

Steps towards digital-based environmental civil engineering in developing countries

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ABSTRACT

Digital skills are becoming increasingly important within civil engineering, along with a growing need for other soft skills applicable in training, research, and practice which should reflect the diversity of modern civil engineering. Civil engineers need to embrace digital technology and develop skills necessary to exploit its benefits. A culture of continuous learning needs to be embedded more deeply in the profession to ensure that individuals can meet skills requirements throughout their careers and, for this, a more flexible approach which will include both academia and industry is needed. In order to achieve it, a project has been realized by Glasgow Caledonian University, which was conducted by Macedonian Association for Geotechnics. The applied methodology and findings are explained below.

KEYWORDS

Digital technology; Skills; Continuous learning; Environmental civil engineering.

1. INTRODUCTION

The rapid changes going on in our daily surrounding affect also the profession, which is evident in civil, geodetic, and geotechnical engineering. In order to be in “trend” and enable increase of the design quality, at least by regular implementing Nature-based solutions (NBS), Building Information Modeling (BIM) and Geographical Information System (GIS), engineers should be supported in continuous learning, as digital skills and soft skills are becoming increasingly important. In fact, it is necessary to embed such culture more deeply, which asks for close cooperation between the academia and industry. In order to have insight into the actual situation and propose directions for future progress, a project has been proposed by Glasgow Caledonian University (GCU) and conducted by Macedonian Association for Geotechnics (MAG). Although it is based on a local research, having in mind the seminars held in recent period within the wider region, the findings can be applied generally.

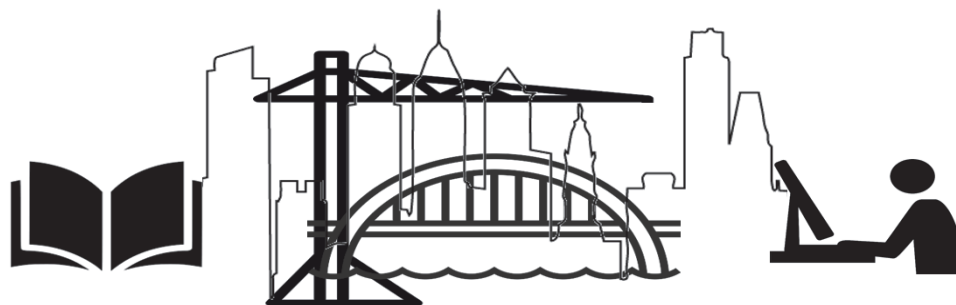


Figure 1. Academia-industry support in civil engineering.

2. PROJECT METHODOLOGY

2.1. General

The project commenced with engagement of academia and industry in N. Macedonia in February, 2021. It was closed in June, after two successfully conducted surveys, video-courses organized between the surveys, and structured interviews with selected participants conducted at the end of the research.

2.2. Content of surveys and replies

The GCU team designed a capability and needs assessment survey, which was administered by MAG and Faculty of Civil Engineering (UKIM GF). This survey aimed at establishing a baseline of knowledge and application of digital civil engineering and covered a sample of academics, researchers and industry professionals, representative of the local civil engineering environment. Engaging also with the Chamber of Chartered Architects and Chartered Engineers of N. Macedonia (CCACENM), beside the MAG membership, the questionnaire survey was promoted with the wider CCACENM membership. At the conclusion of the survey, 161 responses were received.

The GCU and MAG teams analysed the results of the survey within the first month of the project. The summary of the results is shown below:

- More than 80% of the respondents identified themselves as Civil Engineers (incl. Geotechnical and Geodesy), with the rest identifying themselves as researchers, academics or students.
- 50% were civil engineering graduates (B.Sc. Hons level), 35% had a Masters degree, 5% had a Ph.D. in Civil Engineering, and the rest were students and ordinary B.Sc. graduates.
- Formal training in digital skills and technologies, if provided, was usually part of the external activities, as well as the undergraduate/post-graduate education - the latter relating to GIS.
- The majority of the respondents considered BIM and GIS as the technologies they would like to develop to enhance their professional practice.
- 60% of the respondents do not use digital skills such as GIS and BIM in their practice, cf 25% who use GIS and 15% who use BIM.
- Of the respondents who have used BIM, 80% use it in day-to-day work.
- Of the respondents who have used GIS, 65% use it in day-to-day work.
- The most desired (more than 85% of the respondents) format for enhancement of the digital skills and technologies was continuous professional development (CPD) training.

