 (71%) occurred in the construction industry (National Statistics Office [NSO], personal communication, 22 March 2023). Their increasing frequency prompted a British citizen to launch an EU Parliament petition in 2021 claiming that Malta was not meeting the required Occupational Health and Safety (OHS) standards. Following this petition, the European Parliament's Committee on Petitions requested more information on the state of OHS in Malta. In its response, the OHSA argued that Maltese legislation was in line with EU regulations, that the number of accidents and fatalities had decreased, while resources for enforcement had increased (Xuereb, 2022). Attention to the sector increased further following the tragic death of a young worker, Jean Paul Sofia, on a construction site in December 2022. Despite initial resistance from the government, public demonstrations, led by the victim's mother, resulted in a public enquiry being held. This investigated the circumstances of this particular accident and more general aspects related to safety in the construction industry. The

Correspondence to: L. A. Fiorini (luke.fiorini@um.edu.mt)

Year	Total number of persons employed	Workers in the construction industry	Injuries in the construction industry	Percentage of workers injured in construction	Fatalities at work	Fatalities in construction sector
2016	208,132	14,063	473	3.36 %	7	4
2017	220,489	15,186	485	3.19 %	1	1
2018	232,306	14,578	482	3.31 %	4	4
2019	251,398	16,149	444	2.75 %	3	3
2020	261,839	15,195	407	2.68 %	8	4
2021	266,226	17,176	389	2.26 %	9	9
2022	283,341	17,526	362	2.07 %	16	9

Table 1: Injuries and Fatalities covering the years 2016-2022 (NSO, personal communication, March 22, 2023).

public enquiry uncovered several failings within the sector and its regulation, including the lack of consultation between stakeholders, including health and safety practitioners and the organisations that regulate aspects of the construction industry (Zammit McKeon et al., 2024).

This study aims to investigate the perceptions of health and safety professionals on the current state of occupational health and safety in the Maltese construction industry and identify potential improvement areas.

The objectives of the study are therefore:

1. To determine if the state of OHS in the construction industry has changed over the years.
2. To identify the perceived problems and challenges currently faced by health and safety practitioners.
3. To explore the perceived improvements that can be made in the construction sector in Malta.

2 Literature Review

2.1 Legislation

Chapter 424 of the Laws of Malta, the Occupational Health and Safety Authority Act (XXVIII of 2000), established the OHSA, listed its responsibilities and several Legal Notices (L.N.) were promulgated under this Act. L.N. 88 of 2018 Workplace (Minimum Health and Safety Requirements for Work at Construction Sites) Regulations [S.L.424.36] is of particular interest to this study as it sets out minimum requirements for construction sites. This legal notice replaced L.N. 281 of 2004, which previously regulated safety on construction sites (Fiorini, 2018).

L.N. 88 of 2018 lists the client, the contractors and the project supervisor (PS) as construction site stakeholders. The client, who is any legal or natural person for whom a construction project is carried out and who is legally responsible for a project, must appoint or assume the role of a PS. The PS is "any natural or legal person responsible for health and safety supervision of a project, appointed by a client". A PS must apply the prevention principles of the Act and other subsidiary legislation as appropriate. Other duties include coordinating contractors or subcontractors, as well as site visits and meetings to monitor the work. OHS practitioners work on construction sites when hired by the client as PSs, independent consultants or full-time employees, usually for large construction companies (on a full-time or contract basis).

2.2 Key Stakeholders

In this section, the stakeholders listed in L.N. 88 of 2018, the clients, contractors, and OHS practitioners, who regularly take on the role of PSs, are discussed further. Masons are also discussed, as they are often involved and on the receiving end of many construction accidents.

2.2.1 Masons

Masons require a licence to work. According to Article 96 of the Code of Police Laws, the Masons' Board is authorised to examine all applicants for a mason's licence. However, the Kamra tal-Periti (Chamber of Architects and Civil Engineers) (2019) argued that the requirements for this licence are not specified. Among the shortcomings highlighted are the unspecified skills and formal qualification requirements and the lack of a public register of licensed masons, which calls into question the training of masons in modern construction technologies, materials and practices. This poses a risk to masons themselves, their work colleagues and the public (Kamra tal-Periti, 2019).

2.2.2 Clients and contractors

Clients can be categorised according to their size. Smaller clients are often unaware of their safety obligations, while large clients regularly work on large construction sites and take an active role in prevention. These cli-

ents are more likely to believe that good health and safety standards save money in the long term (European Commission, 2011). In fact, the OHSA 2013, 2014 reports that larger construction companies are more committed to OHS, invest more in safety and that large projects no longer have high accident rates despite more workers and longer duration (OHSA, 2013, 2014). This is consistent with European findings, where an EU-wide enforcement campaign found a direct correlation between construction site size and compliance. Large construction sites (with more than 50 employees) had higher compliance rates than smaller construction sites (European Commission, 2011).

Clients can also impact OHS culture via their choice of contractors (European Commission, 2011), including during the procurement stage (Young et al., 2019) when clients can require contractors to submit fully costed complete OHS documentation. Failure to do so can cause cost versus safety issues (Young et al., 2019). In fact, to improve OHS attitudes, the European Commission (2011) suggests that national legislation should require OHS preventative measures in tenders (European Commission, 2011). The Karmra tal-Periti has been advocating for the registration of contractors based on regulations and mandatory training for several years. Studies of registration schemes from other countries have shown mixed results in terms of their impact on quality and safety (Kleiner, 2015; Mitchell, 2020; Vokes & Pye, 2013).

2.2.3 OHS practitioners

In addition to other tasks, PSs must consider occupational health and safety on a construction site during project planning and execution, draw up an OHS plan and monitor its implementation.

OHS practitioners have a problematic relationship with the OHSA. A Criminal Court decision in 2022 found that informing the client and workers on site of violations is insufficient to fulfil a PS's role, and indirectly implied that PSs are to report OHS shortcomings to the OHSA (Gauci & Magri, 2022). Conversely, OHS shortcomings on a construction site can lead to PSs being prosecuted (Zammit McKeon et al., 2024). Furthermore, by reporting deficiencies to the OHSA, PSs' are essentially reporting their employer.

A performance audit by the NAO (2016) recommended that the legal responsibility for appointing a PS during the design phase should be shifted from the client to a more knowledgeable stakeholder such as designers, engineers and/or architects, while the contractor should select the PS during the construction phase. It has also been argued that unqualified individuals were performing the role of a PS (NAO, 2016; Zammit McKeon et al., 2024) and that the OHSA should maintain a register of competent PSs and only they should be allowed to undertake the role (NAO, 2020). The Malta Occupational Safety and Health Practitioners Association (MOSHPA) has proposed that the OHSA randomly assign PSs from a register after developers and contractors have paid an administration fee (Times of Malta, 2022). This would provide OHS practitioners with some protection from vindictive developers.

The occupational health and safety profession is not properly regulated in Malta. Malta only maintains a voluntary register for such practitioners that is managed by the OHSA (Fiorini & La Ferla, 2023). Currently, the minimum requirements for inclusion within this register include possessing an undergraduate diploma in OHS, relevant experience and competence in the field, and continued professional development since obtaining the qualification (OHSA, n.d.-b). Over the years, OHS has developed into a complex field where practitioners must consider various factors that may influence workers' safety and their physical, mental and social well-being. In view of this, the Centre for Labour Studies at the University of Malta which has offered a diploma in OHS since 1997 commenced offering a degree in the topic in 2016. It has been argued that a qualification should be mandatory to work in OHS and that the minimum qualification for new graduates should be a degree (Fiorini & La Ferla, 2023).

2.3 Known risk factors

A number of factors are known to influence accident rates and standards within construction. Three key factors are discussed in the following section; migrant workers, a lack of training and levels of enforcement.

2.3.1 Migrant workers

Migrant workers are among the most vulnerable members of society, often employed in 3D jobs: dirty, dangerous and demanding (sometimes degrading) jobs that are often hidden from the public and policymakers unless and until accidents happen (Quandt et al., 2013). Migrant workers earn less, work longer hours and have worse working conditions than non-migrant workers (Gammarano, 2020; International Labour Organization [ILO], 2015; Moyce & Schenker, 2018; Salminen, 2011). They often take more risks, are likely to work without training or personal protective equipment (PPE) and are less likely to voice their concerns about unsafe conditions (Flynn, 2014; Ronda Pérez et al., 2012).

Over a twenty-year period, almost 30% of fatal accidents in Malta have involved foreign workers (Fiorini et al., 2024). The proportion of non-fatal and fatal accidents at work among migrant workers is increasing (Fiorini & La Ferla, 2021), suggesting that more migrants are working in hazardous occupations. The opposite is true for

Maltese workers, increasing the reliance on migrant labour in the industry (Central Bank of Malta, 2019).

Malta rarely retains foreign labour. 25% of foreign workers entering the Maltese labour market leave within the first year, while 50% leave one to two years later (I. Borg, 2019). As a result, companies often have to hire new employees and are less likely to invest in training (I. Borg, 2019). However, adequate levels of OHS depend on the provision of appropriate training for migrant workers (O'Connor et al., 2014). Injury rates appear to decrease proportionally with the integration of migrant workers into the local society. According to Salminen (2011), migrant workers generally had a higher injury rate than native workers in the first five years of employment, but after five years it fell below that of native workers.

A leading issue amongst migrant construction workers internationally (Shepherd et al., 2021) and in Malta (Horvat Cardona, 2023) is poor language competency. Language and literacy problems affect safe working practices (Hide et al., 2003). Managers often choose the best English speaker among migrant workers to translate for others. Misunderstandings can occur if the employee's English is not as good as the supervisor believes. The situation can also be exploited for personal gain by the employee saying something different to management than to their colleagues (O'Connor et al., 2014). It has therefore been suggested that migrant workers should be offered appropriate language training and job skills, possibly with the support of a government agency such as Jobsplus (Debono et al., 2013). Relevant materials also need to be translated, with the format, content and message tailored to the target group (Brunette, 2005). Relevant measures have been implemented in Malta, with the OHSA producing documents on OHS for migrants in eight languages (OHSA, 2022) and trade unions producing documents on workers' rights in various languages (Debono & Fiorini, 2023).

2.3.2 Training

Many OHS accidents are caused by workers' actions and bad habits (Hide et al., 2003; Winge et al., 2019). Several studies have shown that formal and professional OHS training can improve behaviour and reduce injuries (Greene et al., 2005; Spangenberg et al., 2002), while conversely, bad habits are more likely to persist when training is informal and on the job (Hide et al., 2003).

Falls are the leading cause of fatal accidents in construction worldwide (Nadhim et al., 2016), and the situation is no different in Malta (Fiorini et al., 2024). A lack of training is an important factor in the occurrence of falls (Nadhim et al., 2016). In Malta, the Kamra tal-Periti (2019) has also raised concerns that anyone with demolition or excavation machinery can carry out excavation work without training and technical knowledge. The report emphasises the need to act quickly and classify contractors according to the qualifications of workers and equipment (Kamra tal-Periti, 2019). Contractors must certify their work according to several European building regulations. In Malta, the lack of registered contractors and proof of qualifications allows amateurs and unskilled labourers to provide services to consumers, which "often has tragic consequences" (Kamra tal-Periti, 2019, p. 34).

In 2016, a skills card was introduced to certify the skills of various construction-related professions. While this was a positive step forward, it remained a voluntary measure, meaning that only a fraction of those working in the sector received such a card (Zammit McKeon et al., 2024). It has been suggested that the skills card is made mandatory, is accompanied by a safety card and that it is issued only if the applicant is proficient in English or Maltese (Zammit McKeon et al., 2024).

2.3.3 Enforcement: Site visits and issuing of fines by the OHSA

Three instruments are used in Malta to enforce OHSA regulations on construction sites: Prosecutions, Stop Orders (SOs) and Administrative Fines (AFs). OHSA inspectors can order a construction site to cease operations if serious health and safety violations are detected. A verbal order is followed by a written order for these SOs within three days. The SO remains in place until the breaches are rectified (NAO, 2016). During an audit conducted by the NAO, four of the five sites audited received SOs. Despite this, one site that had received an SO continued to operate the next day. This raised questions about the effectiveness of this enforcement action (NAO, 2016).

The OHSA issues fines in accordance with L.N. 36 of 2012. The fines range from €250 to €450. Once the fines have been imposed, a follow-up visit is carried out to ensure infringements are rectified. The OHSA can prosecute if these violations are not addressed. The NAO (2016) found that the maximum administrative fine was disproportionate to some of the offences they were intended to deter (NAO, 2016). In terms of prosecutions, 526 cases were initiated between 2018 and 2023. During this period 516 cases were concluded. These cases include all prosecutions by the OHSA in all sectors. A further 119 cases were pending in 2023 (Zammit McKeon et al., 2024). In comparison, the OHSA issued 662 stop orders and 462 administrative fines in 2022 alone (OHSA, 2023).

Inspections and penalties have been shown to reduce injuries in the years following inspections (Gray & Mendeloff, 2005; Levine et al., 2012; Mischke et al., 2013).

Penalties can also encourage employers to improve safety and address problems (Haviland et al., 2010). Indeed, inspections, penalties and higher fines have been associated with fewer injuries in Malta (Fiorini et al., 2024), while many Maltese companies only take OHS action after inspections or fines (S. Borg, 2015; European Agency for Safety and Health at Work, 2019) or for legal reasons (European Agency for Safety and Health at Work, 2019). Against this backdrop, the NAO has criticised the OHSA for promoting a system of self-regulation, which it described as "utopian and unrealistic" (NAO, 2016, p. 50) given a widespread cultural disregard for safety and non-compliance with OHS regulations. This method of regulation was also criticised during the Jean Paul Sofia Public Enquiry (Zammit McKeon et al., 2024). The OHSA's resources, which have not kept pace with the booming construction industry, have likely impacted their ability to conduct site visits and enforce regulations. In 2011, OHSA officials physically inspected each of the 250 construction sites for which they received Construction Notification Forms (CNFs) (OHSA, 2011). By 2019, 2,450 CNF forms had been received. By this time, the OHSA were sampling construction sites for inspections (OHSA, 2020).

3 Method

3.1 Research design

A qualitative research design was used. Qualitative research methods were used as they allow for the exploration of words, meanings and reasons and are well-suited to determine new information and root causes (Bryman et al., 2022).

The research protocol received ethical clearance from the Research Ethics Committee of the Faculty of Economics, Management and Accountancy at the University of Malta.

3.2 Participants and the context of the study

Participants who were qualified OHS professionals, and as a minimum held a diploma in OHS and two or more years of experience in the construction industry were sought. This strategy was chosen as it mirrors the criteria of the OHSA voluntary registry of competent persons. A purposive sample was used for this study as the individuals were specifically selected to meet the established criteria (Padgett, 2017). Potential participants were identified and contacted through the OHSA's registry of competent persons which provides public contact details for those who opt to do so. Few participants were recruited in this manner, and further participants were recruited via snowball sampling.

Table 2 provides an overview of the background information of the participants. Due to Malta's small population and the small number of workers in the industry, the number of years worked has been categorised to protect the anonymity of the respondents. The qualifications listed in Table 2 refer to participants' highest qualification in OHS. All participants are Maltese and male; this reflects the demographics of individuals who work in the field.

Participant	Qualification in OHS	Years of Experience in the construction industry
1	Diploma	more than 15
2	Diploma	less than 5
3	Masters	between 5 and 15
4	Masters	more than 15
5	Masters	more than 20
6	Diploma	more than 20
7	Diploma	between 5 and 15
8	Masters	between 5 and 15
9	Degree	between 5 and 15
10	Degree	between 5 and 15
11	Degree	more than 20
12	Diploma	more than 20

Table 2: Summary of Participants' Relevant Information.

3.3 Interview guide and the interviewing process

After analysing the available literature, an interview guide was created by the researchers (RF and LAF). The interview guide contained questions based on the main research question and the study objectives as recommended by Given (2008). The guidelines of Bell and Waters (2018) were used to formulate and structure the questions. The interview guide was divided into three parts. Firstly, the participants were asked about their background, professional experience and education. The second part consisted of six semi-structured questions. Participants were asked to discuss the state of OHS in the construction industry, the changes they had observed over the years, the challenges they encountered when carrying out their roles, and how health and safety in the construction industry could be improved. Participants were also asked to reflect upon initiatives they had implemented that had a positive effect and the difficulties they encountered when implementing these changes. The third part of the interview allowed participants to clarify or add to the discussion to conclude the interview.

Interviews were conducted by the first author (RF), all

of which ($N = 12$) except one were conducted face-to-face and recorded using a laptop in a private room. One interview was carried out over the telephone. Shuy (2002) found that face-to-face interaction promotes small talk, politeness, joking, nonverbal communication, and human connection.

3.4 Data capturing and analysis methods

The principles of Thematic Analysis (Braun & Clarke, 2006) were used to analyse the data. The interviews were first transcribed (RF) and then read repeatedly. Key points and ideas were noted, and initial codes were created for all the data. Subsequently, themes and subthemes were identified and discussed between the two researchers. All relevant data was combined and a report was formulated by both researchers (Braun & Clarke, 2006).

3.5 Limitations

Whilst the sample is small, and formal statistics on the number of OHS practitioners operating in construction are unavailable in Malta, it is believed that less than 50 individuals who hold a minimum of a diploma in OHS carry out this role. The current sample would therefore constitute around a quarter of the qualified individuals working in the sector. The data collected is specific to the situation in Malta, and thus the findings may not be generalisable to other countries. Despite this, many of the findings appear in line with international research.

4 Results and Discussion

4.1 Objective 1: State of change in OHS over time

In line with the first objective, participants were asked if they thought the OHS situation in construction in Malta had changed over the years. All participants stated that they had observed an improvement over time, which is consistent with previous findings (Fiorini & La Ferla, 2021; Fiorini et al., 2024).

> *"To be honest there was an improvement. Because when I started, health and safety was non-existent. Nothing at all. I remember going to sites with no equipment, no procedures, nothing."*

The participants attributed the improvement to several factors. The introduction of the OHSA, the introduction of legislation, the positive influence of health and safety organisations and consultants in the industry, improved levels of education among practitioners and others working to improve levels in the country. The positive impact of social media was also mentioned, which participants felt had put pressure on organisations and authorities to act. However, most participants agreed that there is still much more improvement to be made. Participants felt that Malta lags behind other developed countries in construction OHS, and referred to the number of fatalities in the construction industry.

> *"From my perspective, I think that there is some work to be done. We are nowhere near the UK for instance."*

In addition, the participants mentioned that there is a high rate of unreported accidents in the construction industry. Less progress has been made in Malta in terms of fatal accidents than in reducing non-fatal accidents (Fiorini et al., 2024). Underreporting of non-fatal accidents and health problems has been previously reported (Occupational Health and Safety Authority, 2011) and although there is no evidence to support this, underreporting may have increased in the construction industry due to the increasing reliance on migrant labour.

4.2 Objective 2: Issues and Challenges

The second objective sought to identify the perceived issues and challenges that OHS practitioners are currently facing when performing their roles. Four themes were identified: stakeholders in the industry, the role of OHS practitioners, training, and the increase in foreign workers.

4.2.1 Stakeholders in the industry

All participants agreed that the client and the contractors (the developers) have a major influence on the level of OHS. The clients are in a strong position to determine the project standards as they both finance the project and determine who and what will be involved in the construction project (European Commission, 2011). Despite this, participants discussed how OHS levels differed between construction sites, with some sites having rules and procedures and others having nothing. Whilst some clients and contractors had a reputation for promoting a good level of OHS, others had a very poor reputation.

> *"There are large differences between developers, that is clients and contractors, from one project to another. It ranges from very good to quite poor"*

This suggests that the authorities should try to flag problematic developers and focus more resources on these organisations. Despite the important role of contractors in safety, they remain unlicensed and unregistered (Zammit McKeon et al., 2024). In 2007, the Kamra tal-Periti (2007) argued in favour of registering all contractors based on a set of conditions, which the government

endorsed in 2020 (Kamra tal-Periti, 2020). This would ensure that only registered contractors with a solid safety record would be allowed to work and consequently be engaged by clients. Positively, regulations are in place to make registration and licensing mandatory by the beginning of 2025 (L.N. 166 of 2023).

Participants also described how developers and management's commitment to OHS improved the OHS behaviour of workers. When management prioritised OHS, workers followed suit. This has already been found in the literature (Bayram et al., 2017).

> *"If the management shows interest in health and safety then the workers will show interest in health and safety. . . and they would adopt health and safety."*

Participants also expressed concern about clients not complying with OHSA enforcement and PS stop work notices. In line with this, the NAO (2016) expressed concern about clients who did not comply with such instructions and questioned the effectiveness of enforcement. However, Fiorini et al. (2024) demonstrated that enforcement in Malta was associated with fewer non-fatal accidents, in line with foreign studies. The lack of commitment to safety by clients and contractors and unresolved safety issues have led to OHS practitioners resigning from projects. This was a drastic measure to avoid being held legally responsible for the inadequate state of health and safety on these construction sites. Practitioners also did this when they were threatened by clients for disrupting their projects and wasting their time and money trying to implement OHS measures.

> *"When I have a client or a contractor who does not see eye to eye with me on safety issues in critical areas I pull out."*

Several developers were described as seeing safety as an expense and not an investment. Participants acknowledged that safety can be costly and that those developers looking to carry out a construction project whilst investing as little as possible would avoid investing in safety measures. Indeed, most participants stated that many developers prioritised completing the project on time above all else.

> *"Some contractors do not invest in safety because safety is an expense, safety is seen as a waste of money. They want to get the job done, they have deadlines."*

The long-term benefits of high levels of OHS were more likely to be recognised by large contractors than small contractors. Participants found working with smaller contractors challenging due to their lack of resources and lack of awareness of their OHS responsibilities. Several studies have found that larger companies invest more in OHS and are generally more compliant with their obligations (European Commission, 2011; Hide et al., 2003). This has also been noted in Malta (OHSA, 2013, 2014).

4.2.2 The role of OHS practitioners

Several issues revolved around participants having problems fulfilling their roles. One key issue was that OHS practitioners are paid by the contractor or the person commissioning the job. Practitioners often felt uncomfortable or feared for their jobs if they put pressure on an uncooperative developer or turned to the OHSA.

> *"What are the chances that the health and safety officer would actually report his employer to OHSA?"*

This concern has featured in public statements by practitioners and the MOSHPA, who highlighted that practitioners who reported their employer could end up being blacklisted and unemployable in the construction industry (Times of Malta, 2022; Zammit, 2022a).

Participants also stated that the roles and responsibilities of OHS practitioners on construction sites are unclear. This was due to vague legislation and a lack of supporting guidelines for OHS practitioners. In practice, this resulted in differing standards between practitioners.

> *"What is the role of the project supervisor? Because this is something that is unclear, where one has many different interpretations in the law. What is a competent person? What qualifications are required? What exactly is the role of the project supervisor? The role of the consultant?"*

Via their website, the OHSA offers guidelines related to construction. Amongst them, a document provides information regarding construction-related roles, including the role of the client and PS (OHSA, n.d.-a). However, the qualifications needed for different safety-related roles such as the PS are not covered. Guidelines for certain types of work equipment are also provided, as are links to related European guidelines. However, these do not include some topics that concern participants, such as guidance on the required frequency of inspections at construction sites, or the information that should be included in some OHS documentation. Consequently, practitioners stated that they sometimes argued with clients that they needed to visit their project more frequently, only

to be rebuked and allowed on-site at a lesser frequency. Furthermore, the quality of OHS documents produced by practitioners varied, with practitioners unsure of what was expected of them:

> *"The OHSA, BICC (Building Industry Consultative Council) and all other entities that in one way or another are involved in construction, none of these have ever issued guidelines on what are the minimum requirements to be included in an OHS plan."*

In a related finding, several participants stated that there is a lack of relationship between the OHSA and practitioners working in the field, or their representatives. Participants stated that there was little coherence between the communication and efforts of OHS practitioners and the OHSA. Others complained that the OHSA does not support OHS practitioners, and felt that the Authority does not value higher education.

> *"There is no chemistry between project supervisors and the OHSA. The OHSA doesn't even support or protect the project supervisors, instead, it is trying to destroy project supervisors."*
>
> *"[People] who go to university and spend two to five years studying, for the OHSA it means absolutely nothing."*

In 2022, MOSHPA publicly expressed concern about the manner in which PSs are summoned to OHSA meetings when safety deficiencies are identified, where they are also informed that they have the right to be accompanied by a lawyer (Times of Malta, 2022). This practice could be linked to a recent court ruling which stated that PSs who identify hazards, inform clients and workers about them and detail the actions to be taken are not doing enough to fulfil the role of the PS as defined by law (Gauci & Magri, 2022). Nevertheless, the current study suggests that PSs are often not in a position where they can enact or push for needed change. It has also been argued that the same judgement, although not explicitly written, could be interpreted to mean that PSs should report shortcomings to the OHSA and risk incriminating themselves in the process (Gauci & Magri, 2022). During data collection, several participants expressed concern about this judgement. However, some of these issues may be resolved in the future, as the OHSA is working on revisions to L.N. 88 of 2018 concerning OHS in construction sites. Furthermore, efforts to open dialogue between practitioners and the OHSA have been noted since data collection.

The commercial aspects of the job also had an impact. In order to be competitive, OHS practitioners reduced the cost of their services and in the process, carried out fewer site visits. Participants felt that this was possible due to the lack of standards in the industry. Participants also expressed concern that some OHS practitioners took on more sites than they could manage. In fact, the OHSA found that one PS was overseeing 500 sites simultaneously (Zammit, 2022b). Possibly exacerbating this situation is the fact that there are no guidelines on who is competent to take on the role of a PS, and there is limited regulation on who can work as an OHS practitioner in Malta (Fiorini & La Ferla, 2023). More highly qualified individuals, who may be more diligent and recognise the ethical implications of their work, may be competing with individuals who have invested less in their training or have not analysed such implications.

4.2.3 Training and awareness

The importance of worker training was emphasised by all participants. The majority pointed out that sufficient training must be provided for high-risk activities, such as working at height, but that it is rarely provided. As a result, health and safety professionals were regularly confronted with negative working practices and attitudes:

> *"I've seen a number of people who don't want to use a harness, or others who use it and use it incorrectly. I've seen harnesses tied to twenty cement bags... and if the line cuts through the bags...".*

Falls from height are the most common cause of death on construction sites in Malta (Fiorini et al., 2024) and internationally (Nadhim et al., 2016). A lack of training is a contributing factor (Nadhim et al., 2016). In line with this, the Kamra tal-Periti (2019) expressed concern that labourers are allowed to work on-site without any basic training, in contrast to several European building regulation frameworks that require contractors to be certified to certain standards.

Participants also expressed concern that the skill card is insufficient in terms of allocated course time and contents for high-risk tasks, such as working at height.

> *"[The skill card gives the perception that] after 40 minutes talking on working at heights the worker is an expert, where in reality working at heights training takes a number of hours and involves theory and practice"*

4.2.4 Foreign workers

All participants were concerned about the influx of foreign labour into the construction industry, triggered by a

high demand for workers that could not be met by the Maltese workforce. Indeed, the percentage of Maltese construction workers has decreased over the years and the industry relies more on migrant labour (Central Bank of Malta, 2019).

The influx of foreign labour has brought with it a number of challenges, including the working conditions offered to these workers and cultural differences. Comments from participants emphasised the lack of regulation in relation to migrant workers' skills:

> *"Agencies bring workers without any screening, the next day they are on the job and that's it."*

Participants expressed frustration that foreign workers were often those accustomed to working in less industrialised or developed conditions, with poor OHS standards:

> *"Their culture in OHS is much lower than ours... We have been struggling to increase our standards and then all of a sudden you had an influx of foreign workers with no idea of health and safety."*

Research indicates that migrant workers are more likely to take risks on the job and to carry out work without proper training (Flynn, 2014; Ronda Pérez et al., 2012). The regular turnover of migrant workers subsequently makes it more difficult to raise standards in Malta, with many migrants leaving the country within months or years of arriving (I. Borg, 2019). However, a lack of instruction also contributed to migrants' negative OHS attitudes.

> *"Migrant workers do not apply any safety, and I don't blame them. Because they are not instructed. They are not knowledgeable... When it comes to legislation and safety and all of this, they are very laid back. And I think this is one of the biggest problems."*

Dangerous working conditions, however, were often perpetrated by the worksite, with participants suggesting that developers took advantage of such workers:

> *"I've faced some situations where the risks were high, and I was astonished, and I stopped the work right away. These people were put in dangerous situations just because they are immigrants and don't even know their rights."*
>
> *"[Migrant workers are] forced to work in inhumane situations and you find them there, working in construction sites without awareness, nothing. Some of them really want the job, and they do everything the master says. So, they are not assertive. So, if they tell them to go and work in a precarious situation, they will do it... This is one of the biggest challenges I think that we find in construction."*

Accidents among migrant workers appear to be on the rise in Malta (Fiorini & La Ferla, 2021), and a local study by Debono and Vassallo (2020) found that many Filipino workers in Malta struggle with negative workplace conditions, including in the construction industry, with almost half of respondents stating that their health or safety was at risk due to their work. Similarly, respondents indicated that migrant workers often do the same work as local workers for a lower wage. This was often coupled with longer working hours and poorer working conditions than non-migrant workers. Research by the International Labour Organisation (ILO) corroborates these statements and adds that migrant workers are often victims of human rights violations, abuse, human trafficking and violence (ILO, 2015).

