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Collaboration and Integration in Project-Based Supply Chains in the Construction Industry

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Abstract: This study investigates whether integrative and collaborative practices of the construction industry can be exclusively attributed to integrated project-delivery methods or whether traditional project-delivery methods also foster integration within project-based design teams. Project managers assessed team collaboration and the integration of teams into 46 construction industry projects in The Netherlands. Explanatory factor analysis (EFA) was used to identify the components that explained collaboration and integration within project design teams. Using analysis of variance of factor scores, the main finding of the study was that, in the construction industry, collaboration is an independent component in integrative and collaborative practices that can be reliably assessed in research. Furthermore, this study provides evidence suggesting that both traditional and integrated project-delivery methods might lead to collaboration over time. The third finding is that different project-delivery methods were not significantly different in terms of the dimensions of integration and collaboration, except in the component of inclusive decision making within the building team and for strategic partnering. The findings suggest that relying on the type of project-delivery method is not sufficient for managers communicating about the level of supply chain integration and collaboration. **DOI: 10.1061/(ASCE)ME.1943-5479.0000592.** © *2018 American Society of Civil Engineers.*

Author keywords: Supply chain integration; Collaboration; Construction industry; Project-based supply chains; Project-delivery method.

Introduction

Supply chain integration and collaboration is used to improve performance by establishing close relationships and the alignment of activities between upstream and downstream actors in the supply chain (Carter et al. 2009; Barratt 2004). In construction, both integration and collaboration are seen as ways to increase the efficiency and quality of production processes (Akintoye et al. 2000; Bresnen and Marshall 2000; Khalfan and McDermott 2006; Bygballe et al. 2010).

There is little consensus on the definitions of integration and collaboration (Fabbe-Costes and Jahre 2008; Leuschner et al. 2013; Meng 2013; Burgess et al. 2006). *Collaboration* is herein defined as being a soft aspect of supply chain management (Kache and Seuring 2014). This people-focused concept deals with social relationships, such as trust and commitment (Burgess et al. 2006). *Integration* herein refers to practices that are performed at a project level. These practices concern tangible activities or technologies, such as the shared use of a building information model or using a shared office that allows face-to-face communication (Van der Vaart and Van Donk 2008; Eriksson 2015).

There is a strong focus on integration and collaboration at the project level in construction-related research (Meng 2012; Lahdenperä 2012; Izam Ibrahim et al. 2013). In these studies, integrated project-delivery methods, such as project alliancing, are primarily believed to foster integration practices among diverse organizations involved in delivering construction projects (Lahdenperä 2012; Izam Ibrahim et al. 2013). The most commonly used method is the traditional design-bid-build approach (D'Agostino and Bridgers 2010; Royal Institute of British Architects 2012), which is characterized by a phased approach in which design and production are separated. By definition, the traditional approach does not entail integrative activities. However, ignoring the level of integration and collaboration in traditionally procured projects may deny the long-term relationships that many construction industry firms have developed with their major clients (Carter et al. 2009; Egemen and Mohamed 2006). Notwithstanding, according to Dewulf and Kadefors (2012), traditional construction contracts often lead to distrust and conflicts in project teams. Alternatively, integrative activities may give rise to conflicts in project teams that eventually result in poor collaboration (Edmondson and Nembhard 2009).

Thus, there is a need for research that explores the level of integration and collaboration in project-based supply chains in construction. To meet this need, this study addressed the question of whether integrative and collaborative practices can be exclusively attributed to

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integrated project-delivery methods or whether traditional project-delivery methods can also foster integration and collaboration.

To this end, a multidimensional questionnaire was developed on the basis of a theoretical framework of supply chain integration and collaboration. It was validated using construction projects that relied on different project-delivery methods, believed by many researchers to foster different levels of integration and collaboration. In this paper, the authors first discuss the results of the exploratory factor analyses used to validate the questionnaire, before comparing the outcomes they found between traditional and collaborative project-delivery methods.

Theoretical Framework

There is a lack of a clear definition and understanding of the concept of supply chain integration and collaboration (Kache and Seuring 2014; Burgess et al. 2006). To develop a theoretical framework, the authors examined the extensive literature reviews performed by Eriksson (2015), Kache and Seuring (2014), Leuschner et al. (2013), Van der Vaart and Van Donk (2008), Fabbe-Costes and Jahre (2008), and Frohlich and Westbrook (2001) and compared their underlying variables (Fig. 1).

After reviewing the concepts and underlying variables from each article, a theoretical framework consisting of seven concepts was developed for this study: (1) scope of integration, (2) integration of activities, (3) duration of integration, (4) financial integration, (5) information sharing, (6) inclusive decision making, and (7) collaboration. In the next section, the seven concepts are further defined, followed by the four project-delivery methods used in this study.

Scope of Integration

The scope of integration concerns the "nature and number of organizations or participants included in the integrated supply chain" (Fabbe-Costes and Jahre 2008, p. 135) and the timing of their involvement in the project (Eriksson 2015) (Fig. 1). It could include customers (downstream), internal (across) functions, suppliers (upstream), competitors, and noncompetitors (Barratt 2004; Frohlich and Westbrook 2001). The importance of timing has been pinpointed in many studies, suggesting that key contractors and suppliers should be involved early in a project to contribute their knowledge, experience, and skill to the design (Eriksson 2015).

Integration of Activities

The integration of activities concerns project-related activities that are undertaken together and the physical facilities that are shared by the organizations or participants that are part of an integrated supply chain. This concept is referred to by Fabbe-Costes and Jahre (2008) as *integration of processes and activities* and by Van der Vaart and Van Donk (2008) as *practice* (Fig. 1). Eriksson (2015) referred to activities that were performed to build a project team, for example, *team-building activities*, and to the facilities used by the project team, such as *colocation of project team members*. Integration of activities should not be confused with tools and techniques for process improvement, such as six sigma or total quality management, which are often used to support the integrative effort.

