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Factors affecting the market development of steel construction

Abstract

Purpose: The steel construction market has undergone gradual development in the past decades given its profound impacts on environment, economy, and society. The current study aims to facilitate a better understanding of the major drivers and issues behind the market development of the steel construction industries around the world.

Methodology: A three-step desktop search was conducted to select relevant research outputs published in the past 20 years. The research methodology in conducting these studies and their research trends were analyzed. Then the potential influencing factors for the market development of steel construction were identified through a content analysis of the selected studies.

Findings: A total of 59 articles were identified accordingly. These influencing factors were divided into five main themes, namely, contextual, institutional, industrial, project-related, and individual factors. In terms of the frequencies of these factors appeared in previous studies, "continuous development of standards, codes, and specifications" and "advance in product and process technology" were the top two driving forces in the market development of steel construction, while "cost issues" was the most frequently reported obstacle.

Originality/value: The study takes an initiative to establish a practical classification framework that can be dedicated to illuminating the critical issues or success factors affecting the development of the steel construction market. This framework can help policymakers, industry practitioners, and researchers achieve sustaining success in steel construction in the developed, emerging, and inactive markets.

Keywords: Structural steel, Drivers, Obstacles, Literature review

1 Introduction

Construction, including all types of buildings, transport networks (e.g., bridges, tunnels, rail track), and span structures (e.g., offshore platforms, exhibition halls, stadiums), creates considerable demand for a wide variety of steel solutions. There is a history of more than two centuries of using steel in construction sector (Dowling and Burgan, 1998). Steel solutions have considerable merits over traditional materials such as timber and concrete in terms of ductility, reliability, recyclability and aesthetics. With mounting concern regarding sustainable development in construction, steel solutions can deliver remarkable sustainable benefits at the design, execution, in-use and demolishment phases (Burgan and Sansom, 2006; Zhong and Wu, 2015).

The advantages that steel offers to the construction sector and built environment have long been recognized as evidenced by the increasing global market share of structural steelworks. The US leads in the market development of steel construction (Davies, 2000). It is reported that the steel-framed building sector owns a 50% share of the building construction industry in the US (Ansley *et al.*, 2007). Europe also holds a significant position on the successful application of steel construction. Over 95% of single-story industrial and 70% of multi-story nonresidential buildings in the UK use steel as the primary framing material (Shollock *et al.*, 2016). An increasing trend in the application of steel construction is also observed in other European countries, such as Portugal (Lamas, 2006) and Finland (Kouhi *et al.*, 2000). An upsurge of interests toward the adoption of steel structures has been observed in developing countries. Applications of steel space structures and steel bridges manifest considerable vitality in China (Yang, 1998; Dong *et al.*, 2000). In Brazil, there has been a relatively rapid increase in the application of steel structures for modern buildings and bridges (Batista and Ghavami, 2005). In Southern Africa, a multi-story structural steel framing with proper design and planning is considered to save developers over 25% on construction time and 15% on project costs, thereby driving the extensive use of steel in construction (Dundu, 2011). In addition to these active steel construction markets, the widespread use of structural steel in construction has not happened in Hong Kong (Wong, 2003) and North Cyprus (Celikag and Naimi, 2011).

The reasons behind the active or sluggish markets of steel construction have been addressed. Makins (1983) advocated that the contributory factors included the availability of steel products that satisfy user requirements and the ability of a central organization to formulate effective marketing strategies. Owens and Wood (1998) underscored five influential factors on the use of steel in construction in Europe, namely, national economic factors, regulatory framework, availability of cost and technical information, supply chain issues, and construction culture. Dowling *et al.* (2001) further heightened the importance of the government's initiatives on environmental and sustainability issues, as well as the strong influence of steel institutions on driving the adoption of structural steelworks. Moore and Tordoff (2007) summarized several industry collaborative initiatives by the British Constructional Steelwork Association (BCSA) toward the success of steel construction in the UK. Apart from these contributory factors, there are several issues associated with the depressed market of the constructional steel sector. The lack of experienced engineers, training and fabrication facilities and the prevalence of reinforced concrete structure were the major factors that make structural steel unfavourable in North Cyprus (Celikag and Naimi, 2011). In Hong Kong, high construction cost resulted from unpopularity in the application of structural steel discourage developers to choose this construction method (Wong, 2003).

Previous studies tend to primarily focus on addressing region-specific factors for the active or inactive steel construction markets, which may lack of a broad understanding about the common issues associated with the development of the global constructional steel market. The current study performed a systematic literature review, with an aim to synthesize and classify the major factors behind the market development of the steel construction industries around the world. A better and deeper understanding of the identified main issues can help policymakers, industry practitioners, and researchers achieve continuous success in steel construction.