Most participants stated that the language barrier on construction sites is a major problem, as migrant workers often lack basic English or Maltese literacy skills. Participants explained that OHS professionals sometimes have to find someone to translate, resort to drawings or use Google Translate to convey an important safety message. Participants emphasised that contractors often do not prioritise English language skills or even disregard them. This situation is not limited to Malta and has been described as a contributory factor in various accident investigations that impacted safe working practices (Hide et al., 2003).

4.3 Objective 3: Recommendations for improvement

The third and last objective sought to explore potential avenues for improvements. Six themes were identified: stakeholders in the industry, the role of OHS practitioners, collaboration between authorities and entities, training and raising awareness, foreign workers, and enforcement.

4.3.1 Stakeholders in the industry: clients and contractors

The participants suggested that occupational health and safety requirements should be defined before the start of a construction project, especially if several contractors are involved. For larger projects, these could then be included in the tendering process. The European Commission (2011) has made the same recommendation. Studies show that prioritising OHS during the procurement process is essential for creating effective strategies and a strong safety culture (Young et al., 2019).

Participants emphasised the need to introduce contractor licensing to ensure that qualified workers are employed on construction sites. Some suggested that a contractor who has a serious accident should be disqualified from participating in public contracts for 12 months. Participants also suggested linking the duration of the blacklist to the severity of the accident. This approach would also allow contracting authorities to select contractors based on their safety records.

> *"I would start with setting up a register, where you have the contractors registering according to their capabilities.... according to the level of management, training, skill. Because that makes a difference in health and safety. And also if they have training in health and safety and the equipment being used."*

Mandatory licensing of contractors and ensuring that workers are qualified has been suggested previously (Kamra tal-Periti, 2020; Zammit McKeon et al., 2024). However, the results on the impact of contractor licensing on service quality and OHS are mixed (Kleiner, 2015; Mitchell, 2020; Vokes & Pye, 2013).

Several participants stated that stakeholder education is crucial to create a mindset where OHS is not only seen as a financial and operational burden but as an integral part of the construction project.

> *"From the very beginning, all players, stakeholders, from the developer downwards, in order to work in this field, should be given both the opportunity and in many cases the obligation to actually be educated in health and safety management."*

Participants felt that OHS awareness would improve if stakeholders understood their legal obligations. To this end, the European Commission (2011) emphasised the importance of clients understanding their responsibilities and that appropriate coordination takes place to ensure OHS.

4.3.2 The role of OHS practitioners

Most participants emphasised the need for more frequent monitoring of construction sites, a recommendation that had already been highlighted by the Kamra tal-Periti (2019). Participants highlighted that this was difficult to implement as practitioners were in competition with each other and were driving down prices by carrying out fewer inspections. Participants emphasised the need for a code of practice and conduct that the OHSA should develop with OHS practitioners to regulate OHS services. These standards would help clarify issues such as who is competent, what is required of a PS, and how often inspections are required.

> *"If not every day, [inspections should take place] at least when there are changes in the work. Within the current system, the commercial aspect of the role created by the practitioners in the industry would make this very difficult for one to compete and this point ties with the need to regularise and standardise the guidelines for OHS practitioners working in the industry."*

Several participants recommended that the OHSA establish a database of all industry practitioners who provide OHS services as PSs or consultants. One purpose of this registry would be to randomly assign an OHS practitioner to manage the worksite of clients or contractors seeking such services. Participants suggested that these practitioners would be paid by the client and would report directly to the OHSA, the client and others as required. This proposal has previously been suggested by MOSHPA as a possible way forward, whereby PSs would fall under the OHSA and clients would pay an administrative fee to the OHSA for providing the service (Times of Malta, 2022) Indeed, the OHSA has been advised by the NAO (2020) to consider shifting the statutory duty to appoint a PS from the client to a more technical and capable stakeholder (NAO, 2020). The current proposal would reduce the race to the bottom between practitioners but is unlikely to be favoured by those wishing to compete commercially.

Participants expressed confusion about the requirements needed to fulfil the position of PS. This included whether a PS must be registered on the OHSA's competent list for OHS practitioners and whether there are any additional requirements. According to the NAO, the OHSA should ensure that only competent PSs supervise construction sites (NAO, 2020). The OHSA rejected this proposal as there are not enough people on the register of competent persons to fulfil this role and suggested that such a requirement would stifle the industry (NAO, 2020). Participants also disagreed on the minimum requirements that a PS should have. Some emphasised the value of a university degree, while others felt that a PS need not be highly qualified and that diploma-level training would suffice. These suggestions were probably influenced by the qualifications held by the participants themselves. Those who favoured higher qualifications pointed out that there was scope for specialisation within the PS role, while expressing frustration that OHSA did not value higher education.

> *"Construction involves a huge number of skills"*

4.3.3 Training and raising awareness

The majority of participants emphasised that training is important and necessary for everyone working on a construction site. Participants stated that workers are ill-informed and recommended that such training should be provided when workers are learning their skills and that it should be tailored to their position.

> *"When studying to become a builder, you can't have generic health and safety training but more detailed training".*

Scientific studies have consistently shown that OHS training improves behaviour and attitudes while reducing accidents and lost time (Greene et al., 2005; Hide et al., 2003; Spangenberg et al., 2002). The participants' suggestions are also consistent with those relating to the mandatory introduction of a skill and safety card (Zammit McKeon et al., 2024).

Several participants also spoke of the importance of involving workers in OHS decisions and approaching them positively. Participants noted that workers regularly had useful insights and ideas that went beyond those of the developers. Worker involvement in OHS has proven benefits, such as enhancing risk assessment (Popma, 2009), and would be facilitated by better OHS culture and training (Bayram et al., 2022).

4.3.4 Foreign workers

While participants expressed concern about problems related to communication, few offered solutions. Where possible, participants resort to using a member of staff as a translator.

One recommendation was to involve Identity Malta in the process to help employees with their skills and language knowledge. The Centre for Labour Studies had previously suggested involving JobsPlus in such an endeavour (Debono et al., 2013). The recent public enquiry recommended that language skills should be a prerequisite for obtaining a mandatory skills card (Zammit McKeon et al., 2024). The current findings suggest that this could be a fruitful measure.

4.3.5 Collaboration between authorities and entities

Several participants shared the view that various authorities and entities were not collaborating on OHS matters and agreed that there is a need for cooperative communication. Participants also felt that at times there was overlap between entities that should be tackled.

> *"I would have the OHSA carry out meetings to improve the inter-communication between government departments vis-a-vis construction sites. This is an area which is lacking. The Planning Authority have the site technical officers, OHSA is not part of the Planning Authority's permit. Then you have the BCA and the OHSA doing more or less the same work. . . "*

The suggestion highlights findings from the public enquiry (Zammit McKeon et al., 2024). Since data collection, relevant positive measures have occurred in this respect, such as the OHSA forming part of the BICC, with representatives on the advisory board and working groups (OHSA, 2024). Kamra tal-Periti (2019) recommended consolidating building regulations into one legal act to allow building codes to be published and enforced by a single body, promoting better and simpler standards. The proposal was supported by many institutions and organisations (Kamra tal-Periti, 2020). It is unclear if this is needed, but collaboration between the different agencies and stakeholders appears paramount.

4.3.6 Enforcement, fines and site inspections

Participants stated that more enforcement by OHSA is needed, but also acknowledged OHSA's limited resources. The NAO (2016) also emphasised the importance of enforcement in the local context due to the cultural disregard for OHS. Participants also pointed out that education was very important but was a long-term strategy, whereas currently enforcement was needed to improve the situation.

> *"The immediate need is more supervision, monitoring, and enforcement. But that alone will not get us far. It has been proven that a policing type of health and safety management does not get you far. On its own, it's just an impetus for people to go around it."*

All study participants emphasised the need for higher financial penalties proportional to incidents on site. Participants mentioned that clients sometimes told OHS practitioners that they did not mind fines.

> *"When you fine them [major contractors], 500 Euros it's like having a cup of coffee for them."*

The NAO (2016) found that administrative fines do not act as a sufficient deterrent for certain offences. Several participants emphasised that fines should be supported by an interruption of work on the site and other sites of the contractor accused of a violation. Participants noted that the interruption of work was often much more costly for developers than the fine.

> *"For me it's not about only giving a fine. For me, it's a fine, stopping the work and closing the site down completely. So, if the contractor has four sites and I find a problem on one site, I shut down all four sites. We have to be harsh. It's the only way to get an effect."*

Studies show that enforcement reduces injury rates (Haviland et al., 2010; Mischke et al., 2013). In addition, many Maltese companies only take action due to OHS inspections or fines (S. Borg, 2015).

Participants also felt that the way OHSA selects its sites for inspections needs to be changed, describing the current process as "a formality". Indeed, the NAO (2016) recommended that the OHSA should prioritise its inspections based on the tasks, risks and duty holders' OHS track record at construction sites.

5 Conclusion and Final Recommendations

Overall, the study found that OHS has improved over the years in the construction industry. However, it was felt that it still falls short of the desired standards compared to other developed countries.

The study sheds light on several issues. Many developers view OHS as an unwanted and unnecessary expense. While this is not true of all developers, some have a negative OHS reputation. These developers ignored stop work orders issued for safety violations and some OHS practitioners withdrew from their projects because they feared that accidents were inevitable. These problems generally seem to be more common among smaller developers. Despite the important role that property developers play in fostering a positive or negative OHS culture, there is no mandatory licensing of contractors in Malta, which means that anyone can take on this safety-critical task without any experience or training. It is therefore suggested that the OHSA should target developers who are known to pay little attention to health and safety. This can be done through targeted education campaigns in the hope of changing perceptions, and also through enforcement. Mandatory licencing of contractors also seems necessary, and regulations are in place for this to be implemented by 2025. Licensing should be coupled with mandatory health and safety training.

Health and safety practitioners struggled to make an impact when working with less receptive developers as they were essentially dealing with their employer. Practitioners were concerned about their reputation with clients and contractors if they took too strong a position, as this could negatively impact their current and future employment opportunities. Practitioners also felt that there was a lack of formal standards and guidelines in the industry, which made it difficult for them to make their case. Rather, clients and contractors were able to impose their own standards, for example by requiring fewer site visits. Participants also complained that they were not supported by the OHSA, but instead feared that they could be prosecuted for shortcomings on construction sites that they could not control. However, some OHS professionals did not help the situation by competing commercially and driving down prices by offering less comprehensive services. This was exacerbated by a lack of standards within the sector and a lack of standards regarding who is legally recognised as competent to take on the role of a PS. In light of these situations, OHS practitioners would be emboldened by agreed OHS standards for the construction sector, set and enforced by the OHSA in consultation with OHS professional organisations and other stakeholders. These should promote a climate in which OHS requirements are established before construction begins. Consideration should also be given to making OHS an important criterion in the tendering process, so that property developers with a poor safety record cannot bid for government tenders. PSs being held responsible for standards that they cannot enforce also requires tackling. One option could be to shift responsibility to those who have day-to-day management of the construction site and its workers. Fixed standards are also needed for the qualifications required for the position of a PS. Currently, these are not specified, leading to an environment where poorly qualified individuals offering substandard work make it difficult for the qualified to work at a competitive level.

Problems were also identified in relation to workers, particularly due to their lack of training. This led to poor OHS attitudes and behaviours. When training did take place, it was often perceived as inadequate and irregular. Training related to the safety card was also seen as insufficient, with training related to working at height being particularly criticised. This is not only dangerous for the worker, but also for their colleagues and the general public. Therefore, all employees should be adequately trained. This should be done before starting work and, as suggested by the participants, should be part of the workers' skills training and thus integrated into the skills card requirements, which should also be mandatory.

Participants also commented on the influx of migrant workers and its impact on the construction industry. Participants acknowledged the need for additional labour in the construction industry and the limitations of the local labour market. Participants highlighted the lack of worker vetting, which resulted in the employment of migrant workers lacking skills and language competency. Migrant workers often received no training and participants de-

scribed situations in which migrant workers worked under worse conditions than local workers. Migrant workers should therefore be subject to the same OHS training requirements as national workers, and one clause of the skill card should be proficiency in English or Maltese. As the participants pointed out problems with working conditions that go beyond OHS, other entities, such as the Department of Industrial and Employment Relations (DIER) should also be involved and possibly carry out regular joint inspections with the OHSA.

Participants also pointed out that enforcement was not regular enough and that fines, when imposed, were not deterrent enough. Participants also felt that cooperation between Government agencies was insufficient and led to unnecessary overlap and ambiguity, both technically and legally. It is therefore clear that the OHSA needs additional resources to carry out more regular inspections, while the fines need to be revised. It would appear that while higher fines are more effective, stopping work, possibly on more than one site by the same developer, could have a more significant impact on improving standards. In order to find a common way forward, a forum bringing together the various government authorities, agencies and entities, as well as practitioner bodies and educational establishments may be warranted.

Acknowledgements The authors would like to acknowledge all the OHS practitioners who took part in this study.

References

Bayram, M., Arpat, B., & Ozkan, Y. (2022). Safety priority, safety rules, safety participation and safety behaviour: The mediating role of safety training. *International Journal of Occupational Safety and Ergonomics*, *28*(4), 2138–2148.

Bayram, M., Ünğan, M. C., & Ardıç, K. (2017). The relationships between ohs prevention costs, safety performance, employee satisfaction and accident costs. *International Journal of Occupational Safety and Ergonomics*, *23*(2), 285–296.

Bell, J., & Waters, S. (2018). *Doing your research project* (Seventh edition). McGraw Hill Education.

Borg, I. (2019). *The length of stay of foreign workers in Malta*, Central Bank of Malta.

Borg, S. (2015). *Evaluation of the EU occupational safety and health directives: Country summary report for Malta* [https://ec.europa.eu/social/BlobServlet?docId=17119&langId=fi], Milieu Ltd.

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology*, *3*(2), 77–101.

Brunette, M. J. (2005). Development of educational and training materials on safety and health: Targeting hispanic workers in the construction industry. *Family & Community Health*, *28*(3), 253–266.

Bryman, A., Bell, E., Reck, J., & Fields, J. (2022). *Social research methods*. Oxford University Press.

Central Bank of Malta. (2019). *Developments in the foreign workforce in Malta* [https://www.centralbankmalta.org/file.aspx?f=92659].

Chapter 424. (2000). *Occupational Health and Safety Authority Act (XXVIII of 2000), Laws of Malta* [https://legislation.mt/eli/cap/424/eng].

Debono, M., Baldacchino, G., Borg, A., Fiorini, L., Rizzo, S., & Zammit, E. (2013). *Memorandum to political parties contesting the general election being held on 9th march 2013* (tech. rep.) (https://www.um.edu.mt/library/oar/bitstream/123456789/97991/1/Centre_for_Labour_Studiesbiennial_report_2011-2012_2013.pdf). University of Malta.

Debono, M., & Fiorini, L. A. (2023). Malta: Trade union resilience in a changing environment. In J. Waddington, T. Müller & K. Vandaele (Eds.), *Trade unions in europe* (pp. 763–798). Peter Lang.

Debono, M., & Vassallo, M. T. (2020). Predictors of employment outcomes among Filipino workers in Malta. *Xjenza*, *8*(1), 16–31.

European Agency for Safety and Health at Work. (2019). *Third European survey of enterprises on new and emerging risks (esener 3)* [https://osha.europa.eu/en/publications/third-european-survey-enterprises-new-and-emerging-risks-esener-3].

European Commission. (2011). *Non-binding guide to good practice for understanding and implementing directive 92/57/eec on the implementation of minimum safety and health requirements at temporary or mobile construction sites* [https://op.europa.eu/en/publication-detail/-/publication/96b5fe83-ef7d-4628-9af0-e02b25810c1d]. Publications Office of the EU.

Eurostat. (2020). *Accidents at work — statistics by economic activity* [https://statistical.proquest.com/statisticalinsight/result/pqpresultpage.previewtitle?docType=PQSI&titleUri=/content/2020/1600-S295.40303.xml].

Fiorini, L. A. (2018). *Two thousand kilometres away from the Danish model: Transposition, implementation and enforcement of EU occupational safety and health legislation in Malta* [https://www.um.edu.mt/library/oar/bitstream/123456789/97184/1/Two%20thousand%20kilometres%20away%20from%20the%20Danish%20model.pdf], European Commission.

Fiorini, L. A., Camilleri, L., & Gauci, M. (2024). Occupational accidents in Malta and the role of the occupational health and safety authority: A twenty-year analysis. *International Journal of Occupational and Environmental Safety*, *8*(2), 12–30.

Fiorini, L. A., & La Ferla, F. M. E. (2021). The development of occupational health and safety in Malta. In M. Debono & G. Baldacchino (Eds.), *Working life - the transformation of the Maltese workplace: 1960-2020* (pp. 217–236). Malta University Press.

Fiorini, L. A., & La Ferla, F. M. E. (2023). The development of health and safety in Malta: The contribution of the Centre for Labour Studies, University of Malta. In L. A. Fiorini (Ed.), *Centre for labour studies 2021-2023 biennial report. 40th anniversary edition* (pp. 70–77). Centre for Labour Studies.

Flynn, M. A. (2014). Safety & the diverse workforce. *Professional Safety*, *59*(6), 52–57.

Gammarano, R. (2020). *Covid-19 and the new meaning of safety and health at work* (tech. rep.) (https://ilostat.ilo.org/covid-19-and-the-new-meaning-of-safety-and-health-at-work/). International Labour Organization.

Gauci, M., & Magri, J. (2022). From the bench: Construction project supervisors and the problems with our laws [https://timesofmalta.com/articles/view/from-the-bench-construction-project-supervisors-and-the-problems-with.957778]. *Times of Malta*.

Given, L. M. (Ed.). (2008). *The sage encyclopedia of qualitative research methods*. Sage Publications.

Gray, W. B., & Mendeloff, J. M. (2005). The declining effects of osha inspections on manufacturing injuries, 1979–1998. *ILR Review*, *58*(4), 571–587.

Greene, B. L., DeJoy, D. M., & Olejnik, S. (2005). Effects of an active ergonomics training program on risk exposure, worker beliefs, and symptoms in computer users. *Work*, *24*(1), 41–52.

Haviland, A., Burns, R., Gray, W., Ruder, T., & Mendeloff, J. (2010). What kinds of injuries do osha inspections prevent? *Journal of Safety Research*, *41*(4), 339–345.

Hide, S., Atkinson, S., Pavitt, T. C., Haslam, R., Gibb, A. G., & Gyi, D. E. (2003). *Causal factors in construction accidents*, Health and Safety Executive.

Horvat Cardona, M. (2023). *An assessment of workplace health & safety in the construction industry: The case of Serbians working in Malta* [Unpublished dissertation], University of Malta.

International Labour Organization. (2015). *Ilo global estimates of migrant workers and migrant domestic workers: Results and methodology* (tech. rep.). International Labour Office.

Kamra tal-Periti. (2007). *The urban challenge — our quality of life and the built environment* (tech. rep.) (https://kamratalperiti.org/wp-content/uploads/urbanChallenge.pdf).

Kamra tal-Periti. (2019). *A modern building & construction regulation framework for Malta. Public consultation paper* (tech. rep.).

Kamra tal-Periti. (2020). *A modern building and construction regulation framework for Malta* (tech. rep.) (https://kamratalperiti.org/wp-content/uploads/a-modern-building-construction-framework-for-malta.pdf).

Kleiner, M. M. (2015). Reforming occupational licensing policies [https://conservancy.umn.edu/handle/11299/190817].

Legal Notice 166 of 2023. (2023). *Construction industry licensing regulations, Laws of Malta*. [https://legislation.mt/eli/ln/2023/166/eng].

Legal Notice 36 of 2012. (2012). *Occupational health and safety (payment of penalties) regulations, Laws of Malta*. [https://legislation.mt/eli/ln/2012/36/eng].

Legal Notice 88 of 2018. (2018). *Workplace (minimum health and safety requirements for work at construction sites) regulations, Laws of Malta*. [https://legislation.mt/eli/sl/424.36/eng/pdf].

Levine, D. I., Toffel, M. W., & Johnson, M. S. (2012). Randomized government safety inspections reduce worker injuries with no detectable job loss. *Science*, *336*(6083), 907–911.

Mischke, C., Verbeek, J. H., Job, J., Morata, T. C., Alvesalo-Kuusi, A., Neuvonen, K., Clarke, S., & Pedlow, R. I. (2013). Occupational safety and health enforcement tools for preventing occupational diseases and injuries. *Cochrane Database of Systematic Reviews*, *2013*(8), CD010183.

Mitchell, M. (2020). Colorado occupational licensing and credential portability [CE Think Tank Newswire. https://search.proquest.com/docview/2376908141].

Moyce, S. C., & Schenker, M. (2018). Migrant workers and their occupational health and safety. *Annual Review of Public Health*, *39*, 351–365.

Nadhim, E. A., Hon, C., Xia, B., Stewart, I., & Fang, D. (2016). Falls from height in the construction industry: A critical review of the scientific literature. *International Journal of Environmental Research and Public Health*, *13*(7), 638.

National Audit Office. (2016). *Performance audit: An analysis on OHSA's operations: A case study on the construction industry* [https://nao.gov.mt/wp-content/uploads/2022/07/OHSA-April16.pdf].

National Audit Office. (2020). *Malta: Report on verification of effectiveness: A follow-up on the 2016 analysis on OHSA's operations — a case study on the construction industry* [https://nao.gov.mt/wp-content/uploads/2022/07/OHSAJune2020.pdf].

Occupational Health and Safety Authority. (2011). *Occupational health and safety in Malta — a snapshot of prevailing standards* [https://www.ohsa.mt/sites/default/files/2022-07/ESF%20research.pdf].

Occupational Health and Safety Authority. (2011). *Report of activities for the period 1st january 2011 — 31st october 2011* [https://www.ohsa.mt/sites/default/files/2022-10/AR-OHSA-2011.pdf].

Occupational Health and Safety Authority. (2013). *Report of activities for the period 1st november 2011 — 31st december 2012* [https://www.ohsa.mt/sites/default/files/2022-10/AR-OHSA-2012.pdf].

Occupational Health and Safety Authority. (2014). *Report of activities for the period 1st january 2013 — 31st december 2013* [https://www.ohsa.mt/sites/default/files/2022-10/AR-OHSA-2013.pdf].

Occupational Health and Safety Authority. (2020). *Report of activities for the period 1st january 2019 — 31st december 2019* [https://www.ohsa.mt/sites/default/files/2022-10/AR-OHSA-2019.pdf].

Occupational Health and Safety Authority. (2022). *Strategic plan for occupational health and safety 2022-2027* [https://www.ohsa.mt/sites/default/files/2022-06/Strategic-Plan-2022-2027_0.pdf].

Occupational Health and Safety Authority. (2023). *Report of activities for the period 1st january 2022 — 31st december 2022* [https://www.ohsa.mt/sites/default/files/2024-01/AR-OHSA-2022.pdf].

Occupational Health and Safety Authority. (2024). *Report of activities for the period 1st january 2023 — 31st december 2024* [https://www.parlament.mt/media/127969/ohsa-annual-report-2023_ps-vetted.pdf].

Occupational Health and Safety Authority. (n.d.-a). Competent person register [https://www.ohsa.mt/sites/default/files/2023-10/Competence-Registration-20231004.pdf].

Occupational Health and Safety Authority. (n.d.-b). Regolamenti dwar is-Saħħa u s-Sigurtá waqt Xogħol ta' Kostruzzjoni — Mistoqsijiet Frekwenti (FAQs) [https://www.ohsa.mt/sites/default/files/2023-02/Regolamenti-dwar-is-Sahha-u-s-Sigurta-waqt-Xoghol-ta-Kostruzzjoni.pdf].

O'Connor, T., Flynn, M., Weinstock, D., & Zanoni, J. (2014). Occupational safety and health education and training for underserved populations. *New Solutions*, *24*(1), 83–106.

Padgett, D. K. (2017). *Qualitative methods in social work research* (Third edition). Sage.

Popma, J. R. (2009). Does worker participation improve health and safety? Findings from the Netherlands. *Policy and Practice in Health and Safety*, *7*(1), 33–51.

Quandt, S. A., Arcury-Quandt, A. E., Lawlor, E. J., Carrillo, L., Marín, A. J., Grzywacz, J. G., & Arcury, T. A. (2013). 3-D jobs and health disparities: The health implications of latino chicken catchers' working conditions. *American Journal of Industrial Medicine*, *56*(2), 206–215.

Ronda Pérez, E., Benavides, F. G., Levecque, K., Love, J. G., Felt, E., & Van Rossem, R. (2012). Differences in working conditions and employment arrangements among migrant and non-migrant workers in Europe. *Ethnicity & Health*, *17*(6), 563–577.

Salminen, S. (2011). Are immigrants at increased risk of occupational injury? A literature review. *The Ergonomics Open Journal*, *4*(1), 125–130.

Shepherd, R., Lorente, L., Vignoli, M., Nielsen, K., & Peiró, J. M. (2021). Challenges influencing the safety of migrant workers in the construction industry: A qualitative study in Italy, Spain, and the UK. *Safety Science*, *142*, 105388.

Shuy, R. W. (2002). In-person versus telephone interviewing. In J. G. Gubrium & J. A. Holstein (Eds.), *Handbook of interview research: Context and method* (pp. 537–555). Sage.

Spangenberg, S., Mikkelsen, K. L., Kines, P., Dyreborg, J., & Baarts, C. (2002). The construction of the Øresund link between Denmark and Sweden: The effect of a multi-faceted safety campaign. *Safety Science*, *40*(5), 457–465.

Times of Malta. (2022). Editorial: Project supervisors and the OHSA need a healthier relationship [https://timesofmalta.com/articles/view/editorial-lifesaving-partnership-ohsa-supervisors-workplace-safety.985904].

Vokes, C., & Pye, K. (2013). Licensing domestic contractors: An international perspective an assessment of international schemes for the licensing of building trades operating in the home [https://www.pyetait.com/wp-content/uploads/2015/08/licensing-domestic-contractors.pdf].

Winge, S., Albrechtsen, E., & Mostue, B. A. (2019). Causal factors and connections in construction accidents. *Safety Science*, *112*, 130–141.

Xuereb, M. (2022). Deaths at construction sites: EU monitors Malta's health and safety measures [https://europe-cities.com/2022/05/20/deaths-at-construction-sites-eu-monitors-maltas-health-and-safety-measures/].

Young, B., Seidu, R., Nganga, D., Robinson, H., & Ebohon, O. (2019). Driving health and safety in construction through procurement strategy. *Proceedings of the 1st Association of Researchers in Construction Safety, Health, and Well-Being (ARCOSH) Conference*, 76.

Zammit, M. L. (2022a). Construction supervisors 'risk blacklisting' if they raise safety concerns [https://timesofmalta.com/articles/view/construction-supervisors-risk-blacklisting-raise-safety-concerns.984704].

Zammit, M. L. (2022b). Toy helmets and flimsy harnesses: Shoddy safety practices at work revealed [https://timesofmalta.com/articles/view/toy-helmets-flimsy-harnesses-shoddy-safety-practices-work-revealed.979220].

Zammit McKeon, J., Deguara, C., & Cassar, M. (2024). Rapport tal-inkesta pubblika. Jean Paul Sofia li miet fit-3 ta' Dicembru 2022 [https://cdn-others.timesofmalta.com/2fb259a2c1ee5ee8d41f9680dbae4ded3462895d.pdf].

Scicluna, D. et al. (2024). *Xjenza Online*, 12(2):121–134.

Xjenza Online: Science Journal of the Malta Chamber of Scientists
www.xjenza.org
DOI: 10.7423/XJENZA.2024.3.03

Research Article

Identification of Candidate Sites for an Offshore Green Hydrogen Production Plant Concept with Integrated FLASC Energy Storage in Malta's Exclusive Economic Zone

D. Scicluna[*1], **O. Pirotti**[1], **R. N. Farrugia**[1], **T. Sant**[2], **D. Buhagiar**[3]
[1] *Institute for Sustainable Energy, University of Malta, Malta*
[2] *Department of Mechanical Engineering, University of Malta, Malta*
[3] *FLASC B.V., Netherlands*

Abstract. The integration of Hydrogen (H_2) production systems with offshore renewable energy (RE) generation could create opportunities for future decarbonisation of the maritime sector. However, the intermittency of wind and other offshore renewables presents several challenges with respect to power generation and electrolyser shutdowns and start-ups. In such situations, it could be advantageous to integrate energy storage systems (ESS) to ensure, as far as possible, the uninterrupted operation of stand-alone offshore systems by balancing the renewable electrical power surpluses with the deficits, or shortfalls. The Floating Liquid Piston Accumulator using Seawater under Compression (FLASC) technology, a patented Hydro Pneumatic Energy Storage (HPES) system specifically designed and developed at the University of Malta for marine deployment, was the ESS of choice for integration into an offshore green hydrogen production plant. This research report is related to the HydroGenEration ("*Hydro-pneumatic Energy Storage for Offshore Green Hydrogen Generation*") project that investigates the feasibility of using the FLASC storage technology for hydrogen production subject to Mediterranean wind conditions. Apart from the technical feasibility, a necessary requisite for a stand-alone, offshore hydrogen production plant is the identification of suitable offshore sites and of potential end-users, such as maritime sector operators as consumers of the H_2 fuel. Project HydroGenEration explores potential deep-water sites in the central Mediterranean basin, and specifically in proximity of the Maltese Archipelago, as a basis for more representative numerical modelling of the technology concept. A high-level candidate site identification exercise was therefore conducted. The zones identified as potential candidate sites for the HydroGenEration project concept were predominantly within the areas declared in the more recently launched 2023 document: "National Policy for the Deployment of Offshore Renewable Energy - A Draft for Public Consultation", defining the future role for offshore renewables in Malta's Exclusive Economic Zone (EEZ).