Duration of Integration

Duration of integration was a concept adopted from Eriksson (2015) and involves the length of a relationship over a series of projects (Fig. 1). Eriksson (2015) called for explicit investigation into this dimension of supply chain integration in construction, arguing that most studies had focused on manufacturing industries "in which there is an implicit assumption of long-term relationships." (Eriksson 2015, P. 41) In construction-related literature, it is often stated that the discontinuous nature of construction projects makes it difficult or almost impossible to build long-term relationships

Concepts of supply chain integration used in each article and variables covered by each concept

Variables	Eriksson (2015)	Kache & Seuring (2014)	Leuschner et al. (2013)	Fabbe Costes & Jahre (2008)	Van der Vaart & Van Donk (2008)	Frohlich and Westbrook (2001)	This article
1 Interpersonal/people focused		Collaboration	Relational integration		Attitudes		Collaboration
2 Trust and Commitment							
3 Long term orientation	Duration of integration						Duration of integration
4 Number and nature of parties	Scope of integration	Integration	Scope of integration	Scope		Direction	Scope of integration
5 Timing of involvement	Duration of integration						
6 Functions	Depth of integration			Integration of actors			
7 Selection criteria	Strength of integration						Collaboration
8 Processes/activities		Integration	Operational integration	Integration of processes and activities	Practices	Extent (degree)	Integration of activities
9 Interaction/communication					Patterns		
10 Sharing of physical facilities				Integration of flows			
11 Decision making					Patterns		Inclusive decision making
12 Financial transparency		Risk/ performance		Integration of flows			Financial integration
13 Sharing of risks, costs and rewards							
14 Information sharing		Information sharing	Information integration			Extent (degree)	Information sharing
15 ICT				Integration of systems & technologies	Practices		

Fig. 1. Comparison of studies on supply chain integration based on concepts and underlying variables

[e.g., Bygballe et al. (2010); Briscoe and Dainty (2005)]. However, some studies have shown that long-term relationships in construction do exist and play a critical role in improving performance [e.g., Pellicer et al. (2016); Koolwijk et al. (2015); Meng (2012); Saad et al. (2002)]. For instance, long-term integration enhances the possibilities for continuous improvements (Bresnen and Marshall 2000).

Financial Integration

Financial integration involves the sharing of risks, costs, and rewards along the chain and sharing of sensitive financial information to evaluate the financial performance of the single entities in the supply chain. This concept is referred to by Kache and Seuring (2014) as *risk/performance*. Fabbe-Costes and Jahre (2008) included this concept as a part of the integration of flows (Fig. 1).

Sometimes one firm in the chain has to work less effectively than necessary to raise the overall efficiency of the entire supply chain (Kache and Seuring 2014). If incentives are not aligned, a firm may optimize its own production instead of the production of the chain. To make supply chain partners look beyond the realm of their own company and to improve the performance of the entire chain, incentives need to be aligned; that is, the risks, costs, and rewards should be shared across the network on a fair basis (Das and Teng 2001; Mentzer et al. 2001; Narayanan and Raman 2004). The sharing of sensitive financial information, in this respect, is key to being able to define what the sharing of risks and rewards on a fair basis requires (Gunasekaran and Ngai 2007).

Information Sharing

Information sharing deals with the sharing of information among the members of the supply chain and the use of information technology to exchange and manage information. Leuschner et al. (2013) referred to this concept as *information integration* (Fig. 1).

Information sharing is an important facilitator of an effective and efficient supply chain because it provides enhanced coordination between partners and gives a better understanding of the needs of the client (Sahin and Robinson 2005; Li and Lin 2006; Leuschner et al. 2013; Kache and Seuring 2014). Information technology (IT) enables firms to rapidly exchange and manage information. IT can make information more accurate and available in a timely way, which can lead to higher performance (Stank et al. 1999). In construction, IT is also seen as an important enabler of supply chain integration (Papadonikolaki and Van Oel 2016; Eriksson 2015).

Inclusive Decision Making

Inclusive decision making concerns the level of involvement of top and middle management in the project and joint decision making by the client and suppliers. Inclusive, or involvement in, decision making is considered by Van der Vaart and Van Donk (2008) to be part of interaction patterns between the focal firm and its suppliers and/or customers (Fig. 1).

For supply chain integration to be long lasting, it requires inclusive decision making. Key partners need to be involved in decision making and allowed to voice their concerns and opinions (Eriksson 2015). All partners should consent to proposals for the integration of activities. Unless there is inclusive decision making, sub optimization of the chain may occur (Arshinder et al. 2011).

Collaboration

Collaboration concerns the interpersonal processes and reflects the level of trust and commitment between people and also the sense of belonging to a team in the supply chain (Kache and Seuring 2014). Leuschner et al. (2013) considered trust and commitment to be part of relational integration.

Because construction is a project-based industry, collaboration should be considered at the project-team level because interorganizational and intraorganizational collaboration will change per project and over time (Briscoe and Dainty 2005). Changes in team composition across projects and over time will affect team learning, because extra-role behaviors, such as speaking up and showing commitment, will be present only if team members trust each other and feel safe (Edmondson and Lei 2014; Savelsbergh et al. 2015). Therefore, collaboration enhances team learning and holds a strong relationship with team performance.

Interdependence between Integration and Collaboration

Integration is herein considered an activity-focused concept. When companies decide to integrate their activities, they accept becoming vulnerable to the actions of other firms. They are willing to become vulnerable because they expect another firm to be capable of performing a particular action that is important to them without taking advantage of them (Mayer et al. 1995). Moreover, integration requires that the firms involved invest resources, while the benefits of integration do not always come so easily (Leuschner et al. 2013). Before partners are willing to share sensitive financial information, an environment in which all partners are allowed to make money is required as is trust that the other partners will not misuse the information that is shared (Eriksson 2015). Integration, thus, requires a long-term vision and commitment of the firms involved (Handfield and Nichols 2002; Kwon and Suh 2004; Leuschner et al. 2013; Eriksson 2015).