Based on the results of the questionnaire survey, the research team organised a short intensive modular training programme to cover the major aspects of digitalization of civil engineering identified in the survey. The developed learning and teaching materials for capacity building included recorded webinars and were delivered online as a block release within a 6-week period. At the end of the “learning” period, the viewing results for each module were as shown in Table 1 below:

Table 1 Number of viewings for each of the learning modules as recorded 6 weeks after the posting.

Module no	1	2	3	4
Module description	Sustainable use of vegetation in NBS	Application of CAD and BIM in NBS	Basics of GIS for Civil Engineering	Application of GIS in Civ. Eng.
Number of views	34	16	20	29

Feedback in the form of an open-comment expectation/satisfaction survey was collected after each of the four modules. It was noticed that the interest for NBS and CAD/BIM is equal, while reduction is noticed for GIS, which is due to the wider presence of GIS than BIM in daily engineering practice. The results of the module questionnaire survey showed that almost everyone found the topics covered in the modules important for developing digital skills and contributing to the change in perception of

the topic. The respondents showed interest in further learning on these topics, either in the form of an organised training, CPD course or university-based course, or summer schools/site visits (Table 2).

Table 2 Further learning preferences.

Module no	1	2	3	4
Module description	Sustainable use of vegetation in NBS	Application of CAD and BIM in NBS	Basics of GIS for Civil Engineering	Application of GIS in Civ. Eng.
Further Learning	Conceptual and detailed design with vegetation; input parameters and physical/mechanical properties	Geo-environmental risks; Use of existing databases and maps for integrated modelling	Interoperability and collaboration of different digital systems;	GIS and BIM in design and construction; Visualisation and technical detail design

The design and numerical modelling of slope stability with vegetation, as well as the integration of existing maps/databases in the different design stages were the main learning points from the modules which the respondents found most applicable in their day-to-day work.

Module questionnaire survey showed that the GIS-related digital skills are currently required in most workplaces (80%, cf.20% of the respondents who were not sure). The majority of the respondents were not sure if the BIM-related digital skills are required in the workplace (60%, cf. 33% who responded that these skills are required). The majority of the respondents (more than 65%), however, perceived their employers as promoting digitalisation in day-to-day work.

2.3. Findings from structured interviews

After the completion of the course, the project partners analysed the feedback in detail, carried out a thematic analysis and jointly developed a programme for a debrief workshop which was hosted by MAG and included the GCU team as moderators/facilitators in the panel discussion between the local academic and industry participants, randomly selected from the course attendees. They covered wide range of engineers (civil, geodesy, geotechnical, architecture), academic levels (B.Sc., M.Sc., Ph.D.), age/experience (junior, medium and senior engineers), roles (investor, designer, contractor, supervisor, education, software dealer), professional bodies (MAG, Macedonian Committee on Large Dams, Macedonian Association of Structural Engineers, CCACENM, Economy Chamber of N. Macedonia - ECNM), regions (participants from Skopje, Bitola, Ohrid, Struga), gender etc. The thematic analysis resulted in the following being identified as the major discussion points:

- Barriers in the implementation of digital skills in civil engineering
 - Economic (e.g. costs of software, training, equipment; sources for their covering; costs of analysis)
 - Legislative (e.g. lack of appropriate standards; absence of clearly stated possibilities for conducting GIS/BIM analyses)
 - Social (e.g. inadequate/non existing training)
 - Technical (e.g. non-existent/low expertise; non-awareness of the benefits of GIS/BIM; limited asks for their implementation; non-exhaustive program tasks; orientation of companies towards local market needs)
 - Environmental (e.g. resistance to change, motivation for changes, obstruction of processes, confidence in results)
 - Time (e.g. length of course, available obligation-free period for engineers)
 - Education (e.g. BIM is not involved in the regular study curriculum at UKIM GF)
- Enablers of the implementation of digital skills in civil engineering
 - Awareness raising throughout the formal education (GIS is involved in the study curriculum at UKIM GF)
 - Interest among postgraduate students for exploring BIM