Keywords: Floating Wind; Green Hydrogen; Energy Storage, Electricity Stabilization

1 Introduction

Research aimed at decarbonizing industry and the transport sectors, especially marine transport, can contribute significantly to achieving greenhouse gas (GHG) emissions reductions. Optimizing the efficiency and economic feasibility of the hydrogen (H_2) and green hydrogen fuel production process in particular, its storage, transportation, and use, can create the right conditions for the development of a renewable, clean, carbon-free economy,

ECU—Energy Conversion Unit
EEZ—Exclusive Economic Zone
ESS—Energy Storage System
ERA—Environment and Resources Authority
EWA—Energy and Water Agency
FLASC—Floating Liquid Piston Accumulator using Seawater under Compression
HPES—Hydro Pneumatic Energy Storage
HGE—HydroGenEration
PCS—Pressure Containment System
PEM—Proton Exchange Membrane
SAC—Special Areas of Conservation
SPA—Special Protection Areas
SWH—Significant Wave Height

Correspondence to: D. Scicluna (diane.scicluna@um.edu.mt)

especially in the case of the maritime transport sector. The use of hydrogen as a fuel in this sector represents a new, environmentally-friendly mode of non-polluting global transportation.

One way to produce hydrogen using renewable energy resources is by means of the electrolysis process. It consists of the splitting of water into hydrogen and oxygen by using electricity. Using electrolysis promises economic and environmental benefits if supplied by electricity coming from renewable sources (Ahmed et al., 2024; Gao et al., 2022; Zaini et al., 2023). In addition, the 'green' hydrogen produced will allow for the replacement of fossil fuels in those sectors of the economy in which direct electrification is currently not possible, and which will depend on the availability of a physical fuel for an indefinite time in the future.

Hydrogen production through electrolysis using treated water and electrical energy is an established process. The challenge of using renewable sources such as solar and wind to supply such plant is the resources' inherent intermittency. This not only results in lower efficiency of the hydrogen production plant equipment and a reduction in the amount of hydrogen produced but in addition, the amount of "ON"/"OFF" cycles causes degradation of the electrolyser cells and consequently results in more frequent equipment replacements, ultimately affecting the cost of hydrogen produced. Issues with "ON"/"OFF" cycling is further highlighted in (Honsho et al., 2023; Kojima et al., 2023; Weiß et al., 2019).

And who are the end-users? For example, the prospect of converting a fishing fleet to the use of hydrogen as a fuel for motive power would lead to a significant reduction in Carbon Dioxide (CO_2) emissions into the atmosphere, resulting in improved living conditions for marine organisms and an increase in the quantity and quality of fish landings. Maritime passenger travel and freight transportation is not an environmentally-friendly industry. Studies show that some of the largest ships produce more Nitrous Oxide (N_2O) and Sulphur Dioxide (SO_2) emissions per year of operation than all road vehicles. In 2021 alone, such emissions increased by 833 million tons of CO_2; an increase of 4.9% (European Marine Observation and Data Network, n.d.).

After consultations, the International Maritime Organization (IMO), together with the UN Shipping Agency, decided to limit SO_2 emissions from 2020. In 2021, the European Parliament included maritime shipping in the EU Emissions Trading Scheme (IMO, 2021, 2023). Creating additional routes for ships as well as implementing international policy tools to accelerate the development of fleets equipped with fuel cell engines could help make this industry a potential consumer of hydrogen fuel.

The Mediterranean Sea is a link between major sea-lanes connecting Europe, North Africa, and the Middle East. The Mediterranean Sea is connected to three major maritime transport passageways namely the Strait of Gibraltar, the Suez Canal, and the Bosporus. Therefore, the Mediterranean Sea is an important element of modern maritime transportation routes and is also a link between Asia and Europe (Plan Bleu, 2021). The Maltese Islands are strategically positioned in these shipping corridors.

The present research report discusses part of the work undertaken in the nationally-funded project HydroGenEration, which explored the potential for implementing offshore green hydrogen production integrated with energy storage in the vicinity of the Maltese islands. The scope of integrating the FLASC energy storage device is to close the gap between the fluctuating renewable energy (RE) electricity supply and the electrical requirements, or load, imposed by an islanded offshore H_2 production system. The FLASC concept was also investigated in the following earlier works (Borg et al., 2023a; Buhagiar & Sant, 2017; Cutajar et al., 2021; Settino et al., 2022). Integrating FLASC into the green H_2 production process would allow for an improved decarbonised offshore hydrogen production process. But this does not stop here; producing the H_2 in that same environment which supplies the raw material itself, i.e., seawater, and producing a clean fuel that can be used by nearby end-users, offer additional benefits and reductions in production and supply chain emissions.

This research project also focused on the identification of candidate sites for the HydroGenEration project concept based on various technical and geophysical criteria and constraints. These include the climatology and the bathymetric features of the seas around the Maltese archipelago, environmental aspects and the identification of stakeholders driving the diverse economic activities underway in territorial waters, in the Fisheries Management Zone and farther afield in the Exclusive Economic Zone (EEZ). Such prospects were defined in the "Preliminary Market Consultation – PMC for the proposal of economic activities within Malta's Exclusive Economic Zone" (Continental Shelf Department, 2022), which served as a basis for the shortlisting of potential candidate sites for the HydroGenEration project concept.

More recently, sites for offshore renewable energy projects were also defined in the "National Policy for the Deployment of Offshore Renewable Energy - A Draft for Public Consultation", (Energy and Water Agency & Ministry for the Energy, Environment and Regeneration of the Grand Harbour, 2023), which confirmed that the methodology used for the HydroGenEration site selection process had been sound.

The scope of this research report is to highlight some

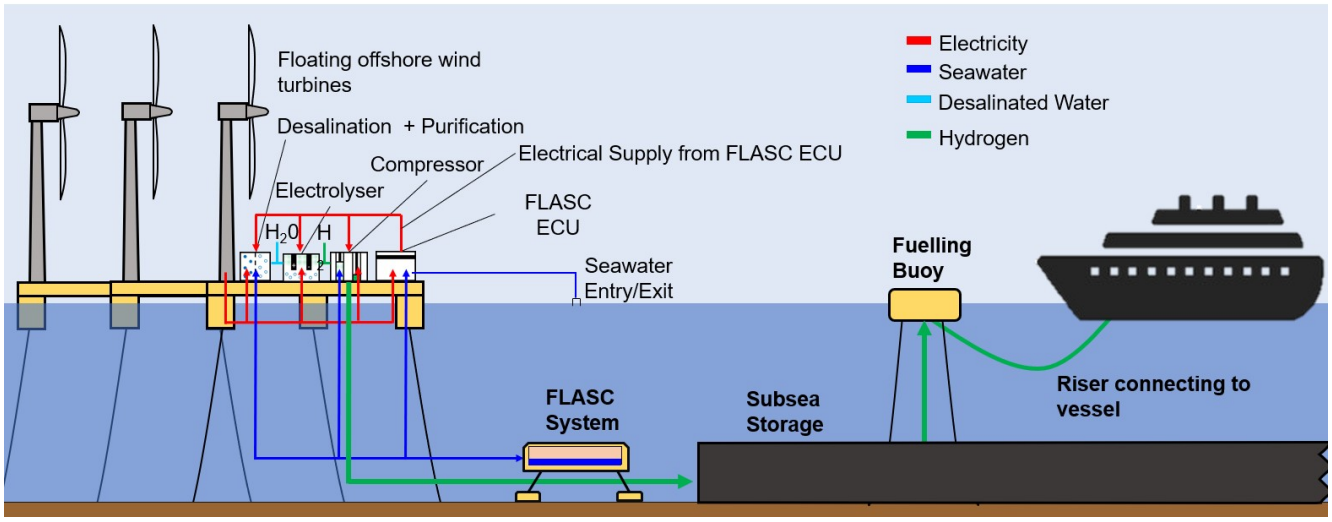

Figure 1: The HydroGenEration project concept system showing a modular three wind turbine "cluster" which was used as a basis for the numerical modelling.

of the main challenges for implementing offshore wind in the Mediterranean Sea. Furthermore, this also aims to highlight the technical benefits associated with implementing an energy storage system (ESS) such as FLASC with respect to the intermittency of renewable energy resources and its effect on the "ON"/"OFF" cycles of the electrolyser. Finally, this study also highlights the process undertaken for the candidate site assessment part of the project. Finally, the research project also identifies the potential end users that will benefit from the hydrogen produced.

The concept of offshore floating platforms has been well established by the Oil and Gas Industry. In recent years, the original idea has expanded to include the concept of multi-integrated floating platforms and technologies such as energy islands as those found in Denmark (Danish Energy Agency, 2023). Energy islands consist of artificial islands that are used as a hub for offshore wind farms in order to facilitate better connections between the electricity generated and the energy system in the surrounding area. Other related projects and technologies that are making use of similar concepts are the Jidai concept (DNV, 2015), the Sealhyfe project (Lhyfe, 2023), the Aquaventus project (Aquaventus, 2024), the Dolphyn Hydrogen project (Dolphyn Hydrogen, 2024), the Wind4H2 project (Settino et al., 2022) and the MUSICA project (MUSICA, 2024).

2 Materials and Methods

The HydroGenEration (HGE) concept built on earlier experiences gained in the WIND4H2 project (Settino et al., 2022). In the current HydroGenEration system (Figure 1) the concept system 'cluster' would consist of:

i) three 10 MW floating offshore wind turbines (WTs) which can, at any stage, be replicated in a modular way to upscale the H_2 production concept system;
ii) a floating WT platform-mounted water Desalination and Purification plant, an Electrolyser and an Ionic Compressor;
iii) a floating WT platform-mounted FLASC Hydro Pneumatic Energy Storage (HPES) system consisting of a topside ECU and a seabed-mounted Pressure Containment System (PCS). This latter module will be connected to the topside ECU by means of electrical and hydraulic risers; and
iv) a H_2 storage system with one or more floating refuelling stations. The H_2 storage system will be placed on the seabed and the refuelling station/s will be moored in a vessel berthing/refuelling zone.

For the scope of the HGE project, the scaled-up concept system would consist of a 10 x 10 MW WT array comprising three identical HGE concept system clusters and one additional wind turbine.

The results of a Decision Matrix compiled for this part of the study identified and enabled justification of potential locations suitable for the hybrid concept project for integrating a deep offshore wind farm, energy storage and hydrogen production units to sustain an offshore green hydrogen production plant and offshore refuelling station.

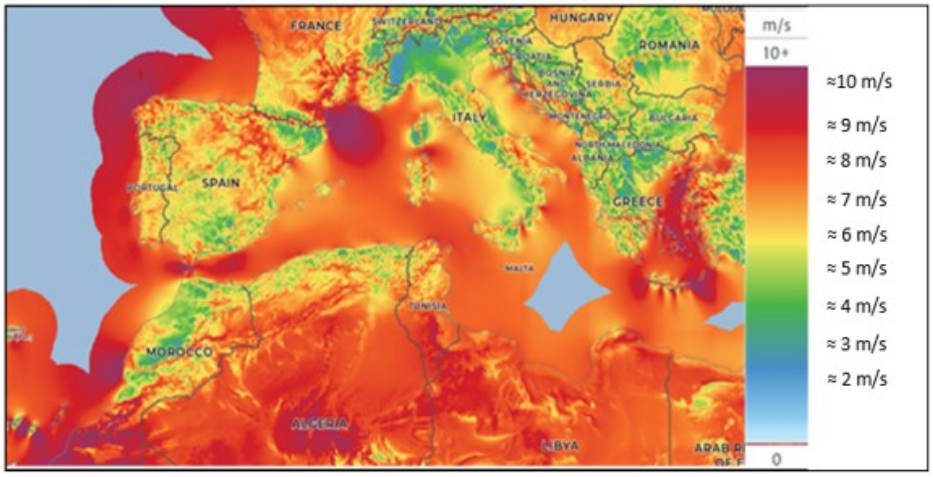

Figure 2: Wind resources at a height of 100 m in the Mediterranean Sea (Global Wind Atlas, 2023).

2.1 Metocean Conditions of the Mediterranean Sea

The wind climate in the central Mediterranean is more variable compared to that in the North Sea, but despite its lower wind speeds and higher variability, the Mediterranean still offers a reasonable potential for RE generation, as shown in Figure 2 (Davis et al., 2023) where the long-term wind speed at a height of 100 m is shown.

The sea depths around the Maltese islands, and especially within Malta's Exclusive Economic Zone (EEZ), present a significant challenge to introducing offshore wind turbines. At such sea-depths, traditional bottom-fixed structures are not viable, making floating structures the only remaining option. Floating structures for wind turbines can allow access to marine spaces having greater sea depths, which are located farther away from the shore. By increasing the distance of the wind plant from shore, the floating turbines will encounter stronger and less turbulent winds, allowing for increased electrical power generation. However, the costs associated with mooring, installing and operating floating offshore wind turbine support structures necessitate a compromise between the sea depth and the distance from ports and harbours, while also striving to maximise energy capture. If such an RE generation plant were to be connected to the onshore grid network, then such costs would increase significantly with distance to shore.

In addition to the sea-depth, it was also important to consider the metocean conditions at deep offshore sites for such a project concept. The term 'metocean conditions' refers to local surface winds, wind-generated surface waves, swells and ocean surface currents, deep water currents and basin circulation, amongst others. Although seawater is abundant and readily available for use in an offshore hydrogen production process, the lifetime of the H_2 production system components may be significantly shortened due to the high salinity of the Mediterranean Sea, thereby increasing the cost of additional system components, their maintenance, and their replacement.

The Mediterranean Sea is a comparatively small and partially-enclosed sea, which affects the characteristics of the sea waves generated within. The average wave period in the Mediterranean Sea was found to be of around 6 to 8 seconds and so, significantly shorter than waves in open ocean areas where wave periods can be between 10 to 20 seconds or more (Drago, 2006; Environment and Resources Authority, 2013; Galdies, 2022; Transport Malta, 2013). Studies have shown that on average, the significant wave height (SWH) around the Maltese Islands does not exceed 2.5 m, and that SWHs generally occur during the winter months (Drago, 2006; Environment and Resources Authority, 2013; Galdies, 2022; Transport Malta, 2013). The less extreme wave heights occurring in the seas around the Maltese Islands are advantageous when compared to conditions in the North Sea, where the offshore wind sector is thriving, given that floating offshore structures are required to be resilient and to have a safe clearance between the maximum wave height and critical components. However, storms referred to as medicanes, do occur in the Mediterranean Sea. Although such storms are not a common occurrence, medicanes present a natural occasional hazard and can induce increased wave heights, posing significant challenges to the design and operation of fixed and floating offshore structures (Galdies, 2022).

Another important factor to consider is the seabed around the Maltese Islands. According to data obtained from various studies, the north-eastern coastal zone of the Maltese Islands is characterised by gently sloping to-

pography, which transitions offshore as a gently sloping rocky bottom. Further offshore, the sea-bed constitution changes from sedimentary rock to a mixture of sand, cobbles, pebbles and small boulders. In certain areas, patches are also covered by a thin layer of sand (Foglini et al., 2015; Micallef et al., 2013).

In contrast, the southwest side of the Maltese islands' coastlines are made up of cliffs and an accumulation of weathered rock fragments at the foot of these cliff faces, otherwise known as boulder screes (Foglini et al., 2015; Micallef et al., 2013). Such characteristics are important to consider as they can affect the type of mooring anchors which can be used for offshore floating structures, subsequently also affecting the overall project cost. Sea depths also increase much more significantly close to the coast on this side of the island group.

2.2 Interfacing of the FLASC Energy Storage System

The incorporation of an ESS such as FLASC into the HydroGenEration concept strives to address one of the largest issues present in the renewable energy industry i.e., that of intermittency of renewable energy sources. The FLASC system consists of two core modules:

i) the Energy Conversion Unit (ECU), and
ii) the Pressure Containment System (PCS).

The ECU system consists of a modular hydro-electrical interface which houses the pumps, hydraulic turbines, controls and power conversion equipment required for a HPES system. Meanwhile, the PCS consists of pressure vessels providing a storage volume for seawater and compressed gas (air in this case), in a pre-charged state.

In order to incorporate the FLASC ESS into the offshore wind turbine design, it is important to take into consideration the requirements of the FLASC system with respect to the metocean conditions in the Mediterranean Sea. One of the requirements of the FLASC system in its closed cycle configuration is that the system is more adapted for installation in waters not much deeper than 100 m and such a factor was also taken into consideration when conducting the assessment of potential candidate sites for the HGE concept system.

Given that the system will be installed in waters of up to a 100 m depth, it would also be possible to use the deep seawater having lower temperatures present at such sea depths to the system's advantage. The cool deep seawater being used in the PCS can be extracted and used as part of the water desalination and cooling processes in the hydrogen production system.

The behaviour of the FLASC ESS was tested under measured high resolution wind scenarios using scheduling windows of different durations. The term 'scheduling window' refers to the time frame during which uninterrupted electrical power is fed to the plant equipment provided by the FLASC ESS. Subsequently, these techniques were also used in the optimization of the HGE concept system.

2.3 Hydrogen End users in the Mediterranean Sea

In identifying maritime sector operators that may switch to hydrogen fuels in the coming decades, various facets of the maritime sector should be considered. Fishing is one of the backbone industries of Mediterranean Basin economies. Of course, this sector is closely linked to offshore zones and will therefore be near any future offshore sources of renewable electricity generation. The diversity of the underwater world has contributed to the development of the small-scale commercial fishing fleet. This sector accounts for about 85% of the total fishing industry. Fishing in the Mediterranean Sea typically takes place at sea depths ranging from 10 to 800 meters. Given the comparatively greater depths of the Mediterranean in coastal areas, most fishing is concentrated closer to the shore and up to depths of about 400 meters (Food and Agriculture Organization of the United Nations, 2022).

Malta's own fishing fleet consists of some 2,741 vessels, the vast majority of which are small, coastal fishing vessels. Overall, 46% of the vessels are less than 5 meters in length. Meanwhile, another 49% of such vessels boast a length of up to 9 meters. About 4% reach lengths of up to 14 meters. Less than 1% of the total reach lengths of 15 to 19 meters and more than 20 meters combined. Only 25 of all fishing vessels are trawlers. Vessels rely on diesel or diesel-electric, gasoline and very rarely benzene engines for their motive power (National Statistics Office, 2022b).

In order to promote the transition of marine vessels to hydrogen propulsion for motive power, it is important to involve all stakeholders in developing green maritime policies, developing a chain of marine hydrogen plants integrated with energy storage systems, and the setting up of offshore hydrogen refuelling stations with a standardised refuelling system for ships.

2.4 Assessment of Potential EEZ Candidate Sites

When considering potential sites for implementing floating offshore wind turbines, energy storage and co-located H_2 production, storage and refuelling infrastructure, it is necessary to ensure that such a plant would be able to coexist with other existing or future offshore installations, with marine leisure and maritime industrial activities, as well as be capable of operating in the vicinity of environmentally sensitive or protected sites. An Exclusive Economic Zone

(EEZ) has been defined as "an area that extends beyond the country's territorial waters and that partially or fully coincides with the continental shelf of the country, without prejudice to a final designation of the zone itself" (Grech, 2022).

In project HydroGenEration, a high-level site identification exercise was conducted based upon the Malta Government Continental Shelf Department's report: "Preliminary Market Consultation for the Proposal of Economic Activities within Malta's Exclusive Economic Zone", published in 2022 (Continental Shelf Department, 2022).

According to the Malta Maritime Forum (MMF), the ideal designation for the EEZ's Area 1, comprising of Hurd's Bank, should be retained for shipping purposes, such as marine traffic and anchorages. On the other hand, the EEZ's Area 2 was defined as an ideal area for implementation of marine projects, such as floating alternative energy installations, aquaculture projects and refuelling infrastructure.

Site selection is one of the most crucial parts of any candidate project and research such as Cradden et al. (Cradden et al., 2016) and Diaz et al. (Diaz et al., 2018), were used as a guide to determining the criteria for the site selection process of an offshore wind farm.

For the preliminary site selection of a hybrid offshore project such as the one being conceptualised by project HydroGenEration, a number of different technical and environmental aspects were taken into consideration, such as:

- proximity to ship bunkering sites (Transport Malta);
- distance from the shoreline;
- proximity to maritime shipping and leisure routes and corridors (Planning Authority, 2016);
- exposure to local wind conditions (National Statistics Office, 2022a);
- exposure to sea waves (National Statistics Office, 2022a);
- dependence on bathymetric characteristics (Continental Shelf Department, 2022);
- requirements for seabed conditions (Environment and Resources Authority, 2013);
- proximity to environmentally sensitive sites (such as NATURA2000 sites, Special Areas of Conservation (SACs) and Special Protection Areas (SPAs)) (Environment and Resources Authority, 2023);
- co-existence with fisheries and aquaculture sites (Food and Agriculture Organization of the United Nations, 2022), and
- simplified wind turbine array layout designs.

In addition to the criteria presented above, it is critical to keep in mind the different sea-depth characteristics present within the two designated areas, defined as Area 1 and Area 2, within the EEZ.

Array	Type	Crosswind Spacing	Downwind Spacing	Approx. Array Length [km]	Approx. Array Width [km]
1	Linear	$6 \times D$ 1,200 m	-	10.8	0.2
2	Rectangular	$6 \times D$ 1,200 m	$9 \times D$ 1,800 m	4.8	1.8

Table 1: Key dimensions used for the two types of simplified wind turbine arrays, each having 10 × 10 MW wind turbines (where D is the WT rotor diameter).

Given that the current research project is focusing on floating wind turbines and on seabed-mounted energy storage along with hydrogen production and H_2 fuel storage systems, it was reasonable to assume that costs for site surveying, preparation, installation, mooring and anchoring, maintenance, and decommissioning at end of life, will all increase significantly for increasing sea depth. The proposed HydroGenEration concept system is intended to be off-grid, meaning that it will not be connected via cable/s to an onshore electricity distribution network or to land-based consumers. Conversely, by moving further offshore and out of the 'land shadow', it would be possible to access stronger and more consistent winds for increased renewable energy (RE) electricity generation. Consequently, it would be important to achieve a balance between distance from the shore and sea-depth. In order to achieve a compromise between costs, wind resources and environmental conditions, areas having sea depths in excess of 200 m were excluded from the site identification process. Additionally, at this stage the intention is not for the offshore hydrogen being produced to be conveyed by pipeline towards the shore, but to be stored offshore subsea and to supply maritime end-users or bulk H_2 carriers with the H_2 fuel by means of one or more refuelling buoys.

Therefore, the proposed sites were also zoned closer to the offshore designated ship bunkering sites so that seagoing vessels anchored there could be one of the potential end-users. The wind turbine arrays were simplified assuming two arrangements, namely:

i) a linear array and
ii) a rectangular arangement (see Table 1).

These arrays were designed to give maximum exposure to the individual turbines under prevailing wind conditions in the vicinity of the islands, i.e., for winds blowing from the West to Northwest sectors. Consequently, the arrays

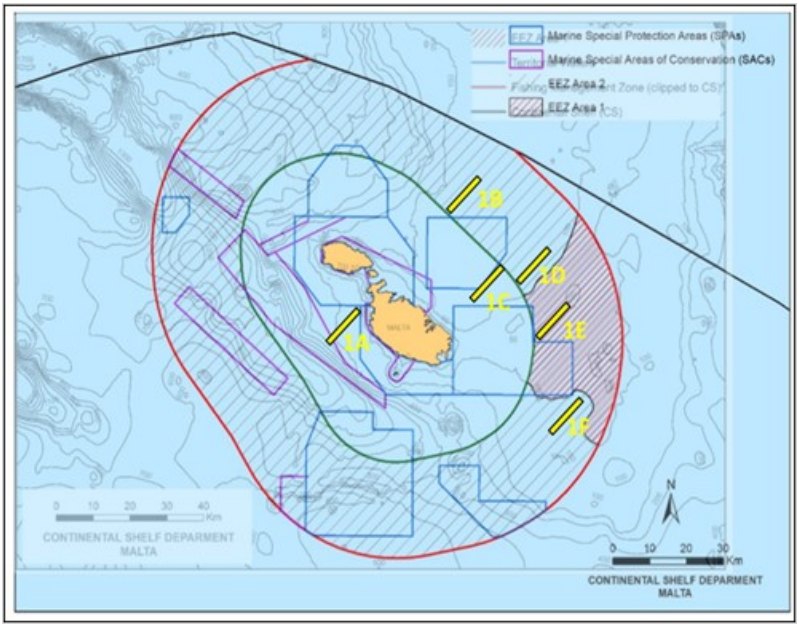

Figure 3: Visual Representation of the Linear Array considered in the HydroGenEration project. Base maps with kind permission of the Continental Shelf Department (Continental Shelf Department, 2022).

Weighting	Candidate Site Classification
1	Low — Not ideal
2	Intermediate — Offer some benefits
3	High — Offers a lot of benefits
4	Ideal — Ideal site

Table 2: Weighting factors used for shortlisting the candidate sites for the two types of simplified wind turbine arrays, each having 10 × 10 MW wind turbines.

were also placed in a single or double linear arrangement whose main axes run perpendicular to these wind directions.

The two proposed WT arrays were for 10 x 10 MW turbines having a rotor diameter (D) of 198 m and a hub height of 119 m, based on NREL's 10 MW wind turbine characteristics (IEA, 2020). The single linear array can be seen in Figure 3.

A number of different activities underway around the Maltese Islands were considered in this high level analysis. These included activities such as harbour approach routes, protected areas and more. In order to select the ideal candidate site/s for the proposed HydroGenEration project concept, a decision matrix listing all of the criteria or factors considered was mapped out. The criteria were ranked with a weighting ranging from 1 to 4, with number 4 being the most attractive (see Table 2).

3 Results and Discussion

3.1 Estimates of Amount of H_2 Produced

In order to numerically model these scenarios, preliminary calculations for the developed numerical model were run. Wind conditions from the University of Malta's coastal onshore Light Detection and Ranging (LiDAR) wind measurement system (Environment and Resources Authority, 2023) were used to represent wind conditions aloft. The wind speed time series was corrected by a factor of + 0.3 m/s to correspond to offshore wind conditions. The average wind speed at a height of 111 m for the 12-month time frame (year 2016) was computed to be 6.8 m/s. This data enabled modelling of the HGE system behaviour with a 10-minute resolution time series for modelling offshore WTs rated at 10 MW and having a hub height of 119 m. The power curve for the modelled wind turbine was obtained from (IEA, 2020).

The wind data obtained from the coastal LiDAR database confirmed the information about the lower speeds in the Mediterranean basin compared to those in the North Sea as well as higher wind variability, making the data suitable for further processing as a feed into the HGE system numerical models for Mediterranean Sea categorisation. In the case of the wind-generated electricity, wind turbine array wake losses and plant availability were taken as 95% respectively.

The conversion of wind speed into WT power output was carried out using a mathematical model for the 3 wind

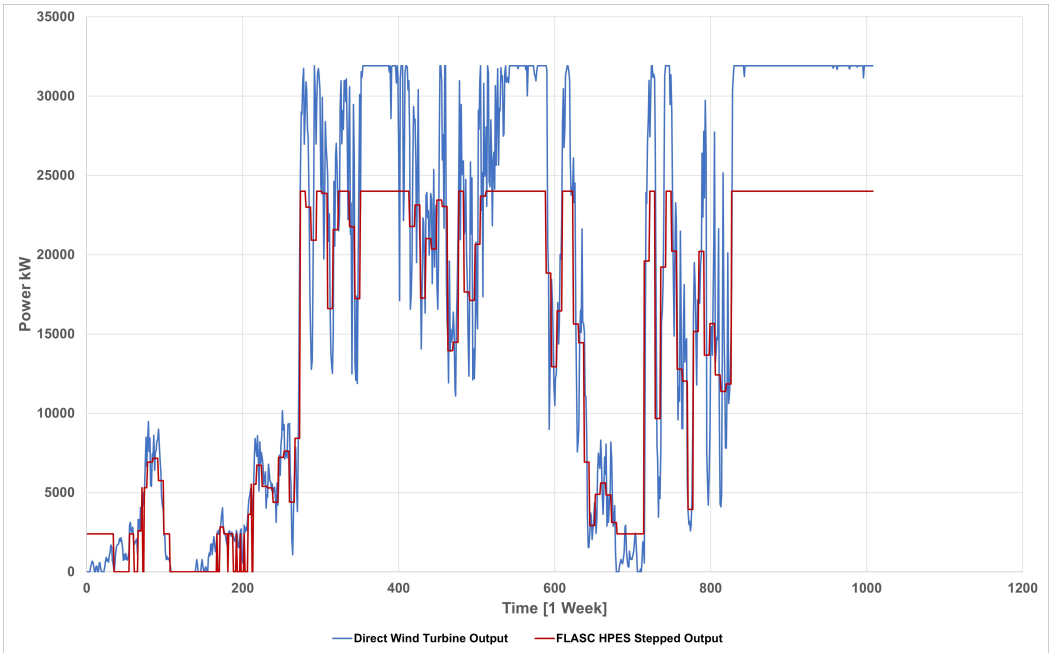

Figure 4: Direct wind turbine output in comparison with the FLASC HPES stepped output in Mediterranean wind conditions for a random week.

turbines, each with a nominal capacity of 10 MW, and similar to that used in earlier work (Settino et al., 2022) for the North Sea offshore wind data. The capacity factor of the wind farm under Mediterranean wind conditions was found to be 38%. These calculations confirm that wind speed and the resulting energy yield in the North Sea are higher than in the Mediterranean, and also show a more intermittent nature of wind in the Mediterranean, thus further highlighting the need for an ESS to smoothen the renewable electrical supply.