Collaboration as a people-focussed concept deals with social relationships, such as trust and commitment (Burgess et al. 2006). From the literature review, it appears that collaboration is to be distinguished from integration, but both concepts are interrelated. Integrative practices constitute the opportunities to develop collaboration; that is, it develops mutual trusting relationship between firms. For partners to get to know each other and build a trusting relationship, the duration of this relationship is important (Eriksson 2015; Zheng et al. 2008). Trust between team members needs to grow with experience (Dwyer et al. 1987). For instance, Maurer (2010) found that project team members who know each other from prior collaborative projects and get involved early in the project have greater opportunities to interact and get to know each other, which lay the ground for mutual trust.

Project-Delivery Methods and the Level of Integration and Collaboration

The four delivery methods examined in this article are design-bid-build (DBB), design-build (DB), building team (BT) and strategic partnering (SP). Although the underlying characteristics of different project-delivery methods may overlap and the boundaries between them can be ambiguous (Pellicer et al. 2016; Franz and Leicht 2016; Mollaoglu-Korkmaz et al. 2011), a description of the essence of each project-delivery method is described separately in this section.

DBB is a project-delivery method in which the owner enters into a contract with an architectural/engineering (A/E) firm that provides design services according to the requirements stipulated by the

owner. The A/E deliverables include full plans and specifications for the construction of a project. These documents are subsequently used by the owner as the basis for a separate contract with a constructor. In this approach, the contractor and subcontractors are not involved in the design phase.

In the DB approach, the owner signs a contract with one entity, a design builder, often according to functional specifications and a basic design (Molenaar et al. 1999). This approach requires integration and collaboration within the design-build entity (Pellicer et al. 2016).

BT is a Dutch approach in which the owner, contractor, A/E, and often key subcontractors work together to develop the basic design into a final design (Chao-Duivis et al. 2013). The owner selects the partners and signs separate contracts with the A/E, contractors, and subcontractors for the design phase. In addition, a collaboration agreement is signed by all building team members, which states the mutual obligations, such as how to collaborate, task division, and decision making (Chao-Duivis et al. 2013). BT offers a greater scope of integration by including key subcontractors in the early design phase.

SP is a delivery method in which the owner enters into a long-term collaborative multiparty agreement with the main contractor, multiple key subcontractors, and an A/E firm. The partners work together from the early design phase. When the final plan accords with all the preset targets, the works are awarded to the partnership. What makes this a *strategic* partnership is that the partners are awarded a follow-up project when they deliver according to preset key performance indicators. Other characteristics of the SP method include decision making by a board of directors representing all key partners, open-book accounting, risk and reward sharing, open communication, and joint team-building activities.

To conclude, the preceding literature review shows that collaboration and integration are interrelated concepts and that supply-chain integration may improve project performance, not only because of the integration of activities but also because of the emerging processes that arise in collaboration. Duration of integration, inclusive decision making, information sharing, and financial integration are considered practices indicating the extent of integration.

Method

To address the question of whether integrative and collaborative practices can be exclusively attributed to integrated project-delivery methods or whether traditional project-delivery methods can also foster integration and collaboration, a multidimensional questionnaire was developed on the basis of the theoretical framework of supply chain integration and collaboration and applied to projects in the construction industry using different project-delivery methods.

Sample

The respondents were project managers, either from a housing association ($n = 27$) or working for a contractor ($n = 19$). Respondents were accessed through a collaborative innovation network (CIN) of 18 housing associations considering the adoption of or already engaging in strategic partnering with contractors. In this CIN, housing associations share their knowledge and experiences about strategic partnerships. Their geographical location in The Netherlands is shown in Fig. 2. Participating organizations were encouraged to contribute projects that were procured through different routes. In all, 46 of the 89 questionnaires were completed, yielding a response rate of 52%.

Fig. 2. Geographical locations in The Netherlands of social housing associations that participated in this study

Data Collection

Data collection took place over an extended period between September 2012 and May 2015 using an online survey. The aim of the survey was to investigate the level of collaboration and integration in projects procured through different routes. Both the design and construction phases of the survey were assessed (Vrijhoef et al. 2014). For this paper, the authors report only the data concerning team collaboration and supply chain integration during the design phase. The data on the construction phase were discarded because it was argued that only the design phase of a traditional DBB project and collaborative project-delivery methods are comparable for the purpose of the study. In the construction phase, different parties are involved in the traditional DBB projects than are involved in the design phase.

Measures

In the first step, the authors took the seven concepts from the theoretical framework and aimed to establish a valid and reliable conceptualization. The authors first analyzed the multiple concepts that were related to each level of integration and collaboration to understand the definition of each. Then, to operationalize each concept, the authors took the measures from the supply chain monitor (SCMon) and connected them to each concept. The SCMon was developed in 2012 to measure the level of supply chain integration and collaboration. It was developed by a team from Delft University of Technology in close collaboration with a CIN of housing associations (Vrijhoef et al. 2014). This effort resulted in 31 measures clustered under the seven concepts (Table 1).

