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Automated and Robotic Construction – a Solution for the Social Challenges of the Construction Sector

Alina-Maria Văduva-Şahhanoğlu*
Mădălina Xenia Călbureanu-Popescu**
Siemon Smid***

Abstract
The main objective of this article is to show that there is an urgent need for automation and robotization in the construction sector, one of the strategic sectors of the economy. To achieve this objective, it has been conceived a review of the economic and political context related to the construction sector. In the world, there is a great demand for investment in construction in order to support economic growth and social transformations with new homes, offices, factories, school, hospitals and infrastructure. This demand will definitely increase due to the urbanization tendency. By 2050, cities will absorb most of the demographic growth of the world. They are also responsible for 2/3 of all greenhouse gas emissions. There are also many challenges regarding human capital such as high unemployment, labour mismatches, and increasing numbers of young people without education, employment and training. Considering the latest changes in the demand and its structure, we believe that the construction industry should quickly evolve in order ensure as result sustainable buildings. This evolution refers to the whole supply chain from design, materials to urban development. In this context, automated and robotic construction is, in our opinion, an exceptional solution to build faster and more efficient.

Keywords: *robotics, building automation, sustainable building, innovative building, building on demand, innovative building*

* PhD Ec., Project Expert, Romanian Association for Technology Transfer and Innovation, Phone: + 40747507677, Email: alinavaduva@gmail.com
** Associate Professor, PhD, University of Craiova, Faculty of Mechanics, Phone:+ 40 722634340, Email: madalina.calbureanu@gmail.com
*** Senior Manager, PricewaterhouseCoopers, Société cooperative, Phone: +352 621334056, Email: siemon.smid@lu.pwc.com

Economic and political context of the construction sector. Construction- a strategic sector of the economy

Global Construction Perspectives and Oxford Economics in 2013 predicts an increase of the global construction market by $6.3 trillion or over 70% to $15 trillion by 2025 compared to $8.7 trillion in 2012. The emerging markets will cover 60% of the global construction activity by 2025 (compared to only 35% in 2005) as there is a great demand for investment in construction in order to support economic growth and social transformations with new homes, offices, factories, school, hospitals and infrastructure. From EU Perspective, the construction sector has a major importance as it represents over % of its GDP and more than % of fixed capital formation. It is the backbone of EU economy and society. This sector, if compared to a company, it would be the biggest industrial employer in Europe and would have the largest economic activity, gathering 20 million people. Furthermore, it is an essential actor in the implementation of the Single Market and other EU policies such as Environment and Energy (Bisch *et. al*, 2011).

Urbanization tendency

The EU28 faces a great tendency of urbanisation as we could see from Table 1 bellow. Cities above 50 000 are defined as clusters of grid cells of at least 1500 inhabitants per square km. Areas outside urban agglomerations are defined as suburbs and towns if they are located in urban clusters of cells with density above 300 inhabitants per square km and a total cluster population of at least 5000.

Table 1: EU28 cities defined according to their density of population

Population class 000s	Category	No. of cities	Population in size class (million)	% of total population
>1 million	Large	23	59.2m	12.2
500-1000	Large	37	27.83m	5.7
250-500	large	62	21.21m	4.4
100-250	Medium	227	36.13m	7.4
50-100	Medium	392	27m	5.6
Towns and suburbs	Small and suburban	-	157.91m	32.6
Rural population	Rural (including very small towns)	-	155.42m	32.1
Total		-	484m	100%

Source: European Union Regional Policy 2011 “Cities of Tomorrow: challenges, visions, ways forward”: 3