Figure 4 illustrates a comparison of the electrical power generated by 3 x 10 MW wind turbines to the power supplied by the same WTs coupled to a FLASC ESS and the resulting smoothened power output under Mediterranean Wind conditions over a period of 7 days. As shown in Figure 4, the use of the HPES system allows for the number of occurrences where the power supply drops to zero to be decreased significantly, thereby stabilising the supply of electricity to the hydrogen production unit.

In order to understand the effects of incorporating the FLASC ESS into the hydrogen production system, a number of simulations were carried out. The simulations investigated the effect of FLASC on the amount of hydrogen produced as well as on the number of "ON"/"OFF" cycles experienced by the electrolyser. From these simulations it was possible to obtain an optimised configuration for the HydroGenEration concept cluster.

The parameters for the optimised HGE system are listed in Table 3. In this series of computations, the trend

FLASC ESS Capacity (MWh)	25
Number of "ON"/"OFF" Cycles	
without storage	1,263
with FLASC storage	435
Total H_2 produced (kNm^3/year)	
without storage	17,761
with FLASC storage	17,820
% Diff.	0.3%
Total Energy Required (MWh)	
without storage	90,939
with FLASC storage	91,240
Total energy produced by WTs	98,625
Curtailed Energy (MWh)	
without storage	7,686
with FLASC ESS storage	7,384
Electrical Energy lost due to overproduction	
without storage	7.8%
with FLASC storage	7.5%

Table 3: Ideal parameters for the HydroGenEration concept 'cluster'.

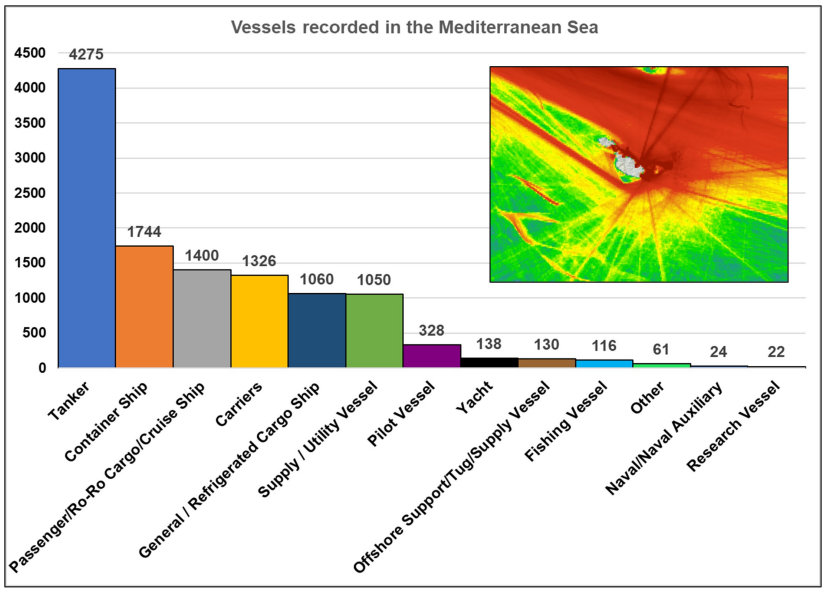

Figure 5: Vessels within the Maltese Ports. Source data (Transport Malta, 2023).

showed a decrease in the number of "ON"/"OFF" Proton Exchange Membrane (PEM) electrolyser cycles for increasing magnitude of the FLASC ESS capacity in all equipment combinations investigated where the FLASC HPES system was integrated, as well as an increase in hydrogen production for equipment combinations with an integrated FLASC HPES system with a capacity range of 20 MWh and higher. In addition, the curtailed energy not available for use in the H_2 production process due to limitations imposed by the technical characteristics of the equipment used, fell to below 10 per cent of the total curtailed energy.

3.2 Candidate Site Identification Results

The decision matrix was considered for both the 'Linear' and the 'Rectangular' WT arrays, as shown in Figure 5. The criteria considered and the rankings given for each location can be seen in the decision matrix seen in Table 4.

From the ensuing results, it was possible to shortlist the more attractive locations for the proposed HydroGenEration project concept. The score for each criterion was assigned based on the possible benefits that the candidate location could provide to the different technical components of the HydroGenEration project concept. The scores were assigned following in-depth discussions within the HGE team and using a decision matrix approach.

The results were ranked as shown in Table 5, from the highest to the lowest scores. The difference between the assigned scores is primarily due to the effect of the footprint of the arrays. The length of obstruction presented by the linear array is longer than that of the rectangular array. Therefore, in order to maintain the required safety distance from the wind farm, vessels would need to take a longer detour for a linear array, whilst the detour for a rectangular array would be shorter. This also results in a larger no anchorage zone being present in the linear array, which may also hinder the installation of pipelines and subsea cables. The most favourable location was found to be Site 2E, followed by Site 1B (see Figure 3).

Once the site selection process had been completed, online webinars were held with local stakeholders in order to get feedback on the locations identified by the HGE team for such a hypothetical concept. The sites selected raised no particular concerns, although one must also mention that in reality such a process would require a much more in-depth analysis based on scientific research and involving as many stakeholders as possible.

These results were also shown to be in line with national policies, specifically with the 2023: "National Policy for the Deployment of Offshore Renewable Energy", a policy that was drafted by the Energy and Water Agency and which was issued for public consultation after the current research project work was carried out (Energy and Water Agency & Ministry for the Energy, Environment and Regeneration of the Grand Harbour, 2023). This national report highlights those areas within the EEZ where RE projects could be implemented. In addition to this, the national report further highlights the criteria which need to be considered for such RE projects, most if not all of which were also taken into consideration in the shown Decision Matrix.

Factor	Linear Array						Rectangular Array					
	1A	**1B**	**1C**	**1D**	**1E**	**1F**	**2A**	**2B**	**2C**	**2D**	**2E**	**2F**
Environmental Activities												
Location with respect to EEZs	1	3	1	3	4	3	1	3	1	3	4	3
Vicinity to Natura2000 sites	4	4	3	4	4	4	4	4	3	4	4	4
Bird Rafting Sites in the Central Mediterranean	2	4	4	4	4	4	2	4	4	4	4	4
Maritime and Related Activities												
Distance from Harbor/port	1	3	4	4	3	2	1	3	4	4	3	2
Harbour Approach Routes	4	2	1	1	4	4	4	1	2	2	4	4
Land reclamation off the coast of Xghajra	4	4	4	4	4	4	4	4	4	4	4	4
Spoil Grounds	4	4	4	4	4	4	4	4	4	4	4	4
Proximity to ship bunkering Site	3	1	2	2	1	2	3	1	2	2	4	2
Subsea telecommunication cables	2	3	2	3	2	4	2	3	2	3	3	4
Proposed LNG pipeline	4	4	2	4	4	4	4	4	2	4	4	4
Existing and Proposed Interconnector	2	4	4	4	4	4	2	4	4	4	4	4
Inter-island travel	4	4	4	4	4	4	4	4	4	4	4	4
Military Activities	4	4	3	4	4	4	4	4	3	4	4	4
Interaction with Aviation	4	4	1	1	4	4	4	4	1	1	4	4
Leisure aquatic activities (diving)	2	4	3	4	4	4	2	4	3	4	4	4
Fishing, Fish Farming and aquaculture activities	1	4	1	1	1	4	1	4	1	1	1	4
Technical and Metocean Conditions												
Prevalent Wind direction	4	4	3	3	3	2	3	3	2	2	2	1
Wind speed	4	4	4	4	4	3	3	3	3	3	3	2
Wave height	3	3	4	3	1	1	3	3	4	3	1	1
Sea depth	2	2	2	2	3	2	2	2	2	2	3	2
Visual impact	1	4	2	4	4	4	1	4	2	4	4	4
Mooring Lines	2	2	2	2	4	3	2	2	2	2	4	3
No. of turbines	4	4	4	4	4	4	4	4	4	4	4	4
Total	**64**	**75**	**60**	**69**	**74**	**74**	**62**	**72**	**59**	**68**	**76**	**72**

Table 4: Decision Matrix used for shortlisting the candidate offshore sites for the HydroGenEration project concept based on the weighting factors presented in Table 2.

Location / Site No.	Score	Location / Site No.	Score
2E	76	2D	68
1B	75	1A	64
1E/1F	74	2A	62
2F/2B	72	1C	60
1D	69	2C	59

Table 5: Results of the Decision Matrix.

3.3 Potential Hydrogen End Users

The use of hydrogen as a fuel for air and marine transport has great potential, as these sectors today cannot be directly electrified and need a physical fuel for their motive power. Hydrogen and ammonia can effectively compete with fuels derived from petroleum. In particular, unconverted hydrogen is well positioned to become a key element for use in short sea voyages, and when converted to methanol or ammonia, can serve as a fuel used by international shipping. The possibility of incorporating the use of hydrogen for marine transport in Malta was investigated in earlier work (Moise, 2021).

Work conducted as part of project HydroGenEration highlighted Malta's favourable location on the busy sea routes across the Mediterranean Sea. This strategic position is well placed to further develop and consolidate the various maritime activities and strengthen Malta as a Mediterranean hub. Already today, Malta's territorial waters have bunkering areas, which enable for the entry and safe anchorage of various vessels. The number and types of vessels that visit Maltese Ports in 2023 can be seen in Figure 5.

For this reason, the development and establishment of an offshore hydrogen production plant can bring with it additional benefits to the Maltese Islands. This is due to the possibility of easy access both for marine vessels that will utilise compressed hydrogen as propulsion fuel in the future and, more realistically, in the near future for marine H_2 carriers to collect the hydrogen being produced offshore and transporting it to other locations for storage and further consumption.

The results of the numerical modelling showed that the volume of offshore hydrogen produced by means of a wind power plant consisting of ten, 10 MW wind turbines with an integrated FLASC ESS, could generate enough H_2 to refill the cargo tanks of approximately 60 hydrogen seagoing carriers (see Table 6) in a year (based on actual wind conditions for 2016).

This means that each vessel will carry to the end-users approximately 70 tons of hydrogen. The quantity of wind-generated electricity required to fill a single H_2 carrier is equivalent to 4,415 MWh. This means that at each refuelling, the H_2 carrier would load about 2% of the total annual hydrogen production from the HydroGenEration project concept in a Central Mediterranean wind climate scenario.

Month	Total Number of H_2 Carrier Offloads
Jan.	6
Feb.	7
Mar.	7
Apr.	7
May	6
Jun.	3
Jul.	3
Aug.	3
Sep.	4
Oct.	4
Nov.	6
Dec.	6
Annual	62

Table 6: Table showing the number of hydrogen carriers which would have been supplied by the HydroGenEration project concept on a monthly basis for the base year 2016.

Not all sectors of the economy can be electrified in the near or foreseeable future, so many technologies will need fuel in the form of raw materials, rather than in the form of clean energy for a long time to come. Examples of these technologies are seagoing vessels used in international shipping, long-range aircraft used in aviation, steel production, and seasonal energy storage technologies which cannot be electrified directly. So, clean, renewable electricity cannot be used in such applications. The solution to this problem may lie in converting electricity, especially that derived from renewable sources, into other physical forms, i.e., turning it into gaseous and liquid carriers. In addition to meeting the physical fuel needs of some industries, such conversion would improve the transport of energy over long distances and minimise transport losses. Hydrogen can act as such an energy carrier in its gaseous, liquid and converted forms. The application of such technologies suggests that the use of hydrogen

in various aggregate states will help to meet about 12% of the electricity demand from end-users and also reduce CO_2 emissions by 10% (OECD, 2022). By incorporating carbon capture and storage technologies into this scenario, it is possible to significantly reduce the CO_2 content in the atmosphere, which in the long term should lead to a zero-emission system (Food and Agriculture Organization of the United Nations, 2022).

4 Conclusions

This research highlights Malta's favourable location on the busy sea routes across the Mediterranean Sea. This strategic position has all the prerequisites for the further development and consolidation of various maritime activities and for Malta to reinforce itself as a Mediterranean hub.

The numerical modelling showed that for three 10 MW wind turbines supplying a 24 MW electrolyser, there will be a marginal increase in the amount of H_2 of 0.3% when a 25 MWh FLASC system is interfaced between the intermittent supply and the H_2 production plant. More significantly, the number of electrolyser "ON"/"OFF" cycles decreased by 66% with integrated energy storage over the 12-month time frame under scrutiny.

Even today, Malta's territorial waters already host bunkering areas, creating the prerequisites for the entry and safe anchorage of various vessels. Ports and harbour infrastructure are also geared to support maritime activities. For this reason, the development and establishment of offshore hydrogen production could bring additional benefits to the Maltese islands. This is due to the possibility of easy access both for seafaring vessels that will, in the future, utilise the compressed hydrogen as a fuel for motive power and more realistically, in the nearer future for seagoing H_2 carriers to collect the hydrogen produced and to transport it elsewhere for storage and future consumption.

The work presented in this research report looks into the technical performance characteristics of an islanded decarbonised H_2 production plant and presents the selection process for candidate site/s suitable for the HydroGenEration project concept by taking into consideration the technical requirements, system interactions and dependence on a number of factors related to the environmental, maritime and energy activities underway in the vicinity of the Maltese Islands.

The results of this work show that the ideal candidate site would be Site 2E, located on the East side of the islands and within Area 1 of Malta's EEZ. Preliminary calculations show that the volume of offshore hydrogen produced by means of the HydroGenEration project concept could generate enough H_2 to refuel about 60 hydrogen carriers based on 2016 wind data in a case study for Central Mediterranean wind conditions. It is important to keep in mind that this work formed part of a process to consolidate the HydroGenEration project concept for offshore, green hydrogen production using electrical energy stabilised by a FLASC ESS.

In conclusion, the HGE project includes a high-level techno-economic analysis to identify the costs of the overall system and to come up with a Levelised Cost of Hydrogen (LCOH) for the concept project, subject to local offshore conditions. Such findings are subject to future national policy adjustments and to further studies and surveys. Additional factors can also affect the results presented in this work.

Acknowledgements

The work presented in this Research Report was undertaken as part of project: "Hydro Pneumatic Energy Storage for Offshore Green Hydrogen Generation – HydroGenEration", financed by the Energy and Water Agency under Malta's National Energy and Water Research and Innovation Strategy (2021-2030) — Grant Agreement Ref.: EWA 64/22.

The WIND4H2 project was supported through the Maritime Seed Award (MarSA) 2019, a joint initiative between Transport Malta (formerly Malta Marittima) and the University of Malta supported by the TAKEOFF Business Incubator, Knowledge Transfer Office and the Centre for Entrepreneurship and Business Incubation (CEBI) at the University of Malta.

The Light Detection and Ranging (LiDAR) system was purchased through the European Regional Development Fund for the setting up of a Solar Laboratory (ERDF 335), part-financed by the European Union.

The authors also acknowledge the help and support of Din L-Art Ħelwa – National Trust of Malta, for hosting the LiDAR wind measurement equipment at the Qalet Marku Tower, Baħar iċ-Ċagħaq, Malta.

References

Ahmed, A., Pompodakis, E. E., Katsigiannis, Y., & Karapidakis, E. S. (2024). Optimizing the installation of a centralized green hydrogen production facility in the island of Crete, Greece. *Energies*, *17*(8), 1924.

Alessandro, F., & Giovannini, C. (2023). Recent and future advances in water electrolysis for green hydrogen generation: Critical analysis and perspectives. *Sustainability*, *15*(24), 16917–16917.

Aquaventus. (2024). Aquaventus, the green energy revolution starts in the North Sea [Accessible at https://aquaventus.org (Retrieved October 18, 2024)].

Borg, A., Sant, T., Buhagiar, D., Cutajar, C., & Farrugia, R. N. (2023a). Numerical modelling of a hydro-pneumatic energy storage system for smoothing power fluctuations from offshore wind. *Journal of Physics: Conference Series*, *2626*(1), 012014–012014.

Borg, A., Sant, T., Buhagiar, D., Farrugia, R. N., & Micallef, C. (2023b). A numerical model comparison of the energy conversion process for an offshore hydro-pneumatic energy storage system. *Applied Sciences*, *13*(12), 7189–7189.

Buhagiar, D., & Sant, T. (2017). Modelling of a novel hydro-pneumatic accumulator for large-scale offshore energy storage applications. *Journal of Energy Storage*, *14*(2), 283–294.

Continental Shelf Department. (2022). Preliminary market consultation — for the proposal of economic activities within Malta's exclusive economic zone [Accessible at https://www.etenders.gov.mt (Retrieved December 4, 2023)].

Cordina, C., Farrugia, R., & Sant, T. (2017). Wind profiling using LiDAR at a coastal location on the Mediterranean island of Malta [Bari, Italy]. *9th European Seminar OWEMES*.

Cradden, L., Kalogeri, C., Barrios Martinez, I., Galanis, G., Ingram, D., & Kallos, G. (2016). Multi-criteria site selection for offshore renewable energy platforms. *Journal of Renewable Energy*, *87*, 790–806.

Cutajar, C., Sant, T., Farrugia, R. N., & Buhagiar, D. (2021). A software tool for the design and operational analysis of pressure vessels used in offshore hydro-pneumatic energy storage. *Journal of Energy Storage*, *40*, 102750.

Danish Energy Agency. (2023). Denmark's energy islands [Accessible at https://ens.dk (Retrieved February 11th, 2025)].

Davis, N. N., Badger, J., Hahmann, A. N., Hansen, B. O., Mortensen, N. G., Kelly, M., Larsén, X. G., Olsen, B. T., Floors, R., Lizcano Casso, G., Lacave, O., Bosch, A., Bauwens, I., Knight, O. J., Potter van Loon, A., Fox, R., Parvanyan, T., Krohn Hansen, B. O., Heathfield, D., & Drummond, R. (2023). The global wind atlas: A high-resolution dataset of climatologies and associated web-based application. *Bulletin of the American Meteorological Society*, *104*(8), E1507–E1525.

Diaz, H., Fonesca, R. B., & Guedes Soares, C. (2018). Site selection process for floating offshore wind farms in Madeira islands. In *Advances in renewable energies offshore*. Taylor & Francis.

DNV. (2015). A new era for hydrogen energy unveiled by summer students at DNV GL [Accessible at https://www.dnv.com (Retrieved October 18, 2024)].

Dolphyn Hydrogen. (2024). Producing ultra low carbon hydrogen economically and at scale [Accessible at https://www.dolphynhydrogen.com (Retrieved October 18, 2024)].

Drago, A. (2006). *WERMED Malta page* [Acessible at http://www.capemalta.net (Retrieved October 2023)].

Energy and Water Agency & Ministry for the Energy, Environment and Regeneration of the Grand Harbour. (2023). National policy for the deployment of offshore renewable energy [Accessible at https://energywateragency.gov.mt].

Environment and Resources Authority. (2013). Physical features [Acessible at https://era.org.mt].

Environment and Resources Authority. (2023). Meps geoportal [Accessible at https://meps.eraportal.org.mt (Retrieved October 22, 2023)].

European Marine Observation and Data Network. (n.d.). Annual maritime route density [Accessible at https://emodnet.ec.europa.eu (Retrieved December 4, 2023)].

Foglini, F., Prampolini, M., Micallef, A., Angeletti, L., Vandelli, V., Deidun, A., & Taviani, M. (2015). Late quaternary coastal landscape morphology and evolution of the Maltese islands (Mediterranean sea) reconstructed from high-resolution seafloor data. *Geological Society, London, Special Publications*, *411*(1), 77–95.

Food and Agriculture Organization of the United Nations. (2022). The state of Mediterranean and Black Sea fisheries [Accessible at https://www.fao.org].

Galdies, C. (2022). The state of the climate 2022 - a multidecadal report and assessment of Malta's climate [Accessible at https://www.um.edu.mt].

Gao, F. Y., Yu, P. C., & Gao, M. R. (2022). Seawater electrolysis technologies for green hydrogen production: Challenges and opportunities. *Current Opinion in Chemical Engineering*, *36*, 100827.

Grech, K. (2022). An exclusive economic zone for Malta [Accessible at https://mmf.org.mt (Retrieved October 2023)].

Honsho, Y., Nagayama, M., Matsuda, J., Ito, K., Sasaki, K., & Hayashi, A. (2023). Durability of PEM water electrolyzer against wind power voltage fluctuation. *Journal of Power Sources*, *564*, 232826–232826.

IEA. (2020). NREL turbine-models power curve [Accessible at https://nrel.github.io (Retrieved October 2023)].

IMO. (2021). IMO 2020 fuel oil sulphur limit - cleaner air, healthier planet [Accessible at https://www.imo.org (Retrieved October 4, 2023)].

IMO. (2023). IMO's work to cut ghg emissions from ships [Accessible at https://www.imo.org (Retrieved September 2023)].

Kojima, H., Nagasawa, K., Todoroki, N., Ito, Y., Matsui, T., & Nakajima, R. (2023). Influence of renewable energy power fluctuations on water electrolysis for green hydrogen production. *International Journal of Hydrogen Energy*, *48*(12), 4572–4593.

Lhyfe. (2023). Lhyfe announces that Sealhyfe, the world's first offshore hydrogen production pilot, produces its first kilos of green hydrogen in the Atlantic Ocean [Accessible at https://www.lhyfe.com (Retrieved October 18th, 2024)].

Micallef, A., Foglini, F., Le Bas, T., Angeletti, L., Maselli, V., Pasuto, A., & Taviani, M. (2013). The submerged paleolandscape of the Maltese islands: Morphology, evolution and relation to quaternary environmental change. *Marine Geology*, *335*, 129–147.

Moise, T. (2021). *Techno-economic feasibility of floating offshore wind-driven hydrogen production for decarbonising maritime transport between Malta and Gozo* [Master's thesis, M.Sc. in Sustainable Energy, University of Malta].

MUSICA. (2024). Multiple use of space for island clean autonomy [Accesible at https://musica-project.eu (Retrieved October 18th, 2024)].

National Statistics Office. (2022a). The state of the climate 2022: A multidecadal report and assessment of Malta's climate [Accesible at https://nso.gov.mt (Retrieved Februar 13th, 2023)].

National Statistics Office. (2022b). Transport statistics 2021 [Accesible at https://nso.gov.mt (Retrieved October 4, 2023)].

OECD. (2022). OECD tourism trends and policies 2020 [Accesible at https://www.oecd.org (Retrieved October 2023)].

Plan Bleu. (2021). Maritime transport in the Mediterranean [Accesible at https://planbleu.org (Retrieved October 2023)].

Planning Authority. (2016). Harbour approach routes [Accesible at https://testsdi.gov.mt (Retrieved October 21st, 2023)].

Settino, J., Farrugia, R. N., Buhagiar, D., & Sant, T. (2022). Offshore wind-to-hydrogen production plant integrated with an innovative hydro-pneumatic energy storage device. *Journal of Physics: Conference Series*, *2151*(1), 012013.

Transport Malta. (2013). Malta significant wave height study [Accessible at https://www.transport.gov.mt (Retrieved October 2023)].

Transport Malta. (2023). Maritime statistics - Transport Malta [Accessible at https://www.transport.gov.mt (Retrieved April 2023)].

Transport Malta. Malta bunkering areas [Accessible at https://www.transport.gov.mt (Retrieved October 20th, 2023)].

Weiß, A., Siebel, A., Bernt, M., Shen, T.-H., Tileli, V., & Gasteiger, H. A. (2019). Impact of intermittent operation on lifetime and performance of a PEM water electrolyzer. *Journal of the Electrochemical Society*, *166*(8), F487–F497.

Zaini, A. A., Hannan, M. A., Al-Shetwi, A. Q., Begum, R. A., Hossain, M. J., Ker, P. J., & Indra, M. (2023). Hydrogen electrolyser technologies and their modelling for sustainable energy production: A comprehensive review and suggestions. *International Journal of Hydrogen Energy*, *48*(72).

Sultana, D. (2024). *Xjenza Online*, 12(2):135–151.

Xjenza Online: Science Journal of the Malta Chamber of Scientists
www.xjenza.org
DOI: 10.7423/XJENZA.2024.3.04

Research Article

A Land Use and Land Use Change Study of the Maltese Islands (1998-2012)

D. Sultana[*1]
[1]*Environment and Resources Authority, Marsa, Malta*

Abstract. A thorough understanding of past spatial and temporal land use variations is critical for evaluating the effectiveness of land use policies and guiding future decisions towards sustainable management. Such knowledge places current land use trends in a historical context, allowing for better modeling of potential future scenarios. This study contributes to this understanding by providing two high-resolution datasets. The first dataset presents a fine spatial resolution land use map of Malta for 2012, with a minimum mapping unit (MMU) of 0.01 km^2. The second dataset offers a very fine spatial resolution map (MMU of 0.0005 km^2) that documents the spatial changes in artificial surfaces and the land uses they replaced between 1998 and 2012. The analysis shows that artificial surfaces in the Maltese Islands covered 48.13 km^2 in 1998, increasing by 4.68 km^2 to 52.81 km^2 by 2012. In 1998, 84% of these artificial surfaces were located within development zones (within scheme), 14% were found outside of combined development and environmental designations, and 2% within environmentally designated areas. Structure Plan policies during this period successfully confined 49% of new artificial surfaces within development zones. However, 48% of new artificial surfaces were constructed outside of development designations, and 3% were built within environmentally protected zones. These findings suggest that the Structure Plan's policy framework was only partially effective in containing urban expansion within designated areas, while environmental policies were more successful in curbing industrial and residential development within protected zones. New artificial surfaces during the study period primarily replaced agricultural land, both used (1.84 km^2) and abandoned (1.40 km^2), as well as semi-natural areas (0.43 km^2). This research highlights a misalignment between the intended objectives of land use policies and the actual land use changes observed over the 14-year period. It underscores the importance of acquiring detailed spatial and temporal data to inform national land use and resource management policies aimed at promoting sustainable land use. An accurate assessment of these variations is crucial for adjusting policy measures to achieve the desired outcomes in future land management efforts.

1 Introduction

1.1 Spatial and temporal variations of Maltese land use

A comprehensive understanding of spatial and temporal variations in land use from 1998 to 2012 is crucial for assessing the impact of land use policies and informing future strategies aimed at promoting sustainable land management. Such insights provide the necessary foundation for placing current land use trends within a historical framework, which in turn enables more accurate modeling of potential future land use scenarios.

Three primary datasets offer partial insights into the spatial and temporal dynamics of Maltese land use during this period: (1) the CORINE land cover data, (2) the MEPA (Malta Environment and Planning Authority) urban development maps, and (3) the spatial distribution and number of MEPA-issued development permits. These datasets, while valuable, each possess inherent limitations that restrict their ability to comprehensively capture land use changes over time.

The limitations of these datasets highlight the need for more detailed and higher-resolution data to fully assess land use dynamics and policy impacts in Malta. A more robust understanding of land use changes requires integrating these datasets with newer, more detailed mapping efforts, allowing for a more precise analysis of land use trends and their implications for sustainable development.

Correspondence to: D. Sultana (daniel.sultana@um.edu.mt)

1.1.1 CORINE Malta

The European Environment Agency's CORINE (Coordination of Information on the Environment) system, specifically the CORINE Land Cover (CLC), provides periodic assessments of land cover and land cover change across Europe. Utilizing a minimum mapping unit (MMU) of 25 hectares (0.25 km^2), the CLC is designed for monitoring large-scale land use changes. While this scale is suitable for broad regional analyses, it has limitations when applied to smaller territories with more intricate land use dynamics, such as the Maltese Islands.

According to CLC analyses, land cover changes in Malta were minimal, with a reported change of only 0.07% between 1990 and 2000, and no recorded changes between 2000 and 2012. Moreover, between 2006 and 2012, no changes were observed in urban areas, agricultural land, or natural cover (European Environment Agency [EEA], 2017, p. 61). However, these results are likely skewed by the CLC's relatively coarse spatial resolution, which fails to capture smaller-scale land use changes that are critical in highly urbanized and spatially constrained environments like Malta.

The inability of CLC data to detect such changes underscores its limitations for detailed, short-term land use monitoring in the Maltese context. To accurately assess land use dynamics, particularly in a setting characterized by rapid urban development and constrained land resources, a finer spatial resolution is necessary. Such detailed analysis is essential for informing land use policy, managing natural resources, and achieving sustainable development goals in Malta.

1.1.2 MEPA base maps and Local Plan maps

The MEPA (Malta Environment and Planning Authority) base maps were designed to represent various land use types across the Maltese Islands, capturing features such as road alignments, yards, stone structures, and built-up areas. These built-up areas were further categorized into hard buildings, soft buildings, and pavements. The maps offered a very fine spatial resolution, accurately delineating the spatial and areal distribution of land uses. However, updates to reflect de facto land use were conducted infrequently, particularly outside development zones (referred to as "within scheme" areas). While updates were more regularly applied to areas within development zones, land use in areas outside combined development and environmental designations often remained outdated, with older, no longer accurate land use classifications persisting.