Table 1. Questions Used to Conceptualize the Concepts under Study

Number	Concepts and questions	Items	Scale
	Scope of integration	2	
1	What kinds of party are part of the project team?		C
2	When did the parties get involved?		O
	1 and 2 combined: How many parties were part of the project team in the design phase?		O
	Integration of activities	3	
3	Did project team members participate in team-building activities?		O
4	Does the project team work and meet in the same location?		O
5	To what level did the client prescribe the design?		O
	Duration of integration	6	
6	Does the way this project is organized fit with the company vision of the client or partners involved?		O
7	To what extent is this project part of a joint long-term strategy to work together?		O
8	In how many projects did the project partners work together before this project?		O
9	Do the project partners have the intention or agreement to work together on the next project?		O
10	To what extent is the project team composed of members that have worked together before?		O
	Financial integration	7	
11	To what extent do suppliers have insight into the project and maintenance budget of the client?		O
12	To what extent does the client have insight in the breakdown of the contract sum (hourly rates, material prices, general costs, etc.) of the suppliers?		O
13	To what extent do all suppliers have insight into each other's cost breakdown structure?		O
14	To what extent do all suppliers have insight in each other's purchase/cost price?		O
15	What kind of arrangement is used to settle pains and gains?		O
16	When a risk/reward fund is used, what happens with the deficit and surplus at the end of the project?		O
17	What kinds of incentive are used to stimulate the project team to perform better?		O
	Information sharing	2	
18	Are project files shared and edited on a shared digital portal?		O
19	Can all project information be accessed by all project team members?		O
	Inclusive decision making	7	
20	What is the level of involvement of clients' top management in the project?		O
21	What is the level of involvement of clients' middle management in the project?		O
22	What is the level of involvement of partners' top management in the project?		O
23	What is the level of involvement of partners' middle management in the project?		O
24	Are decisions made by the client (one-sided) or by the client and suppliers together?		O
25	Are project goals formulated by the client (one-sided) or by the client and suppliers together?		O
26	Did the client and project partners formulate joint objectives that go further than a single project?		O
	Collaboration	5	
27	On which criteria were most partners selected?		O
28	Do you expect that this project team will be kept together for the next project?		O
29	How would you describe the amount of effort team members (commitment) put into the project?		O
30	To what extent do team members feel responsible to speak up and give feedback to each other?		O
31	Is there a sense among team members that they are doing this together?		O

The measures that define the level of supply chain integration and collaboration were included in a pilot survey that also included questions about the respondents' individual and organization backgrounds, project, and contract information. The face validity of the questions was then discussed and shaped with 14 practitioners (i.e., project managers from clients as well as contractors) in three focus groups, and finally operationalized in an online survey. This online survey was first piloted on six projects. Comments from practitioners who participated in this pilot survey were collected and alterations to the survey were made. Most of the reshaping and altering of the survey had to do with the clarity of questions to the practitioners (i.e., jargon). The Questionnaire S1 is available online in the ASCE library.

To evaluate the scope of integration, two questions were asked about the type of partners that were part of the team and the moment these partners became involved in the project. Both variables were combined into an ordinal variable to assess whether the integration of different fields of expertise knowledge was facilitated or not (Eriksson 2015). Regarding the integration of activities, three questions were asked about team-building activities, team colocation, and whether design development was a task for the whole team. To measure duration of integration, five questions were asked about how the projects fit the company vision, the number of projects for which the project partners had worked together in the past, and whether partners have the intention to work together in the future. Financial integration was evaluated by seven questions on the extent to which financial information was shared among the different partners (upstream and downstream), the sharing of risks and rewards by partners, and the incentives used to encourage the project team to perform better. Information sharing was measured by two questions that asked about the use of a digital portal to share files and the actual accessibility of project information to all project team members. To measure inclusive decision making, seven questions were asked that focused on the level of involvement of top and middle management (representing both the client and the suppliers in the project) and the levels of joint decision making and joint goal setting. Finally, for the measurement of Collaboration, five questions addressed the amount of effort (commitment) partners

showed, the sense of belonging among project team members, and the level of participation by project team members in discussions.

Data Analyses

SPSS 23 was used for the statistical analyses. Explanatory factor analysis (EFA) was used with varimax and Kaiser normalization rotation to identify the latent structure of the questionnaire. A minimum factor weight of 0.40 was used for inclusion of questions onto a factor, and scree plots and eigenvalues were used to identify distinct variables or dimensions (Field 2009). A value of 0.5 for the Kaiser–Meyer–Olkin (KMO) criterion was used as a threshold for sampling adequacy (Field 2009). Subsequently, Cronbach's alpha was computed to assess the reliability of the factors identified. The Anderson-Rubin method was used to obtain uncorrelated factor scores (DiStefano et al. 2009) and sum scores were calculated to compare outcomes across different project-delivery methods (Starkweather 2012; Field 2009).

Finally, to explore whether project-delivery methods could be distinguished by a combination of summed factor scores, multivariate analysis of variance (MANOVA) was performed, examining four different project-delivery methods and the level of variance of each factor score for supply chain integration. For this study, bootstrapping (2,000 samples) was used to obtain more reliable estimates because the sample was relatively small ($N = 46$) (Field 2009).

Results

Descriptive Characteristics

Table 2 provides the descriptive statistics of the variables. Table 3 provides the descriptive statistics of the sum scores per factor. Table 4 presents a summary of the descriptive characteristics of the participants. The majority of the respondents was made up of middle-aged (between 31 and 50 years) males. Of the participants, 21.7% had secondary vocational training, 56.5% had a bachelor's degree, and 21.7% had a master's degree.

Table 5 describes the characteristics of the projects. There were 7 DBB, 8 DB, 10 BT, and 21 SP projects. Most projects concerned housing (89.1%) of which 41.3% were new developments and 58.7% were maintenance or renovation works. The number of project partners in the design phase ranged between 1 and 25 (excluding the client) (mean = 7.3). The gross floor area (GFA) varied between 45 and 50,000 m^2 (mean = 7,401 m^2). Most projects were not considered complex (59.7%). Low complexity was characterized by the use of proven technology, simple systems, standard designs, previously used configuration or geometry, and proven construction methods. Projects using unproven technology, complicated systems, nonstandard designs, new configuration or geometry, and new construction methods were considered highly complex projects.

There were no significant correlations ($p < 0.05$) found between the technical complexity, the type of construction works, project-delivery method, and project size, respectively.