The report calls *The Impact of European Demographic Trends on Regional and Urban Development, Synthesis Report*, issued in 2011, states that the European cities develop through the intense migration from rural and it faces new challenges : lack of employment, integration issues, but, as well, there is not adapted infrastructure and there are not enough homes to host the coming people. The question is how will the city dwellers face this new tendency? For the construction field, the answer can come from innovation in the field of performance. Another answer to the urbanisation issue would be the flexibility of urban infrastructures, seen as the capacity of urban infrastructure to serve different purposes (for example new houses for youth as well as for the elderly having an affordable price). The automated and robotic construction methods respond to this demand by developing a mobile factory that can be reutilised up to 300 times, thus offering the possibility of rapidly building new houses. The last above mentioned report also identifies the need to provide "a secure and safe urban environment in order to lower spatial segregation and increase the quality of life of all generations" (p. 15). The automated and robotic construction methods will also address this policy element as the space of the city can be better used by building high sustainable buildings with lower emissions and optimal use of resources.

Sustainable buildings

According to the Communication from the Commission on resource efficiency opportunities in the building sector (Brussels, 1.7.2014, COM(2014) 445 final) Consumption of resources and related environmental impacts throughout a building's lifecycle can be reduced by: improved design and functionality; optimal resource planning and energy efficient products; reducing waste in the construction and renovation processes. When we talk about sustainable buildings, there is a large palette of things that must be considered such as: social, cultural, environmental and financial aspects. More precisely there should standards referring to design, materials, energy, resources and waste (United Nations Environment Programme, 2014). According to a Report issued by US Department of Energy (2008) high performance and sustainable building should: establish goals on sitting, energy, water, materials and indoor environmental quality. It will also take into considerations the entire life cycle of the buildings; optimize energy performance. The total energy consumes for onsite and offsite processes will be measured and verified and new benchmarks will be established; protect and conserve water. The process will employ design and construction strategies that will reduce indoor water, outdoor water and process water consumes; enhance indoor environmental quality by: ensuring ventilation and thermal comfort, moisture control, day lighting, low-emitting materials, protect indoor air quality; reduce environmental impact. The following aspects will be taken into consideration: recycled content, bio based content, using environmental friendly products, waste and material management, ozone depleting compounds. As they aim, as a final result, to build high performance and sustainable buildings, the automated and robotic construction methods represent, in our opinion, the best solution to answer these challenges.

Human capital and construction in Europe

Nowadays EU in confronted to a great number of challenges such as: unemployment, labour mismatches, and increasing numbers of young people leaving education, employment and training. Migration, poverty, social exclusion, increased social costs are more and more realities and household incomes go down (Fotakis, Peschner, 2015). The EU market faces several changes such as: divergences between countries, reduced demand, erosion of human capital and competitiveness, undermined confidence. EU as a whole has been questioned from the perspective of economic fundamentals and overall objectives. Human capital is one of the basic factors of economic growth in the information, knowledge-based economy of the EU as its level of usage determines the innovation component. The economy of post-industrial society is based on using intellectual resources so that organizations become more and more innovative. Innovation area does not include only new products and technologies but also new methods and methodologies of organizing processes (Belyakova, Rogova, 2013: 8-9).

In this context, the nowadays management of companies will shift from material and cash flows to intangible ones based on intellectual values. Information and electronic information technologies have become key resources, thus the number of those employed in intellectual work will increase and the number of those engages in the extracting and processing productions will decrease. Innovation includes, from the perspective of the human capital involved, the following aspects (Mayo, 2007: 189-190): innovative diversified methods for construction organization and management processes; new methods of performance evaluation; establishing new connections between actors from construction of buildings; experimentation of innovative technologies and learning from others; development of new vision of each person involved in the construction process including preparation for the change and dedication; development of new strategies for occupying the market by attracting new customers and creating new markets. Automation and robotization in construction will set new benchmarks for creating international, multidisciplinary teams able to work efficiently. The teams will be made of international standard specialists with already proven results. They will work together in order to offer a new solutions to the development of tomorrow's cities. New jobs and new occupational standards will appear in a high demand industry (the building industry).

