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Meng, X. (2020). Proactive management in the context of construction supply chains. *Production Planning & Control: The Management of Operations*, 31(7), 527-539. <https://doi.org/10.1080/09537287.2019.1657977>

Published in:

Production Planning & Control: The Management of Operations

Document Version:

Peer reviewed version

Queen's University Belfast - Research Portal:

[Link to publication record in Queen's University Belfast Research Portal](#)

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Proactive management in the context of construction supply chains

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ABSTRACT

Proactive management addresses problems in advance. It is advantageous over reactive management that does not respond to any issues until they grow to become obvious and critical problems. However, scarce studies to date investigate proactive management from the perspective of construction supply chains. To overcome the limitation within existing studies, this research explores the significance of proactive management in the context of construction supply chains through a thorough investigation. The investigation in this research adopts a mix of a literature review, a questionnaire survey and a series of interviews. This research provides clear evidence for an increasing prevalence of proactive management in today's construction practice. Proactive management proves to significantly contribute to both problem avoidance/minimization and continuous improvement. Compared to supply chain integration, supply chain collaboration is found to have a closer linkage with proactive management. This research highlights the importance of developing a proactive and collaborative culture in construction.

KEYWORDS

Proactive management; Collaborative working relationship; Project delivery method; Construction supply chain; Building information modeling

1. Introduction

Management can be either proactive or reactive (Bateman and Snell 1999). Reactive management takes actions after problems have arisen (Wilson 2015). Rather than foresight, it is characterized by hindsight (Habegger 2008). ‘Firefighting’ is the metaphor of reactive management (Pavlak 2004). Not all problems can be foreseen. For this reason, reactive management is inevitable in some situations. Unlike reactive management that focuses on cure, proactive management is intended for prevention (Kleindorfer and Saad 2005). Good management should be proactive, analyzing likely problems before they really occur and planning steps to mitigate their consequences (Waters 2011). The importance of proactive management has been increasingly highlighted over the past two decades in various manufacturing organizations. For example, Leong and Ward (1995) identified proactivity as a manufacturing strategy in the global context through a comprehensive literature review. Based on international observations, Noble (1997) recognized proactivity as a competitive advantage of manufacturing firms. Dangayach and Deshmukh (2003) distinguished more mature manufacturing companies from less mature ones in terms of proactivity through an India-wide questionnaire survey. González-Benito (2005) conducted a Spain-wide questionnaire survey to analyze the positive effect of manufacturing proactivity on business performance.

In addition to manufacturing that is process-centric, proactive management has also received an increasing attention from academics and practitioners in other industry sectors. For example, Wallenburg (2009) identified proactive performance improvement as a driver of customer loyalty in the logistics service sector through a Germany-wide questionnaire survey. Based on a questionnaire survey in the Malaysian retailing industry, Lau et al. (2017) acknowledged proactive customer service performance influenced by ethical work climate. Logistics and retailing

characterize process-centric services. As a result, proactive management is found to be applicable to both manufacturing and service sectors that are process-centric. On the other hand, Dey, Kinch, and Ogunlana (2007) demonstrated that proactive management ensures the successful completion of a software development project in Barbados. Wang, Lin, and Huang (2010) proposed a performance-oriented framework and applied the proposed framework to Taiwanese research and development (R&D) projects, in which high-priority risks are required to be managed proactively. Software development and R&D are two main types of projects. As a result, it is possible to find the application of proactive management to both process-centric and project-based industry sectors.

Proactive management means many things. Manufacturing studies on proactive management can be categorized into six groups: (1) studies on proactive scheduling, such as Ryu, Dua, and Pistikopoulos (2007) and Sabuncuoglu and Goren (2009); (2) studies on proactive maintenance, such as Leger and Morel (2001) and Cholasuke, Bhardwa, and Antony (2004); (3) studies on proactive safety management, such as Chang and Liang (2009) and Curcuruto et al. (2015); (4) studies on proactive defect control, such as Lou and Huang (2003) and Falck et al. (2017); (5) studies on proactive environmental management, such as Liu et al. (2010) and Jabbour, Mauricio, and Jabbour (2017); and (6) studies on proactive supply chain risk management, such as Norrman and Jansson (2004), Pujawan and Geraldin (2009), and Grötsch, Blome, and Schleper (2013). Proactive supply chain risk management is a research topic that becomes more and more popular in manufacturing. For example, Norrman and Jansson (2004) provided an approach of proactive supply chain risk management in a Swedish manufacturing firm. Based on a series of interviews in German manufacturing, Grötsch, Blome, and Schleper (2013) revealed the antecedents of proactive supply chain risk management and the positive impact of customer-supplier relationship

on proactive supply chain risk management. These manufacturing studies highlight the importance of supply chain collaboration to proactive risk management.

Construction is a project-based industry sector (Behera, Mohanty, and Prakash 2015). It is a major contributor to the economy (Blayse and Manley 2004). It is not a stranger for proactive management. Similar to manufacturing studies, construction studies look into proactive environmental management (Ofori 1992), proactive maintenance (Edwards, Holt, and Harris 1998), proactive scheduling (Schatteman et al. 2008), proactive defect control (Lundkvist, Mailing, and Sandberg 2014) and proactive safety management (Li et al. 2015). Unlike manufacturing studies, construction studies concentrate on the development of various systems and tools for proactive management. For example, Schatteman et al. (2008) developed a computer system for proactive scheduling, which was applied to a construction project in Belgium. Lundkvist, Mailing, and Sandberg (2014) provided a proactive plan-do-check-act cycle tool for defect control based on a Swedish construction project. Li et al. (2015) proposed a computer system for proactive behavior-based safety management and evaluated the proposed system through a pilot project in Hong Kong. There is a lack of empirical investigation of proactive management in construction to reflect real practice.