Exploratory Factor Analysis of Collaboration and Integration in Project-Based Supply Chain Teams

The 31 questions from Table 1 were analyzed using EFA. EFA identified four latent factors that together explained 65.3% of the variance. Table 6 shows the final factor structure, consisting of four factors, all with eigenvalues of one or higher. From the 31 variables, 12 questions were dropped because of collinearity, low loading, or cross loading (Field 2009; Osborne and Costello 2009). The KMO (0.63) measure verified the sampling adequacy of the analysis, and all KMO values for individual items were above the threshold of 0.5 (Field 2009).

Table 6 shows the factor loadings after rotation. The four factors can be considered reliable scales, with Cronbach's alpha reliability coefficients between 0.70 and 0.80 (DeVellis 2017). All item rest correlations were between 0.45 and 0.79.

Component 1 was characterized and labeled collaboration because it dealt with person-focused elements; that is, it addressed long-term orientation, previous working relations and cohesion between partners, and the joint effort team members put into the project. Component 2 seems to reflect a *financial integration.* The questions that made up Component 2 addressed the extent to which team members share project-related risks and opportunities with each other and whether or not they share financial information. The third component was labeled *inclusive decision making* and concerned the level of involvement of top and middle management within the project and whether joint objectives go beyond one project. The fourth component was interpreted as *information sharing* and reflected the level of information sharing within a project team: how team members are stimulated to share their knowledge by means of incentives and the use of supporting technology among firms in a project. The four components of integration in project-based supply chains in construction are shown in Fig. 3.

Table 2. Descriptive Statistics of Ordinal Variables

	N				
Variable	Valid	Missing	Median	Range	Minimum-maximum
1&2	38	9	6	24	1-25
3	23	24	0	4	0-4
4	44	3	2	3	1-4
5	32	15	3	3	1-4
6	43	4	3	3	1-4
7	43	4	2	3	1-4
8	43	4	2	3	1-4
9	43	4	2	3	1-4
10	33	14	2	3	1-4
11	44	3	2	3	1-4
12	44	3	3	3	1-4
13	44	3	1	3	1-4
14	44	3	1	3	1-4
15	44	3	2	3	1-4
16	23	24	1	8	1-9
17	44	3	1	3	1-4
18	44	3	1	3	1-4
19	44	3	2	3	1-4
20	43	4	1	3	1-4
21	43	4	3	3	1-4
22	43	4	2	3	1-4
23	43	4	3	3	1-4
24	43	4	2	2	1-3
25	44	3	3	3	1-4
26	43	4	1	3	1-4
27	46	1	2	1	1-2
28	38	9	2	3	1-4
29	43	4	3	3	1-4
30	43	4	3	3	1-4
31	43	4	3	3	1-4

Table 3. Descriptive Statistics of Sum Scores per Factor

Factor	N		Mean	Median	SD	Range	Minimum	Maximum	Skewness	Kurtosis
	Valid	Missing								
Collaboration	47	0	0.00	0.00	0.97	3.75	−1.81	1.94	0.05	−0.66
Financial integration	47	0	0.00	−0.35	0.97	4.08	−1.24	2.84	1.31	1.23
Inclusive decision making	47	0	0.00	0.08	0.97	3.57	−1.68	1.89	−0.09	−0.70
Information sharing	47	0	0.00	−0.15	0.97	4.48	−1.40	3.08	1.31	1.48

Table 4. Profile of Respondents

Characteristic	Frequency	Percentage (%)
Age (years)		
20–30	5	10.9
31–40	10	21.7
41–50	21	45.7
51–60	10	21.7
Gender		
Male	41	89.1
Female	5	10.1
Education		
Secondary vocational training	10	21.7
Bachelor's degree	26	56.5
Master's degree	10	21.7
Employment		
Nongovernment (client)	27	58.7
Private (contractor)	19	41.3

Remarkably, several questions about integrative activities, such as team-building activities and working and meeting at the same location, did not combine into a distinct dimension. These questions were dropped because of cross loading or low loading.

Collaboration and Integration across Different Project-Delivery Methods

To investigate whether integrative and collaborative practices can be exclusively attributed to integrated project-delivery methods or whether traditional project-delivery methods might also foster integration, sums of the uncorrelated factor scores were used to compare outcomes across different project-delivery methods. A multivariate test showed that there was a statistically significant difference in levels of integration according to the project-delivery method used [F (4, 12) = 2.21, $p < 0.05$; Wilk's $\Lambda = 0.016$]. The level of integration was significantly dependent on the type of project-delivery method. Only inclusive decision making ($p = 0.02$) differed between project-delivery methods (Table 7).

Post hoc, pairwise comparisons showed the level of inclusive decision making to be different only between the BT and SP methods ($p < 0.01$) (Table 8). This finding means there is a difference in the levels of involvement of top management (board level) on both the client and partner sides, and there is a difference in the joint formulation of long-term goals (that go further than one project).

Conclusion and Discussion

The aim of this study was to investigate whether integrative and collaborative practices can be exclusively attributed to integrated project-delivery methods or whether traditional project-delivery methods might also foster integration. The main finding of the study was that, in the construction industry, collaboration is an independent component in integrative practices, which can be reliably assessed in research (Cronbach's $\alpha = 0.76$). Therefore, and contrary to what was suggested by Eriksson (2015) and Van der Vaart and Van Donk (2008), collaboration should not be overlooked when attempting to understand project-based supply chains. This is important, as others showed that collaboration significantly influences firm or project performance through the development of trust, commitment, and long-term orientation (Chen et al. 2004; Hult et al. 2004; Dyer and Hatch 2006; Leuschner et al. 2013). This finding is also supported by Pellicer et al. (2016), who found that procuring teams with previous working relationships increased the likelihood of project success.

The second main finding of this study concerns evidence suggesting that both traditional and integrated project-delivery methods might lead to collaboration over time. This is an important finding because the dominant approach in the construction industry is based on relationships that are determined by legal boundaries (Meng et al. 2011; Jelodar et al. 2016). This might indeed explain why collaboration as a concept was discarded by Eriksson (2015) and Van der Vaart and Van Donk (2008), or why the influence of collaboration and integration on design quality (Arge 1995; Brown and Adams 2000; Owen et al. 2010; Prins and Kruijne 2011) has been only studied by comparing traditionally procured projects with integrative project-delivery methods.

