Construction Automation: Post-Pandemic Integrated Robotized Construction Sites

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1 ABSTRACT

The interest in automation and robotics in the construction field has grown significantly in the last decade. Smart cities and smart construction depend mainly on applying the concepts of industry 3.0 and 4.0 which adopt the smart construction concepts. They include automation, 3D printing and robotics. Virtual and augmented reality along with the internet of things (IoT) can be useful tools for applying automation and coordination between the operators, engineers and autonomous machines. Construction faces problems after the pandemic due to large on-site crew and machines being used by workers side by side; thus automation is an efficient solution for construction after the pandemic providing a safe environment for working.

This paper is an analytical research work focusing on using robotics and autonomous machines on-site in different construction tasks to mitigate the pandemic effect. It analyses the impact of on-site automation and the challenges facing it. The case study presents a methodology for using integrated on-site robotics and machines and analyses their impact on tasks planning and execution. It ends up with a concept for applying integrated robotised construction on-site depending on smart construction concepts; thus reducing problems that arise when using single tasks robots as site planning and interference of robotics. Also this allows reducing on-site workers and applying social distancing responding to WHO measures as well as solving congestion on site which is necessary for the pandemic constraints.

Keywords: Automation, Robotics, On-site factories, Pandemic, Prefabrication, Construction 4.0.

2 INTRODUCTION

The pandemic affected the construction sector and led to delays and pausing of projects (Alenezi, 2020). This is due to the complicated nature of construction sites where several tasks are executed in parallel. The construction industry lags behind the manufacturing industry in applying advanced technologies. While Japan has been developing and applying automated construction and robotics more than twenty years ago, the construction industry in Egypt still relies on large on-site crew and hazardous working methods (Bock, 2008; El Safty et al., 2012).

Automated construction involves using single task robots for performing specific finishing tasks, material handling and assisting human workers on-site. It developed from working indoor and in factory settings to working outdoor in facade finishing tasks and up to building components assembly (Melenbrink et al., 2020). It also involves general purpose robots as drones, exoskeletons, 3D printers and cable driven robots. Automation levels ranges from operator assistance and up to full automation depending on the nature of tasks performed and site conditions (Bock & Linner, 2016a) However Harari (2016) stated that automated construction differs from automated automobiles industry.

This research objective is to prove that shifting to automated construction and coping with industry 4.0 concepts will be essential to mitigate the pandemic's effect. And to discuss the automation effect on the site's safety and human workers on-site, showing whether automation replaces or cooperates with workers.

In order to achieve these objectives, a literature review of the potentials of automation for the construction sector and the challenges facing construction due to the pandemic was carried out. Then a case study is performed for construction after the pandemic from pre-construction phases to full execution based on the precautionary measures requirements and the autonomous solutions selected for an educational building. The research ends with a discussion of the effect of automation on the construction industry, the challenges facing automation application and a concept for applying construction after the pandemic according to construction 4.0 principles.

ISBN 978-3-9504945-0-1. Editors: M. SCHRENK, V. V: POPOVICH, P. ZEILE, P. ELISEI, C.BEYER, J. RYSER, G. STÖGLEHNER

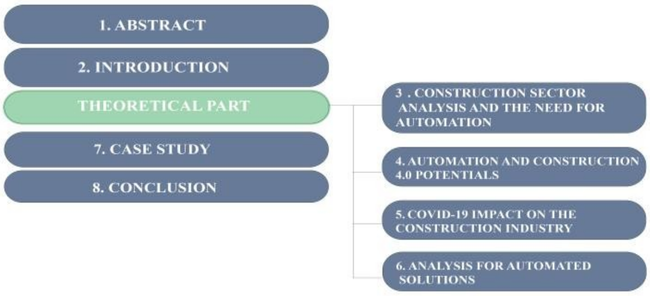

Fig. 1: Research parts (Researchers, 2021)

The research is divided into parts (fig. 1) including a literature review for the construction sector status, the need for automation and its potentials along with construction 4.0 concepts. Then a case study is performed for the automation of an educational building, ending with a concept for applying automation after the pandemic.

3 CONSTRUCTION SECTOR ANALYSIS AND THE NEED FOR AUTOMATION

The construction industry represents about 10-15% of the annual GDP (gross domestic product) of Egypt and enrols almost 15% of the Egyptian manpower (American Chamber of Commerce in Egypt (AmCham), 2020). However, workers are subjected to significant hazards that can result in fatal injuries or death in construction sites. Statistics show that the construction industry critical injuries are about 55,000 yearly (El Safty et al., 2012).

According to Manzo et al., (2018), it is possible to automate about 49% of all construction tasks. The automation potential is approximately 35% for labourers; it is 50 % for carpenters, 42%t for electricians, 50% for plumbers, and 88 % for operating engineers. Whereas in the next few decades, crane operators and bulldozer drivers could be displaced by AI-controlled machines.

