

## Reshaping maintenance and asset management skills towards digital transformation in Portugal

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### Abstract

The reshaping of civil engineering education and training has been found to enhance student performance and improve their skills when facing the challenges of the real world. The industry is asking for engineers with better communication and teamwork skills, and most importantly, a broader understanding of how to solve real working market problems and create value in the marketplace. Moreover, the professional research institutions throughout the world and particularly in Portugal, such as engineering schools, are beginning to integrate entrepreneurship and business concepts into their training options. The present paper intends to present an overview about the challenges for maintenance and asset management, education and training of future generations and reshaping of research institutions. Moreover, a proposal is presented for the reshaping of maintenance and asset management education and training considering Portugal's needs. Additionally, the development of new approaches is presented, as well as a proposal for reshaping maintenance and asset management education and training: roadmap for Portugal needs. The main conclusions of the paper are also stated.

Keywords: Maintenance; Asset Management; Reshaping education and training

### 1. Introduction

Current trends in civil engineering raise questions about the future of the profession, namely the role played in society, in the integrity of infrastructure, as well as in the health of the natural environment. Technology and increasing market demand place additional pressure on how civil engineers perform their roles. The identified challenges raise concerns about future directions, it is necessary for civil engineers to start investing more in research and education and in the application of new technologies [3,19]. Industry and universities should be the organizations responsible for implementing measures to overcome the skills deficit identified in the field of civil engineering, namely regarding infrastructure maintenance. Although universities prepare their graduates well enough to work in industry, they are often only able to provide the theoretical knowledge necessary for an engineer. To improve the skills of recent graduates, it would be important that universities identify industry needs and teach them in the course, providing a close link between industry and university. Universities should also employ professors from the industry, bringing in experts with real-world experience [15]. The researchers of LNEC - National Laboratory for Civil Engineering, in Lisbon, Portugal, cooperate with different stakeholders of maintenance and asset management by bridging knowledge on innovative processing technologies to improve their competitiveness. On this subject, LNEC has/is hosting international conferences and several seminars in the areas of maintenance, asset management, and related fields, as a form of interaction between scientists, students, and other citizens [16].

### 2. Conceptual Overview

#### 2.1 Challenges for maintenance and asset managers future generations

Current trends in civil engineering raise questions about the future of the profession, namely the role played in society, in the integrity of infrastructure, as well as in the health of the natural environment. For decades, civil engineering leaders have warned about the need to invest in the maintenance of existing infrastructure, since the lack of proper maintenance can have drastic consequences for public health, safety, and well-being of users [19]. On the other hand, technology and increasing market demands place additional pressures on how civil engineers perform their roles. The growing use of artificial intelligence leads routine engineering tasks (which should be human domain) to the technologist and technician domain. Likewise, end-users and owners, when looking for low-cost acquisitions, reduce the demand for innovation, instead of a selection based on qualifications and new opportunities that lead to the optimization of the life cycle of the infrastructures. Thus, a basic question arises related to how civil engineers will be able to achieve a necessary and continuous knowledge about the best international practices in the area [3,17,19].

These identified challenges raise concerns about future directions, it is necessary for civil engineers to start investing more in research and education and in the application of new technologies, to have a vision beyond the strategic issues of today and invest efforts on what the civil engineering profession must achieve in the next years [15]. Figure 1 shows the critical mindsets, skills, and experiences that students need.

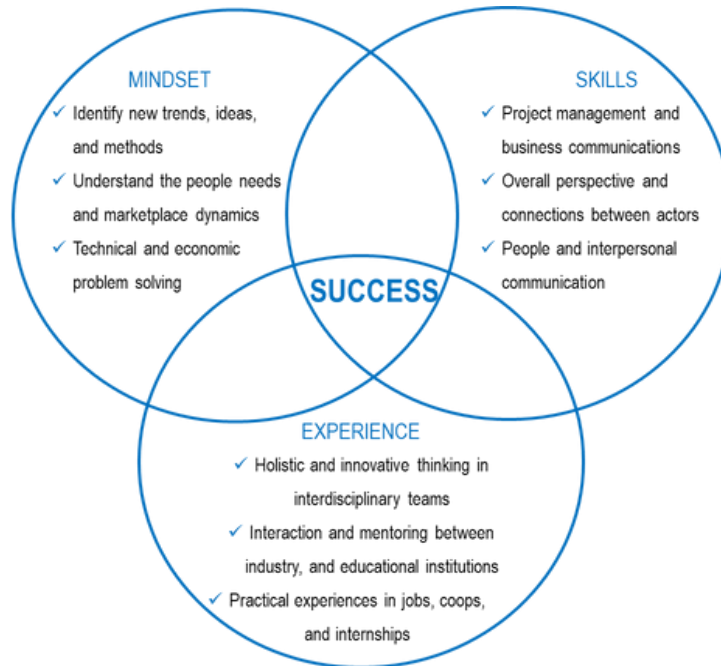


Figure 1 – Students need, adapted from [5]