The current study suggests that both traditional and integrated project-delivery methods can lead and contribute to collaboration in the long-term. It may well be that, irrespective of project-delivery methods—hence, in traditionally procured construction industry projects—collaboration has developed over time, across a series of traditionally procured projects. This might be the case because in the construction industry many firms may have long-term relationships with their major clients (Carter et al. 2009; Egemen and Mohamed 2006), and therefore, they may also have developed long-term relationship with other firms that, in turn, hold similar long-term relationships with the same clients. It might also be the case that suppliers, for example, a contractor, and several subcontractors have developed long-term relationships because they operate together in a particular part of the construction market. In addition, the strong emphasis on type of project-delivery method, while ignoring the actual level of collaboration, might well explain the inconsistent results that were reported by studies investigating whether or not project-based supply chains in the construction industry improved project performance relative to traditionally procured projects (Ibbs et al. 2003; Hale et al. 2009; Raisbeck et al. 2010; Chen et al. 2016; Tran et al. 2016).

The third finding is that different project-delivery methods are not significantly different in terms of the dimensions of integration and collaboration (except for inclusive decision making between the BT and SP approaches). This is apparent in the large

Table 5. Characteristics of the Projects

Characteristics	*n*	Percentage (%)	Median	Mean	SD	95% Confidence interval	
						Lower	Upper
Project-delivery method ($N = 46$)							
Design-bid-build	7	15.2					
Design-build	8	17.4					
Building team	10	21.7					
Strategic partnering	21	45.7					
Function of the buildings ($N = 46$)							
Housing	41	89.1					
Utility	5	10.9					
Type of construction works ($N = 46$)							
New building	19	41.3					
Maintenance/renovation	27	58.7					
Technical complexity							
Not complex	27	58.7					
Complex	19	41.3					
Partners involved in design phase ($N = 38$)			6.0	7.3	5.4	5.5	9.06
Gross floor area of the projects ($N = 36$)			5,062.5	7,401.1	9,005.6	5,354.0	10,448.1

variance found for each factor of project-delivery methods. However, this finding needs further research because the authors used convenience sampling, and despite using bootstrapping to address the problem of low numbers per project-delivery method, they obtained rather low numbers per project-delivery method. Based on Table 7, it could be argued that SP showed higher levels of collaboration, inclusive decision making, and information sharing, while DB showed the highest levels of financial integration.

Finally, the outcomes of this study show that the dimensions that were identified to conceptualize collaborative and integrative practices in the construction industry can best be compared to those suggested by Kache and Seuring (2014) and Leuschner et al. (2013). Like Kache and Seuring (2014) and Leuschner et al. (2013), this study found that collaboration is an independent and important dimension of the integration of activities. Collaboration in the construction industry context seems to represent the level of trust, commitment, and long-term orientation between supply chain partners on both strategic and operational levels. This raises the question of whether a high level of collaboration on a team level is possible without the commitment and long-term focus of strategic management. Walker and Hampson (2003) showed that the level of cooperation within project teams in long-term partnering increases over time. Bowersox et al. (2003) concluded that top management support is necessary to enable collaborative processes between supply chain partners.

While both were included by Leuschner et al. (2013) in their dimension of operational integration, inclusive decision making and information sharing were identified in this study as independent dimensions that describe joint activities, work processes, and coordinated decision making among firms in the supply chain. Particularly in the construction industry, a project requires integrative practices of many different technical and nontechnical fields. Because of a high degree of vertical specialization in the construction industry, knowledge is typically spread across the entire supply chain (Cacciatori and Jacobides 2005). Because construction is inherently a site-specific, project-based activity (Shirazi et al. 1996; Cox and Thompson 1997), the interactions between professionals mainly take place within a temporary organization (Baiden et al. 2006). This project organization can be structured in many different ways (Franz and Leicht 2016) with varying degrees of operational integration among firms, and it may complicate decision making and information sharing; the latter component has been identified in many other studies (Kulp et al. 2004; Saeed et al. 2005; Ireland and Webb 2007; Van der Vaart and Van Donk 2008).

Financial integration constitutes the final dimension of collaboration and integration in construction industry projects and is independent of inclusive decision making and information sharing. This factor has been previously described by Saeed et al. (2005) as the extent to which supply chain members jointly invest in projects of mutual interest. In this study, however, financial integration concerned the extent to which supply chain members share project-related risks and profits, and to what degree sensitive financial information was shared. Although there seems to be elements of information sharing in this dimension of financial integration, financial integration seems to be an independent dimension of collaboration and integration in project-based supply chains. This may be the case because of the temporary nature of many projects in the construction industry. Because most studies of collaboration and integration included in the work of Leuschner et al. (2013) were performed in the manufacturing industry or logistics, and involved different types of supply chains, it might well be that the project-delivery methods were also different, giving rise to financial integration as an independent factor.

Limitations

An important limitation of this study is that convenience sampling was used. To reduce the possibility of misinterpretation, the sample and project conditions were precisely described. Furthermore, the authors did not find any differences between project-delivery methods that could influence the outcomes of this study. Another limitation that results from the sampling approach is that a large share of the projects was procured by social housing associations. In The Netherlands, these associations are private organizations. Therefore, they do not have to comply with EU procurement laws for fair tendering, and this absolution from EU regulations might have a positive influence on the development of long-term relationships between partners.