4 AUTOMATION AND CONSTRUCTION 4.0 POTENTIALS

According to Lee et al., (2018), the fourth industrial revolution emphasises that the base for revolutionary changes in the construction industry is shifting towards digital and information technologies. This in turn enhances the creativity of organisations and leads to better quality assurance. Munirathinam (2020) stated that interconnectivity, automation, machine learning and real-time data are the key concepts of industry 4.0. This enables proper planning and information circulation throughout the project phases. BIM (building information modelling) plays an important role in design and coordination as well as 3D printing; it also enables programming of single-task robots motion and paths. Prefabrication, off-site 3D printing and modular construction market are expected to increase after the pandemic as it allows fabrication of building components in factory settings; thus reducing on-site congestion and decreasing on-site tasks to assembly work. For efficient structure assembly of components, the robot-oriented design concept (ROD) must be applied in the design phase as the assembly is performed by single-task robots or on-site factories. Unmanned aerial systems as drones can be aerial or terrestrial and it is used for inspection and surveying. Work assist as exoskeletons and robots help workers lift heavy loads and decrease injuries (Davila Delgado et al., 2019).

5 COVID-19 IMPACT ON THE CONSTRUCTION INDUSTRY

According to Breisinger et al., (2020) the construction sector employs a large share of Egyptian labour. The government managed to run the projects during the pandemic while monitoring the application of precautionary measures in the construction site; as decreasing the number of workers and social distancing. The construction activities witnessed a decrease of 5% during the pandemic. The pandemic affected the construction sector as a result of the travel ban and lockdown. The material supply is also affected by the lockdown. Social distancing and precautionary measures led to decreasing the number of workers on-site and shifting work and meetings from the conventional work methods to working virtually.

The travel ban affected the material supply and international specialists' presence. The lockdown reduced the working hours and productivity leading to contractual problems. Companies started reducing staff which led to unemployment (Al Amri & Marey-Pérez, 2020). The construction projects' delay was determined as a critical delay. This occurs when contractors do not finalise the project in the contract period (Alenezi, 2020).

According to the (MAP, 2020), the construction sector income witnessed a decrease due to several factors including the materials shortage. The steel production had significantly decreased whereas the cement production slightly increased. This is obvious in the GDP which declined to 8.1% in the second quarter of the fiscal year 2020.

Construction projects were paused due to the lack of demand by the customers, supply chain problems or difficult working conditions during the lockdown with safety measures and government restrictions. This has affected the economy negatively and workers became jobless (Wallace-Stephens & Morgante, 2020).

The labour cost is estimated to increase compared to machines that can still work in close proximity. This is due to the fact of labour shortage due to social distancing and partial lockdown, while machines do not require social distancing or hygienic measures (Wallace-Stephens & Morgante, 2020). Therefore the pandemic accelerated the shift to automation in several industries. The use of robotics in construction reduces communication between humans and could be a good choice instead of them. Robotics are more reliable and efficient and less costly. Also they can be controlled remotely so there is no need to be on- site (Chen et al., 2020).

(Wallace-Stephens & Morgante, 2020) described the construction industry as high Covid-19, high automation risk. It employs mostly men with high levels of young workers (under 30) who are expected to have low levels of education and are lower paid.

In the design phase, engineers and planners worked from home which saved much time and cost. However, working from home cannot displace the site visits and real meetings. Virtual site visits can be a choice for foreign specialists and external visitors; hence virtual reality will play an important role in construction sites (Jones et al., 2020).

Online meetings decrease cost and time and facilitate coordination between the project's teams and stakeholders. This enabled the stakeholders and client to monitor the project progress on site. Videos and digital aids are used to track work progress, safety measures and absent workers on site (Jones et al., 2020).

6 ANALYSIS FOR AUTOMATED SOLUTIONS

This section presents an analysis for automated solutions which can be applied on-site throughout the different phases of construction. Starting from the site preparation phases, substructure work, superstructure work and ending with finishing work. Material handling and storage can also be automated to store and deliver material in time to specific locations. Several systems have been developed by different companies, some examples have been used on-site while others are still in the conceptual phase. The examples presented in this section are the most convenient ones according to the project requirements and degree of automation. However, automated systems are not limited to the mentioned examples.

6.1 Site preparation phase

Excavation and site levelling work is considered a mature technology. A number of autonomous machines have been developed for construction in contrast to the mining industry (fig.2). Research in automation of those tasks is still in progress and only concepts are available as Volvo's autonomous solutions (fig.3). However, add-ons for upgrading conventional construction equipment are being used to achieve different levels of automation; including hardware add-ons (fig.4) or software for programming machines (Bock & Linner, 2016a).