More importantly, almost no construction studies to date investigate proactive management, taking supply chain management into consideration. As a result, little or no research evidence exists for proactive management in the context of construction supply chains. Supply chain management is a concept that has originated and flourished in manufacturing (Griffith and Watson 2004; Blanchard 2010). Using the lessons learned from manufacturing, construction has gradually embraced the concept of supply chain management since the late 1980s or the early 1990s (Pryke 2009). Construction has its own characteristics that distinguish itself from manufacturing. Unlike

process-centric manufacturing, construction supply chain management is project-based (Behera, Mohanty, and Prakash 2015). Production in construction is more complex and dynamic than production in manufacturing (Winch 2010). Compared to a manufacturing supply chain, a construction supply chain involves more members, including project client, designer, main contractor, subcontractors, specialist contractors, and suppliers of labor, materials and equipment (O'Brien et al. 2008). For these reasons, construction supply chains have to face more challenges. Obviously, proactive management is more important for construction supply chains. Inspired by proactive management in manufacturing supply chains, a need is identified for an empirical investigation of proactive management in construction supply chains.

Supply chain collaboration and supply chain integration are two close concepts in relation to supply chain management. People often do not distinguish them and therefore they are often used interchangeably. Actually, they have similar but different meanings. Figure 1 is developed in this research to illustrate these two concepts and distinguish one from the other. Supply chain collaboration refers to collaborative or cooperative relationships between customers and suppliers as supply chain members, or supply chain partners (Blanchard 2010). It describes the extent to which supply chain members work closely together to achieve mutual benefits (Cao and Zhang 2011). On the other hand, supply chain integration is concerned with integrated processes of product or service delivery (Vrijhoef 2011). It shows the scope and strength of linkages between supply chain processes (Flynn, Koufteros, and Lu 2016). As mentioned above, many manufacturing studies highlight the importance of supply chain collaboration to proactive risk management. On the other hand, some manufacturing studies, such as Van Donk and Van der Vaart (2005) and Zhao et al. (2013), provided research evidence for the contribution of supply chain integration to risk/uncertainty management. On the contrary, almost no construction studies

investigate proactive management, taking supply chain collaboration and/or supply chain integration into consideration. It is therefore possible to further identify the need for an empirical investigation of proactive management in construction supply chains.

(a) Supply chain collaboration

(b) Supply chain integration

Figure 1. Supply chain collaboration vs supply chain integration.

SC denotes supply chain.

Building information modeling (BIM) is the next generation of information technology (IT) (Mutis and Hartmann 2018). It is one of the most promising recent developments in the construction industry (Galiano-Garrigos, Mahdjoubi, and Brebbia 2017). The UK government has mandatorily required three-dimensional BIM in all centrally procured public projects since 2016 (Infrastructure and Projects Authority 2016). BIM represents a process of generating and managing digital representations of physical and functional characteristics of building facilities in a construction project (Wu, Li, and Wang 2017). It provides a central model for project participants to share building information (Wang and Meng 2019). It also supports decision-making for design, construction, operation and maintenance throughout the project lifecycle (Bottazzi 2018). Some emerging studies, such as Matthews et al. (2018), start to realize the potential of BIM of enhancing supply chain collaboration. Other emerging studies, such as Zou, Kiviniemi, and Jones (2017), start to recognize the role of BIM in proactive management. However, integrating supply chain management and proactive management is not yet well studied in the BIM environment.

This research aims to explore proactive management in the context of project-based construction supply chains, bridging the knowledge gaps within existing studies. It attempts to cover both supply chain collaboration and supply chain integration. It achieves its aim by answering the research questions about (1) what the current trend of proactive management is in construction practice; (2) whether supply chain collaboration has a positive impact on proactive management; (3) whether supply chain integration has a positive impact on proactive management; (4) what the effect of proactive management on problem avoidance/minimization and continuous improvement is; and (5) how BIM contributes to proactive management in project-based construction supply chains. The research questions are answered through an empirical investigation in the UK construction industry. This research adopts a mix of a literature review, a

questionnaire survey and a series of interviews. It investigates proactive management in both breadth and depth. The findings of this research provide clear evidence for proactive management in construction. This research encourages academics and practitioners to look at project management and supply chain management from a proactive perspective. It provides penetrating insights into proactive management with construction characteristics. Although this research is based on construction, it is hoped that the findings of this research will also be useful for proactive management in other industry sectors.

2. Theoretical background

2.1. Supply chain relationship

Relationships in a supply chain can be divided into intra-organizational and inter-organizational relationships (Mena, Humphries, and Wilding 2009; De Blois et al. 2011). Supply chain relationships generally refer to inter-organizational relationships between customers and suppliers, which can be either non-collaborative or collaborative. Non-collaborative relationships mean traditional relationships. They are adversarial or arms-length (Hoyt and Huq 2000; Saad, Jones, and James 2002). Without the alignment of business objectives, supply chain members under traditional relationships are pulling in different conflicting directions (Barratt 2004; Thomas and Thomas 2005). On the other hand, supply chain members with collaborative relationships work closely together for the achievement of mutual benefits. Collaborative relationships can be either short-term or long-term (Ingirige and Sexton 2006; Grötsch, Blome, and Schleper 2013). In project-based industry sectors like construction, a short-term collaborative relationship is project-specific, focusing on a single project (Lazar 2000; Manley, Shaw, and Manley 2007). In contrast, a long-term collaborative relationship is strategically oriented, being sustained in multiple projects over a period of time (Saad, Jones, and James 2002; Akintoye and Main 2007). In summary, non-

collaborative (namely traditional), short-term collaborative and long-term collaborative relationships represent supply chain collaboration in construction at three different levels.