Table 6. Factor Loadings, Explained Variance, and Cronbach's Alpha Values for Each of the Four Identified Components

Item	Description	Identified components and factor loadings[a]			
		Collaboration	Financial integration	Inclusive decision making	Information sharing
1	What kinds of party are part of the project team?				
2	When did the parties get involved? *1 and 2 combined: How many parties were part of the project team in the design phase?*				
3	Did project team members participate in team-building activities?				
4	Does the project team work and meet in the same location?				
5	To what level did the client prescribe the design?				
6	Does the way this project is organized fit with the company vision of the client or partners involved?	0.67			
7	To what extent is this project part of a joint long-term strategy to work together?	0.64			
8	In how many projects did the project partners work together before this project?	0.69			
9	Do the project partners have the intention or agreement to work together on the next project?				
10	To what extent is the project team composed of members that have worked together before?				
11	To what extent do suppliers have insight into the project and maintenance budget of the client?				
12	To what extent does the client have insight into the breakdown of the contract sum (hourly rates, material prices, general costs, etc.) of the suppliers?				
13	To what extent do all suppliers have insight in each other's cost breakdown structure?		0.82		
14	To what extent do all suppliers have insight in each other's purchase/cost price?		0.85		
15	What kind of arrangement is used to settle pains and gains?		0.72		
16	When a risk/reward fund is used, what happens with the deficit and surplus at the end of the project?		0.67		
17	What kinds of incentive are used to stimulate the project team to perform better?				0.70
18	Are project files shared and edited on a shared digital portal?				0.92
19	Can all project information be accessed by all project team members?				0.73
20	What is the level of involvement of clients' top management in the project?			0.69	
21	What is the level of involvement of clients' middle management in the project?				
22	What is the level of involvement of partners' top management in the project?			0.81	
23	What is the level of involvement of partners' middle management in the project?			0.71	
24	Are decisions made by the client (one-sided) or by the client and suppliers together?				
25	Are project goals formulated by the client (one-sided) or by the client and suppliers together?				
26	Did the client and project partners formulate joint objectives that go further than a single project?			0.68	
27	On which criteria were most partners selected?				
28	Do you expect that this project team will be kept together on the next project?				
29	How would you describe the amount of effort team members (commitment) put into the project?	0.75			
30	To what extent do team members feel responsible to speak up and give feedback to each other?				
31	Is there a sense among team members that they are doing this together?	0.80			
Explained variance after extraction and varimax rotation (%)		18.00	17.22	16.03	14.05
Cronbach's alpha of each factor		0.76	0.80	0.77	0.71

[a]< 0.40 is suppressed.

Future Research

One of the acknowledged limitations of this study is that a large share of the projects was procured by social housing associations. These organizations do not have to comply with public laws for fair tendering. Public laws for fair tendering are often seen as a barrier to developing long-term relationships between public clients and private companies. However, regardless of any regulation, public clients can build long-term relationships by tendering repetitive works under a framework agreement. Furthermore, there are many submarkets of the construction industry in which only a few construction firms provide their services to public clients, such as the Dutch railway industry. In this submarket, comprising some 11 billion Euro per annum, only 1 public client and 10 general contractors are active (ProRail 2017). Under these market conditions, long-term relationships can develop through repetitive works, irrespective of the project-delivery methods used, or any restrictions imposed by legislation. In the future, the authors aim to obtain a

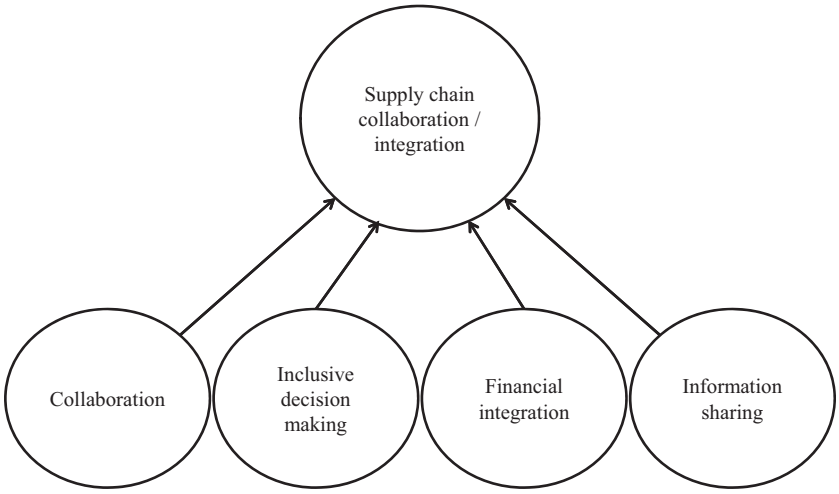

Fig. 3. Four components of collaboration and integration in project-based supply chains in the construction industry

Table 7. Influence of Project-Delivery Method on Relational and Financial Integration, Coordinated Decision Making, and Information Integration

					95% Confidence interval for mean				
Factor	Project-delivery method	*n*	Mean	SD	Lower	Upper	Degrees of freedom (DOF)	F	Sig.
Collaboration	Design-bid-build	7	−0.67	0.36	−1.00	−0.34	3.00	0.97	0.42
	Design-build	8	0.43	1.07	−0.46	1.32			
	Building team	10	−0.40	0.49	−0.75	−0.05			
	Strategic partnering	21	0.25	1.11	−0.26	0.75			
	Total	46	0.00	0.98	−0.29	0.29			
Financial integration	Design-bid-build	7	−0.20	0.96	−1.08	0.69	3.00	2.47	0.08
	Design-build	8	−0.25	1.13	−1.19	0.69			
	Building team	10	−0.26	1.18	−1.11	0.59			
	Strategic partnering	21	0.28	0.80	−0.08	0.65			
	Total	46	0.00	0.98	−0.29	0.29			
Inclusive decision making	Design-bid-build	7	−0.27	1.01	−1.20	0.67	3.00	3.61	0.02[a]
	Design-build	8	−0.24	0.97	−1.06	0.57			
	Building team	10	−0.33	0.97	−1.02	0.36			
	Strategic partnering	21	0.34	0.93	−0.09	0.76			
	Total	46	0.00	0.98	−0.29	0.29			
Information sharing	Design-bid-build	7	0.11	1.12	−0.93	1.14	3.00	1.22	0.31
	Design-build	8	−0.49	0.60	−0.99	0.02			
	Building team	10	−0.23	0.63	−0.68	0.22			
	Strategic partnering	21	0.26	1.13	−0.26	0.77			
	Total	46	0.00	0.98	−0.29	0.29			

[a]Tests of between-subject effects is significant at the 0.05 level.

random sample to determine whether collaboration also plays an important role in other submarkets of the construction industry, for instance, in submarkets where public laws for fair tendering apply.