Fig. 2 (left): Automatic Digging and Soil Removing robot (Tokyu, 2016) Fig. 3 (middle): Volvo compact excavator (Volvo, 2021)
Fig. 4 (right): Add-ons for conventional equipment (ASI, 2016)

6.2 Substructure work

The Pile driving process can be automated based on a 3D model for the soil and piling plan (fig.5). It cuts piles to the desired length after the driving process and allows real-time calculation of the soil parameters during the process (Hovila, 2012).



Fig. 5 (left): Pile driving machine (Hovila, 2012). Fig. 6 (middle): Reinforcement placing robot (Kajima, 2016). Fig. 7 (right): concrete distributor (Kajima, 2016).

For reinforcement positioning, Kajima's reinforcement positioning mobile robot is used (fig.6). While concrete casting is done using Kajima's rail-guided concrete distributor (fig.7). Concrete levelling and compaction are executed using Fujita's Concrete Floor Levelling Robot (fig.8) (Bock & Linner, 2016a).

3D printing using concrete is performed using the gantry system COBOD (fig.9) developed by Peri. Kajima developed positioning and joining of vertical reinforcement robot (fig.10) (Bock & Linner, 2016a).

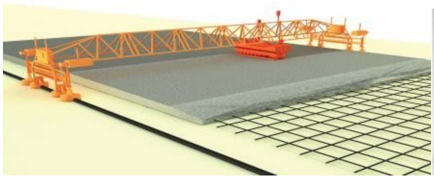

Fig. 8 (left): concrete levelling robot (Kajima, 2016). Fig. 9 (middle): CBOD 3D printer (Peri, 2021). Fig. 10 (right): Vertical reinforcement robot (Fujita, 2016).

6.3 Superstructure work

For handling, assembly and repeated positioning tasks, the big canopy on-site factory is used (fig.11) (Bock & Linner, 2016b). Concrete casting work is done by the compact concrete distribution robot (fig.12) by Kajima which can be programmed or manually guided by a worker. Reinforcement is positioned using the Automated Crane developed by Takenaka (fig.13). The reinforced concrete cores are 3D printed using the COBOD printer (Fig.9).

Bricklaying is performed using fastbrick Hadrian system (fig.14) which is mounted to a truck on which bricks are stored. Another example is SAM100 (fig.15) bricklaying robot which has high productivity and is compact enough to be used on upper floors (Bock & Linner, 2016a).

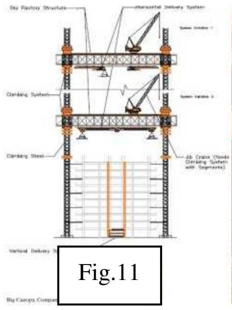

Fig. 11: Obayashi on-site factory (Bock, 2016). Fig. 12: Concrete casting robot (Kajima, 2016). Fig. 13: Reinforcement positioning crane (Takenaka, 2016). Fig. 14: Hadrian system (fastbrick, 2021). Fig. 15: SAM100 (construction robotics, 2021).

6.4 On-site material handling and storage systems

Obayashi developed an automated on-site delivery system consisting of automatic transfer equipment, automated forklift and automated storage rack (fig.16); hence enhancing autonomous operation. Other material handling systems include the Kajima rail-guided system (fig.17). It is more efficient by being programmed after standardising the routes and allows coordinating with the arrival of the materials on-site. Takenaka developed a mini-logistic unit for material transfer (fig.18) (Bock & Linner, 2016a).

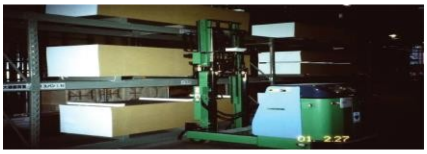

Fig. 16 (left): Material handling system (Obayashi, 2016). Fig. 17 (middle): Rail-guided system (Kajima, 2016). Fig. 18 (right): Automated mini- logistics unit (Takenaka, 2016).

6.5 Finishing Tasks

Finishing tasks include exterior finishing for façade work, as well as interior finishing. Interior finishing includes tile work for floors and walls, wall painting, partitions' and ceiling panels installation.

6.5.1 Exterior façade components installation

Exterior finishing involves the installation of façade glass panels, painting work. Façade panels are installed using two robots depending on the panels' size. Kajima developed two systems for this purpose. A system installed on the roof (fig.19) to assist in lifting large panels while the final fixation is done by workers from inside the building. It operates from the roof by an operator. Another system is the compact lightweight system (fig.20) which assists in panels' installation while operating from inside the building; this in turn limits the panels' height installed and can be used for small windows and façade beams (Bock & Linner, 2016a).



Fig. 19 (left): Panels' installation system mounted to the roof (Kajima, 2016). Fig. 20 (middle): Panels' installation on-floor system (Kajima,2016). Fig. 21 (right): Façade painting system (Kajima, 2016).