Future opportunities in the construction market

The construction sector is of strategic importance to the EU (Bisch et al., 2011) as it delivers the buildings and infrastructure needed by the rest of the economy and society. As one of the strategies in EU programs for 2020 is an increase in sustainable and intelligent way the number of the workplaces, it includes the construction sector as a basic element. It is known that this sector provides about 9% of GDP and over 18 million jobs in the entire EU. Moreover, this sector uses 800 billion of components produced by other industrial sectors and this is leading to increase to 50% the percentage of gross capital just for the sector.

Thus, many of the European Societal challenges are addressed by implementing construction robots technology as it implies: a new operational and organizational structure; a higher productivity – as related to tasks and machines; a higher efficiency – from both construction products and processes; a new approach to health and safety – as it reduces the number of accidents and injuries, and also allows the reintegration of construction workers which have discontinued their work due to working incidents. The financial challenge, obtaining funds for R&D and innovation in the field of construction robotics, could be successfully surpassed through EU finance.

Robotics in construction – market perspective

Construction robots are about better products and processes. Building robots bring higher efficiency to the entire activity of construction of buildings, a lot of satisfaction for beneficiaries, better environmental protection, durability and more accurate predictability of the whole works. Thus the entire building activity and the processes involved will lead to high performance in the industry. When considering best value in homebuilding, it does not refer to finding the lowest cost. Quality and durability are essential things to be considered. However the urbanisation tendency brought the demand for fast and efficient building processes. Building robots meet three main requirements, namely performance, durability and cost efficiency for the entire period of use. There is a great demand for affordable and sustainable constructions especially for individuals generated by the tendency of urbanisation. According to a report by Jones Land La Salle (2010), the advent of robotics in construction in 2010 was a milestone for mankind throughout the world because most of the population lived in cities. The phenomenon is estimated by the World Health Organization that will evolve toward that year ie nearly 60% of the population will live in cities by 2030, and by 2050 over 70% of the population will be concentrated in towns.

The aim of new construction robots is to reduce one-tenth of the building time for a complex building products such as a high-rise building (Linner, 2013). Robotics can offer a durable and strategic method to build, efficiently and in a shorter time, quality homes. The field of Construction Robotics has got an increased importance in the last two decades among the research areas for Robotics. The Japanese entities, the leaders in the field of Robotization and Automation in Construction, in the 90s, had as main focus the development of new robotic systems and in the automation of existing machinery. They intended to automate construction processes in both the house building and civil construction. Unfortunately, due to the “bubble economy” crisis in Japan as well as due to unfulfilled expectations, the RAC was strongly reduced in the following years. Just a few construction robots succeeded to enter the market. Nowadays, the tendency is again reversed and new research area has been initiated. The present research activities in the field of RAC focus on new technologies (both software and hardware).

It includes components such as: sensors, automated inventory, human operator’s field safety and security etc. The worldwide industrial robots sales value, including industry software and engineering was in 2011 of US $ 25.5 billion out of which Europe represents almost 1/3 of industrial robots worldwide (according to European Robotics market 2012). Japan and Korea are leaders on the worldwide industrial robots in construction market so Asia remains in this domain the biggest market in the world. Balaguer and Abderrahim (2008: 001-002) consider it is precisely the specific of the construction environment the factor that acts as a powerful barrier in the implementation of RAC. The domain is characterised by using heavy objects, elements with big tolerance, low standardisation level, average industrialisation and pre-fabrication and the actors are insufficiently coordinated: architects, builders, suppliers etc.). Due to these characteristics it is very difficult to increase the level of automation and increase productivity in this domain. Table 2 shows the most important market barriers for this implementation process, ranking from 1- most significant to 7 least significant (Mahbub, 2008: 236).

From the perspective of the implementation, according to the same author (Mahbub, 2008) the main barriers in construction robotics are: R&D Innovation Cost is very high as it includes an increase in capital intensity and highly qualified workplace; high costs for updating the existing technology to the latest state of the art; training costs for using technology and costs related to the tailoring of the construction operations; incompatibilities with current practices and operations; the needed technologies are either very difficult to find, either do not exist; psychological barriers referring the acceptance of the new technologies. Robotization implies a complete restructuring of the organizational structure and of workforce. These changes will lead to different relationship between players in the industry.

