

ROBOTIZING WORKFORCE IN FUTURE BUILT ENVIRONMENTS

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ABSTRACT. The aim of this paper is to define challenges for Automation and Robotics in construction (A+R) to enhance client and social value. Construction contributes to a positive living environment for society and is the largest sector of Europe's economy with a size of around 2,500 billion Euros. Ten research projects have been analyzed to select the challenges for development. These challenges present a road map for Automation and Robotics in construction particularly on Human-machine technologies, Process management and Performance engineering.

Key words: *Human-machine technology, Automation, Robotics, Performance engineering, client value, society value*

INTRODUCTION

The aim of this paper is to define challenges for A+R to enhance client and social value. Construction contributes to a positive living environment for society and is the largest sector of Europe's economy with a size of around 2,500 billion Euros. [1]

Without embracing the performance concept, the transition of the building, construction and property industry into a client-focused, knowledge-based and services-based industry, characterized by sustained innovation and excellence will be extremely difficult to achieve. Or, in other words, the comprehensive application of the performance approach in practice will facilitate and hasten this transition. [2]

According the European Commission three priorities are in the heart of the policy Europe 2020:

Smart growth (developing an economy based on knowledge and innovation), Sustainable growth (promoting a more resource efficient, greener and more competitive economy) and Inclusive growth (fostering a high-employment economy delivering economic, social and territorial cohesion). [3]

The construction sector faces the following challenges and A+R needs to address and to adapt them: climate change, demographic change, energy supply and security,

food shortages and environmental concerns. Construction can offer society more convenience by low maintenance, automation, flexibility, health improving features and optimal environmental integration. [1]

METHOD

A road map to reach added value for end-users and society with the help of mechanization, robotization and automation technologies has been described by Maas and Van Gassel [4]. Human-machine technologies lead to performances by the help of various management approaches. See Figure 1. To find challenges a number of research projects have been carried out during the last 20 years at the Eindhoven University of Technology.

These projects are:

- Human-machine technologies, (i) method analyzing activities on the construction site, (ii) method analyzing Activities Daily Living (ADL), (iii) method designing modular building systems.
- Process tools: (iv) collaborative working during design meetings, (v) quality monitoring in Design-Build projects, (vi) lean construction management in projects.
- Performance engineering for the built environments: (vii) active aging society, (viii) automated data collection, (ix) safety and (x) building services.

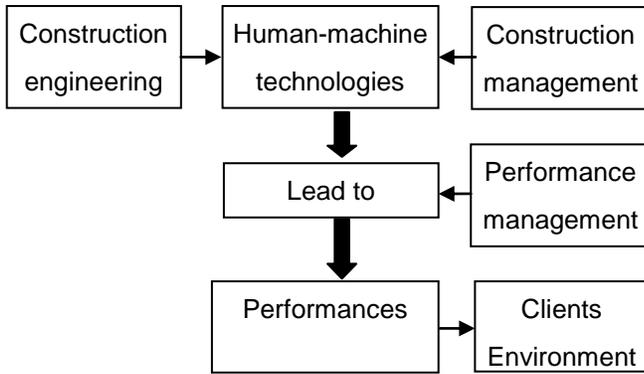


Figure 1. Relationships between management, engineering and performances [4].

In this paper we report about these research projects by answering the following questions: (1) what was the problem? (2) what was the research objective? and (3) what are the challenges c.q. the new knowledge for A+R?

3. DESCRIBING RESEARCH PROJECTS

In this paragraph we describe the ten research projects:

i. *Method analyzing activities on the construction site.*

Building objects are produced by people who perform the necessary tasks using equipment. On basis of preconditions, the process designer can have a particular task to perform by a specific combination of a worker and equipment. The worker performs a number of tasks and the equipment does the rest.

Nowadays, more and more suitable technologies are becoming available. In order to use these technologies successfully, it is essential to have a good understanding of the work processes of an object that is to be built.

Mechanizing, robotizing and automating construction processes is necessary in order to reduce production times and costs, improve working conditions, avoid dangerous, allow work to be performed that people cannot do and increase performance.