## 2.2 Education and training of future generations and reshaping of research institutions

Industry and universities should be the organizations responsible for implementing measures to overcome the skills deficit identified in the field of civil engineering, namely regarding the infrastructure maintenance. In industry, specific postgraduate programs stand out, as the needs of each company are very different and the best place to develop your necessary skills is the company itself. However, the burden of responsibility in this matter must be in the hands of the universities, which must be the driving force behind the implementation of measures to overcome the existing challenges. Although universities prepare their graduates well enough to work in industry, they are often only able to provide the theoretical knowledge necessary for an engineer [6,15]. To improve the skills of recent graduates, it would be important that: i) universities identify industry needs and teach them in the course, providing a close link between industry and university; ii) engineering and technology programs and software that are used in industry must be addressed at universities (in lectures for the general public and in classes for students); and iii) universities should employ professors from industry, bringing in experts with real-world experience to provide a different perspective and outline for students the skills and abilities they would like to see in graduate engineers. It is also verified that many students are not mentally prepared for the expected work when they get a job as an engineer. The skills that are taught at university do not always reflect the roles and responsibilities assigned to them in the industry and it is unquestionable that the industry considers digital skills to be indispensable for working in the industry. [4,19].

## 2.3 LNEC as a research/professional and training institution

The National Laboratory for Civil Engineering (LNEC), is a public research institute, dedicated to science and technology, which carries out its activity in the large field of engineering, habitat, and environment sciences, comprising construction materials, public works, housing and urban planning, and hydraulics and transportation networks. Over the past decades, LNEC conducted studies and high-level consultancy in more than 40 countries, on all continents, and currently maintains nearly 300 agreements and consortia for Teaching and Research purposes with various entities around the world. At present, LNEC employs about 560 people, plus 140 science research fellows. Researchers have PhD degree or equivalent and represent 30% of the staff. LNEC's model of organization enables expertise's complementarity of different knowledge domains resulting in a benefit regarding support to industry. In developing its activity, LNEC aims to contribute to safety and quality of the works, protection, and rehabilitation of the natural and built patrimony,

technological innovation in the construction sector and in the fields of water and environment. The activities related to regulation, standardization and quality of construction are equally relevant.

The Strategy for Research and Innovation at LNEC for 2021-2027 is directed to progressively increasing the R&D&I in the overall activity and frames projects that meet the needs of society in the fields of built heritage, cities and territories, natural resources, risk and safety and development of instruments for innovation. The definition of priority themes was focused on the relationship with priorities of Horizon Europe and Cohesion Policy. LNEC is an active actor of the Portuguese Construction Technology Platform (PTPC), an industrial driven platform, which assumes, at national level, the mission of the European Construction Technology Platform (ECTP), i.e., promotes innovation and competitiveness of the construction industry. Since the year 2000 until present, LNEC has developed activity in characterization of recycled aggregates processed from construction and demolition waste (CDW). In this field, seven technical specifications for the application of recycled materials in different construction works have been elaborated. LNEC is an active player on RILEM Technical Committees concerning the valorization of waste, namely TC 198-Use of Recycled Materials and TC 217-Progress of Recycling in the Built Environment.

The researchers of LNEC cooperate with different stakeholders of maintenance and asset management by bridging knowledge on innovative processing technologies to improve their competitiveness. On this subject, LNEC has/is hosting international conferences and several seminars in the areas of maintenance, asset management, and related fields, as form of interaction between scientists, students, and other citizens [16].