2 Research methodology

2.1 Data collection and analysis

The current literature review conducted a three-step desktop search, guided by Darko *et al.* (2017) and Chan and Owusu (2017), to retrieve relevant research outputs. As a starting point, Scopus, which is considered as an effective search engine to conduct a literature review and has archived most of research papers in the field of engineering, management, and construction (Hong and Chan, 2014), was used to select relevant documents for the chosen topic. It can offer results of better accuracy than other search engines such as Web of Science, PubMed or Google Scholar (Falagas *et al.*, 2008). To obtain a workable number of search results, the keywords including *steelwork* OR *steel framed* OR *structural steel* OR *steel construction* OR *steel structure* OR *composite structure*, AND *market* OR *industry* were searched under the "title/abstract/keyword" field of Scopus, as well as *driver* OR *opportunity* OR *success* OR *benefit* OR *obstacle* OR *barrier* OR *constraint* OR *problem* OR *challenge* OR *issue*. The search was limited to subject areas such as engineering, energy, environmental science, business, management, economics, econometrics, finance, social science, decision sciences, and multidisciplinary. The studies published between 1998 and 2017 were sourced. Although the academic (peer-reviewed) journal papers are considered as a significant contribution to an in-depth understanding of the body of knowledge on a specific topic, book chapters, conference papers, business articles, and technical reports are not excluded in the current exercise as these sources could provide further academic and practical information on subject matter. Articles written in languages other than English were not included. As a result, 991 document results were initially retrieved from Scopus (searched in November 2017). Examination of title, abstract and full document (if accessible) was undertaken to scrutinize these articles that either partially or fully addressed the subject matter (Chan and Owusu, 2017) of the market development of steel construction. In total, 25 publications were found mainly covering journal articles and conference papers. The results of this pilot search indicated that *Journal of Constructional Steel Research* and

Journal of Cleaner Production have published the most articles (i.e. at least two papers) relevant to the market development of steel construction.

Afterwards, the authors realized that the search keywords were not exhaustive because some potential articles were missing. For example, Lamas (2006)'s study "describes the influence of Professor Patrick Dowling in the author's career and in the development of steel structures in Portugal based on university research and teaching and the creation of the Portuguese Association for Steel and Composite Construction". Batista and Ghavami (2005) emphasized that "the relatively rapid increase in the application of steel structures for both low and tall buildings and the modern bridges in Brazil are the results of an extensive effort of the steel producers and the improvement of steel courses and research programmes in several universities and institutions during the last two decades". These studies implied some reasons behind the development of steel construction, even though they did not mention any keywords such as "driver" or "factor" in "title/abstract/keyword" field of the article.

To achieve a comprehensive literature search results, a target journal search was performed in the second step. The journals/proceedings that explicated the subject matter with more than two papers (Osei-Kyei and Chan, 2015; Chan and Owusu, 2017) identified in the first step were selected as the target journals/proceedings. Their titles were searched under "source title" of Scopus, and the keywords *steel* AND *construction* were searched under the "title/abstract/keyword" field. The selection criteria for relevant papers were consistent with those in the first step, in terms of subject area, publication year, language, and relevance. Then a total of 22 articles were obtained in this stage.

The reason why the Google Scholar was not employed in the first search step was that it fails in implementing the most basic Boolean OR operation correctly (Jacso, 2005). However, while Scopus is limited to be coverage of open access sources, Google Scholar covers open access databases and single publisher databases (Neuhaus *et al.*, 2006) such as government and academic websites (Bakkalbasi et al., 2006). Because of its broader range of data sources, the use of Google Scholar generally results in more comprehensive citation coverage (Harzing and Van der Wal, 2008). For the completeness of a literature search, a manual search on the selected articles' references, author's biography, citation tracking and "related documents" search option of Google Scholar was performed to identify further relevant works. Additional 12 articles were retrieved accordingly. In all, 59 articles were finally selected for content analysis, which could provide sufficient information regarding the potential factors that may influence the market development of the steel construction industry.

The selected studies were sorted by year of publication, source type, affiliation(s), and research origin. The specific market sector and research methodology employed in these studies were outlined to address their research interests and trends. A wide range of contributory factors to the development of steel construction was extracted through a content analysis of the selected studies. These factors were initially coded together as the same category. For example, "improved methods of engineering design" (Owens, 2000) was coded as a driver of "adoption of workable design and construction solutions", and "many were caused by developments in joining techniques and fabrication" (Bjorhovde, 2004) was classified into a driving factor called "advance in product and process technology". "Steel structures are too expensive" (Arzel, 1998) and "relative economics of steel against its major competitor, concrete" (Lobo and Wildt, 1998) were coded as the same obstacle "cost issues". Subsequently, the identified drivers and obstacles were further classified into different sub-categories. For instance, "economical and efficient construction" and "ease of construction" are relevant to the "Buildability" of a construction project (Wong *et al.*, 2007) that was coded as a sub-category. Afterwards, the defined sub-categories were further grouped into different themes from macro- to micro-levels. For example, the sub-categories "Buildability" and "Constructability" were divided into "Project-related" factor, whereas "Technology" and "Supply Chain" were the "Industrial" factors. During the coding process, each category was then compared with others continuously for refinements until each of them represents a clear and distinct theme (Hon *et al.*, 2010).