2.2. Project delivery method

As mentioned above, supply chain integration refers to integrating supply chain processes. Similar to supply chain relationships that generally focus on inter-organizational relationships, supply chain integration usually refers to external integration, namely inter-organizational integration, especially in this research, although integration can be divided into internal and external integration. In the construction industry, project delivery methods as systems by which customers or their agencies organize supply chain processes, such as design, construction, operation and maintenance in construction projects, and suppliers deliver products or services show the extent of supply chain integration (Miller et al. 2000; Palaneeswaran, Kumaraswamy, and Zhang 2001; Mahdi and Alreshaid 2005; McDermott and Khalfan 2012). There are many project delivery methods in construction, among which design-bid-build (D-B-B), design and build (D&B) and public-private partnership (PPP) are the three major ones.

D-B-B is a traditional method of project delivery. When it is adopted in a construction project, the client employs architects and engineers to design the project and a main contractor to build what architects and engineers have designed (Cushman et al. 2001). Architects and engineers employed by the client are responsible for the design and the completion of drawings and specifications. On the other hand, the main contractor selected by the client through competitive bidding is awarded the construction contract to build the project based on design drawings and specifications. This traditional method separates design and construction processes and therefore they are carried out in sequence (Gajurel 2014).

D&B overcomes the separation of design and construction processes. It refers to the merger of design and construction processes into a single point of responsibility (Beard, Loulakis, and Wundram 2001). In some cases, a design-builder appointed by the client of a project is able to take both design and construction because the design-builder has in-house designers, including architects and engineers (Thomas 2006). More frequently, the client of a project can appoint a joint venture between a design firm and a contractor for the implementation of design and construction (Hess et al. 2007). Unlike D-B-B, D&B is an integrated method of project delivery because one entity is responsible for delivering the entire project.

PPP is often known as design-build-finance-operate (DBFO) and other types of PPP can be considered as the variants of DBFO (Hodge and Greve 2005; Sadka 2006; Bovis 2013). It means that a group of private-sector companies design, build and finance a public-sector project under a concession agreement with its client. Once the project is delivered, the group of private-sector companies are allowed to operate the project during the concession period, typically 20-30 years. At the end of the concession period, the group of private-sector companies transfer the project to the public-sector project client. Under PPP, the responsibility of the group of private-sector companies covers design, construction and operation as three phases of the project. In addition to project delivery through design and construction, PPP also integrates operation and sometimes maintenance as well.

Among the three major project delivery methods, PPP represents the most integrated supply chains, which is followed by D&B. On the other hand, D-B-B characterizes the most fragmented supply chains. In addition to D-B-B, D&B and PPP, it is possible to find some other project delivery methods in the construction industry, such as management contracting (MC) and construction management (CM). MC and CM highlight the role of management contractors and

construction managers in managing and coordinating construction activities on sites (Murdoch, Champion, and Hughes 2015). For this reason, they are not included in this paper due to less relevance to supply chain integration.

2.3. Proactive management indicator

In this research, clear and proper role definition, proactive project planning, regular performance measurement, and early warning of problems are identified through the literature review as four indicators of proactive management in project-based construction supply chains. They are discussed here in detail one by one.

2.3.1. Clear and proper role definition

As mentioned above, a construction project involves a large number of key participants as supply chain members at different tiers (O'Brien et al. 2008). The involvement of multiple parties introduces an uncertainty arising from the ambiguity about roles and responsibilities (Ward and Chapman 2003). Proactive management deals with problems in advance, making full use of early opportunities in the project environment (Patel 2010). To ensure the smooth running of a construction project, roles and responsibilities of each party should be well defined at early stages and meanwhile all parties must understand and accept their roles and responsibilities in advance of undertaking the project (Chan, Ho, and Tam 2001; Crimm, Morris, and Wharton 2009). This is because clear and proper definition of roles and responsibilities at early stages allows project parties to well develop plans, proactively take steps, and effectively avoid conflicts. On the other hand, ambiguous, incomplete and other inappropriate definition of roles and responsibilities should be addressed as early as possible before it becomes critical (Chua and Godinot 2006).

2.3.2. Proactive project planning

Based on clear and proper definition of each other's roles and responsibilities, it is important for project participants to well develop their plans at early stages of a construction project. Undoubtedly, construction projects with poor planning are subject to various problems (Zou, Zhang, and Wang 2007; Sun and Meng 2009). Project planning forms the basis of how to run a project (Chitkara 1998). Project objectives should be clearly understood and well matched when developing project plans (Oberlender 2014). Well-developed plans include appropriate procedures and proactive measures that enable project participants to monitor and control the execution of their work (Sanders 2011; Delaney 2016). Construction projects are usually complex and dynamic, in which changes are inevitable (Sun and Meng 2009). Project plans should involve flexibility to changes (Ford and Bhargav 2006; Osipova and Eriksson 2013). Proactive change management is highlighted because it anticipates possible changes and prepares response options in advance (Ibbs, Wong, and Kwak 2001). Proactive and flexible change management allows project participants to modify original plans as necessary to adjust to changes (Walker and Shen 2002).