### **3. Development of new approaches for maintenance and asset management education and training**

Universities have a significant responsibility in providing the knowledge skills necessary for engineers to succeed in industry. However, the following recommendations for improvement by the industry are highlighted: i) greater involvement with the industry in order to identify programs, software and expected skills, in the area of maintenance and asset management, for implementation in daily practice; ii) use of relevant software in the field to develop familiarity and basic understanding on the part of students and extend skills and transfer this knowledge to other similar programs; and iii) invite industry speakers to discuss the software and technologies used in the sector and introduce students to the desired skills and abilities [3,17,19]. While universities are responsible for providing the necessary academic and theoretical foundations for graduate engineers, the industry is responsible for providing the necessary practical experience for graduates, as well as facilitating the transition from university to an engineer dealing with real-world problems. Recommendations are that industry should [19]: i) allow greater communication with universities, suggest ways on how the curriculum can be improved and provide information to universities to enable more relevant education for students ; ii) encourage more industry professionals to volunteer for speaking engagements, either as a guest speaker primarily to discuss the programs they use and skills they would like to see or to deliver learning modules; iii) participate in facilitating more job opportunities and/or internship placements, as per their responsibility to graduate students, and have greater contact with the industry, such as on-site visits; and iv) provide graduate or cadet programs to students to better assist with their university transition and develop the relevant digital skills they will need to fulfil their role. Lastly, the government has significant influence when it comes to implementing new digital technologies in the industry through the implementation of appropriate policies and legislation, as well as helping with funds and capital to drive specific new initiatives. The following is highlighted [15,19]: i) implement strategies that require the entire maintenance and asset management industry to implement digital technologies in accordance with the applicable standardization (e.g. ISO 55000); ii) providing grants and subsidies to universities and industrial organizations that are willing to implement new technologies; and iii) establish working groups that assist the public and private sectors, as well as universities in innovating their work practices. On the other hand, LNEC, as a governmental research and training institute, has an important role in the interconnection between the academic and theoretical part, taught by universities, and the practical part needed by the industry. LNEC can bring these two parts together, to prepare national and international conferences, workshops, post-graduations, and training courses that combine the two purposes and include the necessary innovation related to maintenance and asset management applied to civil engineering.

### **4. Proposal for Reshaping maintenance and asset management education and training: Roadmap for Portugal needs.**

#### **4.1 Challenges and strategies for implementing a national action plan**

Given the current state, in the field of maintenance and asset management, it is considered that the Portuguese reality could materialize in the not too distant future [3]: i) Better visualization / better impact; ii) Increased productivity thanks to greater and better ease in structuring information; (iii) greater and better organization of documentation; iv) Integrate

and link vital information such as specific material suppliers, location details and quantities required; (v) Acceleration of response to situations; (vi) Reduction of costs and delays; (vii) creating/improving/increasing the development potential of the construction industry and related fields [1,7,9].

However, there are challenges that need to be overcome, such as [1,8]: i) There is still some lack of demand; ii) Some current entrenched practices; iii) Need for more qualified resources than the existing ones. Despite the challenges to be overcome, strategies can be identified (Figure 2) to encourage the dissemination and generalization of maintenance and asset management procedures in the construction sector in Portugal in the coming years, such as: i) Imposition by the public sector; ii) Publicize and promote successful cases; iii) Minimize impediments and encourage maintenance actions as well as proper asset management of any type of asset; iv) Develop skills in the areas of maintenance and asset management, particularly those related to digital transformation and Construction 4.0.

## 4.2. National action plan proposal

Considering what was presented in a schematic way in the previous point, a proposal for the modernization of maintenance and asset management in Portugal in the coming years may generally comprise the strategies previously presented for each of the challenges, as well as the actions that take place to sum up (Figure 2). For the challenge, lack of demand, the imposition by the public sector and the dissemination of success stories were identified as challenges. In the first case, the following strategies are envisaged: i) Creation of an “IT Centre”; ii) “collaborative work”; iii) “make mandatory implementation”. With regard to the action Creation of an IT Center, the following are considered as the most relevant line of action: i) Proposal for the development of a national strategic plan; v) interconnection between maintenance and asset management in a digital transition environment, for example through BIM and other national construction information systems; vi) adaptation of standards applicable to maintenance and asset management and their dissemination throughout the national technical environment (owners, consultants, designers, builders, public works owners, operation and maintenance managers). About the Collaborative work action, it is recommended that this should be developed by different bodies and within the scope of pilot projects that consider all actors in the AECO (Architectural, Engineering, Construction and Operation) sector to consolidate the dissemination of maintenance plans and asset management actions. The mandatory presentation of maintenance and asset management plans will bring benefits related to transparency in the exchange of information and minimization of possible errors inherent to the activities involved. In the second case, dissemination of success stories, within the scope of the action “Disclosure of strategies and results obtained in Portugal and other countries”, the aim is to disseminate success stories