- Forthcoming re-accreditation of study programs at UKIM GF enables possibility for involvement of new subjects, e.g. BIM platform
- Possibility to update the existing legislation (the new Construction Law is in process of adoption; a Rulebook for Geotechnics is in process of preparation)
- Potential (young and mid-career professionals)
- Existing and future willingness among engineers for upgrading skills and knowledge
- Pre-trained engineers
- “Education” of the clients
- Use of digital technology for learning and construction/design
- Innovation and communication
- Ongoing digitalization in several branches
- Use of open source and BIM-compatible software
- Need for a drive from the professional organisations/industry (involvement of UKIM GF and MAG; readiness of CCACENM and ECNM to support initiatives)

The panel discussion aimed at development of a roadmap for capacity building and implementation of digital skills in civil engineering in N. Macedonia. It shows several parallel lines of series of actions:

1. Training - presenting the GIS and BIM as tools that facilitate, enable control, allow timely reporting, allow preparation of reports, adjust savings, logistic, show a complete picture of the facility, at any stage, and integrate processes in the facility, so that the trainees become aware about their meaning, needs and application, and increase their competencies. The teamwork is necessary, with clearly divided tasks, designed upon the requirements of the investor. For that purpose, it is necessary to educate the staff and to have a critical mass.
 - a. Engineers – either/both beginners or experienced, at:
 - i. CCACENM - on a course. Attending the lectures and demonstrating application could be valued with certain points for CPD
 - ii. Institutions/specialized companies - for small groups of engineers, not necessarily just designers, but investors and supervisors as well (it is anticipated that a BIM expert should be part of each such team)
 - iii. Conference - organizing a special parallel session, which can be planned for the occasion of inter/national conferences hosted by professional associations.
 - b. Investors - presenting the benefits of the new platforms from the aspect of integrating all the positions in the project (especially the complex ones, as capital infrastructural), so that the whole realization process can be modelled and monitored *via* BIM. Such approach increases its quality due to providing input data and databases for the BIM needs in design and/or construction and/or repair phases, which can, but not necessarily, be involved from the very beginning. Thus, the investors will encourage engineers to prepare and deliver the design in a format that is compatible with appropriate platforms in the digital era. This way the exchange and interoperability of data and documents is enabled, which can be drastically slowed down or limited in administrative institutions. The investors should become aware that BIM will increase the accuracy, quantity control, financial flow, construction speed, and can be adapted to personal requirements and needs (construction, supervision, monitoring, reconstruction), etc. Some of the potential trainees, mainly under the auspices of the Government, are: Public Enterprise for Roads; Public Enterprise for Railways; Ministry of Transport and Communications; Ministry of Agriculture, Forestry and Water Economy; Ministry of Economy; Ministry of Health (a capital state clinical centre is in process of design); the mining industry and quarries.
 - c. Establish educational centre - synchronization among institutions, for strong and common appearance. The young and inexperienced could be trained at the university, while the experienced engineers at a course. The programmes will be designed

according to the needs of investors, respecting the pre-knowledge of software, in order to achieve a certain quantum of knowledge in a given period.

2. Legislation

- a. Prepare a strategic document.
- b. Construction Law - is in process of adoption, thus it is recommended to involve articles that consider:
 - i. preparing the design in form that enable input parameters for application of BIM or BIM-compatible software
 - ii. application of platforms (i.e. actual software and technological solutions) which allow time, quantity and financial monitoring of (realization of) projects and preparing databases for enabling interoperability between different project phases (this should be added in the part concerning content of project documentation)
 - iii. contract conditions with construction company
 - iv. content of the project task
 - v. model for involving the construction company during the design phase
 - vi. contract forms
 - vii. allow competitiveness of small companies and avoid their endangering
 - viii. allow transition period
- c. Attention for legislative compatibility, to avoid legal vacuum and conflicts with other laws, e.g. Public Procurements Law
- d. Prepare by-laws or rulebook for implementation of platforms or include them in professional rulebooks, as it is already in Austria.

