

# **INTEGRATED AND FLEXIBLE PROJECT SUPPLY CHAINS AND NETWORKS - DEVELOPING A RESEARCH PLATFORM**

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## **ABSTRACT**

To an increasing degree industries are organising their activities in projects which requires flexible solutions to manage operations, supply and distribution, as well as activities related to reverse logistics. More than before project-based industries such as construction and humanitarian disaster response are focusing on supply chain management and on developing and managing business relationships in their supply networks. For such industries, flexibility is needed to adapt to individual projects. There is also a need for developing multiple relationships with partners that have different “status” and roles in the chains and the projects, resulting in a plurality of relationships. Finally, due to more market turbulence and increases in man-made and natural disasters, better preparedness for facing higher risks and uncertainties through more flexible solutions is required. At the same time, integration in supply chains and networks is often considered to be a core of cost effective and customer-oriented solutions. The purpose of this paper is to develop a conceptual research platform for studies of project supply chains and networks with a focus on how they can be both flexible and integrated.

A systematic review of papers in logistics/SCM on combinations of flexibility and integration as well as related concepts is undertaken and shows that the vocabulary needs to be developed and stabilised as many different concepts are used and not always properly defined. It is also concluded that few studies provide in-depth understanding of means for combined flexibility/integration, which calls for more research. Hence, results from the review are used as basis for propositions on regarding means such as standards and modular design and how this impact on the way relationships can be managed. This forms the basis on which a research platform for future research in project-based contexts is developed. The study suggests that modularity and use of standards may give increased understanding of flexible and integrated solutions and that this may impact on development and management of relationships in project-based supply networks. The focus has been on literature concerning inter-organisational SCM literature and it is suggested that further research should go more deeply into the project marketing literature. Scrutinising the concepts of systems selling, systems integration and links between temporary and permanent networks will contribute to further understanding of how to combine flexibility and integration. Further research should also be based on empirical studies within for example construction, event logistics and humanitarian disaster response. The paper contributes with a research platform including definitions and discussion of how the concepts are linked. A structured mapping of means and enablers is provided and propositions more specifically related to modular design and standardization are offered.

Keywords: *Integration, Flexibility, Supply chain, Supply network, Literature review, Modular design, Standardization, Project, Temporary.*

## **1. INTRODUCTION AND PURPOSE**

To an increasing degree industries are organising their activities in projects which requires flexible solutions to manage operations, supply and distribution, and activities related to reverse logistics. More than before project-based industries such as construction and humanitarian disaster response are focusing on supply chain management and on developing and managing business relationships in their supply networks (e.g. Cova and Salle 2005). For such industries, flexibility is needed to adapt to individual projects. There is also a need to develop multiple relationships with partners that have different “status” and roles in the chains and the projects resulting in a plurality of relationships in networks. Finally, due to more market turbulence and

increases in man-made and natural disasters, better preparedness for facing higher risks and uncertainties through more flexible solutions is required. At the same time, integration in supply chains and networks is often considered to be a core of cost effective and customer-oriented solutions.

The basic assumption in this paper is that project supply chains and networks must be based on a combination of flexibility and integration to obtain low cost and high customer service and still be adaptable to changes. The research question we pose is: ‘how to combine and what are the means for doing this’. The logistics/SCM literature on flexibility on the one side, and integration on the other, is rather inconclusive. There is disagreement as to whether integration leads to less flexibility (e.g. Gadde and Håkansson 2001, Towill and Christopher 2002, Lee 2004, Jahre and Fabbe-Costes 2005, Hertz 2006). Recent literature reviews conclude that prior flexibility and integration research has a narrow focus and that more research on supply chain flexibility (Stevenson and Spring 2007) and integration (Power 2005, Fabbe-Costes and Jahre, 2008) is needed. Furthermore, the vocabulary is varied with many concepts being used, e.g. leanness and agility, leagility, adaptation and adaptability. Hence, a conceptual mapping defining the concepts and clarifying links between them is necessary.