The implicit know-how of the builders and the construction process designers has to be made explicit before re-designing the construction process.

The builder's implicit know-how comprises knowing how to choose the sequence of the building elements, how to join the elements, where the elements fit in the construction as a whole and how they to be positioned.

We have developed a method to analyze and categorize construction activities in term of variables of a worker-equipment system.

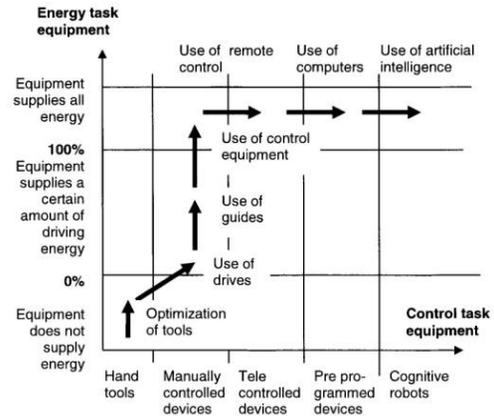


Figure 2. Mechanization phases by construction work.

The challenge is designing new products with appropriate working methods which can be easy to robotize the workforce. [5, 6]

ii. *Method analyzing Activities Daily Living (ADL).*

This research focuses on finding the appropriate working method to enhance end-user value for aging-in-place. Older adults prefer to stay in their own environment and enjoy remaining independent and socially integrated. However, our current built environment is largely unsuited to perform daily activities.

Activities of Daily Living have been categorized and scales were developed to assess older adults' needs and capabilities.

Katz et al [7] describe six basic activities of daily living: bathing, dressing, toileting, moving in and out bed and chair and feeding, while Lawton [8] mentioned eight instrumental activities ability to use telephone, shopping, food preparation, house-keeping, laundry, mode of transportation,

responsibility for own medication, and ability to handle finances.

Robotics and home automation equipment in the broadest sense can support and improve daily living. In a Dutch study by the Rathenau Instituut [9] the researchers “noted that most research efforts and funding seem to be focused on the very high-tech end of the robotics scale”. We developed a method to analyze ADL’s with a more user-oriented and multi-disciplinary approach.

This method is used by novice designers (MSc in Architecture, Building Services and Human Technology Interaction) during their courses. They analyzed a real end-user problem and designed methodically an improvement.

The challenge is to use this working method to decrease the gap between technology push and users push. [10]

iii. *Method designing modular construction systems.*

The Modular Building Institute (MBI) defines modular construction as a method of construction that “utilizes pre-engineered, factory-fabricated structures in three-dimensional sections that are transported to be tied together on a site”. The buyer of a modular building has some special reasons to choose for this method, such as a short delivery time and that the building is flexible and demountable. The production in factory, the transport over public road and installation at the construction site give the manufacturer a lot of opportunities to mechanize, robotize and automate the production processes..

It is a complex design process where a wide range of designers are involved, where marking and financial aspects are important. Based on a long experience with several successful implemented modular systems in the Netherlands the authors developed a design method for the modular builders. The method consists of three design feedback tools: an object tree, a four-step system analysis guideline and a ranking system.

This research made the authors aware that the organization of collaborative design needs an appropriate preparation. [11]

iv. *Collaborative working during design meetings.*

A building assignment is complex and asks collaborative working to achieve added value of users and society by purposefully facilitating construction processors. The problem today is that the collaborative working is not well organized and managed by lack of insight in relevant process variables.

Desk research and case study research has been carried out to identify variables enhancing collaboration efficacy during meetings in construction. In this research we consider a meeting as a black box with an input and output. We are interested in the relation between input and output.

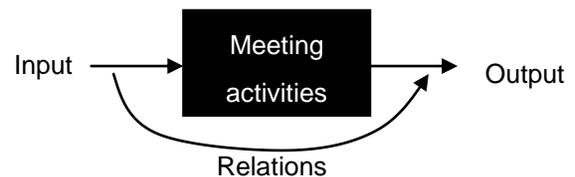


Figure 3. Meeting activities considered as a black box.