This inconsistency in updates resulted in base maps that functioned as a mosaic of time-specific land use depictions, with many regions failing to reflect contemporary land use or built-up environments. Additionally, key data concerning the extent of development in 2000 and 2012 is not available, as confirmed by personal communication with MEPA (10 October 2016). Consequently, these maps do not provide a reliable or up-to-date representation of land use and therefore limit the ability to perform accurate spatial and temporal analyses of land use dynamics in the Maltese Islands.

1.1.3 Number and areal extent of permits

In parallel, trends in development applications and permits provide insight into the pressures exerted on land resources by the construction sector. For example, between 2010 and 2011, the number of permissions granted for new dwelling units decreased by 11%, from 4,444 to 3,955, with 83% of the permitted units being apartments (Malta Environment and Planning Authority [MEPA], 2011). Although this dataset provides valuable information on the volume and location of applications, it does not capture the associated changes in impermeable surfaces, which are critical for understanding the broader environmental and spatial impacts of development. Consequently, while these datasets offer some insights into development trends, they fall short of providing a comprehensive understanding of the changes in land use and associated impacts on land resources.

1.2 This study

The present study provides two distinct datasets that offer insights into land use in Malta. The first dataset is a high-resolution land use map for the year 2012, with a minimum mapping unit (MMU) of 0.01 km^2. This dataset offers a spatial resolution 25 times finer than that of the CORINE land cover inventory for the same period (which has an MMU of 0.25 km^2), thereby providing more detailed spatial information. The second dataset presents an even finer spatial resolution map, with an MMU of 0.0005 km^2, which captures land use changes from 1998 to 2012. This map specifically focuses on the transformation of artificial surfaces, defined here to include residential, industrial, port/airport, quarry, green urban areas, and greenhouse land uses (see Table 2 for detailed definitions). The resolution of this land use change analysis is significantly more refined than the 0.05 km^2 MMU of the CORINE land cover change dataset (http://land.copernicus.eu/pan-european/corine-land-cover), thus enabling a more precise assessment of spatial changes.

These datasets provide crucial insights into how national land use policies have influenced the spatial distribution and changes in land use over time. However, it is important to clarify that while this study documents land use change, it does not evaluate the legal status of any expansion in impermeable surfaces, such as whether such

developments were legally permitted.

2 Maltese context

2.1 Socio-economic context of the period under consideration (1998-2012)

The period from 1998 to 2012 saw significant demographic and economic changes in Malta, which influenced land use dynamics. The population increased from 386,397 in 1998 to 421,364 in 2012, with population density rising from 1,223 to 1,333 persons per km^2, far exceeding the EU average of 117 persons per km^2 (National Statistics Office Malta, 2011).

Economically, Malta's gross value added grew by 69% between 1995 and 2004 and by 62% from 2004 to 2014, driven by a shift from agriculture, fisheries, and manufacturing to a service-based economy, particularly tourism, professional services, and information technology (Grech, 2015). Economic growth placed increasing pressure on land resources, particularly through real estate investment (Sustainable Development Directorate Malta, 2015).

2.2 Policy control on development during the period under consideration (1998-2012)

The 1992 Development Planning Act (DPA) (Cap. 356.) set out the legal framework for planning in Malta. The DPA presented a hierarchical system of development plans and planning policies on which decisions regarding land use change are based. Chief among these is the 1990 Structure Plan (SP) for the Maltese Islands. The SP established 320 policies providing strategic land use regulation at the national level (MEPA, 2004). The SP inter alia provided a strategic direction that guided Malta's development over a twenty-year period (1990-2010). The plan also sought to channel urban development activities into existing built-up areas (Ministry for Development and Infrastructure, 1990). On a strategic level, the SP divided the Maltese Islands into five broad categories: existing built-up areas, temporary provision scheme, primary development areas, non-urban areas and ODZ settlements. Each category consisted of policies that set out broad guidelines for development control. Site-specific development guidelines and policies were further elaborated upon in the individual Local Plans (LPs).

LPs (Figure 1) provided local level interpretations of the national strategic policies set out in the SP. Five of these local plans were approved in 2006: the North Harbour Local Plan (NHLP), the North West Local Plan (NWLP), the Gozo and Comino Local Plan (GCLP), the Central Malta Local Plan (CMLP) and the South Malta Local Plan (SMLP). Two LPs had been approved in 1995 and 2002 respectively: Marsaxlokk Bay Local Plan (MBLP) and the Grand Harbour Local Plan (GHLP) (the latter was reviewed in view of Smart City development approved in 2007). The SP and LPs were supported by a set of supplementary planning guidance notes (planning policies) (MEPA, 2010). These LP indicated where development could take place and the criteria against which development proposals would be assessed by the previous Malta Environment and Planning Authority (MEPA), the designated competent authority. The main function of the LP was to guide development by seeking a sustainable balance between economic, social and environmental needs (MEPA, 2006, p. 1).

2.3 Environment designations aims

Malta's unique habitats and species are protected through various designations, including Areas of Ecological Importance (AEI), Sites of Scientific Importance (SSI), Bird Sanctuaries, Nature Reserves, Special Areas of Conservation (SAC), and Special Protection Areas (SPA). By 2008, approximately 20% of Malta's land area was under some form of environmental protection.

It is important to note that environmentally designated sites are not a system of strict nature reserves where all human activities are excluded. Rather, these designations aim to ensure the sustainable management of natural areas, allowing for ecologically and economically viable human activities rather than enforcing strict exclusion zones.

3 Materials and Methods

3.1 Remote sensing versus visual interpretation of land use and land use change

Change detection, as defined by Singh (1989), is the process of identifying differences in a phenomenon by observing it at different times. While remote sensing (RS) data is widely used for land use change detection (Chen et al., 2012; Coops et al., 2006; Lunetta, 1999), its effectiveness depends on the object's spectral changes (Deer, 1995; Green et al., 1994; Jensen, 1983; Singh, 1989). Various change detection techniques and methods have been developed; however, the selection of the most appropriate change detection method is challenging (Lu et al., 2004).

Typically, a threshold value is applied in change detection algorithms to distinguish change from no-change. The technique, however, is beset by various issues, namely, the appropriate selection of threshold values identifying change (Jensen, 2005; Lu et al., 2004; Xian et al., 2009; Zuur et al., 2007). If threshold values are too low or high, areas of change may be mis-, under- or over- detected. Another key limitation affecting change detection techniques is the application of RS data sets of different spectral range. RS dataset consisting of different

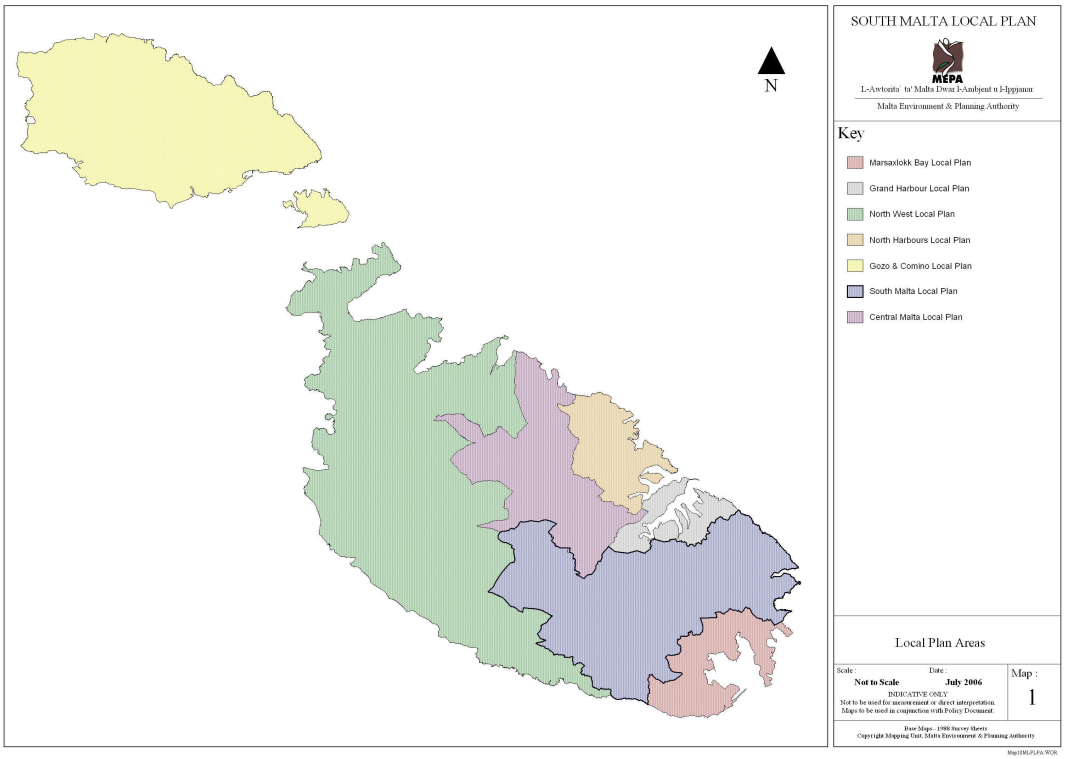

Figure 1: Map showing the distribution and extent of Local Plans.

spectral information raises questions about selecting classification algorithms and threshold values (Fung, 1992; Hussain et al., 2013). The classification of coarser resolution image will also overlook certain features, making a match to features observed in the finer scale remote sensing difficult. Different resolutions may also prevent an accurate overlay, further complicating change detection (Bontemps et al., 2008).

The available MEPA orthophoto datasets for 1998 and 2012 differ significantly in both spatial resolution and spectral range, with the 1998 dataset being coarser and having a lower spectral range than the 2012 dataset. Given these disparities, as well as the inherent limitations of remote sensing-based change detection methods, this study employed manual interpretation for land use assessment and change detection. Human operators were able to account for these variations and extract nuanced information that pixel-based methods often struggle to capture (Hussain et al., 2013).

3.2 Data used (1998 and 2012 orthophotos) and GIS software

Orthophoto datasets of the Maltese Islands were created from aerial imagery captured in 1998 and 2012. These orthophotos, geometrically corrected for topography, lens distortion, and camera tilt, allow for accurate measurement of distances and areas. Land use and land use changes were assessed using these orthophotos with the support of GIS software.

3.3 Land use and land use change detection methods

3.3.1 Study of land use 2012

The 2012 orthophoto data set was used to assess land use and land cover over the entirety of the Maltese Islands. A minimum mapping unit of 0.01km^2 was established. The resulting land use map is distinct from previous land use maps for this period (2012) in that it combines various elements which, in previous maps, may have been individually focused upon, to the detriment of other key elements. The land use map presented in this study (i) applies a very fine spatial resolution, (ii) applies a consistent methodology in identifying land use across the Islands, (iii) assesses land use across the Islands at a fixed point in time (2012), and (iv) applies, where relevant, information from various other nationally recognised land use datasets to add land use and cover information that may be difficult to conclusively identify with the sole use of orthophoto images. Data sets that were referred to in the interpretation of land use are: MEPA Mapping Unit base maps, MEPA Ecosystems Management Unit terrestrial biota habitats, and MEPA Ecosystems Management Unit agricultural land. These data sets are based on site in-

Land use and reference number	Description
2.5: Abondoned and degraded arable land	The category includes agricultural areas that have been disused for an extended period of time and are vulnerable to soil erosion and degradation. Identifying features may include agricultural fields (i) predominantly occupied by steppe terrestrial habitat; (ii) not listed as Used Agricultural Area (UAA). (iii) clearly in state of abandon, distinguishing features may include: dilapidated rubble walls, gullying soil erosion etc. (iv) showing a colour difference compared to fields in use, (v) having undergone significant change in cover with the intent of changing overall area use (e.g. paving, entertainment areas, soil compaction) that increase the risk of land degradation.
3.4: Degraded semi-natural land	The category includes natural areas (steppe, garrigue, mixed forests, beaches, dunes and sand plains) that have been degraded through various human activities and are consequently vulnerable to soil erosion and degradation.
3.2.3.1: Steppe and garrigue	Steppe is characterised by herbaceous plants especially grasses; it is devoid of trees and mainly comprises annuals. During the dry season, steppe appears dry and impoverished because most plant species will, at the time, exist in the form of seeds. Garrigue is characterised by low-lying, usually aromatic and spiny woody shrubs that are resistant to drought and exposure. This habitat type often composed of kermes oak, lavender, thyme and white cistus. There may be a few isolated trees.
3.2.3.4: Maquis	Maquis generally consists of small oaks, oleasters, arbutus, lentiscus, junipers, briarwood and an understorey/undergrowth of cistus and low heathers.

Table 1: Land use class and distinguishing criteria for non CORINE land uses used in the Maltese 2012 land cover study. Descriptions for 3.2.3.1. and 3.2.3.4. are taken, in part, from CORINE.

vestigations and are therefore considered a reliable source of very fine-resolution data.

The land use classes (and their reference numbers) and the criteria used in distinguishing between various land uses follow those applied by the standard CORINE methodology (http://www.eea.europa.eu/publications/COR0-landcover). The land uses assessed follow: (1.1.1) continuous urban fabric, (1.1.2) discontinuous urban fabric, (1.2.1) industrial and commercial units, (1.2.2) road networks, (1.2.3) port areas, (1.2.4) airport areas, (1.3.1) mineral extraction, (1.3.2) dump sites, (1.3.3.) construction sites, (1.4.1) green urban areas, (1.4.2) sports and leisure, (2.1) arable land, (2.2) permanent corps, (3.1.3) mixed forests, (3.3.1) beaches, dunes and sand plains, (3.3.2) bare rock and (4.2.1) salt marshes. The number in from of the land uses are standard reference numbers applied in CORINE studies. In view of the finer spatial resolution assessed in this study, a number of land use classes were added that are not available in the CORINE land use framework. These are: (3.2.3.1) steppe and garrigue, (3.2.3.4) maquis, (3.4) degraded semi-natural, the three of which are subdivisions of the CORINE land use class 3.2.3 sclerophyllous vegetation; (2.5) abandoned and degraded arable land, a subdivision of the CORINE land use class 2.1 arable land. A description of identifying criteria for the above non-CORINE land use classes is provided below (Table 1).

3.3.2 Study on the change in artificial surfaces 1998-2012

The 1998 orthophotos were assessed in terms of presence of impermeable and/or man-made surfaces. The assessed impermeable surfaces and their descriptions are presented in Table 2. A minimum mapping unit of 0.0005km^2 was applied. Roads and road infrastructure are not included in the study and are therefore not mapped. Identifying and distinguishing criteria for the above listed impermeable surfaces are described in Table 2.

Once artificial surfaces were identified in the 1998 orthophotos, the 1998 artificial surfaces layer was overlain onto the 2012 orthophoto. Areas demonstrating an increase or decrease in artificial surfaces equal to or greater than 0.0005km^2 were identified as new polygons pertaining to an artificial surface class. The land use which was replaced by new (2012) artificial surfaces was identified from the 1998 orthophotos. The previous land use was categorised as: agricultural land, abandoned agricultural land turning into semi-natural or degraded land, natural land, quarry, dump, construction site, landscapes and gardens, and artificial land use that did not fulfil MMU in 1998 but expanded and in 2012 fulfilled MMU. In addition to the listed distinguishing criteria, contextual information

Land use and reference number	Description
1: Residential and Lodging (guesthouses and hotels)	Residential areas in city and village centres, around the edge of urban district centres, and certain urban districts in rural areas. These units consist of blocks of flats and groups of houses (not divided by roads), individual houses and residential gardens (with an area < 0.001km^2). Due to the often similar nature of residential units (e.g. blocks of apartments), guesthouses and hotels, these three land use categories have been considered in the same land use category. This category of the nomenclature does not include scattered agricultural habitation (comprising agricultural building or shelters).
2: Industrial	Industrial complexes which demonstrate a footprint and plan layout that is atypical of residential units. Also includes associated landscaped areas and car parks which are predominantly artificially surfaced (cement, asphalt, tarmac) with minimal vegetation.
3: Ports or Airports	Ports: includes infrastructure of port areas, including dockyards and marinas. Industrial and commercial units located in immediate proximity should be singled out and defined as industrial or commercial units. Airport: includes airport installations: runways, buildings and associated land. Buildings (terminal buildings, hangars, workshops, warehouses, storage tanks), and associated spaces are included in the airport surface area.
4: Quarry	Areas with open-pit extraction of construction material (sandpits, quarries) or other minerals (open-cast mines) are included in this category. Rehabilitated quarries used for agricultural purposes fall under the appropriate agricultural cover category
6: Green urban area	Includes public parks, private green areas, and cemeteries with vegetation. The category also covers camping grounds, sports grounds, leisure parks, golf courses, racecourses, etc.
21: Green houses	Have a highly discernible surface colour and overall rectangular plan layout.

Table 2: Land use class and distinguishing criteria used in the 1998-2012 land use study. When the integer before the class reference code is 1, it denotes land use in 1998, and 4 denotes land use in 2012.

and the spatial aspect of the real-world objects and their spatial relationships, along with their arrangements, were also considered when attributing an observed land use to a particular land use class. Despite a rigorous methodology and a strict adherence to the outlined criteria, one cannot definitively ensure a correct attribution of land use to either of the classes listed in Table 2; this is particularly the case for certain industrial and residential land uses. Having identified the spatial distribution and temporal change of artificial surfaces, national areas subject to particular land use policies pertinent to the year 2012 were overlain onto the combined 1998-2012 artificial surfaces map. National land use policy layers used in this study follow: (i) industrial schemes, (ii) development zone and rationalisation scheme, (iii) outside development zone (ODZ) category 1, 2 and 3 settlement scheme, (iv) Environmental AEI, SSI, Beaches, TPA, Historical trees, (v) SAC national, (vi) SAC international and (vii) SPA. These policy designations have been divided into two categories of similar overall land use policy aims and objectives. The first category is termed "within planning designations" and consists of areas within the development zone, rationalisation, most UCA, ODZ category 1, 2 and 3 settlements and Industrial schemes. The second category is termed "combined environment protected areas" and consist of Areas of Ecological Importance (AEI), Sites of Scientific Importance (SSI), beaches, Tree Protected Areas (TPA), historical trees, Special Areas of Conservation (SAC) and Special Protected Areas (SPA). Areas outside the above listed schemes are classed under a third category that has been termed "outside combined development and environmental designations".

4 Results

4.1 Study of land use 2012

In 2012, land use in the Maltese Islands (Figure 2) was dominated by agricultural land in either of the following forms: arable land (52%), abandoned and degraded arable land (3%) and permanent crops (1%). Impermeable surfaces, which include continuous and discontinuous urban fabric, industrial and commercial units, port and airport areas, and construction sites, take up (24%) of the Maltese Islands. Natural and semi-natural areas cover 19% of the Islands; such areas include steppe and garrigue, degraded semi-natural areas, bare rock, maquis, mixed forests, salt marshes and beaches (Table 3).

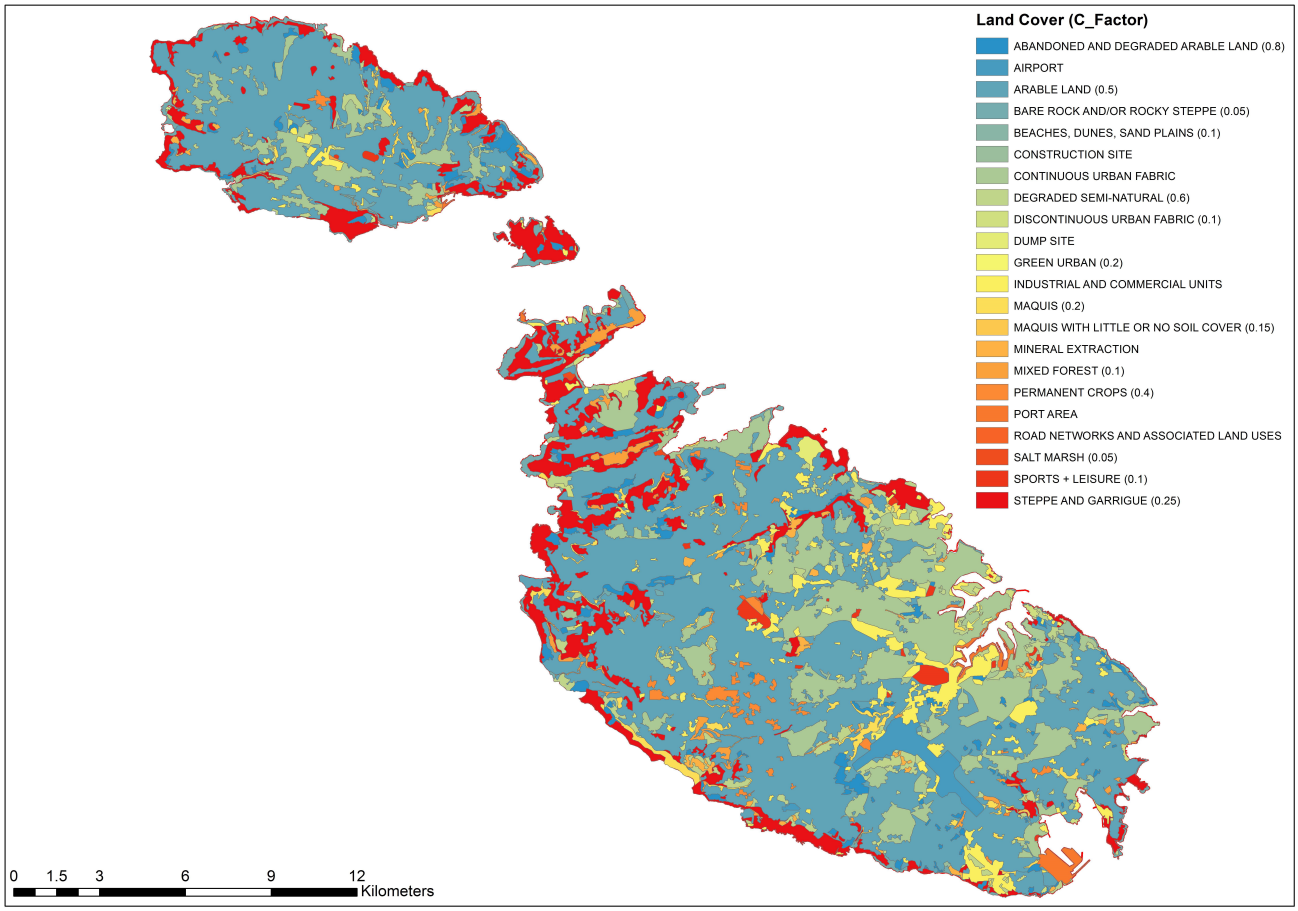

Figure 2: Detailed map showing spatial distribution of land use and land cover in the Maltese Islands for the year 2012.

Land use class	CORINE Ref. code	Area [km^2] Malta 2012	Land use [% of total MT land area]
Arable land	21	164.50	52.11
Permanent crops	22	2.91	0.92
Abandoned and degraded arable land	(25)	9.56	3.03
Degraded semi-natural land	(34)	7.42	2.35
Continuous urban fabric	111	53.09	16.82
Discontinuous urban fabric	112	3.34	1.06
Industrial and commercial units	121	12.83	4.07
Port areas	123	1.96	0.62
Airport areas	124	3.86	1.22
Mineral extraction	131	2.09	0.66
Dump sites	132	0.60	0.19
Construction sites	133	0.28	0.09
Green urban areas	141	0.26	0.08
Sports and leisure	142	1.95	0.62
Mixed forests	313	4.20	1.33
Beaches, dunes, and sand plains	332	0.12	0.04
Bare rock (and rocky steppe)	421	5.75	1.82
Salt marshes	421	0.15	0.05
Steppe and garrigue	(3231)	36.01	11.41
Maquis	(3234)	4.78	1.51

Table 3: Land use class, their total area (km^2) in 2012 and their respective land area relative to total Maltese terrestrial land area.

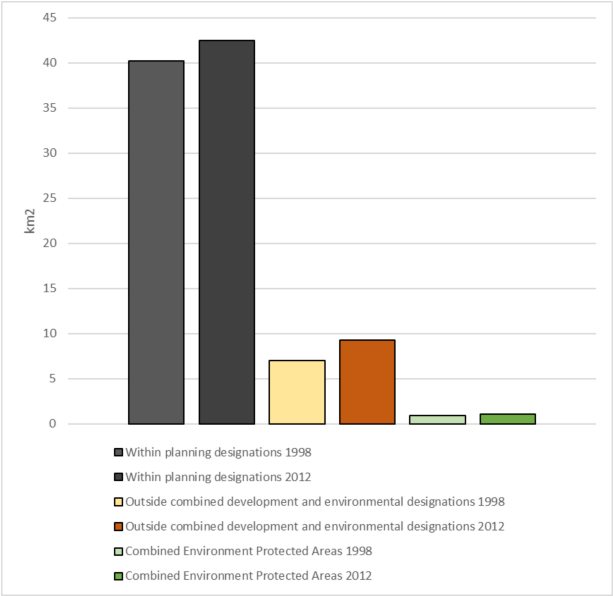

Figure 3: Graph showing the footprint (km^2) occupied by artificial surfaces observed in 1998 and 2012 as well as their distribution within planning designations, within combined environment protected areas and outside combined development and environmental designations.

4.2 Change in artificial surfaces 1998-2012

4.2.1 Study on the change in artificial surfaces 1998-2012

Results of change in artificial surfaces, and land uses preceding new 2012 artificial surfaces are presented in the Appendix. A highlight of key results follows. Artificial surfaces in the Maltese Islands amounted to 48.13km^2 in 1998 and increased by 4.68km^2 to a total of 52.81km^2 in 2012. Artificial surfaces observed in 1998 were predominantly concentrated within scheme (84%), and are also present outside combined development and environmental designations (14%) and in environmentally designated zones (2%). Expansion of new artificial surfaces between 1998 and 2012 amounted to 4.68km^2 (Table 4) Structure Plan policies were successful in confining 49% of new artificial surfaces within scheme. However, 48% of new artificial surfaces were constructed outside combined development and environmental designations and 3% of new artificial surfaces were constructed within environmentally designated zones (Figure 3).

New 2012 artificial surfaces were predominantly constructed on and replace agricultural surfaces used agricultural areas (39% of 2012 new surfaces) and abandoned agricultural areas (30% of 2012 new surfaces). A total of 0.54km^2 (or 12% of new 2012 artificial surfaces) are land uses that were below the MMU in 1998 and in 2012 fulfilled the MMU; this implies an increase in footprint of

	Artificial surfaces 1998 (km^2)			New artificial surfaces built between 1998 and 2012 (km^2)			Artificial surfaces 2012 (km^2)		
Local Plan	Planning designations	Outside designations	Environment areas	Planning designations	Outside designations	Environment areas	Planning designations	Outside designations	Environment areas
MSLP	10.51	2.97	0.155	0.55	0.68	0.005	11.06	3.65	0.16
CZLP	9.79	1.03	0.032	0.53	0.28	0.007	10.32	1.31	0.039
GCLP	5.39	0.59	0.145	0.32	0.33	0.025	5.71	0.92	0.17
NHLP	6.14	0.11	0.074	0.35	0.09	0.01	6.49	0.2	0.084
NWLP	4.72	1.47	0.452	0.39	0.55	0.091	5.11	2.02	0.543
GHLP	2.76	0.43	0.005	0.1	0.01	0.003	2.86	0.44	0.008
MBLP	0.92	0.38	0.055	0.03	0.33	0.001	0.95	0.71	0.056
Sum	40.23	6.98	0.92	2.27	2.27	0.14	42.50	9.25	1.06
%	84	15	2	48	48	3	80	18	2
Total		48.13			4.68			52.81	

Table 4: Change in artificial surfaces across the Maltese local plans categorizes into areas within planning designations, areas within combined environment protected areas, and areas outside combined development and environmental designations.

the particular artificial land use.

A closer look at changes in land covered for residential and industrial artificial surface shows that between 1998 and 2012 residential areas increase by 1.89km^2 and industrial areas increased by 1.87km^2. Most new residential areas were accommodated within planning designations (81%), however, more than half of the new industrial areas (59%) were developed outside the planning designations (Table 5).

4.2.2 Withing planning designations

The following section presents land use change that took place within the development zone, rationalisation, most UCA, ODZ category 1, 2 and 3 settlements and Industrial Schemes. The land use change results for combined planning designations may be less than the individually summed designations (sections 3.2.2.2, 3.2.2.3 and 3.2.2.4); this is since a number of planning designations overlap.

Results of change in artificial surfaces (Figure 4) and land uses preceding new 2012 artificial surfaces are presented in the Appendix. A highlight of key results follows. Artificial surfaces within planning designations amounted to 40.24km^2 in 1998 and increased by 2.27km^2 to a total of 42.51km^2 in 2012 (81% of 2012 total artificial surfaces of the Maltese Islands). In 1998, artificial surfaces within planning designations are predominantly residential (35.01km^2) and industrial (4.75km^2) (Table 4). Between 1998 and 2012 residential areas increase by 1.53km^2 and industrial areas increased by 0.70km^2 (Table 5). New 2012 artificial surfaces were predominantly constructed on and replace abandoned agricultural areas (41% of 2012 new surfaces) and used agricultural areas (40% of 2012 new surfaces). A total of 9% of new 2012 artificial surfaces are land uses that were below the

		Artificial surface (km^2)	Artificial surfaces increase (1998 to 2012) (km^2)
WITHIN PLANNING DESIGNATIONS	1998 Residential	35.01	
	2012 Residential	36.54	1.53
	1998 Industrial	4.75	
	2012 Industrial	5.44	1.53
COMBINED ENVIRONMENT PROTECTED AREAS	1998 Residential	0.47	
	2012 Residential	0.51	0.04
	1998 Industrial	0.22	
	2012 Industrial	0.28	0.06
OUTSIDE COMBINED DEVELOPMENT AND ENVIRONMENTAL DESIGNATIONS	1998 Residential	1.78	
	2012 Residential	2.11	0.33
	1998 Industrial	3.56	
	2012 Industrial	4.67	1.10
ACROSS ALL MALTESE ISLANDS	1998 Residential	37.26	
	2012 Residential	39.15	1.89
	1998 Industrial	8.52	
	2012 Industrial	10.39	1.87

Table 5: Changes in land covered for residential and industrial artificial surface.