Table 2: Barriers to market

Ranking	Barriers
1	High initial costs/ Financial Commitment from end-users
2	The fragmentation characteristic of the market
3	The difficulty to use and necessary adaptation process of the new technology
4	Incapability with the current processes and practices in the construction industry
5	Low technology literacy of the participants to the construction process, need for specific training and even for different skills and competences
6	Unavailable locally and difficult to obtain
7	Not accepted by workers

Source : Mahbub, 2008: 23

The Study on "The cost of non-Europe: the untapped potential of the European Single Market" by London Economics and PricewaterhouseCoopers EU Services (April 2013: 328-383) shows other important factors that discourage innovation in the construction industry: construction companies rely on suppliers for innovation instead of developing knowledge themselves, or in partnership with specialist R&D organisations; it is very hard to find a replicable solution; the construction domain involves projects that are very different from each other in terms of function (residential/non-residential/civil), organisation (simple residential/complex non-residential), implementation and execution (design/build/operate/own/transfer), and geographical and historical circumstances; customer demand in the construction industry may be a driver as it may sometimes be an obstacle as well to innovation; regulations, as legislation, standards and norms may shape the development of new products, materials and behaviours; hidden innovation, as many innovative activities in the construction sector are difficult to track as they may involve organisational innovation that is not based on cutting-edge research, and often occur at the company-consultant-client interface rather than in R&D labs.

The term "robotics building" appeared after about 30 years; then in Japan they have been researched and developed over 550 systems that include both robots realization of construction, operations and automated systems without human manipulation. North America, although pretty much involved in this industrial branch, developed through cooperation between Japanese universities and construction companies in the robotics innovative technologies in construction. One example is the system introduced in the Netherlands by a major European construction company; "BAM" .This was more like a mechanized construction system. A particularity of the system is the high ratio of prefabrication. Most of these systems is represented by prefabricated interior walls, prefabricated concrete façades – sometimes with the glazings included – and all these are supplied on the construction site and will be installed by specific workers. Except for few individual projects, in Europe construction robotization was on a smaller scale and has been usually focused on specific areas of construction.

There is no value chain which is universally accepted and applied by the construction industry. This may be due to the complexity and fragmentation of the sector's supply chain. Like in any other industry, the value and complexity of work pieces or products rises along the value chain. We may identify two main categories of stakeholders: internal stakeholders and external stakeholders. The internal stakeholders are generally members of the project consortium or are financial service providers. The external stakeholders are those who are affected significantly by the construction project. According to a Report by London Economics and PricewaterhouseCoopers EU Services, called "The cost of non-Europe: the untapped potential of the European Single Market" (Final report, April 2013, p. 330) there are the following typical internal stakeholders: Users : end or intermediate users of the built premises; Designers: the authors of the architectural and technical design; General contractors: companies that are specialised in building processes and technical aspects of building; Manufacturers : producers of parts and elements used in construction; Distributors : commercial/technical intermediaries between manufacturers and contractors; Suppliers: firms that provide materials to manufacturers; Service providers: firms that are totally or partly in charge of the exploitation and/or maintenance of the building; Inspection, certification and regulatory body: they ensure the implementation and enforcement of the legislation in the field.

Among the external stakeholders we may mention: communities; social services; research organizations and universities; trade and industry; local residents; real state owners; inspection and certification organizations; political organizations; governmental authorities etc. From the perspective of the EC, the construction sector is extremely fragmented and it includes a high number of SMEs with significant differences in terms of performance between Member States. The sector still faces the difficulty of disseminating and applying best practices from a country to another. In these conditions "*better value-chain integration would significantly increase the scope for spill-over innovation effects from collaboration*". Even if there is a proven need and it could be marketable, the immediate realisation of construction robots in Europe is, in our opinion, still hard to achieve as it needs massive adaptation of technology, of structures and products. A combination of short-term funding, long-term funding of industry consortia representing the whole value chain, in combination with innovation and technology transfer strategies, can create in a step-by-step approach and by the combination of short-term and long-term development programs, and economically feasible approaches for automated/robotic on-site construction.