Another topic for further research concerns deepening the authors' understanding of collaboration. Collaboration consists of both firm- and team-level variables. This raises the question, for instance, of whether having a long-term orientation or previous working relationships on a firm level leads to a greater effort by project team members in a project.

Managerial Implications

The findings demonstrate that merely relying on the type of project-delivery method for comparison is not sufficient for managers to communicate about the level of supply chain integration and collaboration. Managers should look deeper into the way the project has been organized and the resources used. The four dimensions of supply chain integration and collaboration in this project can be used for that purpose.

The findings inform managers that collaboration is an independent and important dimension of collaboration and integration. Owners who require construction on a more regular basis should be more aware of the relationships they could develop with their suppliers, irrespective of the project-delivery method they use, and use this relation as leverage in their projects. Owners who build occasionally, unfortunately, are not able to give a long-term perspective to their suppliers. However, these owners could look, in a procurement process, for an integrated supply chain that shows high levels of collaboration to deliver their project.

Table 8. Pairwise Comparison between Project-Delivery Methods for Each Component

Dependent variable	Type of project-delivery method (I)	Type of project-delivery method (J)	Mean difference (I-J)	Standard error	Significance[b]	95% Confidence interval for difference[b] Lower	Upper
Collaboration	Design-bid-build	Design-build	0.04	0.51	0.93	−0.98	1.07
		Building team	0.05	0.48	0.93	−0.93	1.02
		Strategic partnering	−0.46	0.43	0.29	−1.32	0.40
	Design-build	Design-bid-build	−0.04	0.51	0.93	−1.07	0.98
		Building team	0.00	0.46	1.00	−0.93	0.94
		Strategic partnering	−0.50	0.41	0.22	−1.32	0.32
	Building team	Design-bid-build	−0.05	0.48	0.93	−1.02	0.93
		Design-build	0.00	0.46	1.00	−0.94	0.93
		Strategic partnering	−0.51	0.38	0.19	−1.26	0.25
	Strategic partnering	Design-bid-build	0.46	0.43	0.29	−0.40	1.32
		Design-build	0.50	0.41	0.22	−0.32	1.32
		Building team	0.51	0.38	0.19	−0.25	1.26
Financial integration	Design-bid-build	Design-build	−1.042[a]	0.48	0.04	−2.02	−0.07
		Building team	−0.26	0.46	0.58	−1.18	0.67
		Strategic partnering	−0.839[a]	0.41	0.05	−1.66	−0.02
	Design-build	Design-bid-build	1.042[a]	0.48	0.04	0.07	2.02
		Building team	0.79	0.44	0.08	−0.11	1.68
		Strategic partnering	0.20	0.39	0.60	−0.58	0.99
	Building team	Design-bid-build	0.26	0.46	0.58	−0.67	1.18
		Design-build	−0.79	0.44	0.08	−1.68	0.11
		Strategic partnering	−0.58	0.36	0.11	−1.31	0.14
	Strategic partnering	Design-bid-build	−0.839[a]	0.41	0.05	0.02	1.66
		Design-build	−0.20	0.39	0.60	−0.99	0.58
		Building team	0.58	0.36	0.11	−0.14	1.31
Inclusive decision making	Design-bid-build	Design-build	−0.13	0.47	0.78	−1.07	0.81
		Building team	0.31	0.44	0.48	−0.58	1.21
		Strategic partnering	−0.75	0.39	0.06	−1.54	0.05
	Design-build	Design-bid-build	0.13	0.47	0.78	−0.81	1.07
		Building team	0.45	0.43	0.30	−0.42	1.31
		Strategic partnering	−0.61	0.37	0.11	−1.37	0.14
	Building team	Design-bid-build	−0.31	0.44	0.48	−1.21	0.58
		Design-build	−0.45	0.43	0.30	−1.31	0.42
		Strategic partnering	−1.060[a]	0.35	0.00	−1.76	−0.36
	Strategic partnering	Design-bid-build	0.75	0.39	0.06	−0.05	1.54
		Design-build	0.61	0.37	0.11	−0.14	1.37
		Building team	1.060[a]	0.35	0.00	0.36	1.76
Information sharing	Design-bid-build	Design-build	0.54	0.50	0.29	−0.47	1.55
		Building team	0.27	0.48	0.58	−0.70	1.23
		Strategic partnering	−0.17	0.42	0.68	−1.03	0.68
	Design-build	Design-bid-build	−0.54	0.50	0.29	−1.55	0.47
		Building team	−0.27	0.46	0.55	−1.20	0.65
		Strategic partnering	−0.72	0.40	0.08	−1.53	0.10
	Building team	Design-bid-build	−0.27	0.48	0.58	−1.23	0.70
		Design-build	0.27	0.46	0.55	−0.65	1.20
		Strategic partnering	−0.44	0.37	0.24	−1.19	0.31
	Strategic partnering	Design-bid-build	0.17	0.42	0.68	−0.68	1.03
		Design-build	0.72	0.40	0.08	−0.10	1.53
		Building team	0.44	0.37	0.24	−0.31	1.19

Note: Values are based on estimated marginal means.

[a]Mean difference is significant at the 0.05 level.

[b]Adjustment for multiple comparisons was least significant difference (equivalent to no adjustments).

Supplemental Data

Questionnaire S1 is available online in the ASCE Library (ascelibrary.org).

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