2.2 Overview of the selected studies

A high concentration of publications that considered potential factors affecting the market development of steel construction was published in 1998, with a peak of 26 articles (Figure 1). These studies were mostly published in the Journal of Constructional Steel Research, which was contributed by the Second World Conference on Steel in Construction held in May 1998 in San Sebastian, Spain. However, a slight research interest on the chosen topic was observed after the year of 1999, as evidenced by a few publications regarding this matter. Nearly 80% of the selected articles were published in peer-reviewed journals (Figure 2), among which the Journal of Constructional Steel Research was the primary source. Research institutes contributed to most of the publications, followed by industry stakeholders, including steel manufacturers, architects, consultancies, and construction firms (Figure 3). Steel institutes and collaboration among research institutes, steel institutes, and industry stakeholders also had marked impacts on the sharing of experience and transfer of knowledge to improve the steel construction industry. Figure 4 shows that the UK overwhelmingly had the most publications that focused on identifying the reasons behind the market development of steel construction, followed by other European countries, China, and the US. Cross-border research on the chosen topic was rare (e.g., Lobo and Wildt, 1998).

The methodology employed in these studies could be broadly divided into seven types of approaches. Figure 5 illustrates the frequencies of the research methods used. The first type reviewed the historical and contemporary development of the steel construction industry (e.g., Dundu, 2011; Moore and Tordoff, 2007; Batista and Ghavami, 2005). In general, these studies: 1) began with an overview of the history and *status quo* of the steel construction industry by presenting chronological events in the industry; 2) the major construction applications and best practices of structural steel projects or technologies were presented thereafter; 3) detailed comments on these applications were provided; 4) opportunities or challenges to the steel construction industry were discussed; and 5) conclusions and recommendations for developing steel construction industry were offered. The second type focused on the existing problems within the industry. It went further to introduce specific work plans or guidelines (e.g., education and training programs; Cox, 1998) that could solve those problems and offer best practices. The third type was state-of-the-art reviews that presented the most recent scientific research and technical advancements in structural steelwork (e.g., Bjorhovde, 2004, 2009). This type of article often summarised the current knowledge and highlighted the importance of the need for further research and development. The fourth type, known as case study, was conducted to produce fresh insights into typical steel construction projects (e.g., Wong, 2003). These studies demonstrated the advantages of structural steelworks by offering their distinctive features and good work practices. Industry forum (e.g., Schexnayder, 2005; Tilley, 1998) or interview survey (Tingley et al., 2017; Simonen et al., 2011) was adopted in previous studies to solicit the ideas and views from design and construction professionals regarding practical problems within the steel construction industry. The last type employed a mixed method that included the analysis of secondary data source and survey (e.g., Owens and Wood, 1998). This method could provide comprehensive information about the contributory factors to the growth of the steel construction market.

3 Factors affecting the development of steel construction

The issues introducing new prospects or depression of the steel construction industry were grouped into five broad themes, namely, contextual, institutional, industrial, project-related, and individual factors. They were further classified into 18 sub-categories, in which 24 drivers and 22 barriers were ascertained (Table 1). In terms of the frequencies of these factors considered by previous research, it is shown that "continuous development of standards, codes, and specifications" and "advance in product and process technology" were the top two driving forces to the growing steel construction market, while "cost issues" was the most frequently reported obstacle.

3.1 Contextual factors

Market opportunities for steel construction are generally associated with national economic factors (Owens and Wood, 1998; Dowling *et al.*, 2001). A significant reduction of using steel was observed during the economic recession in Brazil in the 1980s, while steel became common from the 1990s during which national economic stability achieved (De Nardin and El Debs, 2013). The rapid growth of steel construction was beneficial from the growing economy in many marketplaces such as the UK (Moore and Tordoff, 2007) and Japan (Kanno *et al.*, 2012). Urbanization and demographic changes can support the growth of steel-intensive construction projects because of the increasing demand for public areas, playground facilities, and other urban furniture, reflecting the rapid economic growths in many developing countries. The demand for structural steel has been dramatically increasing as a result of the boom in construction of tall buildings and large span structures in China and Southern Africa (Yang, 1998; Shi, 2012; Dundu, 2011).

The need for safe buildings to be constructed in the earthquake zones (e.g., Japan) has urged the adoption of structural steel regarding its strength and ductility against strong seismic loading (Kanno *et al.*, 2012). Sustainable construction is a critical concern because of its high economic significance and strong social and environmental impacts (Zhong and Wu, 2015). Steel construction can facilitate sustainable development in terms of efficient use/reuse of available resources, reduced waste and water consumption, and labour saving. The burgeoning demand to achieve sustainability worldwide can shift to construction practices with sustainable steel solutions (Burgan and Sansom, 2006).