in the areas of maintenance and asset management to raise awareness among AECO sector stakeholders of the benefits of its implementation, as well as encourage the generalization of its good practices in Portugal in the short/medium term. Regarding “Competitions” Maintenance and Asset Management, the aim is to promote the participation of entities involved in the implementation of maintenance and asset management strategies, in the AECO sector, in international initiatives sponsored by organizations of recognized merit and already identified, as well as promoting new initiatives at national level [7,20]. For the challenges of some currently entrenched practices and need for more qualified resources than the existing ones, strategies were identified that dynamically interrelate with each other, namely, to minimize impediments. With regard to the “Community Growth actions”, it is recommended to promote: i) contact with local authorities with a view of establishing a closer relationship for synergies and support for the growth of the maintenance and asset management community, for subsequent dissemination of knowledge to designers, builders and participants in local architecture, construction and engineering activities; ii) direct contact with large companies to support the implementation of innovative and efficient maintenance and asset management strategies; iii) synergies with software companies to create products that are simpler and cheaper to use; iv) the development of free use modules for different situations. To “Promote Leadership” at national level, it is intended to enhance the use of maintenance and asset management standards, as well as to promote advice aimed at effective implementation, achieved through the development of guidelines for collaborative work about maintenance and asset management; ii) working groups dedicated to legal and contractual issues; iii) AECO, exploration and maintenance multidisciplinary working groups. Finally, with the aim of “Creating a Training & Productivity Fund” for maintenance and asset management (MAM Fund – Maintenance and Asset Management Fund), the following are envisaged: i) application to national or international structural funds to support their widespread implementation in Portugal; ii) the definition of business-level schemes and a collaboration regime for maintenance and asset management projects. With regard to the action “Equipping future generations”, the following are considered as structuring lines of action: i) awareness-raising actions; ii) contact with universities to support the definition of disciplines in the area of Maintenance and Asset Management; iii) agreements with universities and other institutions of the scientific and technological system, in order to develop master's and doctoral theses and disseminate knowledge; iv) promotion of seminars, sessions, workshops, dissemination (for technicians and national students); v) development of specific programs and internships (national and international); vi) establishment of protocols with professional entities (engineers, architects, etc.) to encourage and promote maintenance and asset management in the national technical

environment; vii) Center of Excellence in Maintenance and Asset Management; viii) development of applied research in the area [8,9,20].

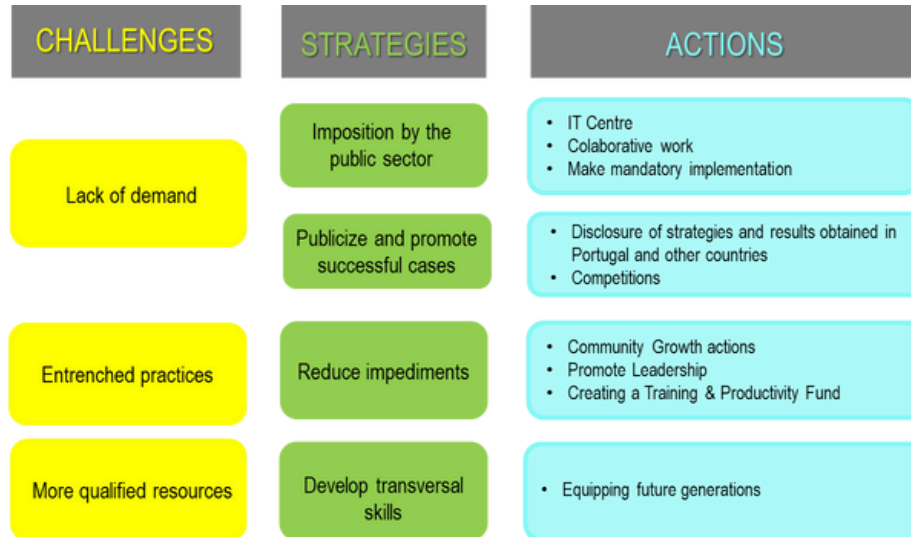


Figure 2 – Challenges, strategies and actions for reshaping maintenance education and training