The purpose of this paper is to develop a conceptual research platform for studies of project supply chains and networks with a focus on how they can be both flexible and integrated. Based on the assumption that flexibility as well as integration is necessary to obtain this, a systematic literature review of papers concerning the combination of flexible and integrated supply chains was undertaken. These results were used as a starting point for going deeper into the means. Together this provides the basis on which a conceptual framework with according propositions is developed, forming the platform for future research in contexts requiring innovative solutions. Section 2 presents the research design of the study. In section 3 results from the reviews are presented and discussed, drawing up the research platform with six propositions for further research. The paper ends with concluding remarks in section 4.

## 2. RESEARCH DESIGN

The study started with an exploratory literature review to search for the means – or enabling factors – to combine integration and flexibility in project-based supply chains as well as in more general logistics/SCM suggested in prior research. Main result of this quest was that: 1) there are few studies on this question that concern project-based supply chains; 2) Linked to flexibility and integration many other concepts were used; 3) Concepts were unclearly defined and; 4) The literature is characterized by overlaps as well as complex links between the concepts. It was decided to undertake a systematic literature review to overcome these limitations and provide a relevant conceptual platform for studies on how to combine integration and flexibility in supply chains that could apply to studies of project based supply chains.

### 2.1. Selection of flexibility/integration papers

Table 1 summarizes the concepts we found in the literature related to ‘integration’ and ‘flexibility’. We thus used truncation and combined integrat\*, adapt\* or lean\* on the one side with flexib\*, adaptab\* or agil\* on the other.

Table 1: Main concepts used in literature search on flexibility/integration papers

Related to integration	Related to flexibility
Integration / integrated	Flexibility / flexible
Adaptation / adapted	Adaptability / adaptable
Lean / leanness	Agile / agility

Using Business Source Complete, we searched for articles published between 2000 and 2008 (incl.) in academic peer reviewed journals with ‘supply chain’ and pairs of the aforementioned truncated words. Table 2 provides the results of the search.

Table 2: Results on integration/flexibility in logistics/SCM literature 2000-2008

<b>Keywords</b>	<b>Resulting no. of articles</b>
Adapt* - Flexib*	22
Adapt* - Adaptab*	22
Adapt* - Agil*	10
Lean* - Agil*	35
Lean* - Flexib*	14
Lean* - Adaptab*	1
Integrat* - Agil*	43
Integrat* - Flexib*	107
Integrat* - Adaptab*	7

After checking for overlaps, and considering the different scopes for studies of flexibility (Duclos et al., 2003) and integration (Fabbe-Costes and Jahre, 2008), papers with an inter-organisational approach to SCM were selected. This selection is in line with the conclusion made by Stevenson and Spring (2007) that more research on supply chain flexibility is required as opposed to the major part of flexibility research concerning (manufacturing) plants. We ended with 44 papers that seemed relevant based on their title and abstract. After a systematic review, six of these were eliminated because they were out of scope, resulting in a final database of 38 articles (marked with\* in the reference list) that were coded.

## **2.2. Coding of flexibility/integration papers**

In line with our objectives of stabilizing vocabulary, identify possible relationships between concepts and searching for means to combine flexibility and integration, the 38 papers were coded using the following items: (1) Research approach; (2) Use and definitions of the selected keywords in table 1; (3) Relationships between the keywords; and; (4) possible means/enablers mentioned and/or studied. Table 3 provides details of the coding procedure, whereas the appendix presents an overview of the results.

Table 3: Coding papers – Items, codes and rules

Items	Codes	Rules
Use of key words	Yes/No	Yes [No] if the concept is [not] used with the correct meaning in the paper.
Definition of key words	Yes/No	Yes [No] if the concept is [not] defined in the paper. Every definition was put in the database.
Others related words defined?	Yes/No	Yes [No] if other related words are used and defined in the paper. Every definition was put in the database.
Link between concepts?	Yes/No/ Indirectly	Yes [Indirectly] if relationships between concepts are [indirectly] mentioned in the paper. Every link was reported in the database <sup>1</sup> .
Means/enablers to combine?	Yes/No/ Indirectly	Yes [Indirectly] if means/enablers to combine integration and flexibility are [indirectly] mentioned in the paper. Every mean was reported in the database.