3.2 Institutional factors

Policy restrictions on limiting the use of structural steel hindered the steel construction markets in Romania (Bancila *et al.*, 1998) and Lithuania (Kvedaras *et al.*, 1998); the wide use of structural steel started after the elimination of these official restrictions. Government's roles are important to drive the market development of steel construction (Dowling *et al.*, 2001). Nowadays many government authorities around the world have adopted relevant policies that aim to incentivize the use of structural steel. For instance, the Japanese government have launched several financial schemes to aid the local steel manufacturers expand overseas markets (Katayama *et al.*, 2007). The Chinese government's investments on bridges and railways offer a stimulus for the adoption of steel structures (Yang, 1998).

The steel institutes/associations and technical service centers have played profound roles in enhancing the extensive use of structural steel in construction (Lamas, 2006; Baddoo, 2008; Moore and Tordoff, 2007; Dowling *et al.*, 2001). These organizations are intended to transfer advanced technology into work practices and broaden potential markets for steel construction. They have exerted numerous efforts in formulating effective market strategies, disseminating research findings, and increasing capabilities of construction actors. These organizations offer specifications, codes, standards, technical services, and quality assurance certifications to industry practitioners. They are active in research, education, and collaboration, and all aspects involved in the construction of steel structures. Through delivering education materials, professional journals, conferences and seminars, the steel institutes provide a platform of knowledge transfer for industry practitioners and other parties interested in the use of structural steel, thereby developing and expanding the markets of steel construction.

A lack of marketing promotion due to inactive steel institutions was one of the key reasons that explain the unpopularity of steel buildings in Latin America (Arzel, 1998). Effective marketing by the steel institutes, ranging from publicity and collaboration to technical services and education to members, made a significant contribution to expanding the steel construction market in Australian (Rehbein, 1998), the UK (Moore and Tordoff, 2007), and Southern Africa (Dundu, 2011). In addition to these industrial marketing activities, organizational activities undertaken by industry stakeholders, such as steel manufacturers, exerted great efforts in developing their products and providing technical support to their clients (Pedrazzi and Lozano, 1998), thereby potentially increasing the competitiveness of these steel materials.

The research community exhibits a wide range of advantages in driving excellent achievements in steel construction. Researchers contribute to the advancements of steel technologies and compatible design codes and standards (Baddoo, 2008). Given the need for significant breakthroughs in structural engineering practices, effective collaborations between researchers and practitioners have been explored to promote state-of-the-art steel technologies (Dundu, 2011).

Engineers without adequate knowledge and experience in structural steel design were reluctant to choose steel in North Cyprus (Celikag and Naimi, 2011) and in North

America (Allen, 2010). Teaching on the subjects of structural steel design philosophies and standards in universities are salient to the initial adoption of structural steel for future engineering and architecture graduates (Lamas, 2006). Continuing education is also necessary to enable practicing engineers to adopt proper steel designs (Allen, 2010). Education and training may ensure a continued supply of professionals and skilled labors with design know-how, and potentially change the attitudes and beliefs of future managers and employees (Cox, 1998). These beneficial activities can promote a certain culture in the steel construction industry, thereby facilitating a growing marketplace of steel construction (Batista and Ghavami, 2005).

3.3 Industrial factors

Contemporary construction practices and modern/futurism architecture considerably influence the adoption of steel structures (Ocio, 1998). Traditional construction practice using reinforced concrete has been proven with economic advantage and competitiveness. This situation happened in many marketplaces, such as Spain (Ocio, 1998), Latin America (Arzel, 1998), North Cyprus (Celikag and Naimi, 2011), Brazil (Lobo and Wildt, 1998), Lithuania (Kvedaras *et al.*, 1998), and Hong Kong (Wong, 2003), where architects and engineers were resistant to choose steel solutions. However, problems in reinforced concrete construction in North Cyprus, such as poor workmanship and shortage of skilled labors, drove the changes toward the consideration of structural steel as an alternative material for construction (Celikag and Naimi, 2011).

The limited use of structural steel in construction works in South America was attributed to a conservative construction culture (Arzel, 1998; Lobo and Wildt, 1998). Dowling *et al.* (2001) stressed the importance of a culture of continuous improvement as one of the principal factors that can bring success in steel construction. The positive construction culture toward continuous improvement enables practitioners to favourably consider steel over traditional competing materials, and further transform this standpoint within the steel construction supply chain (Dowling *et al.*, 2001).

Advances in products, fabrication methods, joining techniques, and protective systems boost the competitiveness of steel construction (Dowling and Burgan, 1998). In addition to hot-rolled steel products, cold-formed steel sections with satisfied durability have been used as primary structural members in low- to medium-rise residential houses (Davies, 2000). Structural stainless steel with long-term durability and ductility has been developed for a wider application (Baddoo, 2008). It offers better retention of strength and stiffness than carbon steel at elevated temperatures; hence, enhanced fire resistance may reduce the need for protective fire coating in structural steel members (Gardner, 2005). The application of fire-resistant steel technology not only avoids a number of problems in fireproofing coating, but also changes the attitude regarding poor fire resistance function of steel-framed buildings (Kanno *et al.*, 2012). While the high material prices of steel products hinder their applications in construction sector (Gardner, 2005), technological advances bring reducing cost on the other hand (Kanno *et al.*, 2012; Robinson, 1998).