2.3.3. Regular performance measurement

Performance measurement is a proactive approach (Yun et al. 2016). Performance should be measured on a regular basis (Haji-Kazemi, Andersen, and Krane 2013). Progress review meetings provide important opportunities for regular performance measurement. They can be considered as a central forum for exchanging the information about project execution (Gorse and Emmitt 2003). During review meetings, work progress is compared with planned objectives and preset targets (Hughes, Tippet, and Thomas 2004; Sears, Sears, and Clough 2008). As a result of progress review, potential problems come to the surface. In other words, performance measurement at regular intervals helps to identify early warning signs of various problems (Williams et al. 2012).

Based on regular performance measurement, performance can be monitored and controlled in a proactive way and therefore it is not necessary to rectify poor performance after it becomes a reality (Baiden, Price, and Dainty 2006). Generally, benchmarking refers to measuring the performance of an organization and comparing it with the performance of best practice organizations. Benchmarking exercises make project participants more likely to succeed through learning from those who can provide best practice experience (Costa et al. 2006; Williams et al. 2012).

2.3.4. Early warning of problems

Early warning of potential problems is widely recognized in construction as an important mechanism of proactive management (Nikander and Eloranta 2001). It facilitates sound management in construction projects using foresight as opposed to hindsight (Rowlinson 2018). With early warning mechanism, issues are identified as early as possible when they are still in infancy. This means that early warning mechanism obliges projects parties to uncover an issue when it is first anticipated or encountered rather than leave it to develop into a major problem (Jones, Savage, and Westgate 2003). In a construction project that introduces early warning mechanism, each party is required to notify another of any matters that could affect the project (Forward 2002). Early warning mechanism applies to quality defect, time delay, cost overrun, safety accident and any other performance problems, which can be seen from existing studies on early warning in construction projects, such as Arditi and Gunaydin (1997), Pewdum, Rujirayanyong, and Sooksatra (2009), and Ding and Zou (2013). Generally, the earlier it is possible to warn of potential problems the more options there are to deal with them (Sears, Sears, and Clough 2008).

3. Hypothesis development

Among manufacturing studies on proactive supply chain risk management, Norrman and Jansson (2004) defined supply chain risk management as collaborating with supply chain partners to apply appropriate tools to deal with risks. Instead of individual supply chain members' proactive management, Norrman and Jansson (2004) put emphasis on collaborative proactive management because supply chain members work together in proactive ways and they are willing to share risks. Grötsch, Blome, and Schleper (2013) identified customer-supplier relationship as an antecedent of proactive supply chain risk management and demonstrated the positive impact of customer-supplier relationship on proactive supply chain risk management in manufacturing. According to Grötsch, Blome, and Schleper (2013), supply chain risk management is rooted in the social exchange theory whose focus is social relationships. Similar to Norrman and Jansson (2004), Grötsch, Blome, and Schleper (2013) believed that collaborative relationships lead to improved working environments in manufacturing supply chains, such as higher investment to deal with risks and joint effort for risk management. As a result, it is more likely for risk management to be proactive and effective. Unfortunately, there is a lack of construction studies that investigate the impact of supply chain relationships on proactive management. To translate proactive management into the construction context, the following hypothesis is proposed, in which supply chain relationships are described at three different levels, namely non-collaborative, short-term collaborative, and long-term collaborative:

H1: Supply chain relationships have a positive impact on proactive management in project-based construction supply chains.

Supply chain integration is similar to but also different from supply chain collaboration. As a manufacturing study, Van Donk and Van der Vaart (2005) provided a case study to illustrate the

need for supply chain integration to address uncertainty issues, which means that uncertainty increases the need for supply chain integration. Based on a global database of manufacturing plants, Zhao et al. (2013) revealed the negative relationship between demand variability risk and customer integration. Zhao et al. (2013) also found that supplier delivery risk is negatively related to both supplier integration and customer integration. Supply chain integration refers to integration with upstream suppliers and downstream customers (Jespersen and Skjott-Larsen 2005). According to Zhao et al. (2013), supply chain risks are barriers to supply chain integration. From the other point of view, the findings of Zhao et al. (2013) can be interpreted as the benefits of supply chain integration for supply chain members to deal with risks in manufacturing supply chains. On the whole, the number of manufacturing studies that link supply chain integration and risk/uncertain management is not large. Meanwhile, proactivity is not emphasized in such studies. Similar to manufacturing studies, construction studies pay little or no attention to the impact of supply chain integration on proactive management. The intention to bridge this knowledge gap results in the following hypothesis, in which D-B-B, D&B and PPP as three major project delivery methods are used to show supply chain integration at three different levels in the construction industry:

H2: Project delivery methods have a positive impact on proactive management in project-based construction supply chains.

Proactive management addresses problems in advance, avoiding possible problems or minimizing their negative consequences. For this reason, it has drawn an increasing attention from construction researchers and practitioners. As mentioned above, construction studies concentrate on the development of various systems and tools for proactive management and the evaluation of the proposed systems and tools through individual cases. There is a lack of empirical investigation of proactive management in the context of construction supply chains from a broad perspective.