The results of this research indicate that the variable aim of the meeting, the way of control and used tools (working methods) have a relation with the number of collaborative working during the meeting and after the meeting.

This knowledge can help construction managers to prepare and lead more powerful collaborative working. [12]

v. *Quality monitoring in Design-Build projects.*

Worldwide clients are not longer satisfied with contractors doing their very best in construction but who are not reliable for the performance of the building and not reliable for the use of the road or tunnel. This is the consequence of the traditional discussion between designers and contractors in the building process. Clients are moving more and more to performance based contracting. The first

challenge with this shift to performance based contracting is the selection of the proper contractor and supplier. The second challenge is the monitoring of the actual quality of the work of contractors and suppliers.

The aim in the research is to investigate systematic contract management in Design-Build projects. Two questions have been answered in this research: 1) which factors will influence the compliance of the contractor in the Dutch infrastructural projects? and 2) What are the key process characteristics of the monitoring system as implemented in the Dutch infrastructural design build projects?

The challenge for automated technology is to develop systems, devices, algorithms to monitor actual quality characteristics real time. Data and information from these systems will support clients in their communication with contractors, designers, suppliers. [13]

vi. *Lean construction management in projects*

The problem is that a large numbers of interfaces in construction between designers, contractors, subcontractors, suppliers cause a significant amount of waste in construction. Waste means in this case more than just physical, material waste in construction. It also means: redoing design work, waiting time, less efficient work division between suppliers, less efficient working order. The questions to investigate are: How to measure, calculate this inefficiency? How to compare projects and companies from the viewpoint of lean management? The aim in this research is to develop a method to make this comparison from the viewpoint of lean management?

In the past Womack [14] compared competences in the automotive industry by using typical characteristics for the automotive industry. In this research the Womack approach has been transferred to construction by transforming the characteristics of the automotive industry to typical characteristics for the construction industry. Aspects to research are productivity in terms of: spend hours, duration time,

investment, direct costs, engineering hours, supplier's costs and construction site preparation.

This research will be executed by studying archives. The challenge for automated technologies is to develop systems, devices to monitor productivity characteristics real time.

vii. *Active aging society.*

The construction sector plays a key role in a number of application domains of gerontechnology: housing, mobility, communication, leisure and work. In addition to Architecture & Building, it concerns information and communication, mechatronics and robotics. With the number of aging people rapidly growing in the (developed) world it is not enough to develop tools, equipment to support people. What society needs is an inclusive design of the whole built environment. Society needs an infrastructure that supports people's mobility. Society needs even aging people participation in economy.

The aim of European Year of Active Ageing and of the taskforce "Improving the economy in an ageing society by architecture and construction" is to develop a road map for R+D at the interface to Automation and Robotics and Aging.

The challenge for Automation and Robotics is to support the domains of architecture and civil engineering. This support must create and "inclusive" Built Environment for economical, health and societal reasons.

viii. *Automated data collection to meet performance requirements.*

In the Dutch railway sector three 'change programmes' are initiated since the mid 90s in order to deal with the changed management conditions:

First 'Life cycle management' aims at the realisation of a systematic approach to underpin and optimize investments in new construction, maintenance and renewal. Costs of ownership, including penalties for track possessions, have to be analysed for a period of 50 years. Second 'Performance-based contracts' are being introduced for the maintenance and incident management. Contractors with approved

quality control systems can acquire this type of contract for periods of 5 years. Their efforts will increasingly be monitored based on agreed performance indicators. Third 'Maintenance window scheduling' is triggered by more stringent safety demands for maintenance works.

This research discusses the transformation of the contract requirements for the track into measurable requirements and some of the measuring systems that are used to monitor the track condition. Improvement of the performance of technology can stimulate the wider use of DBFMO contracts.

