



Adopting Industry 4.0 in Construction Industry

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Abstract: Industries are often restrained to meet their aim in relation to productivity. This is due to the complexities and capabilities such as to cope with changing environment, for example technological developments and digitisation. Low productivity and ability for innovation are argued to be caused by the traditional nature of some industries. Hence, modern technology and/or concept like Industry 4.0 were developed for such industries to succeed in the modern world. This includes construction industry that demands for improvements to meet the clients' needs such as faster production, increased quality and budget control. Thus, construction industry may benefit greatly by adapting to Industry 4.0 environment. This paper aims to address how construction industry and Industry 4.0 converge together, by focusing on the managerial efforts in construction industry: project management and strategic management. This paper is based on review of literature to examine the managerial efforts and relevant sets of critical success factors that have greater influence on construction industry, and establishing the importance of Industry 4.0 to construction industry. A framework has been conceptualised to show how construction industry links to Industry 4.0 by focusing on the managerial efforts. Future study in real life environment is required to support the components of the proposed framework, as well as to test and validate its application amongst practitioners.

Keywords: Construction industry, industry 4.0, strategic management, project management

1. Introduction

Industries strive to deliver high-end services and product at the lowest cost, improving performance, and maximising profits as much as possible [1]. However, capabilities of some industries to achieve those are often restricted by the traditional nature of the industries themselves. For example, the complexities of inter-organisational communication and cooperation between the participating parties of a construction project are often miscommunicated that cause project delays [2]. In order to ensure the required level of performance improvements, such traditional industries needed to be transformed to a compatible level to allow interactions with the intelligent manufacturing systems that exist in some other industries [3]. "Industry 4.0" potentially allows such adaptation with the fast growing and advancements of modern technology and information systems, and offers benefits such as faster production, increased quality, improved control and minimised waste, among others [4]. It was introduced to promote the digitisation of manufacturing in order to overcome inferences such as big data, artificial intelligence, rise in analytics and business intelligence capabilities, as well as advancements in transfers between digital instructions and physical world (i.e. production environment) [5]. Digitisation in manufacturing allows the use of robotics and automatic workflows, increased access to information, 3D printing, and augmented/virtual reality, among others [2]. This minimises complexities faced by industries, including construction industry. However, these advancements are changing the way organisations operate such as design, produce, commercialise and generate value [6].

Construction industry is well known for its complication in terms of operation within an organisation and project completions, i.e. achieving organisational goals and project goals [7]. It is facing additional difficulty caused by this change in environment (i.e. technological developments and digitisation) as it affects organisational capability to survive sustainably [8]. The industry is often criticised for the lacking in innovation and low productivity. Construction industry without doubt is maintaining sustainability as it continues to focus on project management in order to achieve project

success. Strategic management appears critical to construction industry too, as project management must meet organisational strategy, and *vice versa*, in order to achieve organisational goals [9, 10]. Other programmes such as building information modelling (BIM) and the application of various digital technologies and systems has been adopted to enhance the productivity of the construction industry [6]. However further concerns arose in the form of interference to the management approach of traditional organisations, project management. Such radical innovations, often linked to employment of new technology, cause deep and complex changes within the organisation [11]. There is, therefore, a need to explore how construction industry may gain from Industry 4.0.

Industry 4.0 offers significant benefits to technologically modern manufacturing industries, but not to the traditionally oriented industries like construction industry. A suitable adaptation of construction industry to Industry 4.0 is necessary, but there is a lack of understanding as to how construction industry and industry 4.0 interact with each other. This paper, therefore, aims to explore the much needed interactions and/or managerial efforts in construction industry to adjust with Industry 4.0. This is approached through identifying the critical success factors (CSFs) of project management and strategic management, and summarising their interactions with industry 4.0 in a conceptual framework, as discussed in the subsequent sections.