Although existing studies may offer initial insights into the importance of proactive problem solving in construction practice, without a broad investigation, it is difficult to demonstrate the effect of proactive management on problem avoidance/minimization, especially in context of project-based construction supply chains. The need for research evidence in this area leads to the following hypothesis:

H3: Proactive management is effective for problem avoidance/minimization in project-based construction supply chains.

Continuous improvement is of great importance for project participants or supply chain partners to achieve their objectives (Griffith and Watson 2004). It represents an endless search for excellence throughout a construction project (Fewing 2013). It can also be defined as a continuous process of finding opportunities for improvement (Atkin and Borgbrant 2010). Without continuous improvement, it is easy for project participants or supply chain partners to drift into ineffective and inefficient ways of working (Bennett and Jayes 1995). A lack of continuous improvement has a danger of succumbing to poor project delivery and failing to achieve project success (Thomas and Thomas 2005). Proactive approaches can be used during planning and control to engender continuous improvement in construction projects (Ferng and Price 2005). Being proactive in the management of construction supply chains encourages continuous improvement (Fewings 2013). However, the critical role of proactive management in continuous improvement is not yet well examined within existing studies. This issue suggests the following hypothesis:

H4: Proactive management is effective for continuous improvement in project-based construction supply chains.

4. Research methods

This research adopts a mixed methodology, including a literature review, a questionnaire survey and a series of interviews. First of all, a comprehensive review of relevant literature provided an up-to-date understanding of existing studies on proactive management in manufacturing, construction and other sectors. The identification of proactive management indicators was another result of the literature review. The literature review also led to the identification of the need for an investigation of proactive management in construction supply chains. A questionnaire survey was carried out in the UK construction industry to investigate its supply chains in terms of proactive management. Subsequent to the questionnaire survey, a group of industrial experts in the UK were interviewed to collect further information about proactive management in construction supply chains. In this research, the questionnaire survey is the main instrument for data collection. Compared to the questionnaire survey in breadth, the interviews are in depth. The questionnaire survey is quantitative while the interviews are qualitative. The interviews support and complement the questionnaire survey. The results of interview analysis are also useful to explain the findings from the questionnaire analysis.

Based on the literature review, four indicators of proactive management are defined in this research: (1) clear and proper role definition; (2) proactive project planning; (3) regular performance measurement; and (4) early warning of problems. They describe proactive management in different key aspects. They are used in the questionnaire to measure proactive management during a construction project. The questionnaire survey is project-specific because each questionnaire response represents a construction project in the UK. There are four sections in the questionnaire. The first section is designed to collect the information about a respondent's role and experience as well as his/her organization's nature. The type of supply chain relationship and

the type of project delivery method in a surveyed project are asked in the second section. The four indicators of proactive management are used in Section 3 to rate the level of proactive management during the surveyed project in terms of a four-point Likert scale: strongly agree (SA=1), agree (A=2); disagree (D=3); and strongly disagree (SD=4). A four-point scale is adopted in this research to avoid the tendency towards neutral. On the other hand, two questions are formulated in the fourth section to rate the level of problem avoidance/minimization and the level of continuous improvement according to a four-point Likert scale from strongly agree to strongly disagree.

The workability of the questionnaire was tested by a group of researchers and practitioners through a pilot study. Their comments and suggestions contributed to the refinement of the initial questionnaire, based on which the questionnaire was finalized. The finalized questionnaire was sent via email to approximately 300 industrial practitioners in the UK construction industry. They were required to answer the questionnaire based on construction projects they experienced recently. They were selected from expert databases and other available sources. They came from different regions of the UK. All of them had more than five years of work experience in project management and supply chain management. The roles of these potential respondents in their organizations included supply chain manager, project manager, procurement manager, design consultant, and site manager. Their organizations had the backgrounds of clients, designers, main contractors, subcontractors, specialist contractors, etc. As a result, the questionnaire sample provided reliability and validity for the empirical investigation in this research.

The questionnaire survey in this research is not longitudinal. The reactive nature of the traditional construction industry is identified from the literature review and confirmed by the interviewees. In this research, questionnaire responses are statistically analyzed using SPSS. Frequency statistics provides the percentage of each proactive management indicator at four

different rating levels. Compared to the traditional reactive practice, it reveals the trend of proactive management in construction practice today. One-way analysis of variance (ANOVA) is a statistical function to compare the means of two or more groups (independent variables) on one dependent variable to see if the group means are significantly different from each other (Urdan 2010). In this research, there are three groups (types) of supply chain relationships: non-collaborative, short-term collaborative and long-term collaborative. Similarly, D-B-B, D&B and PPP represent three groups (types) of project delivery methods. ANOVA is used to compare the means of each proactive management indicator in the three groups of supply chain relationships and the three groups of project delivery methods. Spearman correlation is a measure of statistical dependence between two ordinal variables (Morgan et al. 2011). Four proactive management indicators, problem avoidance/minimization and continuous improvement are all ordinal variables. For this reason, Spearman correlation is used to test if each proactive management indicator is significantly correlated with problem avoidance/minimization and continuous improvement. The use of ANOVA and Spearman correlation contributes to the examination of four hypotheses.