The challenge for automated technologies is that: GPS positioning is not accurate enough to align different measurements and correlate their results; GPS positioning in tunnels is not working; Data files are 5 to 6 Gigabyte and cannot be handled in normal computers; Computers are too slow to analyze the data; Image recognition of defects in track is not accurate enough and therefore not reliable; Typical defects are available by means of photos but cannot be converted to information for a computer to check on these defects; Intrusion detection for line objects (intrusion by people through fences); Very accurate absolute elevation measurements (1 mm) on the track is not possible over long stretches. [15]

ix. Safety.

Construction is unsafe. The work environment is difficult to get under control. It changes for every activity. Equipment and labor force are constantly moving over the site and in the building project. Technical support can reduce the number of accidents and behavioral change towards safety makes a difference. Nevertheless construction is still an unsafe industry compared to other sectors. Figures are not comparable.

The aim of the research is to make worldwide monitoring systems comparable. What are the characteristics of safety and what are the dimensions to measure those? [16]

The challenge for Automation and Robotics is to

develop safer construction methods and interactive systems to guide the labor force during their operations.

x. Building Services.

Building services in all kind of buildings is evolving because of the protection of the user against all kind of diseases. The reduction of the energy use and of the ventilation of living room are essential. The aging of the users of a building asks for dedicated installations. The actual safety and installed security have been investigated. A conclusion is that users are not individual asked for their real needs. The actual applications have been limited to old fashion and proven technology.

To meet the needs of high age users is for the design a analysis conditionally to investigate the user's needs. [17]

DISCUSSION & CONCLUSION

The research projects deliver the following new challenges cq knowledge:

- i. A method to analyze and categorize construction activities in term of variables of a worker-equipment system.
- ii. The challenge to use the described working method to decrease the gap between technology push and users push.
- iii. Modular construction is a complex process where all kind of professionals are involved. A collaborative approach is necessary.
- iv. The challenge by organizing design meetings is an appropriate preparation.
- v. The challenge for automated technology is to develop systems, devices, algorithms to monitor real projects real time. Data and information from these systems will support clients in their communication with contractors, designers, suppliers.
- vi. The challenge for automated technologies is to develop characteristic systems, devices to monitor the productivity real time.
- vii. The challenge for Automation and Robotics to support the domains of architecture and civil engineering. This

support must create and “inclusive” built environment for economical, health and societal reasons.

- viii. The challenge is to acquire and to process data to support the management of performance contracts.
- ix. The challenge for Automation and Robotics is to develop safer construction methods and interactive systems to guide the labor force during their operations.
- x. Users are not individual asked for their real needs. The challenge is to do that.

With these challenges and this knowledge we can redesign Figure 1 into a new road map. See Figure 4.

Finally we can conclude that by using human-machine technologies such as mechanization and robotization an integral approach of various management tools will lead to the real fulfilling the needs of the client and society.

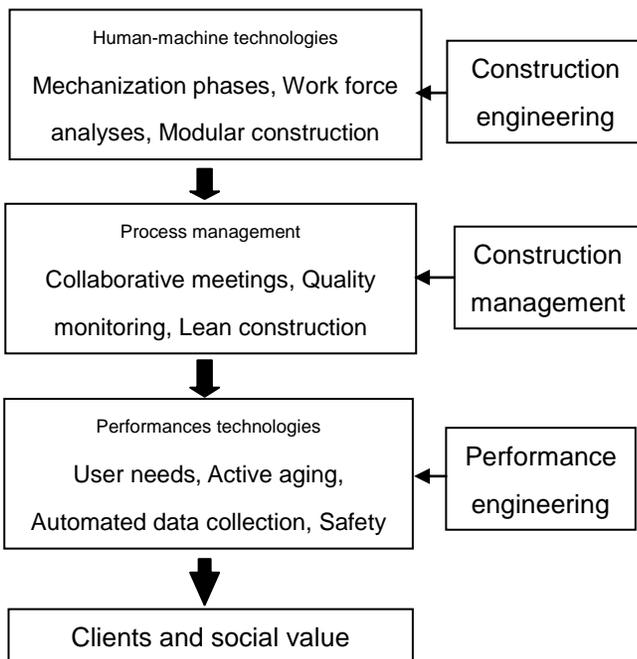


Figure 4. Road map for A+R in construction.

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