Industrialization and automation of downstream facilities are among the leading factors that can increase the competitiveness of steel products (Davies, 2000). With the assistance of modern technologies, the steelmaking sector can facilitate the standardization of structural steel sections with updated design codes (Batista and Ghavami, 2005). The significant improvement in material processing technology can promote the rapid constructability of structural steelworks (Kanno *et al.*, 2012), with desirable structural properties in terms of strength, stiffness, ductility, and serviceability. Modern fabrication techniques for steel connection works can improve the efficiency of handling off-site fabrication (Batista and Ghavami, 2005; Baddoo, 2008). Steelwork contractors with improved productivity and capability can offer viable steel solutions and deliver structural steelworks with efficiency, thereby stimulating a growth in the steel construction market (Moore and Tordoff, 2007). By contrary, limited capability of local fabricators and erectors to undertake structural steelworks is discouraging for decision makers interested in adopting steel solutions (Celikag and Naimi, 2011).

Structural steelworks could be designed efficiently by the means of computing and numerical techniques. Computer technologies such as computer-aided design (CAD), computer-aided manufacturing (CAM), building information modeling (BIM), and radio frequency identification (RFID) have been increasingly used in 3D/4D documentation, cost calculation, module manufacture, fabrication modeling, modular installation, and logistics control for the client. These computer programs aid in managing production and construction processes, which facilitate the accuracy and efficiency of structural steel design (Dowling *et al.*, 2001).

Supply chain activities of structural steel involve steel manufacture, design, detailing, fabrication, surface finishes, delivery, and erection. The integration of supply chain can minimize risks related to cost, quality, availability of steel, and significantly save cost and time, while a broken supply chain is recognized as one of the major constraints to develop a successful steel construction industry (Warren Center, 2007). Supply chain issues can considerably influence the economic benefits of steel construction and further leave negative impacts on the overall project performance

(Love *et al.*, 2005). A non-integrated steel supply chain hindered information flow among contractors, architects, and engineers in the steel-framed building sector of the Australia's construction industry, in which manufacturing and fabrication specialists were rarely involved in the preliminary design phase (Warren Center, 2007).

The national and international structural steelwork specifications, codes of practice, and standards of design, welding, coating, fabrication, erection, and maintenance (Baddoo, 2008; Dowling *et al.*, 2001) offer principles and rules to manufacturers, designers, engineers and labours. A lack of compatible design guidelines and technical tools could limit structural steel applications (Gardner, 2005; Batista and Ghavami, 2005). For example, a lack of local design specifications was considered to hinder application of light gauge construction in Brazil (Batista and Ghavami, 2005). Incompatible design code has been criticized because it is not applicable in modern construction in terms of technical complexity (Owens, 2000). In this regard, Owens (2000) advocated that standard draft should combine mandatory performance requirements and optional application rules. For many decades, extensive effort has been exerted in drafting specifications and standards for manufacture of standardized materials, structural steel design, and workmanship within the fabrication and erection processes (Owens, 2000; Baddoo, 2008; Dowling *et al.*, 2001). The development of standards, codes, specifications, design methods and tools can drive the wide use of steel structures and stimulate the growth of steel market share (Moore and Tordoff 2007; Pedrazzi and Lozano 1998).

3.4 Project-related factors

Buildability and constructability have long been concerned with the aim at achieving overall objectives of the built project in terms of easy, efficient, economical, and construction with satisfied quality (Wong et al., 2006) that can influence the decision making process of the selection of structural materials (Zhong and Wu, 2015). The advantages of structural steel design are widely known because of its remarkable architectural and construction performance. Steel structures enable architects to create their designs with elegant simplicity and transparency, whereas ~~civil~~ engineers can achieve simple functional design. Structural steel is fabricated in off-site facilities and erected on-site, ensuring minimal noise, pollution, and waste generated onsite, as well as efficient, safe, and rapid construction (Burgan and Sansom, 2006). Owners can achieve easy, extension, modification, replacement, and refurbishment .

However, the uncertain viability of steel projects has been widely debated. Steel-framed office buildings may have higher total energy consumption in life-cycle stages than concrete ones (Guggemos and Horvath, 2005), further resulting in greater maintenance and financial costs (Zhong and Wu, 2015). The strength and stiffness of steel is significantly reduced when exposed to the high temperature of fires, which ultimately lead to a detrimental impact on the structural stability and even the collapse of the building. The accidental loads resulting from an object impact, blast, explosions, earthquake and fire can bring enormous challenges to steel projects (Barata *et al.*, 2013).