6.5.2 Facade painting

Facade coatings, spraying and full painting stages are performed by Kajima's painting robot suspended from the roof (fig.21). The material supply system is located on the ground floor and supplies material via a hose. It has a sensor designed to detect wall irregularities and facade elements and openings to avoid them. It has a productivity of up to 290 m2/hour (Bock & Linner, 2016a).

6.5.3 Interior finishing tasks

For tile setting, FCL developed a robot that can be programmed, fully or partially automated. It consists of a mobile platform that can move on tiles and has a storage area on board, a control and power supply unit and a suction end-effector for holding tiles (fig.22). It requires a worker to assist in corners and critical areas by cutting and placing tiles and can work with other similar robots 24/7; thus increasing productivity (Bock & Linner, 2016a).

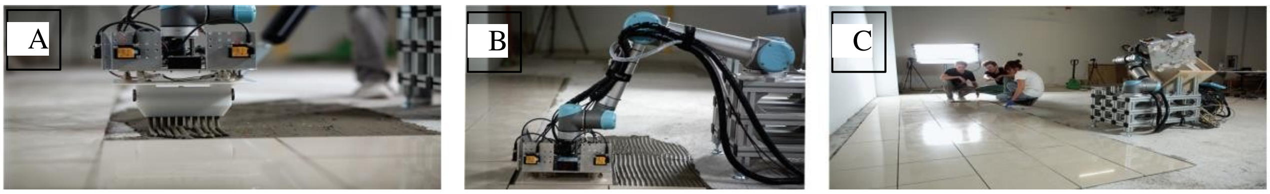

Fig. 22: tiles setting system A) mortar placement, B) tile placement; C) overview of the machine showing tiles placed (FCL, 2016).

The tile setting robot by Hazama and Komatsu consists of a tile setting unit, mortar storage and a gantry system for moving the tiles setting unit along the wall. The tile placement is done in vertical strips (fig.23), strip by strip and only an operator and worker are needed to set the system and prepare the wall for the process. However, the size of the tile is fixed (Bock & Linner, 2016a). Tokyu introduced a fully automated mobile platform system (fig.24) for installing ceiling panels with storage on board. Interior wall finishing can be performed using robots; wall plastering is done by semi-autonomous or assisting robot Anex (fig. 25) which only needs to be positioned by a worker. For fixing light fixtures and fittings, a mobile drilling robot by nlink (fig.26) is used which measures, marks and autonomously drills holes in the ceiling. The robot path can be programmed using a BIM file with only manual positioning of the robot by the operator (Bock & Linner, 2016a). MIT developed an automated robot for the partition framing installation (fig.27). It has a storage area for the channels and an efficient manipulator. It consists of two systems; the trackbot for installing C-channels on ground and ceiling, and the studbot for installing studs (Bock & Linner, 2016a).

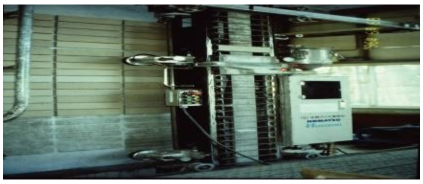

Fig. 23 (left): wall Tiling (Bock, 2016). Fig. 24 (middle): ceiling panel robot (Tokyu, 2016). Fig. 25 (right): wall plastering Robot (Anex, 2016)


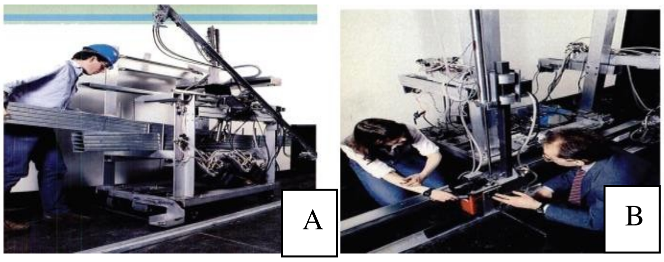

Fig. 26 (left): drilling robot (nLink, 2016). Fig. 27 (right): A) studbot system B) trackbot systems (Bock, 2016)

7 CASE STUDY: FACULTY OF FINE ARTS BUILDING AT PHAROS UNIVERSITY CAMPUS, ALEXANDRIA, EGYPT

The case study illustrates the automation for the faculty of fine arts building at Pharos University in Alexandria. It is a horizontal building divided into three blocks, consisting of a basement, ground floor and seven levels (fig.28). The structural material is concrete and the building footprint area is 3,660 square meters. This case study provides a concept for automating the construction tasks of the building clarifying the changes that would take place in the construction materials to meet the robots' specifications. The facade (fig.29) includes glass panels, windows and a large mashrabiya which will be 3D printed offsite and assembled on-site.