The empirical investigation includes a questionnaire survey and a series of interviews because the former gets easy access to a broad range of survey units while the latter provides a rich source of in-depth information due to direct interaction between the researcher and each interviewee. This explains why more than ten industrial experts in the UK construction industry were further interviewed subsequent to the questionnaire survey. Similar to the questionnaire respondents, the interviewees in this research were selected from different regions of the UK. The interviewees had work experience in project management and supply chain management for more than ten years or even twenty years. All of them held the qualifications from leading professional associations, such as the Chartered Institute of Building (CIOB), Institution of Civil Engineers (ICE), Royal

Institution of Chartered Surveyors (RICS), and/or Royal Institute of British Architects (RIBA). The semi-structured interviews were conducted face to face. An interview guide was well prepared to direct interview conversations. The interviewees provided more in-depth information about proactive management with construction characteristics. The in-depth interviews brought a deeper and clearer understanding of proactive management in the context of construction supply chains.

5. Analysis of questionnaire responses

As a result of the questionnaire survey in this research, approximately 110 responses were returned with the response rate of 36.7%. A very small number of questionnaire responses report the adoption of MC and CM as project delivery methods in the surveyed projects. Since MC and CM have less relevance to supply chain integration, such questionnaire responses are ignored, subsequent to which 100 questionnaire responses that report the three major project delivery methods and the three types of supply chain relationships are used for the statistical analysis of proactive management in construction supply chains.

5.1. Trend of proactive management in construction

Among the four proactive management indicators, proactive project planning receives 91.8% of positive responses (namely strongly agree and agree), which is the highest. On the other hand, regular performance measurement receives 88.4% of positive responses, which is the lowest. The percentages of positive responses for clear and proper role definition and early warning of problems are 89.6% and 89.0% respectively, which can be placed between the two extremes. As a traditional industry sector, construction used to be reactive or less than proactive (Cornick 1999; Cheng, Dainty, and Moore 2005; Harty 2008). The essence of reactive problem solving is crisis management (Loosemore 1998). Reactive management aims to ‘stop the rot’ for serious problems or crises (Olawale and Sun 2010). In addition to previous studies, the reactive nature of the

traditional construction industry is also confirmed by the interviewees in this research (see Section 6). It is found in this research that all the four indicators of proactive management receive more than 88.0% of positive responses. The finding in this research demonstrates the wide acceptance of proactive management in today's project-based construction supply chains. The increasing prevalence of proactive management in its projects and supply chains describes a change agenda for construction today. Construction is going out of the traditional predicament and is more and more embracing proactive concepts and approaches. This is because proactive management makes construction projects and supply chains more likely to achieve success, which will be discussed later in this paper.

5.2. Impact of supply chain collaboration on proactive management

Non-collaborative, short-term collaborative and long-term collaborative relationships describe supply chain collaboration at three different levels. In this research, the questionnaire survey reports 33 projects with non-collaborative relationships, 29 projects with short-term collaborative relationships, and 38 projects with long-term collaborative relationships. As shown in Table 1, the four indicators of proactive management are compared among the three types of supply chain relationships in terms of mean values. It is found that proactive management with short-term collaborative relationships is better than proactive management with non-collaborative relationships. On the other hand, proactive management with long-term collaborative relationships is better than proactive management with short-term collaborative relationships. "Better" means better performance of proactive management in terms of clear and proper role definition, proactive project planning, regular performance measurement, and early warning of problems. For example, the mean values of early warning of problems are 2.09 for non-collaborative relationships, 1.90 for short-term collaborative relationships, and 1.74 for long-term collaborative relationships. The

finding demonstrates a stepwise improvement of proactive management along with the development of supply chain relationships. It illustrates that relationship development is an important consideration if proactive management is to be improved. This is because collaborative relationships create harmonious working environments that make proactive management more reliable and effective. This also explains why Emmett and Crocker (2006) in general and Davis (2008) in construction highlighted relationship-driven supply chain management.

Table 1. Proactive management among supply chain relationships.

Proactive management indicator	Supply chain relationship			Total mean n=100	ANOVA	
	Non-collaborative n=33	Short-term collaborative n=29	Long-term collaborative n=38		<i>F</i>	<i>p</i>
Clear and proper role definition	2.09	1.92	1.76	1.92	3.469	0.035*
Proactive project planning	2.06	1.89	1.68	1.87	4.082	0.020*
Regular performance measurement	2.03	1.96	1.69	1.88	3.353	0.039*
Early warning of problems	2.09	1.90	1.74	1.90	3.731	0.027*

*Difference is significant at the 0.05 level.

ANOVA is used to test the differences in mean values of the four proactive management indicators among the three types of supply chain relationships. ANOVA is a *F* test in which *F* is a ratio of variance while *p* denotes the significance level of mean differences. The results of ANOVA in Table 1 show significant differences among the three groups for proactive project planning ($p=0.020$), early warning of problems ($p=0.027$), clear and proper role definition ($p=0.035$), and regular performance measurement ($p=0.039$). Hypothesis 1 is supported because it is evident that supply chain relationships have a significant positive impact on proactive management without

compromise in any aspect. In statistics, the smaller the p value is the greater influence a supply chain relationship has on proactive management. Among the four indicators of proactive management, relationship development has the greatest influence on proactive project planning. Subsequent to proactive project planning, the influence of relationship development on proactive management is gradually reduced from early warning of problems, through clear and proper role definition, to regular performance measurement. Despite that, the impacts of supply chain relationships on proactive management in different key aspects are at the same significance level of 0.05.