Several project-related factors constrain the adoption of steel structure. The primary factor is a cost-related issue since the economic benefits of the construction of steel structures remain debatable. The perceived high costs related to corrosion and fire protection coating (Gardner, 2005), jointing works (Dowling *et al.*, 2001), transportation, temporary storage, and inspection (Wong, 2003) may limit the prestige applications of structural steelwork. Transportation and storage of large-size prefabricated structural steel members have incurred additional logistic arrangements, as well as vertical transportation using heavy hoisting equipment (Wong, 2003). The increasing labor cost is still driven by a worldwide shortage of skilled personnel for the steel construction and fabrication industries (Shollock *et al.*, 2016). Technical complexity is another major concern. Connection design and detailing have been recognized as the crucial interface between the design and construction phases of structural steelworks (Trebilcock, 1998). Regarding its resistance performance against corrosion and fire, steel structure requires additional protective coating with testing, approval and monitoring procedures. Extra thermal insulation and acoustic insulation are also required for steel structures (Pedrazzi and Lozano, 1998). Thus, engineers or designers tend to use alternative methods that do not involve additional works (Wong, 2003).

The skills, experiences, and expertise of steel actors are undoubtedly important to the spread of steel construction (Jackson, 1998). A shortage of professionals with expertise in steel design and construction, as well as unskillful labors can be the major reasons for engineers who do not prefer steel framed structures (Celikag and Naimi, 2011). The shortage of personnel with experience at the senior level may also adversely affect decision-making toward steel solutions (Jackson, 1998). In North Cyprus, there were a few local fabricators who can provide the builder/developer with pricing and delivery confidence, thereby resulting in an unfavorable situation for structural steelworks (Celikag and Naimi, 2011).

Adverse contractual relationships among contractor, fabricator and designer may impose barriers to smooth communication in the construction of structural steelworks (Schexnayder, 2005). Sometimes inaccurate estimations for cost, time, and delivery of steel-framed structures result from a lack of reliable information and absence of regular communication between detailers, fabricators, engineers, and erectors. Some impractical design drawings are too complicated to erect in the field, possibly resulting in reworks (Schexnayder, 2005; Tilley, 1998). The partnering relationship between main contractors and subcontractors for structural steel projects can bring an improvement in communication and information sharing (Beach *et al.*, 2005). The sharing of conceptual, cost, engineering, and construction information has a significant impact on the success of a structural steel project (Owens and Wood, 1998; Dowling *et al.*, 2001). Improvement of design and construction procedures (e.g. designing, detailing, fabrication, and erection) considerably increases the delivery of efficient and economic steel construction (Dowling and Burgan, 1998).

3.5 Individual factors

Reinforced concrete has long been the primary building material around the world. An efficient, competitive, and well-established concrete-framing industry exists in many marketplaces where structural steelworks may be perceived as more difficult, riskier, and more expensive than reinforced concrete structures. Practitioners in construction industry may be reluctant to change their habits toward steel construction because of little confidence in its design efficiency and long-term credibility. Steel construction is perceived with high risks in terms of unexpected costs and uncertain benefits, which may fail to facilitate a continuing commitment from clients for the adoption of constructional steel (Dowling and Burgan, 1998; Gedge, 2008). Given that architects have power in selecting construction materials, the traditional architectural philosophy in the design of concrete/masonry buildings may result in a resistance to choose steel (Arzel, 1998; Jackson, 1998). Structural engineers who are yet to be fully aware of or unfamiliar with steel technologies (Gardner, 2005; Celikag and Naimi, 2011; Gedge, 2008).

The transformation in attitude from traditional materials to steel remarkably made the market successful in Brazil (Dowling *et al.*, 2001). Clients' need for higher performance structures facilitate continuing commitment to usage of steel products in construction (Dowling and Burgan, 1998; Gedge, 2008). Architects and engineers being aware of steel solutions can move the barriers of using the steel construction technologies (Ocio, 1998). A change in the minds of architects and engineers who decide the material could bring about an increased demand for structural steel (Ocio, 1998).

4 Discussion

4.1 Major factors

The study discerns major drivers and obstacles that can affect the development of the steel construction market insofar as contextual, institutional, industrial, project-related, and individual aspects are concerned. The significance of continuous development of design codes, standards, and specifications in the steel construction industry is remarkably similar around the world. The contribution of Eurocodes and ASTM to the success of the constructional steel market was notable in the UK and US (Moore and Tordoff, 2007; Bjorhovde, 2004), while the lack of compatible design standards hindered the market in Brazil (De Nardin, 2013). The development of design codes, standards, and specifications has been recognized as a key role in enabling the wider application of structural steel in construction (Baddoo, 2008; Owens, 2000). Engineering design without user-friendly standards and guides could be an unsatisfactory situation, which might result in impractical design drawings and misconceived design practices. In view of this, both the engineering design and the materials and workmanship standards that are continuously upgraded can bring economical steel structures and satisfy the demands of the market.

The development of the constructional steel sector has been significantly attributed to the advance in product and process technology. Structural steel materials have undergone significant changes, in conjunction with the developments in connection and coating techniques, bring better structural performance and more sustainable benefits (Bjorhovde, 2004; Dowling and Burgan, 1998). The steel producers continually invest in new manufacturing technology to improve the performance of structural steel in terms of strength, toughness, weldability, and ductility, which satisfy the needs of the customers. Modernization of fabrication facilities assists in improving construction process by streamlining off-site activities, which bring economical performance of structural steelworks. The development of surface protection coating technology is also crucial to wider application of structural steel regarding the improved durability and resistance to corrosion, fire and fatigue. These technical advances contribute to improving structural and economical performance of steel, which meets the needs of the markets and increase the competitiveness of structural steel.