2. Construction Industry

Construction industry is a project based industry and therefore the emphasis is on project management and project success [7]. However, it is argued that project management contributes to the project success. It is limited to achieving project goals only, and do not ensure organisational success [12]. Construction organisations often struggle to maintain success, as they are often affected by changes in environment such as the advancements in technology. Complexities that arise from the project itself, the project's organisational structure and the organisations' dynamic environment, are the key challenges in construction industry [13, 14]. This brings about the importance of strategies which is the action plan that key persons conduct to accomplish goals [15]. Strategies are derived through strategic management, based on the breakdown of the long term goals into multiple short term goals, with regards to the external environment (e.g. production environment, technology input) [16]. Looking from the perspective of construction industry, long term goals are the organisational goals, while short term goals are the project goals. Organisations are realising that projects are undertaken on the basis of strategy adopted [9], while projects require translating corporate strategies into actions [10]. Thus, pursuing strategic management alongside project management in construction industry develops the organisations' capabilities to be innovative to accomplishing project and organisational successes. Furthermore, increase in organisational capabilities e.g. through strategic management, will allow organisations to better adapt to Industry 4.0, which will be injected to projects for improved project success, e.g. through technology based project management.

This innovation capability is a complex concept as it is influenced by a variety of factors. The knowledge of the critical success factors (CSFs) reduces complexity and focuses on the main aspects during the execution process [11]. The advancements of Industry 4.0 that is disrupting the typical management models within construction organisations are directly affecting project success and affecting overall organisational success as well [6]. Hence, identifying and studying the CSFs of project management and strategic management is beneficial as it highlights the areas to focus while advancing towards adapting Industry 4.0.

2.1 CSFs of Project Management

Naoum et al. [17] mentioned that there are various factors (i.e. critical success factors) that affect project performance. Belassi and Tukei [18] stated that critical success factors (CSFs) are categorised into four areas which are: external environment, project manager and team members, organisation and the project. Pinto and Slevin [19] recognised ten CSFs, which include client acceptance, client consultation, project monitoring and feedback, communicating, troubleshooting, technical tasks, top management support, personnel, project mission and project schedule/plan. Varieties of case studies have mentioned factors that drive project towards success, or otherwise failures. It was observed that the factors that affect project performance differ as project characteristics differ from each other [20]. Hyvari [21] suggested that the case studies support a project-specific approach to improve project performance and through this, CSFs that lead to project success can be identified.

As such, a group of seven CSFs of project management have been extracted from literature [21-25], as shown in Table 1. The focus of the paper is to confluence how the managerial efforts lead construction industry to adapt Industry 4.0, hence detailed discussions of these CSFs are withheld and are discussed in greater length in a separate paper, whose focus is to develop CSFs itself. These CSFs were extracted from past papers which discussed numbers of CSFs relevant to project management. The CSFs are then refined and ranked in terms of the frequency of occurrence among the literature gathered and therefore its importance to the practitioners of strategic management. To support the CSFs gathered, further study on the subsequent success factors of CSFs were conducted, identified and gathered. This highlights the focus of each CSF that is significant to the success of project management.

Table 1 - CSFs of project management

CSF PM	
1. Management	- Top management support, clear and effective communication, project manager characteristics, performance management, risk management, stakeholder management, involvement of project team, change management, leadership and team management
2. Project related factors	- Framework conditions, project budget estimation, project brief documents, construction period, material and quality, relationships with other parties, manpower's skills, resource availability and contract and financial support
3. Strategic aspects	- Project goal, client criteria, scope of work, planning process, implementation process and review/evaluation process
4. Organisational Structure	- Project team work, organisational structure, project manager authority and influence and user involvement
5. Technical aspects	- Planning and programming techniques, project cost estimate and control
6. Environment	- External environment, politics, demand creation, legal factors and market intelligence
7. Innovation	- Tools, modern technology, team knowledge and software infrastructure

2.2 CSFs of Strategic Management

CSFs of strategic management should be prioritised as well, during its execution, as absence of the CSFs leads to pitfalls of strategy and overall failure of strategic management [26]. Gates [27] mentioned that in strategic planning (the earliest stage of strategic management), problems occur with regards to management information inadequacy for setting objectives, developing strategies, decision making and measuring results against goals. However, unlike project management, Rockart [28] argued that CSFs are not applied in strategic planning but rather used to gather information in order to solve problems such as those stated by Gates [27]. Hence, for strategic management, CSFs implied are more on CSFs that were considered when information to develop decisions for strategic planning which then forms strategic management to be implemented and as a result determines organisation performance. Therefore, the CSFs are based on the characteristics of CSFs itself, which are: CSF hierarchy, types, uniqueness and stability over time [27]. Even so, varieties of case studies identified different CSFs, which have been summarised in Table 2 [29-33].