5.3. Impact of supply chain integration on proactive management

D-B-B, D&B and PPP are three major project delivery methods in the construction industry. In this research, the questionnaire survey reports 30 projects using D-B-B, 49 projects using D&B, and 21 projects using PPP. As seen in Table 2, means comparison with ANOVA is used to compare the four indicators of proactive management among the three project delivery methods in terms of mean values. The results are twofold. Similar to the impact of supply chain relationships on proactive management, on one hand, a stepwise improvement of proactive management along with the integration of supply chain processes is observed in this research. This means that proactive management under D&B is better than proactive management under D-B-B while proactive management under PPP is better than proactive management under D&B, in which “better” means better performance of proactive management in four key aspects. As mentioned above, project delivery methods can be used in construction to describe supply chain integration. The finding in this research shows that proactive management will be improved step by step if supply chain processes become more and more integrated. In other words, there is a positive impact of supply chain integration on proactive management.

Table 2. Proactive management among project delivery methods.

Proactive management indicator	Project delivery method			Total mean n=100	ANOVA	
	D-B-B n=30	D&B n=49	PPP n=21		<i>F</i>	<i>p</i>
Clear and proper role definition	2.04	1.90	1.80	1.92	1.204	0.305
Proactive project planning	1.96	1.85	1.76	1.87	0.771	0.465
Regular performance measurement	2.03	1.87	1.70	1.88	2.034	0.137
Early warning of problems	2.00	1.92	1.71	1.90	1.685	0.191

Unlike the impact of supply chain relationships on proactive management, on the other hand, there are no significant differences in mean values of the four proactive management indicators among the three project delivery methods (see Table 2). This means that, although proactive management will be improved if supply chain processes become more integrated, the improvement of proactive management is not significant following the integration of supply chain processes. Supply chain collaboration and supply chain integration are two close concepts in relation to supply chain management. Both supply chain collaboration and supply chain integration have positive impacts on proactive management. However, the impact of supply chain integration on proactive management is not as significant as the impact of supply chain collaboration on proactive management. For this reason, supply chain collaboration should be considered in the first place when proactive management is highlighted in construction practice. By comparison, supply chain integration is the second consideration. Supply chain collaboration and supply chain integration have unequal importance to proactive management in project-based construction supply chains.

5.4. Effectiveness of proactive management

Spearman correlation is used in this research to examine the correlation between each proactive management indicator and problem avoidance/minimization and the correlation between each

proactive management indicator and continuous improvement. Table 3 shows a positive correlation of problem avoidance/minimization with each proactive management indicator and a positive correlation of continuous improvement with each proactive management indicator. All the correlations shown in Table 3 are significant at the 0.01 level. The findings provide strong evidence to demonstrate the real effect of proactive management. Hypotheses 3 and 4 are supported. As a result, proactive management proves to be a significant contributor to both problem avoidance/minimization and continuous improvement. Clearly, the findings in this research reveal the critical role of proactive management in ensuring the success of construction projects and supply chains. They explain why proactive management is more and more adopted in today's construction practice. They also support the necessity of replacing reactive management with proactive management.

Table 3. Correlation of proactive management with problem avoidance/minimization and continuous improvement.

Proactive management indicator	Problem avoidance/minimization		Continuous improvement	
	Correlation coefficient	<i>p</i>	Correlation coefficient	<i>p</i>
Clear and proper role definition	0.559**	0.000	0.393**	0.000
Proactive project planning	0.365**	0.000	0.266**	0.009
Regular performance measurement	0.351**	0.001	0.435**	0.000
Early warning of problems	0.414**	0.000	0.274**	0.007

**Correlation is significant at the 0.01 level (two tailed).

In statistics, the smaller the *p* value is, or the bigger the correlation coefficient is, the greater effect proactive management has. Based on the comparison of correlation coefficients, clear and proper

role definition is found to have the greatest effect on problem avoidance/minimization, which is followed by early warning of problems, proactive project planning, and regular performance measurement. On the other hand, regular performance measurement has the greatest effect on continuous improvement, which is followed by clear and proper role definition, early warning of problems, and proactive project planning. Among the four indicators of proactive management, clear and proper role definition, proactive project planning and early warning of problems have more effect on problem avoidance/minimization than on continuous improvement. Regular performance measurement is an exception because it has more effect on continuous improvement than on problem avoidance/minimization. Although there are slight differences among the four indicators, their effects on problem avoidance/minimization and continuous improvement are at the same significance level of 0.01.

6. Analysis of interview results

The interviewees in this research consisted of two supply chain managers, two project managers, two procurement managers, two design consultants, two site managers, and one industry improvement scheme director. Based on a wide range of roles, the interviewees provided industrial practitioners' perception of proactive management and supply chain management. According to the interviewees, the application of supply chain collaboration and integration in construction practice is escalating. This is consistent with the questionnaire survey that reports (1) 29.0% of projects with short-term supply chain collaboration and 38.0% of projects with long-term supply chain collaboration; and (2) 49.0% of projects using D&B and 21.0% of projects using PPP for supply chain integration. The interviewees confirmed the reactive nature of the traditional construction industry identified from the literature review, which is characterized by "firefighting" against arisen difficult problems. According to the interviewees, the construction industry is

increasingly replacing reactive management with proactive management. This concurs with the questionnaire survey that reports more than 88.0% of positive responses for any indicators of proactive management. As a result, the increasing use of proactive management and the escalating application of supply chain management coexist in today's construction practice. The interviewees believed that the concurrent trends are not coincident. Instead, it reflects the interaction between proactive management and supply chain management, especially the interaction between proactive management and supply chain collaboration.