### 4.3. National action plan integrated actions

To respond to the challenges identified in the previous point, several actions have been developed to integrate a national plan of organized and directed implementation about Maintenance and Asset Management. Regarding collaborative work, emphasis should be placed on the creation of working groups in maintenance and asset management within the scope of activities carried out by the Portuguese Construction Technological Platform (PTPC), belonging to the European Construction Technologic Platform (ECTP). Within the developments verified, not only at CEN level but also in the countries that are part of the CEN/BT WG 215 group, it was understood as pertinent the creation of national commissions capable of collaborating in the developments of the CEN and of boosting the dissemination and the implementation of regulatory developments related to maintenance and asset management. In this way, the Technical Commission CT94 - Maintenance and the Technical Commission CT204 - Asset Management whose work has been monitored by various entities of the highest relevance in the national AEC sector. In addition to these two commissions, the Technical Commission CT192 – Facility Management also refers to work that is often interconnected [18]. About the Dissemination of Strategies and Results, reference is made to the organization of international conferences in the area (e.g., WCEAM, ConGrega) with the participation of renowned experts and national and international users. Within the scope of PTPC activities, a forum of great impact in the AECO sector was organized in 2014, under the theme “Until today I was always future” in which, in addition to BIM, gave emphasis to the importance of maintenance and asset management in the future of the industry construction in Portugal. IST and LNEC have been organizing courses and collaborative and dissemination sessions to present the themes in question, as well as ongoing research projects, subordinated to the referred themes. In general, national, and international conferences in recent years, in the field of construction, have increasingly included thematic sessions related to maintenance and asset management. Regarding “Competitions”, it should be noted that, although initiatives of this type have not yet been structured at national level, it has been verified that the Portuguese who implement maintenance plans and asset management actions in their activities, have been winners of this type of initiative at an international level in recent years [7,9]. About the growth of the community in the thematic areas of maintenance and asset management, it has been verified that the number of scientific articles and publications of a technical nature has been increasing significantly in recent years. Companies in the AECO sector, due to the need to operate in international markets where innovative maintenance and asset management approaches already appeared to be an effective reality, have also been investing in the digital transition with a focus on BIM for support. In this way, in Portugal, more and more companies are using innovative maintenance plans and integrated approaches to asset management to respond to international requests, also contributing to the growth of the community. Regarding equipping future generations, the number of specific courses, face-to-face or via the web, in the broad areas of maintenance and asset management has been increasing, as well as initiatives of a more restricted nature, such as some specific training courses taught by public and private universities. In addition to this, various public and private universities have been including content related to maintenance and asset management in their programs of disciplines in the field of construction, as well as their importance and need for implementation in the AECO sector.

There is also a very significant increase in the number of master's dissertations and doctoral theses both presented and in progress in the referred areas. It is expected that this increase will also intensify in the coming years [7,8].

## **5. Conclusions**

This paper intends to present an overview of the current and future trends in construction management and construction engineering and to identify the required skill sets of future civil engineers, namely for maintenance and asset management areas. The importance of digital skills to the graduate and post graduated engineers working in construction is also very important, not only from the perspective of the industry but also from the perspective of the students, that will be the future professionals. It is important to clarify the digital technologies that the construction industry is using nowadays and the digital skills still necessary to facilitate the digital transition in all areas of civil engineering in general, and in maintenance and asset management in particular. The review findings point to: i) digital skills being very important for graduate and post graduated engineers; ii) there are still significant digital skills gap, with most of graduates and post graduates having insufficient skills in planning and programming for maintenance tasks and asset management skills; iii) necessity of overcoming the skills gap by improving the current engineering curriculum. Some skill sets, identified as very important in succeeding as a future engineer in maintenance and asset management areas, still need improvement, namely in what concerns management documents, works simulation and project planning. A proposal for reshaping maintenance and asset management education and training including a preliminary Roadmap for Portugal's needs was presented based on the review, including the challenges and strategies for implementing an action plan based on digital skills transition strategy that outlines some methods for overcoming the digital skills gap. The roles of universities, construction industry and its professional associations and government should be emphasized to give the necessary support for a necessary transition strategy to reshaping maintenance and asset management skills towards digital transformation. The proposal presented for Portugal aims to realize a vision of a modern, highly integrated, and technologically advanced construction sector during the 2020s and for the following decades, which will be led by companies with a high degree of progress and innovation and supported by a workforce with a high degree of qualification and competence, particularly in the areas of maintenance and asset management.

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