The CSFs of strategic management are shown in Table 2. The detailed discussions of these CSFs are withheld and are discussed in greater length in a separate paper, whose focus is to develop CSFs itself. This is due to the focus of this paper which is the confluence of project management and strategic management in construction industry to adapt Industry 4.0. Similar to CSFs of project management, these CSFs were extracted from literature, which studied numbers of CSFs relevant to strategic management. The CSFs are refined and ranked in terms of the frequency of occurrence among the literature gathered and therefore its importance to the practitioners of strategic management. Further study on the subsequent success factors of CSFs were also conducted, identified and gathered to show the focus of each CSF that is significant to the success of project management.

Table 2 - CSFs of strategic management

CSF SM	
1. Organisational behaviour/culture	- Organisational specifics and activities, involvement of employees, processing system and mindset on organisational values
2. Management	- Leadership skills, effective communication, involvement of management and resources planning
3. Organisational orientation	- Security of service, expertise of human resource, trust, employee's commitment and employee's loyalty
4. Strategic aspects	- Strategy formulation and implementation, strategy evaluation and acting in compliance with law
5. Organisational structure	- Creation of organisational structure and assemble control system
6. Innovation	- Feasibility analysis, exploitation of modern technology and application of modern technology
7. Environment	- Competitive market, awareness and practice of cost culture, innovative improvements of cost, time and quality, product development, market introduction and diffusion

3. Industry 4.0

Industry 4.0 refers to the digitisation and automation of the manufacturing process in the form of Cyber Physical System (CPS) [3]. The development of Industry 4.0 aimed at increasing productivity and efficiency of an industry [34]. The concept of Industry 4.0 is that it integrates the emerging technologies that add value to the whole product lifecycle [35]. It is a stage where the human role in the production systems needs to evolve as smart approaches are taking over working activities [36, 37]. The concept of Industry 4.0 is challenging because it demands major changes including the degree of the involvement of human role and the integration of smart working to the whole product manufacturing cycle [2, 38]. Despite that, Industry 4.0 do offer supports for industries to cope with the changes. Furthermore, it may not be beneficial for industries to maintain primitive as advancements in technologies and information systems are rapidly growing.

Industry 4.0 supports industries toward automation and data exchange through its drivers: Internet of Things, Industrial Internet, Smart Manufacturing and Cloud based manufacturing [39]. It focuses on continuous improvements, value adding activities and waste prevention, and increasing productivity [2]. A key feature of Industry 4.0 is it being a smart factory that correlates physical world (e.g. human activities) and virtual world for example augmented-reality systems, advanced robotics and 3D printing [1]. The adoption of advanced digital technologies changes the way products are designed, produced, commercialised and valued. Industry 4.0 is aware of the environment and surrounding [40], and aims to achieve major objectives even in a dynamic environment [39]. Moreover, communication between products, their environment and business partners are enabled through the creation of digital value chains provided in Industry 4.0 [41]. In summary, Industry 4.0 aims to convert traditional practices, to improve performance and management, by interacting with the surrounding environment [38].

Industry 4.0 was originally intended to transform the manufacturing industry, but due to the current advancements of technologies and information systems, construction industry is greatly affected as well [2]. Construction industry faces challenges that may be different than the manufacturing industry. Many challenges create high level of uncertainties in construction industry. They may be described as the complex interrelated process of construction, the participating parties, fragmented supply chain, temporary project team at different stages, the project nature and details, as well as the project requirements [42, 43]. A great effort is required to coordinate and communicate all these in construction industry. Tools and techniques provided by managerial efforts are assisting construction industry greatly. The digital transformation offered by Industry 4.0 is seen as significant to overcome such challenges faced by construction industry.

4. Construction Industry and Industry 4.0: Relationship and Role of CSFs

Construction industry and Industry 4.0 have developed separately and their integration together is still minimal. The emergence of Industry 4.0 is quite recent whereas construction industry is stagnant and slow to adapt new ideas. In fact, construction industry can obtain variety of benefits through Industry 4.0 [44, 45]. The use of robotics and automation workflows instead of conventional construction technology may reduce labour costs, material costs and production time [46]. Furthermore, building quality, delivery time and budget of construction projects can be kept grounded by merging cloud computing and BIM technology [47], including improving collaboration between actors [48, 49]. Managerial efforts and health and safety during project execution can also be more efficient when big data analytics and virtual reality is combined with the conventional practice [50, 51]. So, Industry 4.0 offers a platform for improvements to construction industry and thus the need for construction industry to adapt to it.