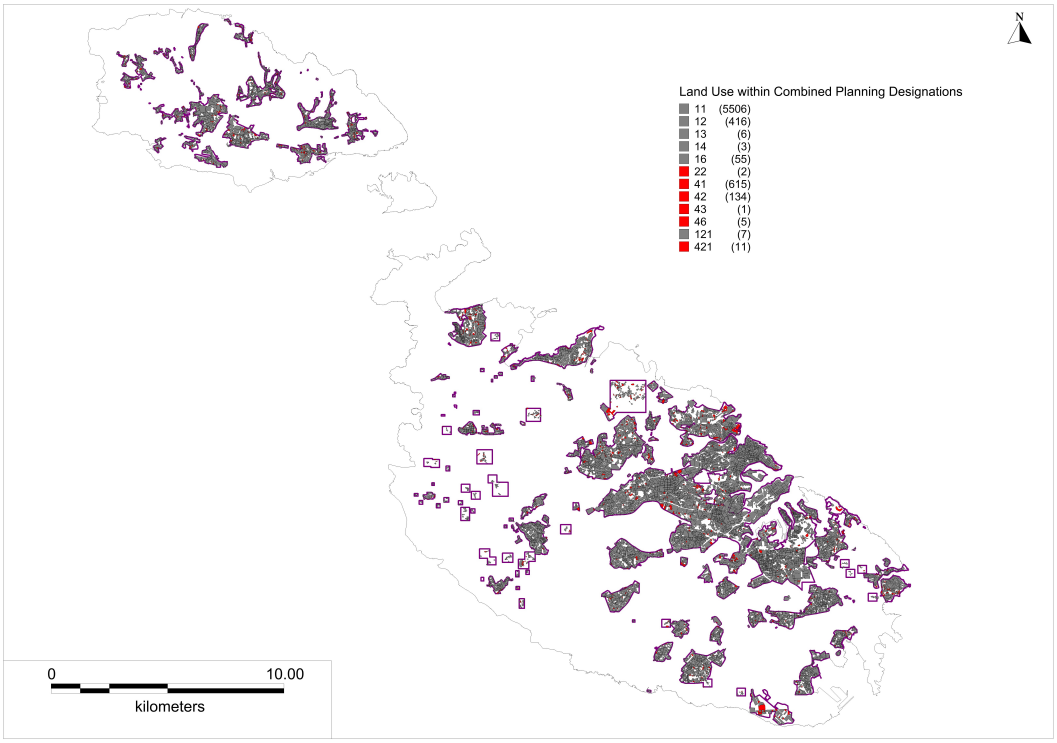

Figure 4: Detailed map showing spatial distribution of areas within planning designations (violet). Artificial surfaces present in 1998 are shown in grey while new artificial surfaces recorded in 1998-2012 land use change study are marked as red. Table (top right of figure) refers to land use classes used in the Maltese 1998-2012 land cover study (Table 3).

MMU in 1998 and in 2012 fulfilled the MMU; this implies an increase in footprint of the particular artificial land use.

4.2.3 Combined Environment Protected Areas

The following section presents land use change that took place within Areas of Ecological Importance (AEI), Sites of Scientific Importance (SSI), beaches, Tree Protected Areas (TPA), historical trees, Special Areas of Conservation (SAC) and Special Protected Areas (SPA).

Results of change in artificial surfaces (Figure 5), and land uses preceding new 2012 artificial surfaces are presented in the Appendix. A highlight of key results follows. Artificial surfaces within environment protected areas amounted to 0.92km^2 in 1998 and increased by 0.14km^{2}2 to a total of 1.06km^2 in 2012 (2% of 2012 total artificial surfaces of the Maltese Islands) (Table 4). In 1998, artificial surfaces within environment protected areas are predominantly residential (0.47km^2 or 51% of artificial surfaces in 1998) and industrial (0.22km^2 or 24% of artificial surfaces in 1998). Between 1998 and 2012 industrial areas increased by 0.06km^2 (49% of total new 2012 artificial surface) and residential areas increase by 0.04km^2 (26% of total new 2012 artificial surface) (Table 5).

4.2.4 Outside combined development and environmental designations

The following section presents land use change that took place outside policy categories termed "within planning designations" and "combined environment protected areas". The outside combined developed and environmental designations therefore consist of policy areas not covered by development zone, rationalisation, and most UCA, Outside Development Zone (ODZ) category settlements, Industrial schemes, Areas of Ecological Importance (AEI), Sites of Scientific Importance (SSI), beaches, Tree Protected Areas (TPA), historical trees, Special Areas of Conservation (SAC) and Special Protected Areas (SPA).

Results of change in artificial surfaces (Figure 6) and land uses preceding new 2012 artificial surfaces are presented in the Appendix. A highlight of key results follows. Artificial surfaces outside planning and environmental designations amounted to 6.98km^2 in 1998 and increased by 2.27km^2 to a total of 9.25km^2 in 2012 (18% of 2012 total artificial surfaces of the Maltese Islands) (Table 4). In 1998, artificial surfaces within planning designations are predominantly industrial (3.56km^2 or 51% of artificial surfaces in 1998) and residential (1.78km^2 or

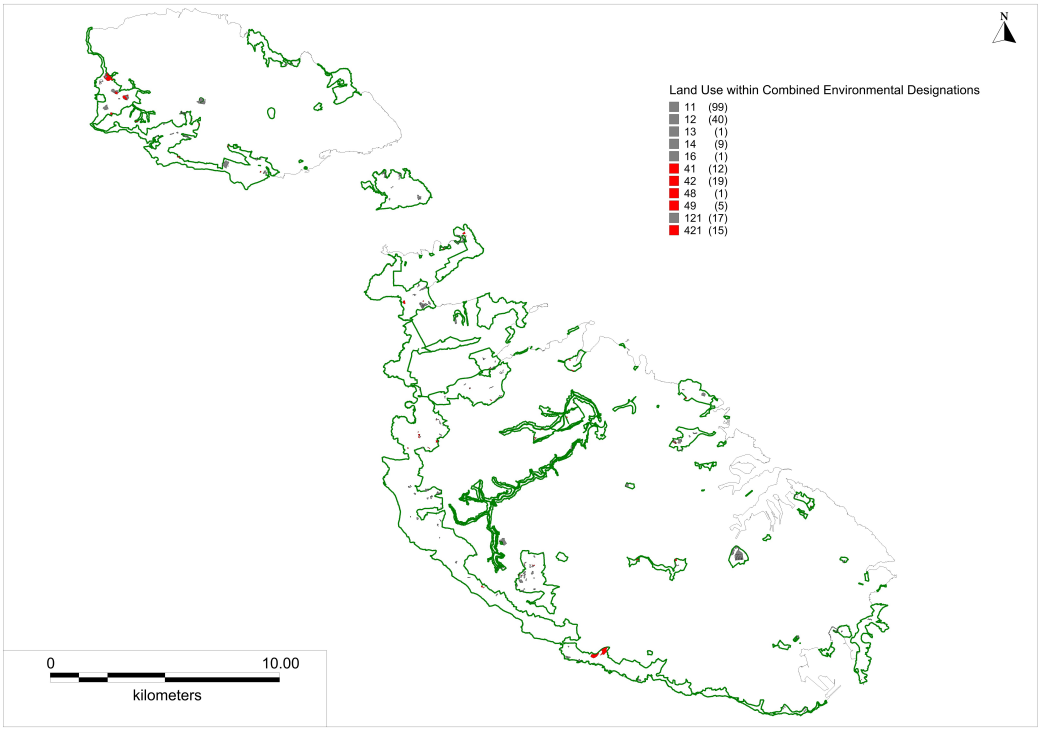

Figure 5: Detailed map showing spatial distribution of combined environment protected areas (green). Artificial surfaces present in 1998 are shown in grey while new artificial surfaces recorded in 1998-2012 land use change study are marked as red. Table (top right of figure) refers to land use classes used in the Maltese 1998-2012 land cover study (Table 3).

25% of artificial surfaces in 1998) (Table 5). Between 1998 and 2012 industrial areas increased by 1.1km^2 (49% of total new 2012 artificial surface) and residential areas increase by 0.33km^2 (15% of total new 2012 artificial surface). New industrial development associated/directly neighbouring the Malta Freeport area (located outside combined development and environmental designations in the south east of Malta) totals 0.237km^2 and is classed as industrial, not ports and airports; this area has falls within the Marsaxlokk Bay Local Plan (MBLP). New 2012 artificial surfaces were predominantly constructed on and replace used agricultural areas 0.94km^2 (42% of 2012 new surfaces) and abandoned agricultural areas 0.48km^2 (21% of 2012 new surfaces). A total of 0.27km^2 (or 12% of new 2012 artificial surfaces) are land uses that were below the MMU in 1998 and in 2012 fulfilled the MMU; this implies an increase in footprint of the particular artificial land use.

5 Discussion

5.1 Total change in artificial surfaces 1998 and 2012

The analysis shows that artificial surfaces in the Maltese Islands covered 48.13 km^2 in 1998, increasing by 4.68 km^2 to 52.81 km^2 by 2012. In 1998, 84% of these artificial surfaces were located within development zones (within scheme), 14% were found outside of combined development and environmental designations, and 2% within environmentally designated areas (Table 4). Between 1998 and 2012, a total of 2.27 km^2 of new artificial surfaces were constructed within designated development zones, an additional 2.27 km^2 were developed outside combined development and environmental designations, and 0.14 km^2 were built within environmentally protected zones.

The MSLP ranks first in terms of new artificial surfaces established by the year 2012 across the Maltese Islands. Total new development amounts to 1.23km^2; 0.55km^2 located within scheme, 0.68km^2 located outside combined development and environmental designations and 0.005km^2 within environment protected areas (Table 4). The MSLP is the LP with the greatest increase in artificial surfaces within scheme and outside combined development and environmental designations. While MSLP covers 20% of the Maltese terrestrial territory, it accommodated 25% of all new artificial surfaces.

The NWLP ranks second in terms of new artificial surfaces established by the year 2012 across the Maltese Islands. Total new development amounts to 1.03km^2; 0.39km^2 located within scheme, 0.55km^2 located out-

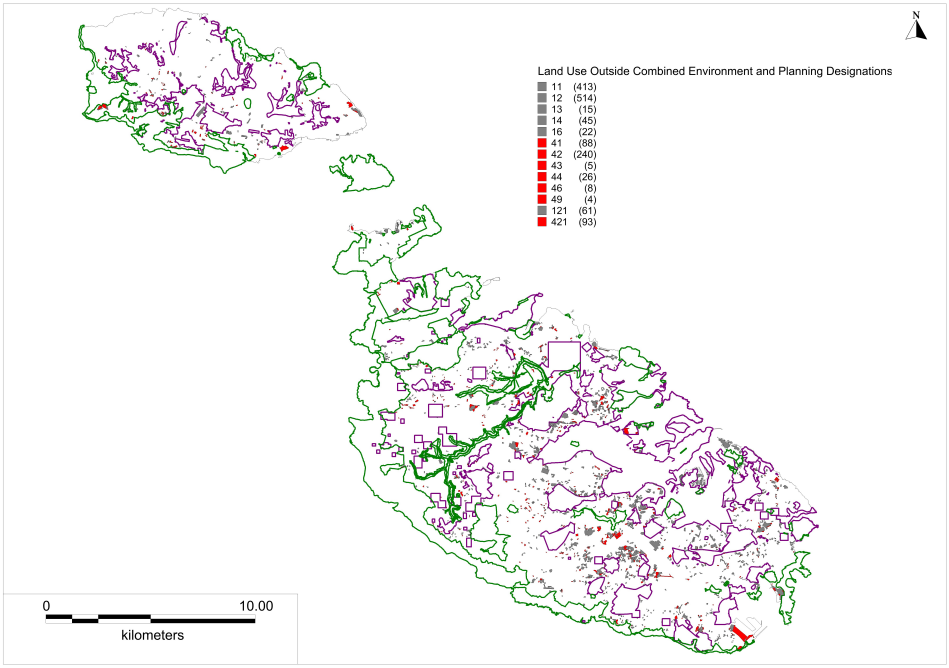

Figure 6: Detailed map showing spatial distribution of outside development zone (areas between combined environment protected areas (green) and areas within planning designations (violet)). Artificial surfaces present in 1998 are shown in grey while new artificial surfaces recorded in 1998-2012 land use change study are marked as red. Table (top right of figure) refers to land use classes used in the Maltese 1998-2012 land cover study (Table 3). Note: new industrial development associated/directly neighbouring the Malta Freeport area (south east of Malta) totals 0.237km^2 and is classed as industrial not ports and airports; this area has falls within the Marsaxlokk Bay Local Plan (MBLP).

side combined development and environmental designations and 0.091km^2 within environment protected areas (Table 4). The NWLP ranks first in terms of land use change within environment protected areas.

The CZLP ranks third in terms of new artificial surfaces established by the year 2012 across the Maltese Islands. Total new development amounts to 0.81km^2; 0.53km^2 located within scheme, 0.28km^2 located outside combined development and environmental designations and 0.007km^2 within environment protected areas (Table 4).

It is worth noting that four of the seven LP demonstrate a growth (1998-2012) of artificial surfaces that is greater outside combined development and environmental designations (ODZ) than within development schemes (WS); MBLP (WS 0.03km^2; ODZ 0.33km^2), NWLP (WS 0.39km^2; ODZ 0.55km^2) MSLP (WS 0.55km^2; ODZ 0.68km^2) and GCLP (WS 0.32km^2; ODZ 0.33km^2). It is important to note that new industrial development associated/directly neighbouring the Malta Freeport area (south east of Malta) totals 0.237km^2 and is classed as industrial, not ports and airports; this area has falls within the MBLP. Three of the seven LP demonstrate a growth of artificial surfaces that is greater within development scheme than outside combined development and environmental designations; GHLP (0.1 WS 0.10km^2; ODZ 0.01km^2), NHLP (0.26 WS 0.35km^2; ODZ 0.09km^2), CZLP (0.52 WS 0.53km^2; ODZ 0.28km^2).

5.1.1 Policy control

The Structure Plan aims to provide strategic direction and context to guide both government and private sector development in Malta over a twenty-year period (1990–2010) (Sustainable Development Directorate Malta, 2015). The structure plan's central goal is "to use land and buildings efficiently and consequently to channel urban development activity into existing built-up areas particularly through rehabilitation and upgrading of urban areas thus constraining further inroads into undeveloped land". On a strategic long term level, the Structure Plan divides Maltese settlements into five broad categories, i.e. existing built-up areas, temporary provision scheme, primary development areas, non-urban areas and ODZ settlements. Each of these categories is typified by key policy which sets out broad guidelines for development control.

Category: Existing Built-up Areas A key objective of the Structure Plan is to promote a significant portion of future urban development within existing built-up areas

while maintaining and enhancing their environmental quality. This strategy seeks to minimize the development footprint on undeveloped land beyond these areas (Ministry for Development and Infrastructure, 1990, p. 35, Policies SET 1–7). To achieve this, the Structure Plan, along with local plans, will enforce stringent controls over development throughout the Islands, ensuring that proposed developments do not adversely affect existing or planned adjacent uses (Ministry for Development and Infrastructure, 1990, p. 40, Policies BEN 1–4).

Category: Non-Urban areas This section outlines key policies from the Structure Plan regarding land use within and outside combined development and environmental designations. Policy SET 11 facilitates development in existing built-up areas, temporary provision areas, and primary development areas, as delineated in the Structure Plan. Conversely, it prohibits any form of urban development outside these designated areas (Ministry for Development and Infrastructure, 1990, p.38, Policy SET 11). While the Structure Plan upholds a strict prohibition on the urbanization of non-urban areas, it acknowledges the necessity of certain built structures, such as farmhouses, parking facilities, and control buildings, which are considered appropriate within the non-urban landscape. Nonetheless, the establishment of such structures will be regulated to preserve and enhance the environmental quality of the countryside (Ministry for Development and Infrastructure, 1990, p. 41, Policy BEN 5).

5.1.2 Policy control

The above discussed Structure Plan policies were successful in confining 49% (2.27km^2) of new 1998-2012 artificial surfaces within scheme, and limiting new impermeable surfaces to 3% (0.14km^2) within environmentally designated zones. Despite this, 48% (2.27km^2) were constructed outside combined development and environmental designations (Table 4). Given these results, it appears that the implementation of the SP policies faced challenges, and the associated aims and objectives may not have been fully realized.

The Structure Plan's strategy was translated into seven Local Plans and a number of supplementary planning policies. The Strategic Plan for Environment and Development (2015) references the State of the Environment Reports and suggests that the implementation of these policies over the past two decades has played a role in managing urban sprawl within the defined development boundaries. However, despite these reported achievements, ongoing efforts are necessary to address the persistent demand for development and further ensure the effective containment of urban sprawl (Sustainable Development Directorate Malta, 2015).

5.2 How much and in what proportions is agricultural, forest and other semi-natural and natural land being taken for urban and other artificial land development? What are the drivers of uptake for urban and other artificial land development?

New (1998-2012) artificial surfaces across the Maltese Islands are primarily associated with the following land uses: residential land uses 1.89km^2, industrial land uses 1.87km^2, free port/airport 0.3km^2 and green houses 0.3km^2. New artificial surfaces within scheme typically pertain to residential (1.53km^2), industrial (0.70km^2) and green urban (0.013km^2) land uses. New artificial surfaces outside combined development and environmental designations are predominantly industrial (1.10km^2), followed by residential (0.33km^2) and airport (0.3km^2) associated land uses (Table 5). New artificial surfaces within environment protected areas are associated with industrial (0.06km^2), green house (0.04km^2) and residential (0.04km^2) land uses (Appendix).

New 2012 artificial surfaces across the Maltese Islands were predominantly constructed on and replace used agricultural areas 1.84km^2 (35% of 2012 new surfaces) and abandoned agricultural areas 1.40km^2 (27% of 2012 new surfaces), and 0.43km^2 (8% of new 2012 artificial surfaces) replaced semi-natural areas. A total of 0.54km^2 (10% of new 2012 artificial surfaces) were land uses that were below the MMU in 1998 and in 2012 fulfilled the MMU; this implies an increase in footprint of the particular artificial land use.

5.3 How does this compare to EU

The CORINE Land Cover analysis for 2000, 2006, and 2012 provides insights into land cover trends across European countries over 12 years. The data reveal that artificial areas experienced the most significant increase among all categories, both in net area and percentage change (EEA, 2017, p. 17). Specifically, artificial areas rose from 207,498 km^2 in 2000 to 218,295 km^2 in 2012, marking a 5.2% increase. The drivers behind this growth have evolved; since 1990, residential sprawl has declined while economic sprawl and urban management have gained prominence. From 2000 to 2006, the rise in artificial surfaces was attributed primarily to housing, services, and recreation (43%), followed by construction sites (21%) and industrial/commercial sites (16%) (EEA, 2019). In the Maltese Islands, residential areas increased by 41%, and industrial areas by 40% during the study period (1998-2012). Notably, the rise in artificial surfaces related to industrial sites is particularly pronounced in Malta, while the increase in residential areas mirrors trends in the broader European Union. However, it is

important to note that the European classification includes recreational surfaces, which are not accounted for in Malta's classification.

The analysis also indicates a decline in agricultural land due to urbanization, land abandonment, and conversion to pastures (EEA, 2017, p. 17). Across the EU, arable land and permanent crop areas decreased from 1,409,012 km^2 in 2000 to 1,401,769 km^2 in 2012, a reduction of 0.5%. From 2000 to 2006, artificial surfaces expanded by 5,486 km^2, with prior land uses comprising arable land or permanent crops (46%), forests and transitional woodland shrub (13%), and natural grassland, heathland, and sclerophyllous vegetation (7.3%). In Malta, the new artificial surfaces constructed by 2012 predominantly replaced agricultural land (39%), abandoned agricultural areas (30%), and previously unclassified land (12%), indicating a significant footprint expansion of artificial land use. These findings suggest that agricultural surfaces in both the European Union and the Maltese Islands are increasingly being converted to artificial uses.

5.4 Way forward

The second goal of the Structure Plan emphasizes the efficient use of land and buildings, directing urban development into existing built-up areas through the rehabilitation and upgrading of urban zones, thereby minimizing encroachment into undeveloped land. Although the national land use policy outlines adequate aims and objectives, enforcement has often been lacking. It is proposed that the cumulative approval of "exceptional" applications, along with instances of unlawful construction, may have significantly impeded the realization of these goals. Future research could assess the prevalence of unlawful expansions and identify the types of development that require closer scrutiny within Maltese local plans.

The Structure Plan aims to limit urban land expansion while accommodating economic development, housing, and community needs through more effective use of existing urban areas. A national analysis could help identify dilapidated, unused, and underutilized structures, offering opportunities for regeneration and reuse rather than further consuming undeveloped land. The Environment Report (MEPA, 2010) highlights that Malta's high urban land cover, driven by population density, raises concerns about land use efficiency. This high urbanization rate is particularly notable in light of the 2005 Census, which revealed that 22% of residential properties were permanently vacant, with an additional 5% classified as temporarily vacant second homes (MEPA, 2010; Vakili-Zad & Hoekstra, 2011). This trend also extends to commercial and industrial sectors (MEPA, 2010). Vakili-Zad and Hoekstra 2011 suggest that a prevailing 'homeownership culture' may lead to an oversupply of properties built for investment rather than genuine housing needs. This points to considerable potential for enhancing land use efficiency, especially given the current oversupply of residential, commercial, and industrial spaces. Investigating the potential of incentives to optimize land use efficiency warrants further study (MEPA, 2010).

The Strategic Plan for Environment and Development (SPED) (2015) supersedes the Structure Plan originally published in 1990 and adopted in 1992, establishing a long-term spatial strategy for development and environmental protection, with 2020 as the first review milestone. This new plan aligns with national policies, integrating social, economic, and environmental objectives (Sustainable Development Directorate Malta, 2015). This research has revealed discrepancies between land use policy aims and actual land use changes over the fifteen-year period from 1998 to 2012. Understanding the spatial and temporal variations in land use in the Maltese Islands is essential for guiding national resource management and land use policy towards sustainable management practices.

6 Conclusions

The areal extent of artificial surfaces in the Maltese Islands in the year 1998 was of 48.16km^2. Artificial surfaces observed in 1998 were predominantly concentrated within scheme (83%), and are also present outside combined development and environmental designations (15%) and in environmentally designated zones (2%). Expansion of new artificial surfaces between 1998 and 2012 amounted to 4.68km^2. Newly constructed artificial surfaces were observed within scheme (49%), outside combined development and environmental designations (48%) and in environmentally designated zones (3%). It is worth noting that four of the seven LP demonstrate a growth (1998-2012) of artificial surfaces that is greater outside combined development and environmental designations than within schemes. New 2012 artificial surfaces across the Maltese Islands were predominantly constructed on and replace used agricultural areas 1.84km^2 (35% of 2012 new surfaces) and abandoned agricultural areas 1.40km^2 (27% of 2012 new surfaces), and 0.43km^2 (8% of new 2012 artificial surfaces) replaced semi-natural areas. A total of 0.54km^2 (10% of new 2012 artificial surfaces) were land uses that were below the MMU in 1998 and in 2012 fulfilled the MMU; this implies an increase in footprint of the particular artificial land use.

The purpose of the Structure Plan was to inter alia "to provide a strategic direction and context to guide both Government and the private sector in matters concerning Malta's development over twenty years (1990-2010)" (Sustainable Development Directorate Malta, 2015).

The structure plan had three central goals amongst which is "to use land and buildings efficiently and consequently to channel urban development activity into existing built-up areas particularly through rehabilitation and upgrading of urban areas thus constraining further inroads into undeveloped land". Various SP policies relate to land use within and outside combined development and environmental designations. In particular, SP Policy SET 11 prohibits any form of urban development outside existing and committed built-up areas (Ministry for Development and Infrastructure, 1990, p. 38, Policy SET 11).

Results indicate that SP policies were successful in confining 49% (2.27km^2) of new 1998-2012 artificial surfaces within scheme, and limiting new impermeable surfaces to 3% (0.14km^2) within environmentally designated zones. Despite this, 48% (2.26km^2) of new 1998-2012 artificial surfaces were constructed outside combined development and environmental designations. Results indicate that the SP policy sets were only partly successful in confining and channelling urban development activity into existing built-up areas (within scheme). Close to half (48%) of the new 1998-2012 artificial surfaces were developed outside combined development and environmental designations. By comparison, environmental policy was successful in limiting industrial and residential growth in environmentally protected sites.

This research reveals a significant discrepancy between the objectives of land use policy and the actual changes in land use that occurred over a fifteen-year period (1998-2012). A precise understanding of the spatial and temporal variations in land use across the Maltese Islands is crucial. This information should inform and guide national resource management and land use policies, ultimately facilitating sustainable land management practices.

Acknowledgements

I would like to express my gratitude to Stephen Conchin for his invaluable contributions to the GIS analysis. I also appreciate the insightful discussions with Darrin Stevens and Miraine Rizzo from the Environment and Resources Authority (ERA). My sincere thanks extend to Emmy Donkers from Wageningen University (Netherlands), as well as Callum Hayles, Hugh Glover, John Kenworthy, Josh Coppin, and Tom Denton from Manchester Metropolitan University (England), and to Francesca Scerri, Gabriel Farrugia, and Daniel Vella from the University of Malta for their assistance with data collection.

References

Bontemps, S., Bogaert, P., Titeux, N., & Defourny, P. (2008). An object-based change detection method accounting for temporal dependences in time series with medium to coarse spatial resolution. *Remote Sensing of Environment*, *112*(6), 3181–3191.

Chen, G., Hay, G. J., Carvalho, L. M. T., & Wulder, M. A. (2012). Object-based change detection. *International Journal of Remote Sensing*, *33*(14), 4434–4457.

Coops, N. C., Wulder, M. A., & White, J. C. (2006). Identifying and describing forest disturbance and spatial pattern. In *Understanding forest disturbance and spatial pattern* (pp. 31–61). CRC Press.

Deer, P. (1995). *Digital change detection techniques in remote sensing* (DSTO-TR-0169), Department of Defence, Australia.

Development planning act [ACT1 of 1992 as amended by Acts: XXI of 1992, XVI and XXIII of 1997, XXIII of 2000, VI and XXI of 2001, Legal Notices 22 and 47 of 2002; and Act VI of 2002]. (1992), Laws of Malta (Chapter 356).

European Environment Agency. (2017). *Malta land cover 2006 and changes analysis* [Available at www.eea.europa.eu].

European Environment Agency. (2019). *Corine land cover 2000 - 2006 changes (raster 100m)* [Available at sdi.eea.europa.eu].

Fung, T. (1992). Land use and land cover change detection with Landsat MSS and SPOT HRV data in Hong Kong. *Geocarto International*, *7*(1), 33–40.

Grech, A. (2015). *The evolution of the Maltese economy since independence* (WP/05/2015), Central Bank of Malta.

Green, K., Kempka, D., & Lackey, L. (1994). Using remote sensing to detect and monitor land-cover and land use change. *Photogrammetric Engineering & Remote Sensing*, *60*(3), 331–337.

Hussain, M., Chen, D., Cheng, A., Wei, H., & Stanley, D. (2013). Change detection from remotely sensed images: From pixel-based to object-based approaches. *ISPRS Journal of Photogrammetry and Remote Sensing*, *80*, 91–106.

Jensen, J. (1983). Urban/suburban land use analysis. In *Manual of remote sensing* (pp. 1571–1666). American Society of Photogrammetry.

Jensen, J. (2005). *Introductory digital image processing: A remote sensing perspective*. Prentice Hall.

Lu, D., Mausel, P., Brondízio, E., & Moran, E. (2004). Change detection techniques. *International Journal of Remote Sensing*, *25*(12), 2365–2401.

Lunetta, R. (1999). Applications, project formulation, and analytical approach. In R. Lunetta & C. Elvidge (Eds.), *Remote sensing change detection: Environmental monitoring methods and applications* (pp. 1–19). Taylor & Francis.

Malta Environment and Planning Authority. (2004). *Annual report and accounts 2004* [available at era.org.mt/].

Malta Environment and Planning Authority. (2010). *The environment report, land sub-report 2008*.

Malta Environment and Planning Authority. (2011). *The environment report, indicators, 2010-2011*.

Malta Environment & Planning Authority. (2006). *Central malta local plan* [available at pawatch.org/].

Ministry for Development and Infrastructure. (1990). *Structure plan for the Maltese islands, draft final written statement and key diagrams*.

National Statistics Office Malta. (2011). Demographic review 2010.

Seif, A., & Mokarram, M. (2012). Change detection of Gil Playa in the northeast of Fars Province. *American Journal of Scientific Research*, *86*, 122–130.