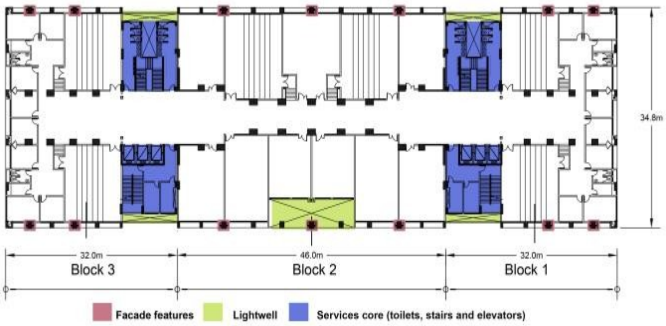

Fig. 28 (left): Building repeated floor plan showing zones (Researchers, 2021). Fig. 29 (right): Building main façade visualization (Youssri Azzam, 2019).

8 METHODOLOGY

This section presents the methodology applied to the case study of the educational building. It starts with the planning tasks and workers' shifts according to the pandemic's constraints and preparing a covid-19 work resume plan. Then performing a survey for tasks that require automation; to decrease on-site crew and time. And finally the development of a concept to apply automation on-site according to the pandemic's measures; starting from pre-construction phases and throughout the on-site tasks. Then a discussion is made to analyse the outcomes of the case study, the requirements to enhance automation application, and the challenges facing automated construction on-site.

8.1 Covid-19 work resume plan

The pandemic imposes changing the way construction projects are implemented starting from pre-construction phases. Social distancing and precautionary measures are a must to mitigate the pandemic effect. Working from home and coordinating through different platforms is one of the solutions to decrease congestion in offices and on-site. It saves time and improves coordination by synchronization of work and data. Virtual reality can be used for training on-site workers remotely. Planning of tasks and workforce would enhance the work sequence and avoid on-site congestion. Also, tasks should be ranked according to the degree of risk of each task and choosing a suitable solution. Some countries imposed preparing a site safety plan by the contractor identifying the necessary measures and precautions on-site, the site access, protective equipment provided, screening, facilities as well as isolation wards in case of infection. Relying on new construction techniques and off-site manufacturing is another solution to decrease time and replace the shortage of on-site workers. A summary for work resume solutions is shown in (fig.30).

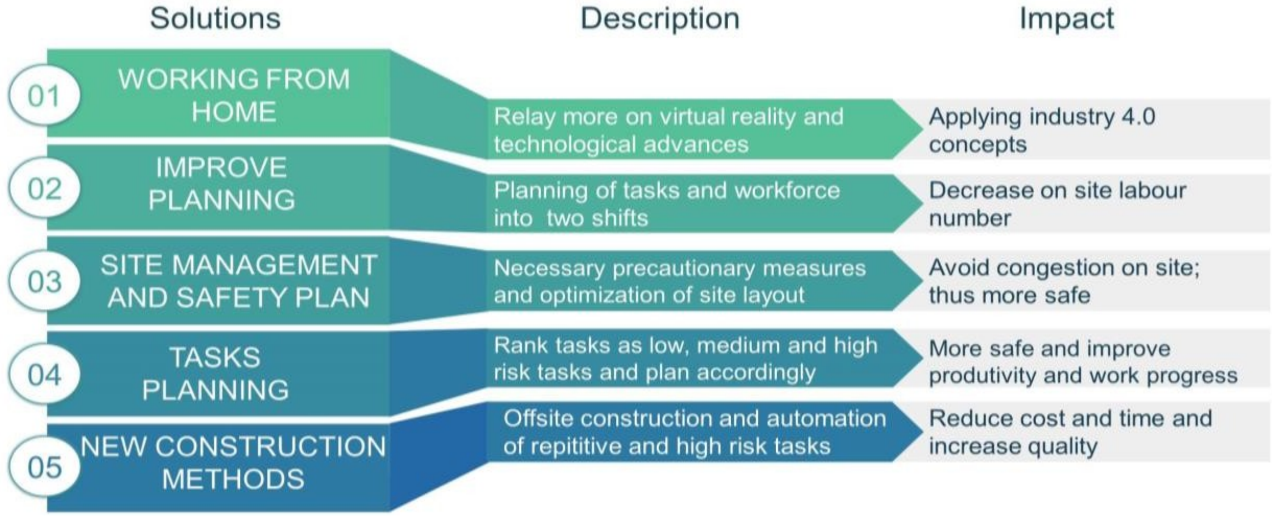

Fig. 30: Solutions for work resume on site and their impact (Researchers, 2021)

8.2 Survey for tasks which require automation

Construction tasks that have a priority for automation are tasks that require a large crew; hence it is a must to reduce on-site workers. Concrete work is an example as it involves several tasks from formwork preparation, reinforcement placement and concrete casting and finishing. Solutions for concrete work include prefabrication of concrete components off-site autonomously and only assembling them on site. Another solution is automation by using robots for each task of the conventional concrete tasks. Automation also involves 3D concrete printing which can be performed using fibre reinforced concrete; hence reducing the need for reinforcement or by placing reinforcement autonomously using robots. Façade finishing work is a high-risk task and accounts for several injuries; thus automation would be safer. Interior finishing tasks require automation as well since it is executed indoor which exposes the workers to the risk of infection.