3. Pre-action

- a. Synchronized contacting, meeting and disseminating information among educational institutions, engineers, companies, investors, media, etc.
- b. Investigate the prospective needs of BIM, in order to deliver product and increase standards
- c. Increase the will of investors, decrease the inertia, shake-up the clumsy legislative institutions
- d. Realize pilot-projects in which BIM application will be asked for in the project task

These parallel processes of education, standards implementation, quality assurance, respecting the engineer costs and values, should also be followed by the increased status and influence of engineers. It should consist of delimitation of obligations and responsibilities; improvement in price regulation, especially in accordance with responsibility; defining criteria and responsibilities; quality control; updating legislation and clearly defining minimum criteria; clear tasks and asks for projects, with no room for manipulation.

3. BENEFITS FOR THE TARGET GROUPS

The benefits per target groups are described below.

At an individual beneficiary (Civil Engineer) level, the undertaken activities contributed to the process of changing attitudes and behaviours while imparting knowledge and developing skills. This was confirmed in the responses from the questionnaire survey but also, more importantly, in the discussions and responses received after the module programme and at the workshop. Namely, the engineers recognized the moment for involving the presented in the modules in the design, especially those who study or upgrade individually, since a systematic approach is still absent. Some of the participants expressed high awareness for the application of novel platforms, as well as a sort of scepticism since - so far - these are not yet foreseen in the legislation nor recognized among the broader client base.

At the institutional level of the beneficiaries (companies, higher education institutions), this project enhanced the overall research/application performance and capabilities, as well as the ability of the local beneficiaries to adapt to change. This was confirmed by the participants from educational institutions which see opportunities to include all the modules in study programs, either as separate subjects or as chapters, while there were also some pioneer researches so far. The representatives from companies are looking for improvements in order to become competitive not only at a local, but also at a regional level.

At the systemic level (professional organisations) the project activities managed to transfer knowledge of the current research policy framework in which individuals and organizations in Europe operate and interact with the external research environment. In that direction, representatives of several professional associations expressed interest in further organization of thematic presentations for their members. For that purpose, several options are available, either through organizing a dedicated event, or during a conference, or as a part of a planned event.

The local academic beneficiaries gained insight and knowledge into multi-disciplinary research associated with the disciplines they traditionally provide which, in turn, contributed towards a transformation of the skills and attitudes towards civil engineering. In the future, this will allow the local academics to shore up sustainability by not only shaping the curriculum offerings but also improving governance by participating in future trans- and inter-national research funding applications. The initiative and help from GCU was found supportive and helpful: research on NBS for improving slope stability has been initiated at the UKIM GF, aiming for their promotion in the region (Serbia, Bosnia and Herzegovina, Montenegro etc.), recognising the lack of such.

The local industry beneficiaries gained a degree of practical knowledge to apply into their work practice and share within the civil engineering industry locally and internationally to win future work. The local industry will benefit from improving their professional infrastructure by transforming their skills and attitudes towards civil engineering and enriching them with knowledge and application of other disciplines.

4. CONCLUSIONS

The aim of this project was to develop and strengthen the digital skills and associated resources of the local academic and industry institutions in N. Macedonia in order to generate transformation which will go beyond performing tasks and will include changing mindsets and attitudes towards digitalisation of civil engineering research and practice. The objectives included demonstration of the environmental civil engineering state-of-the-art to researchers and professionals in N. Macedonia as well as training academic staff to allow them to thrive in a fast-changing global research environment. The above aim and objectives already started realization and are aligned with UN Sustainable Development Goal (SDG) 17: Revitalizing the Global Partnership for Sustainable Development by targeting building technology and innovation capacity in the least developed countries while improving data collection and monitoring for the achievement of the SDG. Although it is based on a local research, having in mind the seminars held in recent period on the wider region, the findings can be applied generally.

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