Relationship of the robotics and automation in construction to other Domains and Markets

Technology providers, such as mechatronics and robotics manufacturers, may take into consideration the opening of new markets in the construction industry. Also the concepts and technologies developed and tailored for construction industry could be diffused into other manufacturing industries. The construction industry could become a testing bed for future manufacturing systems in general (Linner, 2013). An important change in the production technology comes with a necessary change in organisation and administration of the entities applying it, in the product concept, in the informational networks within the company. An increased product complexity generates the need and demand for new manufacturing technology.

Conclusions

Worldwide, construction of buildings industry represents a unique economic activity and which at the moment is among the largest industrial employers. Cities are becoming more and more important in the European, but also in the global economy. Cities will absorb most of the demographic growth of the world. The automated and robotic construction methods will also address this policy element as the space of the city can be better used by building high sustainable buildings with lower emissions and optimal use of resources. When we talk about sustainability and durability in the field of construction, we must consider as well environmental, social and cultural aspects. More concretely, it involves areas such as design and management of constructions, of materials and their performance, of the resources and of the waste. These should be considered under the wider umbrella of urban development. Although there are still significant barriers that have been briefly presented above, the automated and robotic construction methods represent the best answer to nowadays construction area challenges.

Human capital is one of the basic factors of economic growth in the information, knowledge-based economy as its level of usage determines the innovation component. The economy of post-industrial society is based on using intellectual resources so that organizations become more and more innovative. Innovation area does not include only new products and technologies but also new methods and methodologies of organizing processes. Automation and robotization in construction will set new benchmarks for creating international, multidisciplinary teams able to work efficiently. The teams will be made of international standard specialists with already proven results. They will work together in order to offer a new solutions to the development of tomorrow's cities. New jobs and new occupational standards will appear in a high demand industry (the building industry). Thus, many of the societal challenges are addressed by implementing construction robots technology as it implies: a new operational and organizational structure; a higher productivity – as related to tasks and machines; a higher efficiency – from both construction products and processes; a new approach to health and safety – as it reduces the number of accidents and injuries, and also allows the reintegration of construction workers which have discontinued their work due to working incidents. The stimulation needed for this development to happen comes from financing the European R&D and innovation in the field of construction robotics by European Commission as well as by major contractors.

The implementation of automation and robotics in the construction industry is mainly influenced by the characteristics and the specific of the industry itself as well as by companies' attributes, parallel to variable considerations. There is no value chain which is universally accepted and applied by the construction industry. This may be due to the complexity and fragmentation of the sector's supply chain. Like in any other industry, the value and complexity of work pieces or products rises along the value chain. We may identify two main categories of stakeholders: internal stakeholders and external stakeholders. The internal stakeholders are generally members of the project consortium or are financial service providers. The external stakeholders are those who are affected significantly by the construction project. The instant realization of construction robots, through coordinated R&D and technology transfer is difficult to achieve as the approach necessitates a co-adaptation of manufacturing technology, organizational structures and products and thus a radical change of the whole industry. A combination of short-term funding, long-term funding of industry consortia representing the whole value chain, in combination with innovation and technology transfer strategies, can create in a step-by-step approach and by the combination of short-term and long-term development programs, and economically feasible approaches for automated/robotic on-site construction. Technology vendors - especially those in the branch of robotics in construction, building industry seek opportunities to promote their new ideas especially as these concepts and innovative technologies may find later broadcast in other branches of manufacturing industries. The automation of the building process should bring following benefits: creation of high value built environment by fast availability; fast compensation of high upfront cost; minimization of disturbance of functional capability of surrounding city environment; higher degree of capacity utilization of means of production.

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