8.3 Concept development

Applying automated construction during and after the pandemic involves several aspects (fig.31). It starts from the data gathering and work monitoring during construction. This involves construction methods and design requirements to apply automation efficiently. Robot oriented design is a must to adapt to working with robots and manipulators. The major problem during construction is to reduce on-site congestion. This can be achieved by reducing site visits and instead use drones to monitor work on-site. On working with prefabricated components, coordination between on-site construction and components delivery and storage on-site must be planned. BIM links all the phases from data gathering, designing, planning, scheduling to components fabrication and 3D printing industry. In case of limited storage area, the construction consolidation centres are used as it allows storing components in centres or warehouses and acts as a distribution facility and delivers them to the site on time for use without being stored on site.

ISBN 978-3-9504945-0-1. Editors: M. SCHRENK, V. V: POPOVICH, P. ZEILE, P. ELISEI, C.BEYER, J. RYSER, G. STÖGLEHNER

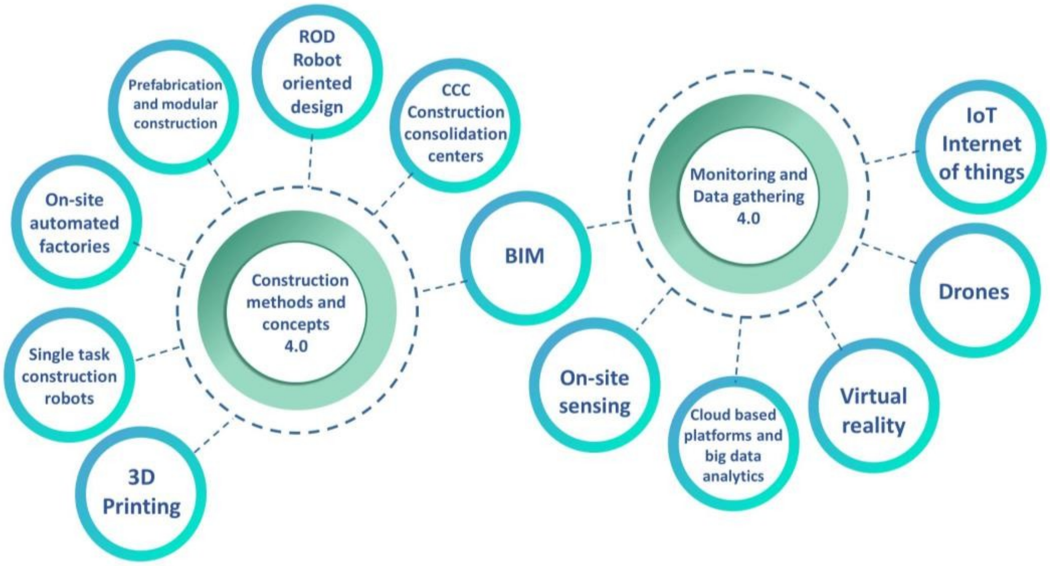

Fig. 31: Automated construction 4.0 concepts (Researchers, 2021)

8.3.1 Site preparation phase

Excavation and site preparation tasks are executed using mature technologies with add-ons for autonomous operation (fig.4). Digging is done with Tokyu digging robot (fig.2) and excavation using Volvo excavation robot (fig.3).

8.3.2 Substructure work

The building's foundations are composed of piles and a raft foundation on top of the piles. The pile-driving process is performed using the pile driving machine fig. (5). The raft foundation is executed using Kajima's reinforcement positioning mobile robot (fig.6). While concrete casting is done using Kajima's rail-guided concrete distributor (fig.7). Concrete finishing work is executed using Fujita's (CALM) (fig.8).

Foundations walls are 3D concrete printed using Peri COBOD machine (fig.9). Reinforcement work is done by Kajima's reinforcement robot (fig.10).

8.3.3 Superstructure work

For decreasing on-site tasks, columns, beams, slabs and stairs are prefabricated and brought on-site for assembly after being stored in CCC due to the limited site area. The building structure is constructed in three phases, since it consists of three blocks. This in turn prevents congestion on-site. The slab type is precast hollow core slab. The Big canopy on-site factory (fig.11) is used for precast components handling and assembly. Then concrete grouting is done using the compact concrete distribution robot by Kajima (fig.12). The reinforced concrete cores are 3D printed using the COBOD printer (fig.9). The reinforcement is positioned using Takenaka's crane robot (fig.13). Brickwork is performed using SAM100 (fig.15) and fastbrick Hadrian system (fig.14).