Singh, A. (1989). Review article digital change detection techniques using remotely-sensed data. *International Journal of Remote Sensing*, *10*(6), 989–1003.

Sustainable Development Directorate Malta. (2015). *Strategic plan for environment and development*.

Vakili-Zad, C., & Hoekstra, J. (2011). High dwelling vacancy rate and high prices of housing in Malta a Mediterranean phenomenon. *Journal of Housing and the Built Environment*, *26*, 441–455.

Xian, G., Homer, C., & Fry, J. (2009). Updating the 2001 national land cover database land cover classification to 2006 by using Landsat imagery change detection methods. *Remote Sensing of Environment*, *113*(6), 1133–1147.

Zuur, A., Ieno, E., & Smith, G. (2007). Principal component analysis and redundancy analysis. In *Analysing ecological data* (pp. 193–224). Springer.

Appendix

WITHIN PLANNING DESIGNATIONS

Local Plan	CZLP	GCLP	GHLP	MSLP	MBLP	NHLP	NWLP		
Land use	km²	km²	km²	km²	km²	km²	km²	Sum land use class (km²)	
1998 Residential	8.8724	4.9394	1.7467	8.8525	0.8370	5.4975	4.2633	35.0088	
1998 Industrial	0.8263	0.4318	0.8827	1.5909	0.0736	0.5392	0.4005	4.7449	
1998 Port/Airport	0.0000	0.0000	0.0513	0.0011	0.0000	0.0000	0.0000	0.0524	
1998 Quarry	0.0193	0.0000	0.0000	0.0000	0.0000	0.0013	0.0094	0.0300	
1998 Green Urban	0.0645	0.0185	0.0748	0.0733	0.0119	0.1041	0.0232	0.3702	
2012 Residential, new	0.3488	0.2953	0.0222	0.2986	0.0252	0.0252	0.2490	1.5273	
2012 Industrial, new	0.1753	0.0278	0.0707	0.2403	0.0014	0.0632	0.1191	0.6977	
2012 Port/Airport, new	0.0000	0.0000	0.0036	0.0000	0.0000	0.0000	0.0000	0.0036	
2012 Quarry, new	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	
2012 Green Urban, new	0.0000	0.0000	0.0047	0.0077	0.0000	0.0000	0.0008	0.0132	
2012 Agricultural landfill, new	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	
2012 Semi natural landfill, new	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	
1998 Green house	0.0054	0.0000	0.0000	0.0000	0.0000	0.0000	0.0235	0.0289	
2012 Green house, new	0.0037	0.0000	0.0000	0.0000	0.0000	0.0000	0.0200	0.0237	
Tot. (1998+2012) dev. in LP (km²)	10.3157	5.7129	2.8566	11.0644	0.9491	6.4934	5.1087	tot. (1998+2012) dev. (km²)	**42.50**
Tot. 2012 dev. in LP (km²)	0.5278	0.3231	0.1012	0.5465	0.0266	0.3514	0.3889	tot. 2012 dev. (km²)	2.27
LP tot. 2012 dev./ MT tot. 2012 dev. (proportion)	0.2330	0.1426	0.0447	0.2412	0.0118	0.1551	0.1717		
LP tot. 2012 dev./ LP (km²/km²)	0.0159	0.0047	0.0127	0.0687	0.0021	0.0246	0.0034		
Rate 2012 dec (km²/yr-1)	0.0377	0.0231	0.0072	0.0390	0.0019	0.0251	0.0278		

COMBINED ENVIRONMENT PROTEXTED AREAS

Local Plan	CZLP	GCLP	GHLP	MSLP	MBLP	NHLP	NWLP		
Land use	km²	km²	km²	km²	km²	km²	km²	Sum land use class (km²)	
1998 Residential	0.0225	0.0043	0.0045	0.1285	0.352	0.0057	0.2673	0.4681	
1998 Industrial	0.0068	0.0390	0.0000	0.0266	0.0000	0.0414	0.1017	0.2155	
1998 Port/Airport	0.0000	0.0000	0.0000	0.0000	0.0197	0.0000	0.0000	0.0197	
1998 Quarry	0.0000	0.1025	0.0000	0.0000	0.0000	0.0241	0.0458	0.1723	
1998 Green Urban	0.0000	0.0000	0.0008	0.0000	0.0000	0.0000	0.0000	0.0008	
2012 Residential, new	0.0000	0.0116	0.0000	0.0052	0.0000	0.0000	0.0203	0.0371	
2012 Industrial, new	0.0068	0.0129	0.0030	0.0000	0.0007	0.0102	0.0312	0.0649	
2012 Port/Airport, new	0.0000	0.0000	0.0036	0.0000	0.0000	0.0000	0.0000	0.0000	
2012 Quarry, new	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	
2012 Green Urban, new	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	
2012 Agricultural landfill, new	0.0000	0.0076	0.0000	0.0000	0.0000	0.0000	0.0000	0.0076	
2012 Semi natural landfill, new	0.0000	0.0954	0.0000	0.0000	0.0000	0.0000	0.0997	0.1951	
1998 Green house	0.0029	0.0000	0.0000	0.0000	0.0000	0.0027	0.0364	0.0419	
2012 Green house, new	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0399	0.0399	
Tot. (1998+2012) dev. in LP (km²)	0.0389	0.1704	0.0083	0.1603	0.0557	0.0841	0.5425	tot. (1998+2012) dev. (km²)	**1.06**
Tot. 2012 dev. in LP (km²)	0.0068	0.0246	0.0030	0.0052	0.0007	0.0102	0.0914	tot. 2012 dev. (km²)	0.14
LP tot. 2012 dev./ MT tot. 2012 dev. (proportion)	0.0198	0.0713	0.0088	0.0151	0.0021	0.0295	0.2651		
LP tot. 2012 dev./ LP (km²/km²)	0.0002	0.0004	0.0004	0.0007	0.0001	0.0007	0.0008		
Rate 2012 dec (km²/yr-1)	0.0005	0.0018	0.0002	0.0004	0.0001	0.0007	0.0065		

OUTSIDE COMBINED DEVELOPMENT AND ENVIRONMENTAL DESIGNATIONS

Local Plan	CZLP	GCLP	GHLP	MSLP	MBLP	NHLP	NWLP		
Land use	km²	km²	km²	km²	km²	km²	km²	Sum land use class (km²)	
1998 Residential	0.3342	0.1493	0.1367	0.4734	0.1330	0.0666	0.4893	1.7825	
1998 Industrial	0.6029	0.2177	0.1632	1.6769	0.1964	0.0460	0.6590	3.5621	
1998 Port/Airport	0.0000	0.0230	0.0277	0.0194	0.0486	0.0000	0.0069	0.1256	
1998 Quarry	0.0544	0.0911	0.0000	0.7258	0.0000	0.0000	0.1021	0.9734	
1998 Green Urban	0.0148	0.0034	0.1024	0.0294	0.0093	0.0017	0.0877	0.2487	
2012 Residential, new	0.0406	0.0798	0.0000	0.0585	0.0159	0.0589	0.0765	0.3302	
2012 Industrial, new	0.2113	0.1640	0.0014	0.3966	0.0721	0.0185	0.2402	1.1042	
2012 Port/Airport, new	0.0000	0.0000	0.0000	0.0460	0.2373	0.0000	0.0177	0.3009	
2012 Quarry, new	0.0021	0.0603	0.0000	0.0989	0.0000	0.0000	0.0664	0.2278	
2012 Green Urban, new	0.0039	0.0000	0.0069	0.0367	0.0000	0.0073	0.0000	0.0548	
2012 Agricultural landfill, new	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	
2012 Semi natural landfill, new	0.0000	0.0512	0.0000	0.0000	0.0000	0.0000	0.0214	0.0726	
1998 Green house	0.0308	0.1111	0.0000	0.0475	0.0000	0.0000	0.1212	0.3106	
2012 Green house, new	0.0169	0.0253	0.0000	0.0445	0.0015	0.0000	0.1518	0.2400	
Tot. (1998+2012) dev. in LP (km²)	1.3119	0.9249	0.4383	3.6536	0.7141	0.1990	2.0189	tot. (1998+2012) dev. (km²)	**9.25**
Tot. 2012 dev. in LP (km²)	0.2748	0.3293	0.0083	0.6812	0.3268	0.0847	0.5527	tot. 2012 dev. (km²)	2.27
LP tot. 2012 dev./ MT tot. 2012 dev. (proportion)	0.1179	0.1413	0.0036	0.2923	0.1402	0.0364	0.2372		
LP tot. 2012 dev./ LP (km²/km²)	0.0083	0.0048	0.0010	0.0857	0.0264	0.0059	0.0048		
Rate 2012 dec (km²/yr-1)	0.0196	0.0235	0.0006	0.0487	0.0233	0.0061	0.0395		

Grech V. et al. (2025). *Xjenza Online*, 12(2):152–161.

Xjenza Online: Science Journal of the Malta Chamber of Scientists
www.xjenza.org
DOI: 10.7423/XJENZA.2024.3.05

Research Article

The Influence of Migration on Malta's Demographic Transition: An Observational Study

V. Grech[1], **S. Cuschieri***[2], **M. Gatt**[3], **C. Cordina**[3], **H. Scherb**[4], **N. Calleja**[3]
[1] *Department of Cardiology, Mater Dei Hospital, Msida, Malta*
[2] *Faculty of Medicine and Surgery, University of Malta, Msida, Malta*
[3] *Directorate for Health Information & Research, Ministry of Health, Msida, Malta*
[4] *Helmholtz Zentrum, German Research Center for Environmental Health, Munich, Germany*

Abstract. The demographic transition model (DTM) refers to the historical change from elevated birth and high death rates to low birth and low death rates in more advanced and higher education societies with higher levels of economic development. Malta is a small, central Mediterranean country (population ≈ 500,000) with a high influx of workers. This study was carried out to ascertain secular trends in births in Malta by nationality of mother, including age standardised fertility rates, population levels and employment trends. The study design uses ecological methodology. Births, age-specific fertility rates (ASFR), population and employment data were analysed for 2000-2020. Total births increased from 4,311 in 2000 to 4,420 in 2021 ($p = 0.0001$) as did proportion of non-Maltese births from 5.2 to 46.7% ($p < 0.0001$). Maltese ASFR only was in significant decline ($p = 0.0003$). Total population increased from 388,759 in 2000 to 520,971 in 2022 ($p < 0.0001$) as did the proportion of non-Maltese workers, which increased from 2.2% in 2000 to 20.6% in 2022 ($p < 0.0001$). Maltese and non-Maltese, part-time and full-time employment rates significantly increased ($p < 0.0001$). The proportion of non-Maltese increased for part-time and full-time workers also increased ($p < 0.0001$). Fertility is falling almost globally with ageing population and declining births and populations. In Malta, domestic labour supply cannot keep up with an influx of foreign workers, weathering its demographic transition at the expense of a rapidly expanding population but the long-term results are of significant concern as infrastructures may not cope and a substantial worker efflux for whatever reason could potentially precipitate a significant economic downturn.

Keywords: Demographic transition, Fertility, Malta, Migrants.

1 Introduction

The Total Fertility Rate (TFR) refers to the average number of children a woman is expected to have over her lifetime, given current birth rates. The Replacement Rate is the TFR needed to maintain a stable population size, without migration. In most developed countries, this rate is about 2.1 children per woman. The extra 0.1 accounts for childhood mortality or women who do not have children. If the TFR falls below 2.1, the population will eventually begin to decline, unless offset by immigration (Gietel-Basten & Scherbov, 2020).

In demography, the demographic transition model (DTM) refers to the historical change from elevated birth and high death rates in low technology, low education and poorly developed societies to low birth and low death rates in more advanced and higher education societies with higher levels of economic development (Galor, 2012; Lesthaeghe, 2020). DTM was first mooted in the late 1920s and early 1930s (Davis, 1945; Landry, 1987), and further refined in the following two decades (Woods, 2000). By the 21st century, DTM with a negative correlation between fertility and development/wealth had become an accepted tenet in social science (Lesthaeghe, 2020; Myrskylä et al., 2009). However, debate continues as to which is cause and effect: fertility or development/wealth (Lesthaeghe, 2020). It is also widely accepted that DTM occurs in phases:

The first stage is pre-industrial with high birth and rates in equilibrium with growth rates < 0.05%, as witnessed since the Agricultural Revolution circa 10,000 years ago since growth was constrained by a limited food supply

Correspondence to: S. Cuschieri (sarah.cuschieri@um.edu.mt)

(Chesnais, 1990; Lesthaeghe, 2020). This remained the case globally until the 18th century, whereupon this balance ended initially in Western Europe (Chesnais, 1990; Lesthaeghe, 2020).

In the second stage, in developing countries, death rates plummet due to a better food supply and improved sanitation, reducing disease and increasing life expectancy (Chesnais, 1990). This was first seen in Western Europe in the 18th century with large population increases (Chesnais, 1990; Lesthaeghe, 2020).

Some countries, particularly in Africa, remain stalled in this stage due to stagnant economic development, and this has in turn been attributed to under-investment, under-researched tropical diseases (e.g. Malaria and HIV), poor maternal education, declines in contraceptive use, increases in adolescent fertility, unmet needs for family planning advice and services and drug abuse (Affinnih, 2002; Ezeh et al., 2009; Schoumaker, 2019). However, this is a broad generalisation of an entire continent, with significant regional variations due to the diversity within the African continent regarding fertility trends (Tesfa et al., 2022).

The third stage results in a reduction in births with female education, contraception, and parental investment in childhood education resulting in population growth levelling off, as first witnessed in the late 19th century in northern Europe (Chesnais, 1990; Lesthaeghe, 2020).

In stage four, births drop further, sometimes well below replacement rates. This results in a shrinking workforce that must support the large and ageing cohort born during stage two. Death rates may actually rise slightly due to lifestyle diseases, such as lack of exercise, obesity and smoking (Chesnais, 1990; Lesthaeghe, 2020).

In the 18th century, Jewish populations of Moravia and Bohemia were some of the first populations to experience DTM, and this occurred prior to similar transitions occurring in other populations in this region, including other European Jews and Christians (Vobecká, 2013). Many countries have traversed DTM swiftly due to swift economic and social change (Chesnais, 1990; Lesthaeghe, 2020). Indeed, DTM has been experienced by almost all developing countries and in Europe for example, virtually all countries have total fertility rates below 2.1 (D'Alfonso et al., 2022)

This is different from the Epidemiologic Transition Model (ETM) which refers to the shift in the primary causes of mortality and disease in a society, due to changes in demographic and economic development. It identifies how disease patterns change as a country progresses through the demographic transition stages via The Age of Pestilence and Famine, The Age of Receding Pandemics, The Age of Degenerative and Man-Made Diseases, and The Age of Delayed Degenerative Diseases. Thus, DTM focuses on population changes (birth rates, death rates, and overall population size) due to economic and social development while ETM explains the shifts in causes of death and disease (from infectious to chronic diseases) as a society undergoes development (Yadav et al., 2022).

Malta is a small, central Mediterranean country that has reached a population of approximately half a million, increasing by 100,000 in the last decade alone (National Statistics Office, 2022) the highest proportionate increase in Europe. This has been due to an influx of workers in several industries, notably gaming, as well as workers attracted by resultant growth in collateral industries such as construction and the hospitality industry (M. G. Vella & Mintoff, 2022).

This study was carried out to ascertain secular trends in births in Malta by nationality of mother, including age standardised fertility rates, population levels and employment trends.

2 Materials and methods

2.1 Definitions

The World Health Organization (WHO) defines age-specific fertility rate (ASFR) as "the ratio of annual births to women at the same age or age-group, in the same year, for a given country, territory or geographical area". ASFR is a measure of the relative frequency of live births (per 1000 population) among different ages in females of reproductive potential. ASFR can then be used to compute Total Fertility Rate (TFR) (World Health Organisation, n. d.).

2.2 Data

Births by maternal nationality was obtained from the Malta's National Obstetric Information System (NOIS) for the period 2000-2021, as well as from Eurostat (European Commission, 2014; Ministry for Health and Active Aging, n. d.) Data was anonymised and aggregated by year. Population data was obtained from the website of the National Statistics Office Malta (nso.gov.mt). Employment data was obtained from the website of Jobsplus Malta (jobsplus.gov.mt). A copy of the data can be found in the Appendix.

Due to data anonymity, data protection and ethics approval were not required.

2.3 Statistical analysis

The ASFR was calculated for each year (2000 – 2021) then the TFR was computed. All tests were two-tailed.

Analyzing trends in demographic and epidemiological data is a straightforward statistical method for explor-

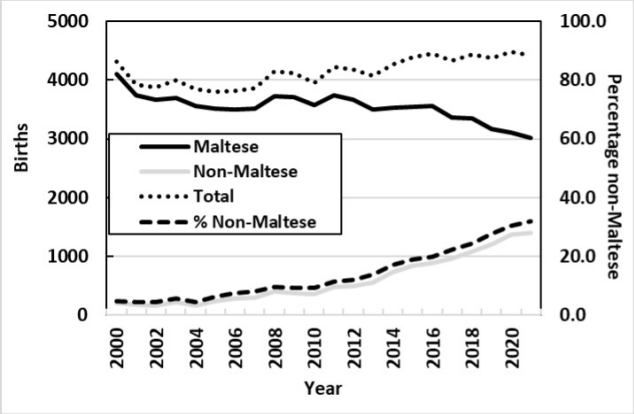

Figure 1: Births by nationality (Maltese and non-Maltese).

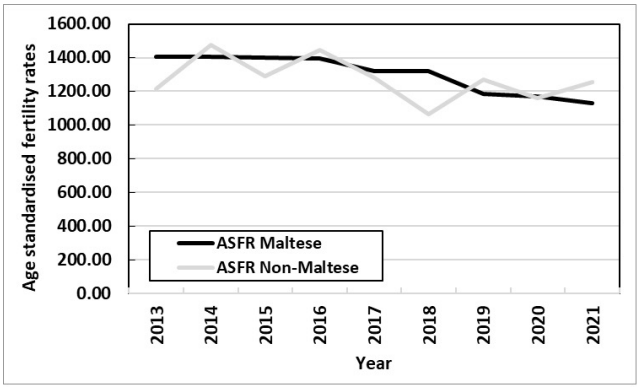

Figure 2: Age standardised fertility rates by nationality (Maltese and non-Maltese).

ing and answering scientific questions. Researchers often investigate hypotheses about how ecological and demographic variables evolve over time, along with their changing factors and interactions. These trends and changepoints can be visualized clearly, and their effects tested and measured using a variety of statistical techniques, including point and interval estimation.

Temporal trends were analysed with Kendall correlation and chi for trend using bespoke Excel spreadsheets (V. Grech, 2018a, 2018b) Kendall (non-parametric) correlation was preferred over Pearson (parametric) correlation due to the relatively small number of datapoints (just over 20). Chi for trend (Cochran-Armitage test for trend), is used to evaluate whether there is a linear trend in proportions across ordered categories and is commonly used where data is organized into contingency tables, and there is a hypothesis that proportions increase or decrease in a stepwise manner across categories. This is thus an extension of the chi-square test of independence but is specifically designed to assess trends.

Additionally, Poisson regression is commonly used for analysing absolute counts, and any overdispersion can be addressed by adjusting the covariance using the deviance divided by the degrees of freedom. These additional three tests were also performed

1. Log-linear Poisson regression (adjusted for overdispersion)
2. Negative Binomial regression
3. Two-way Anova

The main effects tested are time (year) and nationality (dummy variable: Maltese[0] vs. Non-Maltese[1]), the interaction tested is nationality x time.

The software tools utilized for this analysis included MS Excel 365, R version 3.5.1, Wolfram MATHEMATICA 11.3, and predominantly SAS/STAT software version 9.

A p value ≤ 0.05 was considered a statistically significant result.

3 Results

Births by nationality (77,821 Maltese and 12,959 non-Maltese, total 90780) are shown in Fig. 1. Total births increased significantly from 4,311 in 2000 to 4,420 in 2021 (Kendall's tau beta 0.61, $p = 0.0001$). The proportion of non-Maltese births increased significantly from 4.9 to 31.9% (chi for trend 1570.8, $p < 0.0001$). Age standardised fertility rates are shown in Fig. 2. Mean ASFR for Maltese and non-Maltese were 1302.66and 1272.27 respectively. The Maltese rate was in significant decline over the study period (Kendall's tau beta -1.06, $p = 0.0003$) while the non-Maltese rate showed no significant trends.

Population by nationality (Maltese and non-Maltese) are shown in Fig. 3. Total population increased significantly over the period studied from 388,759 in 2000 to 520,971 in 2022 (Kendall's tau beta 1.0, $p < 0.0001$). The proportion of non-Maltese increased significantly from 2.2% in 2000 to 20.6% in 2022 (chi for trend 100149.9, $p < 0.0001$). Employment by nationality (Maltese and non-Maltese, part-time and full-time) are shown in Fig. 4. Maltese full time increased from 133,136 in 2002 to 171,477 in 2022, part-time from 16418 to 27663, non-Maltese full time from 3,514 to 91,284, part-time from 340 to 5,686. All four trends were significant (Kendall's tau beta 0.99, $p < 0.0001$). The proportion of non-Maltese increased for both part-time and full-time workers increased significantly, the former from 2.6% to 34.7%, the latter from 2.0 to 17% (chi for trend 79676.5 and 6816.0 respectively, $p < 0.0001$).

Poisson regression and negative Binomial regression expectedly yield nearly identical estimates with similar precision. All effects are highly significant ($p \leq 0.0005$). Concerning the significance of the nationality x time in-

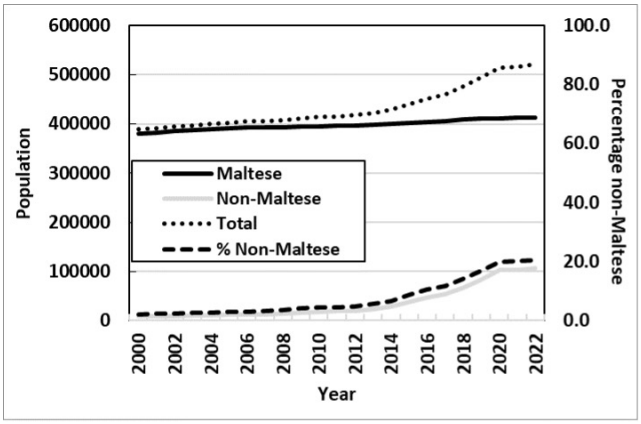

Figure 3: Population by nationality (Maltese and non-Maltese).

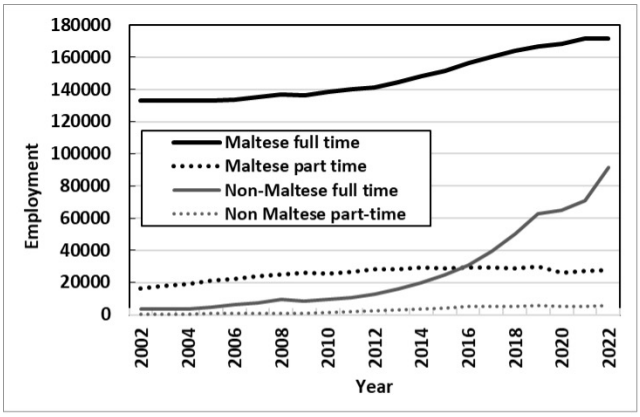

Figure 4: Employment by nationality (Maltese and non-Maltese, part-time and full-time).

teraction, a two-way ANOVA confirms the results of the regression analyses (Tab. 1, and Figs. 5 and 6).

3.1 Discussion

Thus far, Malta has evaded or delayed the seemingly inevitable demographic transition. However, this must be taken in terms of the global and temporal context. Since the Industrial Revolution circa 250 years ago, global wealth and population have surged, but for the first time since the world was afflicted by Bubonic plague (Durand, 1977), the population may shrink dramatically due to a collapse in birth rates (The Economist, 2023). In 2000 the global fertility rate was 2.7 births/woman, above the 2.1 replacement rate at which a population is stable. In 2021, this figure was 2.21 and falling (Statista, n. d.) The fertility rate of the fifteen largest economies by gross domestic product have fertility rates below the replacement rate and this includes most developed countries as well as China and India i.e., more than a third of the global population (The Economist, 2023) Malta's total fertility rate in 2021 was the lowest in the EU at 1.13 (Eurostat, n. d.).

It has been speculated that DTM occurs due to "shifting priorities" which reflect changes in preferences not only for having children, but also parenting norms and life aspirations (Kearney et al., 2022) Declining marriage rates, an increase in the average marriage age, natural loss of fertility with higher age at attempted pregnancy and concerns regarding the economic burdens of having children have also been mooted (Cabinet Office, 2022; Iijima & Yokoyama, 2018) The end result of DTM is a rise in a country's median age and a growing proportion of retirees, coupled with a shrinking labour force (Kuhn & Neusius, 2022). This transition has occurred in most industrialized countries since the end of the nineteenth century albeit in different ways and rates due to social, political and economic differences (Galor, 2012; Lesthaeghe, 2020)

For example, a declining birth rate in the United Kingdom was remarked upon in the medical literature as far back as 1914 (Dunlop, 1914). A similar reduction was noted in the United States since the Great Depression of 1929 – 1939, a decline in almost all groups including teens, Hispanics and college-educated white women (Kearney et al., 2022). The transition has been even more acute in countries such as Japan and Italy (Cabinet Office, 2022; Iijima & Yokoyama, 2018). Furthermore, certain regions of Spain such as the Basque country and Galicia have birth rates below 1 (Bosch, 1998) Indeed, even in China, TFR fell to 1.3 in 2020 (Kuhn & Neusius, 2022).

This transition has also been seen in smaller European countries (like Malta), such as in Luxembourg, wherein younger individuals (aged 0-19 years) are relatively becoming less numerous, while the population bands aged 40-64 and 80 and over is increasing in relative terms (Statistiques.lu, n. d.). The same type of change is also seen in Cyprus, another small European country (Lamnisos et al., 2021).

Most governments view DTM with ensuing aging and declining populations as threats to national influence and to the welfare state (Cincotta & Weber, 2021; de Kaa, 1987). Pronatalist incentives such as restrictions on termination of pregnancy and economically costly state incentives to boost family sizes have repeatedly failed (Cincotta & Weber, 2021; de Kaa, 1987), with very few notable exceptions (Lalljee, 2023). Many countries have imposed strict controls on migration and have attempted integration of these minorities, typically without success (Cincotta & Weber, 2021; de Kaa, 1987).

Malta has experienced continuous economic growth, prosperity and quality of life since the 1960s, shifting from one of the largest relative deficits in the euro area to one

Method	Maximum Likelihood Analysis						
Poisson regression adjusted for overdispersion	Parameter	DF	Estimate	SE	Wald 95 % CL		Wald ChiSq	*p* value
	Intercept	1	8.360	0.032	8.297	8.424	66428.700	< 0.0001
	Nationality	1	-4.807	0.111	-5.025	-4.589	1866.280	< 0.0001
	Time	1	-0.008	0.001	-0.011	-0.005	34.960	< 0.0001
	Nationality x Time	1	-4.807	0.111	-5.025	-4.589	1866.280	< 0.0001
	Scale		2.388	0.000	2.388	2.388		
Negative binomial regression	**Maximum Likelihood Analysis**							
	Parameter	DF	Estimate	SE	Wald 95 % CL		Wald ChiSq	*p* value
	Intercept	1	8.363	0.057	8.251	8.474	21600.400	< 0.0001
	Nationality	1	-4.783	0.099	-4.977	-4.590	2350.410	< 0.0001
	Time	1	-0.008	0.002	-0.013	-0.004	12.290	0.0005
	Nationality x Time	1	0.117	0.004	0.110	0.125	915.050	< 0.0001
	Scale		0.003	0.001	0.001	0.007		
Two-way ANOVA	**ANOVA table ($R^2 = 0.9991$)**							
	Parameter	DF	Anova SS		mean square		*F* value	*p* value
	Intercept	1	95615432.82		95616432.82		20773.9	< 0.0001
	Nationality	1	629728.30		57248.03		12.44	< 0.0001
	Nationality x Time	11	3932645.93		357513.27		77.68	< 0.0001

Table 1: Log-linear Poisson regression (adjusted for overdispersion), Negative Binomial regression and Two-way Anova, with main effects time (year) and nationality (dummy variable: Maltese[0] vs. Non-Maltese[1]), as well as the interaction nationality x time. DF — degrees of freedom; SE — standard error; CL — confidence limits; SS — sum of squares.

of the highest surpluses and this has been ascribed to structural developments, such as improving energy facilities and a decline in import content (A. G. Grech, 2019). Indeed, Malta has developed from a military base into a resilient, robust and diversified economy, despite constraints on natural resources (Malta Employers' Association, 2017). This has been variously attributed to a strong sense of entrepreneurship, to new job creation, a hardworking and flexible labour force, a cohesive society with positive values, infrastructure investment and European Union membership (Malta Employers' Association, 2017). The downside is that wealth inequality has increased significantly over these decades (Georgakopoulos, 2019). Furthermore, the country faces infrastructural challenges that have reduced its attractiveness to investors. Indeed, a recent survey of foreign direct investor companies showed that 70% of respondents view Malta's infrastructure as inadequate to support the anticipated population expansion and an additional 19% perceive infrastructure planning and development as neither adequate nor inadequate, implying a sense of uncertainty/ambivalence with regard to the country's readiness for such population expansions. It is clear that "the growing demands of a rapidly expanding population and economy are exerting considerable pressure on existing systems, highlighting the urgency for comprehensive and forward-thinking infrastructure development" (EY, 2024). Furthermore, Malta needs economic diversification not only by the addition of new sectors, but also by diversifying existing ones to create a state of readiness and resilience in the face of potential economic shocks (Weekly, 2024).