A high cost of structural steelwork can make decision makers reluctant to adopt it, which is the most frequently reported barrier. Many reasons can push up the cost of structural steelwork. Due to a lack of local steel manufacturers and fabricators, steel materials and structures have to be imported from other regions (e.g., Hong Kong, North Cyprus), which leads to the high price of steel materials and transportation and taxation fees are inclusive. A shortage of skilled structural steel labours may further escalate the labour cost (Celikag and Naimi, 2011). Impractical or inadequate engineering design that possible leads to rework ultimately increase project cost (Tilley, 1998). Economical and efficient construction performance undoubtedly is one of the key drivers for wider adoption of structural steelwork. These strengths have been realized in many active markets after remarkable efforts are made to reduce the costs of structural steelwork and improve its long-term benefits. For example, advances in fire engineering remarkably cut down the cost of fire protection, which facilitate the development of steel construction in the UK ultimately (Robinson, 1998). Towards the workable connection design is the major contributor to cost-effective steelwork (Nethercot, 2006). The long term benefits of structural steel in extending the life of existing structures and in reusing steel components have been quantified (Zhong and Wu, 2015), which have a direct impact on the use of structural steel by decision makers.

4.2 Region-specific factors

Over the past two decades, substantial variation in the levels of development between individual countries was observed. Three development paths were identified based upon the literature review: (1) the constructional steel sector expanded to a mature market in many developed countries; (2) the market was emerging to rapid growth in some developing countries; and (3) the demand on structural steelworks was sluggish in some marketplaces. After addressing the common factors affecting the development of the constructional steel markets around the world, it is of interest to identify the region-specific factors that contribute to an active or depressed market. Note that changes in the external and internal environment of the steel construction industry likely occur after these selected studies have been conducted; accordingly, new regional-based opportunities and issues may appear. In view of this, the limitation in the current study is that taking a static capture of previous research may not align with the rapid change of the industry. Despite this, the findings enable interested parties to learn from past experiences of promoting an active steel construction industry.

The North American steel construction sector had profound impacts on overseas industries (Girardier, 1998; Ogden *et al.*, 1998; Pedrazzi and Lozano, 1998). The UK exerted substantial efforts to develop a mature steel construction industry, as evidenced by its high market share (Moore and Tordoff, 2007). The UK steel construction industry even considerably influenced other European regions (Lamas, 2006), by following a similar industrial development path due to comparable social, economic, and cultural background. The development of the European steel construction could be attributed to several communal drivers, including a culture of continuous improvement, widespread European design standards, change of work practice, and availability of technical societies and institutes (Dowling *et al.*, 2001). The Japanese steel construction industry experienced a maturity period after the 1990s (Kanno *et al.*, 2012). Government policies, social development, construction practice, compatible design codes and standards, and advancements in steel products, technologies, and research were the major drivers of its growth (Kanno *et al.*, 2012).

The constructional steel market gradually became mature in these developed countries where new market opportunities were being explored. For example, regarding the declined domestic demand on structural steelworks in the late of 1990s, the Japanese companies explored the possibilities for the development of overseas steel construction projects (Katayama *et al.*, 2008). Steel has become a major contributor to sustainability and resource efficiency in the built environment, with the rates of 91% recycled and 5% reused in the UK (Sansom and Avery, 2014). Regarding a small reuse rate, high cost, storage problem, limited demand, quality assurance problem, and supply chain issues might the major challenges pertaining to structural steel reuse in construction sector (Tingley *et al.*, 2017). These applications call for the evolution of steel technologies and update of design regulations and codes, thereby bringing sustaining success in the constructional steel market.

A large wave of urban growth is revealed in Asia, Africa, and South America over the past two decades. Growing urbanization and demographic changes have triggered the advancement of public utilities and other cross-board infrastructure projects, such as railways, airports, and bridges, which are deemed to increase the demand for structural steelworks. Along with industrial urbanization, large-spanned structures using structural steel are common for industrial buildings (Dong *et al.*, 2000; Dundu, 2011). Substantial changes in work practices to structural steelworks in multi-storey buildings have been reported in Southern Africa (Dundu, 2011), Brazil (Batista and Ghavami, 2005), and China (Shi, 2012).