8.3.4 Material handling

Obayashi's automated on-site delivery systems as well as Takenaka's unit are used on floors (fig.17 and 18). While Kajima's system is used for materials handling on the ground floor upon arrival on-site (fig.16).

8.3.5 Finishing work

Exterior finishing involves the installation of façade glass panels, painting work. Façade panels are installed using two robots depending on the panels' size. Kajima's system installed on the roof is used to assist workers in lifting large panels (fig.19). For small windows, Kajima's robot (fig.20) is used operating from inside the building. Façade painting is executed using Kajima's painting robot suspended from the roof (fig.21). Interior finishing involves tiles setting by FCL robot (fig.22), ceiling panels' installation by Tokyu mobile platform (fig.24) and installing partitions by studbot and trackbot (fig.27).

Wall plastering is done by Annex system (fig.25) and interior wall tiling by Hazama and Komatsu (fig.23). nLink robot is used for drilling holes in the ceiling for fixtures (fig.26).

8.4 Results and Discussion

The case study presented the application of single-task robots along with on-site factory to automate the construction of the educational building. This involves the use of construction 4.0 concepts to make work and coordination easier throughout the project's phases. The objective of the case study was to prove that automation is a safe solution for the pandemic restrictions without affecting work progress. This will be discussed in the following subsections.

8.4.1 Compliance with covid-19 restrictions

By applying automation, the reliance on on-site crew decreases significantly as almost every system requires a few workers; including the operator and one or two helpers in some operator assistance systems. Touchless equipment is an important requirement after the pandemic; thus autonomous systems are a good choice as they are remotely controlled or automated.

8.4.2 Productivity

Automation increases work productivity and decreases the overall schedule. It allows working continuously in two shifts and some systems can work for a full day. Some systems are used for various tasks by integrating different end-effectors; thus reducing the number of equipment used on-site and avoiding congestion. Automated systems allow performing tasks in parallel which cannot be achieved by traditional working methods due to the need to reduce on-site workers.