However, Malta's population is rapidly ageing, a typical fourth phase DTM with increasing life expectancy and decreasing fertility rates (Formosa, 2019), with over 18% of the total population aged 65+ years in 2017, and with projections expecting this country to have one of the fastest ageing populations in Europe (M. Vella & von Brockdorff, 2019) Projections estimate that the 65+ and 80+ aged populations will climb from 17.5% and 3.8% in 2013 to 28.5% and 10.5% of the total population by 2060 (M. Vella & von Brockdorff, 2019). Unmitigated, this will impact the labour market, health care, and long-term care (M. Vella & von Brockdorff, 2019).

Nevertheless, despite low unemployment and increased female participation in the workforce, the domestic labour supply has been unable to keep up with demand and with the skillsets needed.(Malta Employers' Association, 2017). This has resulted in a progressive increase in foreign employees, with 18% of the workforce being foreign in 2017 (Malta Employers' Association, 2017).

Thus, from a protectionist mentality, the country has

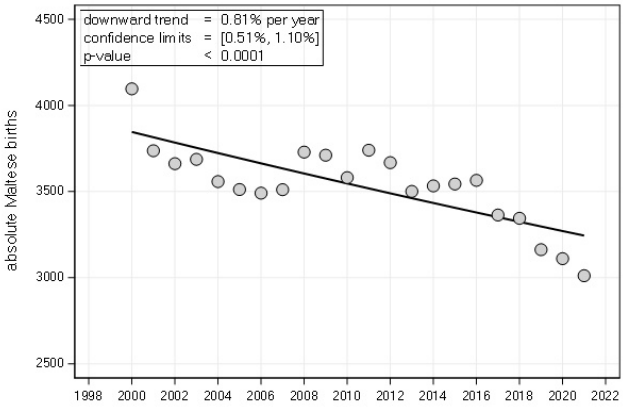

Figure 5: Births in Malta and log-linear Poisson regression trend: Maltese births

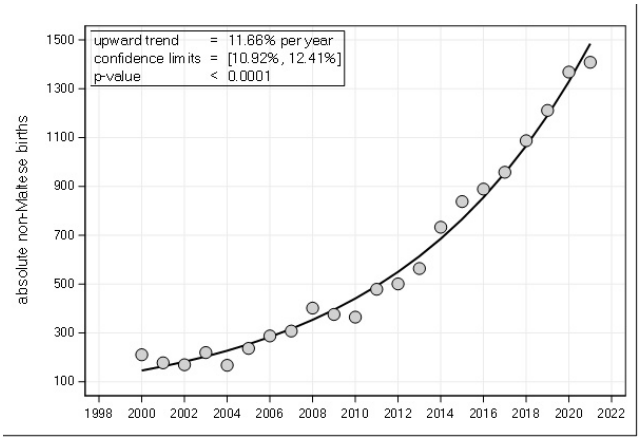

Figure 6: Births in Malta and log-linear Poisson regression trend: non-Maltese births

moved to embrace these workers as necessary to sustain economic growth (Malta Employers' Association, 2017). This is potentially dangerous in that foreign workers are now vital for continuing economic growth under current economic conditions, a potential vicious cycle that challenges Malta's size and the sustainability of the entire economic model (Malta Employers' Association, 2017). This has also been clearly identified as a sustainability threat by the European Commission (European Union, 2020). Indeed, current projections envisage even more foreign workers, such that if the public sector employs 50,000 persons from an estimated labour force of 220,000, > 30% of private sector employees will be foreign, and 30% of Maltese employees will be employed in the public sector since virtually all foreigners are employed in the private sector (Malta Employers' Association, 2017). The trends are concerning - Malta's current Finance Minister has referred to a study by Malta's Economic Policy Department which showed that to maintain an economic growth rate of 4.2%/annum (as recently experienced) with the current economic model, Malta's population would have to increase to 800,000 by 2040, unless a new economic model was developed (N. Borg, 2023).

This is a potentially volatile population proportion as it has been shown that 45% of foreign workers left Malta after a period of between one and two years and only circa 30% remain in the Maltese labour for longer (I. Borg, 2019). This significantly lowers these workers' rate of local economic assimilation (I. Borg, 2019). Furthermore this high worker turnover places significant pressures on the human resource departments, and this is aggravated by the need to source workers from overseas (I. Borg, 2019). Any cyclicality that precipitates significant foreign worker exodus would drop the economy into recession, decreasing labour demand and further exacerbating the exodus in their search for work outside the country, and a recovery phase would be prolonged by the need to reimport workers (I. Borg, 2019).

4 Conclusion

Malta has changed from a country of emigrants to one of returning Maltese emigrants along with an international influx of workers of diverse nationalities and skillsets. The country has been likened to an economic miracle with social and economic metrics comparable with those of the world's major economies (Malta Employers' Association, 2017). It has been stated that "immigration as a solution is unfeasible" (Cincotta & Weber, 2021; de Kaa, 1987), however, Malta appears to have been weathered the European Union's DTM (Palma, 2021; Pinkerton, 1995), with a slow but steady population rise due to an influx of non-Maltese workers (M. G. Vella & Mintoff, 2022) coupled with an increased proportion of births from these workers that has mitigated the drop in Maltese births, as shown in this study. This has bolstered the workforce and since these workers pay tax and national insurance contributions, DTM and its negative consequences have been thus far averted but the long-term results are of significant concern.

Conflict of interest statement The authors all declare no competing interests. This research received no specific grant from any funding agency, commercial entity or not-for-profit organization.

References

Affinnih, Y. H. (2002). Revisiting sub-Saharan African countries' drug problems: Health, social, economic costs, and drug control policy. *Substance Use & Misuse*, *37*(3), 265.

Borg, I. (2019). The length of stay of foreign workers in Malta.

Borg, N. (2023). Malta's population could increase to 800,000 by 2040 - clyde caruana. *Times of Malta*.

Bosch, X. (1998). Investigating the reasons for Spain's falling birth rate. *The Lancet*, *352*(9131), 887.

Cabinet Office. (2022). *Annual report on the declining birthrate 2022 (summary)* (tech. rep.).

Chesnais, J.-C. (1990). Demographic transition patterns and their impact on the age structure. *Population and Development Review*, 327–336.

Cincotta, R., & Weber, H. (2021). Youthful age structures and the risks of revolutionary and separatist conflicts. In *Global political demography: The politics of population change* (pp. 57–92). Springer International Publishing Cham.

D'Alfonso, A., Ludovisi, M., Palermo, P., Serva, A., Polsinelli, V., Bruno, M., Tiberi, A., Tabacco, S., Di Florio, C., & Guido, M. (2022). Sex ratio at birth: Causes of variation and narrative review of literature. *Minerva Obstetrics and Gynecology*.

Davis, K. (1945). The world demographic transition. *The Annals of the American Academy of Political and Social Science*, *237*(1), 1–11.

de Kaa, D. J. (1987). Europe's second demographic transition. *Population Bulletin*, *42*(1), 1–59.

Dunlop, B. (1914). The falling birth-rate. *British Medical Journal*, *1*(2775), 566–567.

Durand, J. D. (1977). Historical estimates of world population: An evaluation. *Population and Development Review*, *3*(3), 253–296.

European Commission. (2014). Eurostat statistics database.

European Union. (2020). EUR-Lex - 52020SC0517 - EN - EUR-Lex [Accessed: February 20, 2025].

Eurostat. (n. d.). Fertility statistics - statistics explained [Accessed: February 20, 2025].

EY. (2024). Future realized. ey attractiveness survey malta - 20 years on.

Ezeh, A. C., Mberu, B. U., & Emina, J. O. (2009). Stall in fertility decline in Eastern African countries: Regional analysis of patterns, determinants and implications. *Philosophical Transactions of the Royal Society of London. Series B, Biological Sciences*, *364*(1532), 2991–3007.

Formosa, M. (2019). Measuring and modelling demographic trends in Malta: Implications for ageing policy. *International Journal on Ageing in Developing Countries*, *4*(2), 78–90.

Galor, O. (2012). The demographic transition: Causes and consequences. *Cliometrica*, *6*(1), 1–28.

Georgakopoulos, I. (2019). Income and wealth inequality in Malta. *International Journal of Social Science Studies*, *7*, 58–71.

Gietel-Basten, S., & Scherbov, S. (2020). Exploring the 'true value' of replacement rate fertility. *Population Research and Policy Review*, *39*(4), 763–772.

Grech, A. G. (2019). From a deficit to a surplus country: The case of malta. *European Scientific Journal*, *15*(4), 130–142.

Grech, V. (2018a). Wasp (write a scientific paper) using excel - 10: Contingency tables. *Early Human Development*, *121*, 65–68.

Grech, V. (2018b). Wasp (write a scientific paper) using excel - 13: Correlation and regression. *Early Human Development*, *122*, 60–63.

Iijima, S., & Yokoyama, K. (2018). Socioeconomic factors and policies regarding declining birth rates in japan. *Nihon eiseigaku zasshi. Japanese journal of hygiene*, *73*(3), 305–312.

Kearney, M. S., Levine, P. B., & Pardue, L. (2022). The puzzle of falling US birth rates since the great recession. *Journal of Economic Perspectives*, *36*(1), 151–176.

Kuhn, B., & Neusius, T. (2022). Will China's three-child policy defuse the demographic time bomb?

Lalljee, J. (2023). Japanese town with high birth rate charges visitors to learn its baby-making tips.

Lamnisos, D., Giannakou, K., & Jakovljevic, M. M. (2021). Demographic forecasting of population aging in Greece and Cyprus: One big challenge for the Mediterranean health and social system long-term sustainability. *Health Research Policy and Systems*, *19*(1), 21.

Landry, A. (1987). Adolphe Landry on the demographic revolution. *Population and Development Review*, *13*(4), 731–740.

Lesthaeghe, R. (2020). The second demographic transition, 1986–2020: Sub-replacement fertility and rising cohabitation-a global update. *Genus*, *76*, 1–38.

Malta Employers' Association. (2017, November). *Malta's demographic challenges a position paper by the Malta Employers' Association* (tech. rep.).

Ministry for Health and Active Aging. (n. d.). Directorate for health information and research [Accessed: February 20, 2025].

Myrskylä, M., Kohler, H.-P., & Billari, F. C. (2009). Advances in development reverse fertility declines. *Nature*, *460*(7256), 741–743.

National Statistics Office. (2022). *Census of population and housing 2021: Final report: Population, migration and other social characteristics (volume 1)* (tech. rep.).

Palma, A. (2021). Fertility trends in european countries. *Acta Universitatis Lodziensis. Folia Oeconomica*, *2*(353), 7–28.

Pinkerton, D. (1995). The european experience of declining fertility: A quiet revolution, 1850-1970. *Continuity and Change*, *10*(2).

Schoumaker, B. (2019). Stalls in fertility transitions in sub-Saharan Africa: Revisiting the evidence. *Studies in Family Planning*, *50*(3), 257–278.

Statista. (n. d.). World - fertility rate 2011-2021 [Accessed: February 20, 2025].

Statistiques.lu. (n. d.). Evolution of the population [Accessed: February 20, 2025].

Tesfa, D., Tiruneh, S. A., Gebremariam, A. D., Azanaw, M. M., Engidaw, M. T., Kefale, B., Abebe, B., Dessalegn, T., & Tiruneh, M. (2022). The pooled estimate of the total fertility rate in sub-Saharan Africa using recent (2010-2018) demographic and health survey data. *Frontiers in Public Health*, *10*, 1053302.

The Economist. (2023). Global fertility has collapsed, with profound economic consequences. *The Economist*.

Vella, M., & von Brockdorff, P. (2019). Pensions across generations: Scenarios for the maltese islands. *Journal of International and Comparative Social Policy*, *35*(3), 280–298.

Vella, M. G., & Mintoff, Y. (2022). *Debt and domination: Maltas usurious economy* (tech. rep. No. 02 / 2022 D). OCCASIONAL PAPERS ON ISLANDS and SMALL STATES.

Vobecká, J. (2013). *Demographic avant-garde: Jews in Bohemia between the enlightenment and the shoah*. Central European University Press.

Weekly, T. M. B. (2024). Malta needs economic diversification not just in new sectors, but also existing ones.

Woods, R. (2000). *The demography of victorian England and Wales* (Vol. 35). Cambridge University Press.

World Health Organisation. (n. d.). Specific fertility rate in women 15-19 years of age.

Yadav, S., Perianayagam, A., Patel, S. A., & Cunningham, S. A. (2022). The role of age inequalities in cause of death in the slow pace of epidemiological transition in India. *Scientific Reports*, *12*(1), 20291.

Appendix A—Data for Figure 1

	Births			
Year	**Maltese**	**Non-Maltese**	**Total**	**% Non-Maltese**
2000	4096	211	4311	4.9
2001	3737	178	3918	4.5
2002	3662	170	3873	4.4
2003	3687	220	3995	5.6
2004	3558	168	3838	4.5
2005	3512	237	3804	6.3
2006	3491	288	3822	7.6
2007	3511	308	3853	8.1
2008	3729	402	4154	9.7
2009	3711	376	4112	9.2
2010	3581	365	3952	9.2
2011	3740	479	4226	11.4
2012	3668	501	4175	12.0
2013	3501	564	4073	13.9
2014	3533	733	4275	17.2
2015	3544	838	4385	19.1
2016	3565	889	4455	20.0
2017	3364	958	4325	22.2
2018	3345	1087	4434	24.5
2019	3163	1211	4379	27.7
2020	3111	1368	4481	30.5
2021	3012	1408	4420	31.9

Appendix Appendix B—Data for Figure 2

Age standardised fertility rate		
Year	ASFR-Maltese	ASFR-Non-Maltese
2013	1403.63	1214.72
2014	1403.26	1475.06
2015	1402.01	1290.20
2016	1393.66	1444.93
2017	1320.81	1280.30
2018	1319.41	1063.06
2019	1184.19	1270.95
2020	1167.45	1157.91
2021	1129.57	1253.27

Appendix Appendix C—Data for Figure 3

	Population			
Year	Maltese	Non-Maltese	Total	% Non-Maltese
2000	380201	8558	388759	2.2
2001	382525	8890	391415	2.3
2002	385077	9564	394641	2.4
2003	386938	10358	397296	2.6
2004	388867	11000	399867	2.8
2005	390669	11999	402668	3.0
2006	392840	12159	405616	3.0
2007	392215	13401	405616	3.3
2008	393107	14725	407832	3.6
2009	394135	16791	410926	4.1
2010	395075	18952	414027	4.6
2011	395850	19139	414989	4.6
2012	397244	20302	417546	4.9
2013	398898	23611	422509	5.6
2014	400404	29020	429424	6.8
2015	401868	37823	439691	8.6
2016	403480	46935	450415	10.4
2017	405976	54321	460297	11.8
2018	408556	67145	475701	14.1
2019	410292	83267	493559	16.9
2020	411384	103180	514564	20.1
2021	412382	103718	516100	20.1
2022	413597	107374	520971	20.6

Appendix Appendix D—Data for Figure 4

	Maltese		Non-Maltese	
Year	Maltese full time	Maltese part time	Non-Maltese full time	Non-Maltese part time
2002	133136	16418	3514	340
2003	132841	17723	3350	420
2004	133210	19276	3617	501
2005	133144	20948	4726	617
2006	133597	22353	6132	707
2007	135130	24017	7484	707
2008	136788	25103	9262	725
2009	136166	26234	8712	818
2010	138285	25803	9529	1158
2011	140101	26720	10708	1680
2012	141409	28092	12637	2205
2013	144526	28468	15842	2849
2014	148494	29401	19793	3778
2015	151748	28942	24682	4321
2016	156226	29351	30811	4955
2017	160366	29302	39234	5175
2018	164192	29063	50254	5394
2019	166758	29969	62563	5473
2020	168368	26154	65094	5281
2021	171395	26990	71110	5285
2022	171477	27663	91284	5686

Bianchi, R. (2024). *Xjenza Online*, 12(2):162.

Xjenza Online: Science Journal of the Malta Chamber of Scientists
www.xjenza.org

News Article

Connect, Collaborate, Conquer: How OiPub Transforms Research Discovery and Discussion

R. Bianchi[*1]
[1] *Independent Researcher, Lija, Malta*

Figure 1: Scan the QR code to explore and discuss cutting-edge research at OiPub.com—join a community of curious minds today!

Keeping up to date with Research is HARD WORK. More and more research is published each year. It is hard to find the research that matters, that elusive work that is perfectly relevant, well written and not 10 years out-of-date. You have got that experiment to run, lectures, various meetings, conferences, articles to write, a few peer reviews and perhaps among all that you might even get some work done on that very important thing you are working on. The one that will hopefully change the world but you never have time for.

Keeping up to date with the latest research is hard work. That is what inspired us to create OiPub. OiPub is a new web platform for researchers where all research papers and outputs are automatically organised into topic streams that you can either access directly, or easily combine into research communities following multiple topics to create a custom stream of information and discussion in any research niche you may desire.

All research in topics and communities is automatically populated. We use international data sources including CrossRef and OpenAire, along with our Natural Language Processing (NLP) topic-recognition systems and custom community relevance and impact metrics algorithms.

This effectively results in custom steams of information that you can use as an efficient literature review in any and every research niche you desire, to keep up to date ("Hot" and "Latest" sort) or find the foundational papers ("Top" sort). These sort options take into account the relevance, impact and recency of a paper such that you can find exactly what you need. Moreover, discussions can also be broadcast by topic, such that any and all interdisciplinary communities following the topic see that discussion and can contribute. The aim here is to reach everyone interested in that topic, both for wider outreach from direct colleagues, as well as from experts in other overlapping fields you may never have thought would be interested.

OiPub is available now in public beta at oipub.com. Development of OiPub was supported by the Malta Council for Science and Technology (MCST). The project was further bolstered by substantial backing from major European initiatives such as the European Open Science Cloud Digital Innovation Hub (EOSC-DIH), the European Grid Infrastructure (EGI), and OpenAIRE.

For more information, please contact us on info@oipub.com

Join us in our mission to make research more accessible and impactful for everyone.

**Correspondence to*: R. Bianchi (robert@oipub.com)

Mifsud, D.V. et al. (2024). *Xjenza Online*, 12(2):163–165.

Xjenza Online: Science Journal of the Malta Chamber of Scientists
www.xjenza.org

News Article

The 2024 COPCA Conference in Valletta

D. V. Mifsud[1*], R. Attard-Trevisan[2], A. V. Verkhovtsev[3], and N. J. Mason[1,4]
[1] *HUN-REN Institute for Nuclear Research (Atomki), Debrecen , Hungary*
[2] *School of Chemistry and Forensic Science, University of Kent, Canterbury, United Kingdom*
[3] *MBN Research Center, Altenhöferallee 3, Frankfurt am Main, Germany*
[4] *School of Physics and Astronomy, University of Kent, Canterbury, United Kingdom*

The physical and chemical changes induced by collision processes are of indisputable significance to various fields of scientific inquiry. Indeed, the transfer of energy during a collision needs to be investigated over multiple spatial and energetic scales, ranging from the nanoscale (e.g., nanolithographic fabrication techniques during focused electron beam induced deposition) (De Teresa et al., 2016; Huth et al., 2012) to the cosmic scale (e.g., cometary or asteroidal impacts with planetary bodies in the Solar System) (Gisler et al., 2011; Toon et al., 1997). The evident multidisciplinary nature of collisions research therefore means that experimental and theoretical methodologies used in one particular field of research may prove useful to solving outstanding problems in another (Solovyov et al., 2024), and thus cross-disciplinary collaborations should be encouraged and fostered in order to further advance the current status of investigative research work. Such was the primary motivation of the inaugural *Collisions Physics and Chemistry and their Applications* (COPCA) *Conference*, held in Valletta in 2022: to bring together researchers from apparently disparate fields whose work relates broadly to collisions on the nano-, meso- and macroscales so as to provide new insights into ongoing research projects as well as foster the establishment of new collaborations.

Following the success and popularity of the 2022 COPCA Conference (Mifsud et al., 2023), it was decided that a follow-on event should be held in 2024. The second iteration of the COPCA Conference was successfully held between 15th – 18th October 2024 at the Valletta Campus of the University of Malta. This year, the Conference was held in concert with a workshop of the COST Action CA20129: *Multiscale Irradiation and Chemistry Driven Processes and Related Technologies* (MultIChem),[1] chaired by Dr Alexey V. Verkhovtsev. The MultIChem COST Action aims to establish a broad, international, interdisciplinary, and intersectoral cooperation aimed at advancing our fundamental understanding of multiscale irradiation-driven processes and related technologies that will allow for major scientific and technological breakthroughs and socio-economic impacts. Through its consideration of the physical and chemical processes induced by the interaction of radiation (e.g., ions, electrons, photons) with matter, which are essentially collisions on the nanoscale, the research interests of the MultIChem COST Action align very closely with those of COPCA Conference. The logos of the COPCA Conference and the MultIChem COST Action are depicted in Figure 1.

The conference programme included a number of sessions on different aspects of collisions physics and chemistry, with a slight emphasis on irradiation-induced phenomena. Such topics included: (i) the use of modelling as a tool for understanding multiscale chemical systems and irradiation-driven phenomena, (ii) the application of high-energy science and the use of synchrotrons and plasmas, (iii) interactions between electrons and molecules, (iv) the applications of radiation science to biology and health sciences, (v) the applications of radiation research to nanoscience and materials engineering, and (vi) radiation and spectroscopy in astrochemical research. An early career researcher (ECR) presentation competition was also held at the end of the first day of the Conference, in which ECRs were given 12 minutes to orally present their PhD or postdoctoral projects. These presentations were then scored by all conference delegates according to pre-selected criteria.

The Conference also included a number of social events

[1] Websites: https://www.cost.eu/actions/CA20129/ and https://www.mbnresearch.com/ca20129-multichem/main

**Correspondence to*: D. V. Mifsud (mifsud.duncan@atomki.hu)

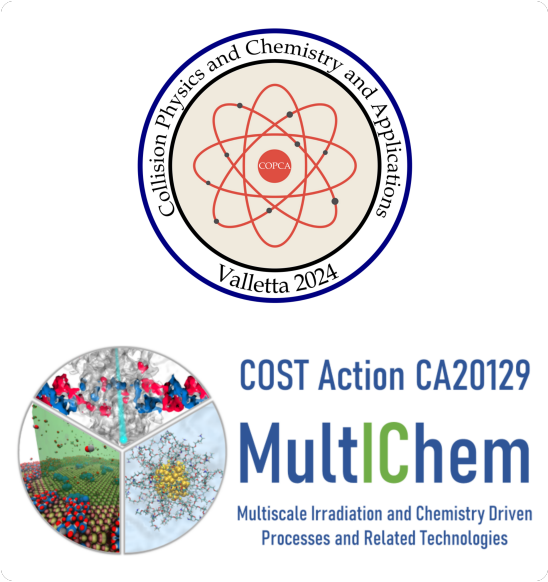

Figure 1: Logos of the 2024 COPCA Conference (*top*) and the MultIChem COST Action (*bottom*).

on Thursday 17th October, including a tour of the Hagar Qim and Mnajdra megalithic temples, where the conference photograph was taken (Figure 2). Immediately following this, a conference dinner was held at the Trattoria AD1530 restaurant in Mdina, during which prizes for the best ECR presentations were awarded. First, second, and third place prizes were respectively awarded to Cauê Souza (Univesity of Kent, United Kingdom), David Matalon (Open University, United Kingdom), and Lars Borchert (Aarhus University, Denmark) by Prof. Nigel J. Mason in his capacity as conference co-organiser. In addition to these prizes, the organising committee of the Conference also awarded Dr Irina Solovyeva the COPCA Dedication to Science Prize in recognition of her commitment to fostering pan-European scientific collaboration.

The Conference itself proved to be a resounding success, and a fitting sequel to the inaugural conference held in 2022. The Conference allowed for collaborators who had previously met in 2022 to meet once again and renew their joint research efforts, as well as for new collaborations to be formed between researchers who had not previously met. Overall, the Conference was attended by 63 delegates and their accompanying persons from universities and research institutes in 15 different countries: Austria, Czechia, Denmark, France, Germany, Hungary, India, Italy, Kazakhstan, Latvia, Malta, Poland, Slovakia, Serbia, and the United Kingdom. The success of the Conference was also gauged through post-meeting evaluation forms that were distributed online to the delegates. A total of 37% of delegates anonymously provided feedback through these forms, with 100% of responding delegates indicating that they were either satisfied or very satisfied with their experience of COPCA 2024 and that they would be interested in attending a future edition of the Conference. Moreover, 96% of responding delegates were satisfied with the scientific programme of the Conference, while 91% were satisfied with the venue and daily catering provided.

Following the conclusion of the 2022 COPCA Conference, a number of areas of improvement were identified for subsequent iterations of the Conference, which were accordingly adopted as goals for the 2024 COPCA Conference. The first of these goals was to increase the participation of female researchers of all career stages: in 2022, only 16% of presentations were delivered by female researchers. In the 2024 COPCA Conference, this share was increased to 23%, with female researchers also acting as chairs for 25% of the sessions held. Although such figures are reflective of a gender imbalance across science in general and physical sciences in particular, it is encouraging to note that the fraction of female presenters at the COCPA Conference is increasing. Indeed, a further increase in the representation of female scientists and researchers will be targeted for future iterations of the Conference.

The second goal that had been outlined in 2022 was the greater internationalisation of the COPCA Conference, with a specific aim to increase the participation of researchers based beyond Europe. In 2022, only one Conference delegate was based at a research institution located outside of Europe (in that year, the delegate had travelled from Colombia). In 2024, this number quadrupled, with researchers based in Kazakhstan and India travelling to Malta to attend the Conference. The increased internationalisation of the COPCA Conference is partly the result of the collaborations established during its previous iteration, and a contribution from different regions of the world will be sought in future events.

The final goal set in 2022 was the increased participation in the Conference of researchers based at the University of Malta, as well as Maltese nationals based abroad. In this regard, the 2024 COPCA Conference was not as successful as the 2022 edition. To entice both demographics (i.e., academics based at the University of Malta as well as Maltese nationals based abroad working or performing research in relevant fields) to attend the 2024 COPCA Conference, it was decided that no conference fee would be levied for these individuals. However, and in spite of a number of invitations being sent to academics working in various Departments of the University of Malta, no presentation at the Conference was delivered by a staff member or student based at the University of Malta. Furthermore, only two of the delivered presentations were

Figure 2: Conference photograph of the 2024 COPCA Conference, taken in front of the Mnajdra megalithic temple during the social excursion.

given by Maltese nationals based abroad. Should future editions of the Conference be held in Malta, more concerted efforts will be made to further encourage local researchers as well as Maltese nationals based abroad to attend and contribute their expertise and research findings.

In conclusion, the success of the 2024 COPCA Conference justifies a future iteration of the event, which is planned to be held in 2026. Aside from the aforementioned goals aimed at increasing the participation of various groups in future versions of the Conference, the next COPCA Conference will also aim to better formalise international and cross-disciplinary collaborations through official European funding streams.

Acknowledgements The authors gratefully acknowledge the Sir John and Lady Mason Academic Trust for assistance in organising the 2024 COPCA Conference. The 2024 COPCA Conference was financially sponsored by Frontiers, and N.J. Mason acknowledges an editorial position at the journal *Frontiers in Physics*. This paper is also based on work from the COST Action CA20129 MultIChem, supported by COST (European Cooperation in Science and Technology). R. Attard-Trevisan gratefully acknowledges the receipt of an EPSRC-DTA PhD Scholarship.

References

De Teresa, J., Fernández-Pacheco, A., Córdoba, R., Serrano-Ramón, L., Sangiao, S., & Ibarra, M. R. (2016). Review of magnetic nanostructures grown by focused electron beam induced deposition (febid). *Journal of Physics D: Applied Physics*, *49*(24), 243003.

Gisler, G., Weaver, R., & Gittings, M. (2011). Calculations of asteroid impacts into deep and shallow water. *Pure and Applied Geophysics*, *168*, 1187–1198.

Huth, M., Porrati, F., Schwalb, C., Winhold, M., Sachser, R., Dukic, M., Adams, J., & Fantner, G. (2012). Focused electron beam induced deposition: A perspective. *Beilstein Journal of Nanotechnology*, *3*(1), 597–619.

Mifsud, D. V., Attard-Trevisan, R., & Mason, N. J. (2023). The 2022 copca conference in valletta. *Xjenza Online*, *11*, 89–92.

Solovyov, A. V., Verkhovtsev, A. V., Mason, N. J., Amos, R. A., Bald, I., Baldacchino, G., Dromey, B., Falk, M., Fedor, J., Gerhards, L., et al. (2024). Condensed matter systems exposed to radiation: Multiscale theory, simulations, and experiment. *Chemical Reviews*, *124*, 8014–8129.

Toon, O. B., Zahnle, K., Morrison, D., Turco, R. P., & Covey, C. (1997). Environmental perturbations caused by the impacts of asteroids and comets. *Reviews of Geophysics*, *35*(1), 41–78.

XJENZA ONLINE
VOLUME 12 ISSUE 2, 2024

Table of Contents

Articles