Unlike the aforementioned mature or growing steel construction markets, Australia, North Cyprus, and Hong Kong have their respective characteristics in driving or impeding the development of steel construction. The demography and size of Australia pose marketing and transportation challenges in terms of distance and remoteness (Rehbein, 1998). The market share of the steel framing building sector in Australia is far behind that in the UK and the US (Warren Centre, 2007). Industry reform calls for a change in the well-established concrete frames to those made of steel in Australia; however, uncertain economic benefits, dwelling industrial capacities, and conservative attitudes are the major obstacles to bring about this change (Warren Centre, 2007). The constraints to the development of steel construction in North Cyprus and Hong Kong are similar (Celikag and Naimi, 2011; Wong, 2003). For many years, these regions evolved with the use of reinforced concrete as the main building structure material, which has been proven efficient and competitive. This traditional norm could profoundly affect the choices of both architectural and structural designs. Structural steel material heavily relies on import because the steel manufactures and fabrication facilities are lacking in these regions, thereby resulting in fluctuating material costs and unexpected risks. The shortage of skilled labors and professionals is another hurdle. In particular, the economic benefits of using structural steel in the building sector have not been proven in Hong Kong, although such benefits have been proven in most developed economies (Wong, 2003). The unpopularity and lower market share cause higher costs of steel construction than the alternatives, which in turn make steel construction unfavorable in Hong Kong (Wong, 2003).

4.3 Methodological issues in previous research

Despite the differences in methodology, the selected studies reproduce a historical sketch or *status quo* of the steel construction industry to identify the specific implications and strategies on promoting the steel construction market. Broad perspectives on potential drivers and issues that may affect the development of the steel construction market can be identified from these studies. However, historical and state-of-the-art reviews have generally relied on the professional and practical experiences of authors. Consequently, the predominant driving forces or obstacles to the development of steel construction from diverse industry stakeholders on the regional, national, or global scales remain unexploited.

Only a few studies have used empirical approach using either the qualitative or quantitative approaches (e.g., case study, survey, industry forum, or mixed method). Owens and Wood (1998) analyzed the key influences on the worldwide use of steel across 15 steel producers and 60 countries. Subsequently, a statistical analysis was performed to assess the relationship between steel market share and key influencing factors. Their study contributed to expanding the knowledge of the predominant factors on the success of steel in construction on a global scale. However, only steel producers participated in this survey, while attitudes toward the use of steel from other stakeholders within the steel construction industry remained unknown.

A review of the recommendations provided by the selected studies shows that a few studies offered substantive instruction and guidance for industry actors to adopt structural steelworks. Some of them do not go further than producing general recommendations with respect of the outlined key drivers or obstacles. For example, 'integrating steel supply chain' was contained in some studies (e.g., Baddoo, 2008). However, such a recommendation was made without considering the conflicting interests and expectations of firms and practitioners involved in the entire supply chain. In fact, the integration of the steel supply chain across a number of separate stakeholders could be a challenge that requires significant changes in both practices of the entire sector, as well as the interests and expectations of its actors (Harty *et al.*, 2007).

4.4 Implications of the study

Based on the review of previous research on the market development of the steel construction industry, two implications are pointed out for the industry and future studies, respectively. First, the current paper takes an initiative to establish a practical classification framework for developing the constructional steel sector, in which five themes of factors are identified, namely, contextual, institutional, industrial, project-related, and individual facets. This framework can be dedicated to illuminating the critical issues or success factors affecting the development of the steel construction market. The different stages of the market development are also considered in this study. For the developed markets, new opportunities and issues may appear in the steel construction industry. Decision makers should prepare for achieving continuous success in steel construction in the next decades. For the emerging and inactive markets, industry practitioners can foster a more active constructional steel market by learning from past successful experiences of the developed societies.

As mentioned before, one of the limitations in the current study is that a static profile of the steel construction markets around the world was captured based on previous research. Many of these studies were published over 10 years ago. The regional, social, economic, and cultural characteristics around the world change dramatically after these studies have been published. In view of this, the current classification framework can be expanded and updated in future works. Moreover, the methodological approaches employed by previous studies, mainly by historical and state-of-the-art reviews, could not identify the predominant driving forces or obstacles. As a result, few of them could offer substantive recommendations for stakeholders who are interested in pursuing steel construction. This limitation calls for depth empirical studies involving all industry stakeholders to help identify decisive factors to succeed in steel construction.

5 Conclusions

Following the global tendency towards achieving a sustainable construction industry, there is an increasing global market share of structural steelworks. In spite of this global trend, development paths of the steel construction markets are different because regional, social, economic, and cultural characteristics are varied. Previous studies tend to primarily focus on addressing region-specific reasons behind the active or inactive steel construction markets. However, there is a lack of a broad understanding about the common issues associated with the development of the global constructional steel market. This paper provides a critical review of previous studies in the field of market development of steel construction. To address the drivers and barriers that affect its market growth, a classification framework is established, consisting of five main themes, namely, contextual, institutional, industrial, project-related, and individual aspects. The findings revealed that "continuous development of standards, codes, and specifications" and "advance in product and process technology" garnered great attention as the top two driving forces to develop the steel construction market, while "cost issues" was identified as the most prevalent obstacle regarding this matter. This study provides a practical framework for decision makers to deepen their understandings of the opportunities and obstacles within the market development and help them promote the industry further.

Conflicts of interest

The authors have no conflict of interest to declare.

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