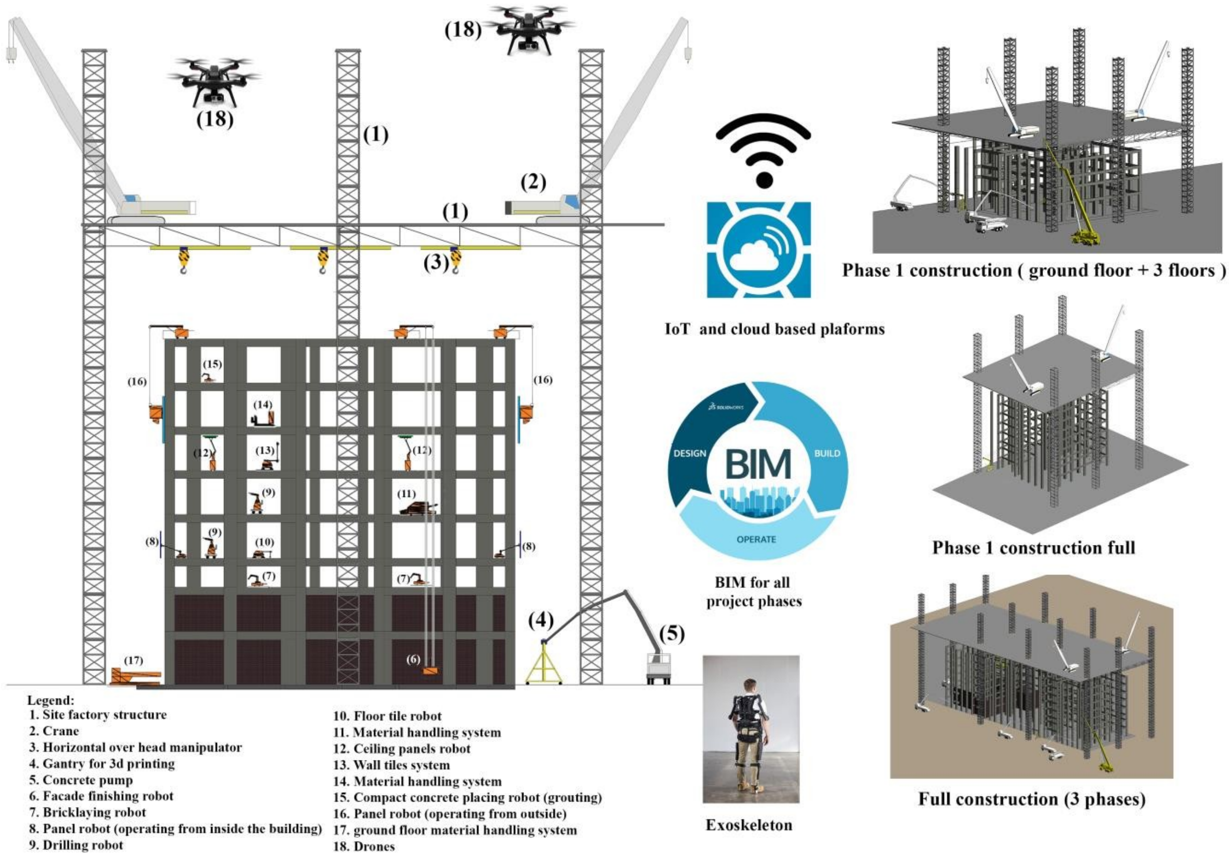

Fig. 32: Building construction progress, robots, systems and technologies used for automation (Researchers, 2021)

8.4.3 New technologies and design considerations

The potential of off-site manufacturing for high-order components as full detailed façade components, or full bathroom modules is expected to increase. Prefabrication of structural components is also gaining attention after the pandemic. This decreases the dependency on professionals to assemble them and allows automated assembly by on-site factories. 3D printing on-site saves time and allows customised designs without using scaffolding, also off-site 3D printing is efficient as it provides a variety of materials and prevents on-site congestion. IoT, connected devices and drones are essential for monitoring work, on-site workers and ensuring social distancing. A summary of the systems used in the case study are shown in (fig. 32)

With increasing automation levels, the design stages become more detailed and complex. The level of detailing increases to avoid errors during execution. To ensure good quality of the produced components, architecture design must cope with robot-oriented design to allow robotic assembly and integration of different systems in on-site factories. Design for assembly and disassembly are new emerging terms that decrease time and waste on-site during construction and deconstruction of buildings. Though the whole system seems more complex than the traditional construction methods, it can be divided into more simple sub-systems and components must be designed accordingly. On-site logistics and robots work cells must be well planned by an expert to avoid conflict between systems operating on-site floor by floor and phase by phase. Due to the lack of on-site storage and the nature of the site, CCC (construction consolidation centres) are used to supply components upon assembly; thus avoiding components damage or improper storage and congestion on-site.

8.4.4 Degrees of automation and construction workers condition

Automation levels vary from operator assistant to highly automated systems, however, full automation is still in the conceptual stage. Although automation decreases the reliance on on-site workers, it does not displace workers completely as automation starts gradually. This allows shifting workers to operators and supervisors on and off-site as well as helping in robotic assembly operations after proper training, so it does not cause unemployment. Due to the high cost of automated systems and shifting to automation, shifting is done gradually and for specific tasks depending on the project's scale and location. In large scale projects, automation saves money for the contractor and provides high quality and decreases materials waste as well as labor insurance cost. However, in remote and uneven terrain sites, some automated solutions would be difficult to use and to set up routes required for their operation or even to ensure systems and workers safety.

8.4.5 Challenges facing automation application

The high initial cost of robotics and automated systems is among the major challenges facing its application. The lack of trained, educated workers who can deal with advanced technologies is another challenge. Laws and regulations are an obstacle for importing, implementing or manufacturing of advanced machines. The time required for setting up equipment must be considered to avoid delays in the project's overall schedule. Drones operation must comply with the country's regulations. The flight zone must be defined for the crew operating the drone showing potential hazards as power lines, high-traffic areas, or high structures and machines on-site which are higher than the drone potential. Coordination with filed crew and work scheduling and planning is necessary to avoid accidents on-site. The complexity of automated systems and their interference in small sites due to improper planning must also be considered.

9 CONCLUSION

Shifting to automated construction and coping with new technologies became essential. The pandemic affected the construction sector by delaying projects and causing financial problems; thus, it is considered a catalyst for automation. Automation of construction tasks and applying construction 4.0 concepts throughout all the project phases is a must to mitigate the pandemic's effect. It helps decreasing on-site crew and replacing them with operators and helpers assisted by robots. However; in order to apply automation efficiently, planning of tasks and systems used must be considered. Proper planning for tasks, workers, and equipment plays a huge role in resource allocation, decreasing time and costs. Also, a robotics specialist must be involved in the planning of automated systems along with site logistics to ensure the integration of systems during operation. Prefabrication of structural components is expected to accelerate construction progress. 3D printing applications are expected to increase on-site for customized designs, and off-site for components in the facade. This in turn saves time, as only on-site assembly is required. Single task robots planning with on-site factory prevents congestion on-site or interference of systems. Robot-oriented design concepts allow components design for assembly and ensure components payloads according to the robots' specifications. However, automated systems and 3D printers' costs would hinder using advanced technologies. Regulations and codes must be updated to allow using new technologies and importing them.

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