The interviewees confirmed the positive impact of supply chain collaboration described by supply chain relationships on proactive management. Compared to the one-way influence of supply chain collaboration on proactive management identified from the questionnaire analysis, the interviewees went one step further. They considered supply chain collaboration as both an input and an output of proactive management. On one hand, supply chain collaboration provides harmonious working environments for the better use of proactive approaches. On the other hand, proactive management avoids or minimizes problems, facilitating supply chain collaboration. Therefore, there is a need to foster a proactive and collaborative culture in the construction industry and its projects. This was a consensus among the interviewees in this research. According to the interviewees, the combination of proactive management and supply chain collaboration will have double effect and create more opportunities to achieve success in construction projects and supply chains.

In contrast to supply chain collaboration, project delivery method that describes supply chain integration is determined before the start of a construction project. It remains unchanged during the project. For this reason, the interviewees did not think that proactive management and supply chain integration have two-way communication although they confirmed the positive impact of

supply chain integration on proactive management. On the other hand, a common understanding of the interviewees was that supply chain relationships are not static. Instead, they are dynamic during a construction project or from one project to another. Compared to supply chain integration, supply chain collaboration described by dynamic relationships is more closely linked with proactive management. Indeed, establishing collaborative relationships join project participants or supply chain members together to implement proactive approaches. Proactive management in turn addresses problems as early as possible, sustaining and developing collaborative relationships. Otherwise, a lack of collaborative relationships will pull project participants or supply chain members in different directions when facing various problems. As a result, it becomes difficult to address problems in advance and problems may grow dramatically. Unsuccessful problem solving is very likely to deteriorate supply chain relationships.

Supply chain management and proactive management are continuously developing in the construction industry. The interviewees took BIM as a good example to illustrate proactive and collaborative ways of working in today's practice. According to the interviewees, BIM has witnessed a rapid development in recent years. It is increasingly becoming the norm. It is revolutionizing design, construction and operation throughout the project lifecycle. The main essence of BIM is collaborative working on a central platform that enables project parties or supply chain partners to share information. In construction projects, many problems are caused by asymmetric information (Xiang et al. 2012; Ceric 2014). The interviewees perceived that, when BIM is used, shared information in a collaborative environment is helpful to overcome information asymmetry, prevent misunderstanding, and avoid problem occurrence.

According to the interviewees, BIM brings about both new technological solutions and new management paradigms in construction projects for proactive management. From the

technological perspective, for example, the virtual visualization of BIM allows designers and/or contractors to detect potential problems, such as physical and clearance clashes, as early as possible before on-site construction starts. From the management perspective, for example, the BIM model enables contractors and/or facilities managers to get involved early so that their expertise can be incorporated into the design decision-making process to avoid design flaws as designers are often less familiar with constructability and practicability. For all these reasons, the interviewees were confident that the increasing use of BIM in the construction industry will build a brighter future for proactive management through online collaborative working.

7. Conclusions

Reactive management leaves minor issues to develop into major problems. It often suffers from serious losses. Unlike reactive management that fights against arisen difficult problems, proactive management takes preventive measures in advance. In this research, clear and proper role definition, proactive project planning, regular performance measurement, and early warning of problems are identified as four indicators to describe different key aspects of proactive management. This research provides clear evidence for an increasing prevalence of proactive management in project-based construction supply chains through an empirical investigation. A general trend is that the construction industry is experiencing a major change from reactive management to proactive management. This research reveals that proactive management has significant contributions to both problem avoidance/minimization and continuous improvement. The finding demonstrates the real effect of proactive management in construction practice. It also explains why the construction industry is increasingly embracing proactive management in its projects and supply chains. The primary reason behind the trend is that, compared to reactive

management, proactive management makes construction projects and supply chains more likely to achieve success.

When comparing supply chain collaboration and supply chain integration, it is supply chain collaboration that has a significant impact on proactive management. This research establishes the interaction between proactivity and collaboration. Supply chain collaboration is recognized in this research as both an input and an output of proactive management. Based on the findings, this research encourages proactive and collaborative ways of managing projects and supply chains in construction. This means that proactive management will become more effective and robust if it combines with supply chain collaboration. Proactive management and supply chain management develops continuously in construction. New technological solutions and management paradigms are infused continuously to support their practice. As an innovation of both technology and management, BIM has a key role to play in proactive management. It is also at the center of supply chain collaboration. For this reason, it can be used as a most recent example to illustrate proactive and collaborative management of construction projects and supply chains.

This research is probably the first research attempt to investigate proactive management in a systematic way from the perspective of construction supply chains. It enables academic researchers and industrial practitioners to better understand the importance of proactive management in construction supply chains, which provides theoretical and practical implications. Every study has limitations, and this research is no exception. The empirical investigation in this research only focuses on the UK construction industry. As a result, this research has a contextual limitation. Further research is recommended to collect empirical data from other countries so that it becomes possible to compare proactive management combined with supply chain collaboration in different construction contexts. As mentioned above, construction learned supply chain collaboration from

manufacturing. Another recommendation is to compare project-based construction and process-centric manufacturing in terms of proactive and collaborative ways of working through an empirical investigation. It is also possible to compare proactive and collaborative ways of working between construction and other project-based industry sectors. It is expected that the comparisons will enable academics and practitioners to achieve a more thorough understanding in this particular field. BIM has a great potential to improve proactive management and supply chain collaboration. A suggested direction for future research is BIM-based proactive and collaborative management of construction projects and supply chains.

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