Despite being demanded to adapt to Industry 4.0, construction industry needs to maintain focus to achieve goals to maintain sustainability of operation. Construction industry needs to adjust the goals with the changes caused by Industry 4.0. The importance to maintain success of project management and strategic management to achieve project goals and organisational goals, respectively, is critical. Thus, the proper execution of both project management and strategic management may influence the integration of Industry 4.0 and construction industry.

In order to adapt and adopt with Industry 4.0, a procedure to integrate it in construction industry need to be developed. Industry 4.0 and construction industry is complex in nature. Dallasega [2] pointed out that apart from BIM being the central technology for digitisation of construction industry, research on managerial efforts with regards to adapting and adopting with Industry 4.0 is still underdeveloped. This paper proposes a framework to show how Industry 4.0 can be adopted to construction industry by focusing on the managerial efforts that existed within construction industry. Exploring the CSFs enhances the management efforts by identifying the information needs of organisational decision-makers and highlighting the areas an organisation should focus on [27, 28]. In addition, CSFs expose the variables that affect the success or failure in pursuit of organisational goals. Therefore, CSFs add value to the management process. In this paper, CSFs presented in Tables 1 and Table 2 have been extracted from relevant literature based on the following criteria: (a) relevant works applying CSFs of project management and strategic management in different environments; (b) most frequent CSFs in past studies; and (c) those are cross checked to avoid repetition. Therefore, in order to support the framework, this paper argue that highlighting CSFs of project management and strategic management as presented in Table 1 and Table 2, could be useful to drive the interaction between construction industry and Industry 4.0.

5. Proposed Conceptual Framework

The proposed conceptual framework is developed as there is a need for construction industry to adopt Industry 4.0, by focusing on the managerial efforts within construction industry. As depicted in Figure 1, the framework presented has three parts: the central part of the framework (a) construction industry achieves project goals and organisational goals through execution of project management and strategic management respectively, whereby application of such management efforts assists in driving construction industry towards Industry 4.0; and Industry 4.0 offers its drivers for construction industry to take benefit from; (b) the seven CSFs of project management to be managed to maximise success of project goals and influence the interaction between construction industry and Industry 4.0; and (c) the seven CSFs of strategic management to be managed to maximise success of organisational goals and influence the interaction between construction industry and Industry 4.0.

Based on the proposed framework, the central part of the framework highlight how both construction industry and Industry 4.0 interact. The return arrows between central part show that both construction industry and Industry 4.0 are offering each other with the components that are within construction industry and Industry 4.0 respectively. Where, construction organisations adapt Industry 4.0 through proper execution of project management and strategic management. Construction organisations shall adjust their project goals and execution of project process to include the drivers of Industry 4.0. Meanwhile strategic management allows construction organisation to identify, plan and implement a strategy for the organisation to operate including the integration of Industry 4.0 to achieve organisational goals. From the Industry 4.0’s perspective, it assists construction industry’s adjustment to the modern manufacturing through the drivers which are cloud based manufacturing, internet of things, smart manufacturing and industrial internet. As project management and strategic management integrates Industry 4.0’s drivers within operation, the accomplishment of project and organisational goals can be enhanced. Benefits mentioned earlier in the paper such as the use of robotics and automatic workflows, increased access to information, 3D printing, and augmented/virtual reality supports lower cost of production due to reduced labour, improves communication and increases quality of product or services.

Moreover, parts (b) and (c) are vital to ensure the success of the interaction. The CSFs of project management and strategic management separately and together influences the improvements within construction industry as well as the adaptation to Industry 4.0. As CSFs are taken care of, the failure of project management and strategic management is minimised. The CSFs of both managerial approaches are important as they are directly affecting each other. Project management commences based on the strategy developed in strategic management whereas strategic management achieve organisational goals by achieving multiple project goals. Therefore, highlighting the CSFs within the framework aims to point out the need for construction organisations to consider the CSFs during the execution of project management and strategic management. Overall, this framework provides insights on how construction industry may adapt and adopt with Industry 4.0 by focusing on the managerial efforts.

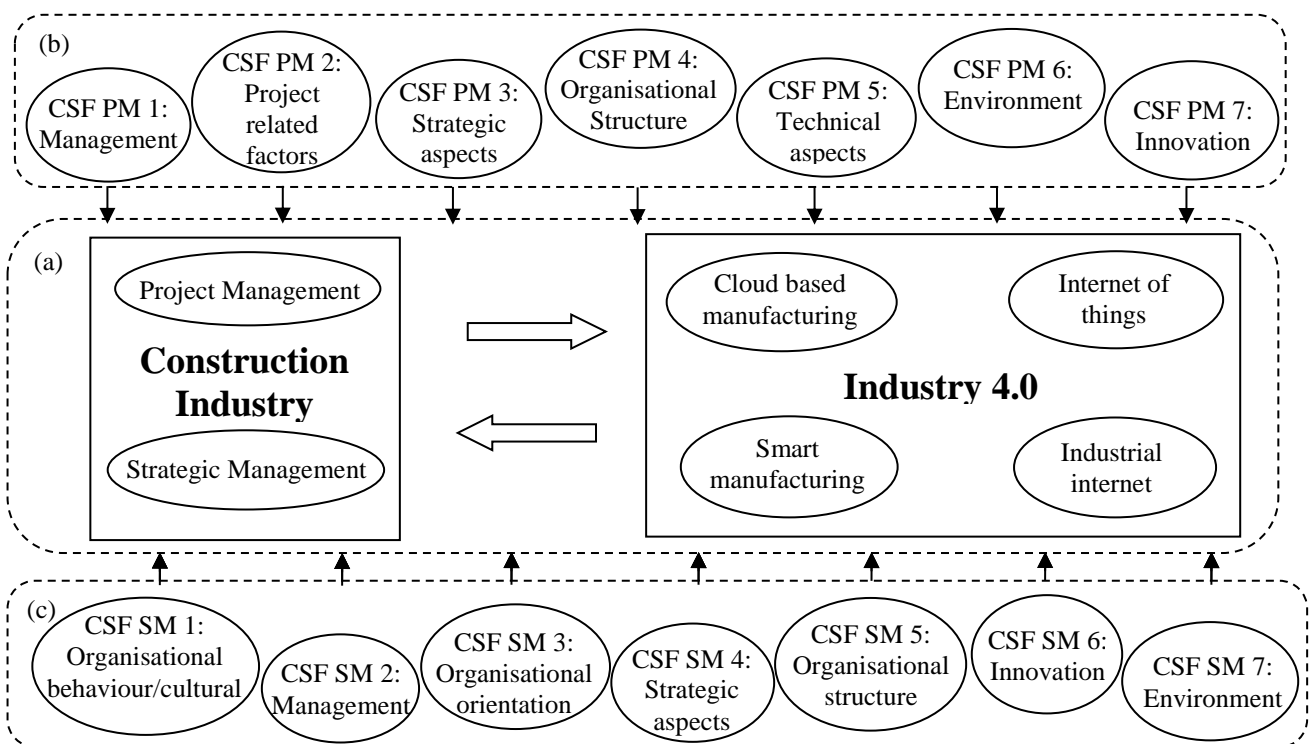


Fig. 1 - Conceptual framework for the adaptation of industry 4.0 in construction industry

6. Conclusions

The traditional nature of manufacturing limits improvements with regards to productivity, quality and budget control, among others. Industry 4.0 offers a platform for industries to evolve and overcome such challenges. Traditional complex industries, like construction industry, is often criticised for its poor productivity and lack of innovation. It also faces additional problems caused by the advancements of technology and information systems. Therefore, construction industry can potentially adapt to Industry 4.0 to improve productivity and innovation. By adjusting the traditional nature of construction industry with the digitisation of manufacturing through Industry 4.0, construction industry may gain many benefits. This includes lower cost of production due to reduced labour, improved communication and increased quality of product or services. However, the convergence of construction industry and Industry 4.0 with regards to managerial efforts is still lacking. With these, considering the three aspects: project management, strategic management and Industry 4.0, a conceptual framework is developed. This paper is however limited to the findings from literature. The three aspects might need to be adjusted further, especially the consideration of working environment within construction industry. Quantitative research is needed to support the CSFs highlighted in the proposed framework. Furthermore, the proposed framework needs to be tested and validated in real life environment.

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