### 2.3. Selection of additional papers

Results from the analysis of integration/flexibility papers (see §3.3) suggested six important means (in ranked order): Information system (IS), Partnership, Information technology (IT), Standardization, Knowledge management and development (KM) and Modularization (modular design). Considering the plug-in/plug-out issues in integrated/flexible supply chains, we have chosen to focus the second step of our research on standardization and modular design. Also, other research (e.g. Fredriksson and Gadde, 2005; Mason and Lalwani, 2008) suggested the use of standards and modular design as solutions. Particularly in project-based industries standards and modularity are suggested as means for customisation (through flexibility) and cost reductions (through integration) (e.g. Gibb, 2001; Modig, 2006; de Waard and Kramer, 2008). A Business Source Complete search for articles between 2000 and 2008 with the search words in title, abstract and/or keywords gave results shown in the table below:

Table 4: Results on modular design/standardization in logistics/SCM literature 2000-2008<sup>2</sup>

Keywords	Resulting no. of articles
Modular* - logistics - project	2
Modular* - supply chain - project	4 (2 not refereed)
Standardis* - logistics - project	4 (2 not refereed, 1 using 'project' differently)
Standardis* - supply chain - project	1

As this did not result in many relevant papers, the selection was complemented through prior literature reviews on use of standards in logistics/SCM (Fabbe-Costes et al., 2006), supply chain integration in project-based industries (Jahre et al., 2006; Bygballe and Jahre, 2006; Jahre et al., 2009), logistics/supply chain integration (Fabbe-Costes and Jahre, 2008; Van der Vaart and Van Donk, 2008) and flexibility (Stevenson and Spring, 2007). Additional papers from the systematic search on standardization/modularity in SCM are marked with # in the reference list.

### 3. FLEXIBILITY, INTEGRATION AND MEANS: PRIOR RESEARCH

Here, results from the literature reviews are presented, with the first three sections summarizing from the systematic integration/flexibility review while section 3.4 provides results from the complementary modular design/standardization literature review.

<sup>1</sup> The database contains every sentence extracted from the papers mentioning links and means which is then given synthetic codes to ease analysis.

<sup>2</sup> In order to double-check for additional papers published on the construction industry as an example of a project-based setting, a search was done, but did not give any interesting result coming up with only 4 articles of which all were identified in the 'project' search.

### 3.1. Use and definitions of integration/flexibility concepts

Thirty-six [twenty-six] out of the 38 use more than three [four] of the keywords, which can thus be considered as “key concepts” when it comes to integration/flexibility. Surprisingly few papers define the concepts used. All papers, except 3 define a maximum of three (14 papers define only one, 9 only two, 7 define three and 3 define four concepts which is the maximum). Five of the papers do not define any of the concepts they use. Table 5 shows that while some concepts are frequently defined, others are not.

Table 5: Number of papers including definition of concepts in flexibility/integration papers

Words for integration	No. of papers	Words for flexibility	No. of papers
Integration / integrated	15	Flexibility / flexible	15
Adaptation / adapted	1	Adaptability / adaptable	2
Lean / leanness	14	Agile / agility	18

Table 6 provides the results of the analysis of the concepts’ definitions that could be found in the integration/flexibility papers.

Table 6: Definition of concepts – synthesis from flexibility/integration papers

Key words	Consensus? Key point	Synthesis of the definitions
Integration / integrated	<b>No</b> different scope (supply chain, network), more or less focused on a particular aspect (e.g. process integration) But common point is to <i>operate as a seamless whole</i>	Integrating the supply chain activities is driven by the need to streamline operations to achieve quality service to customers. Integration is as a process of coordinating activities, resources and organisations in order to function in concert. The higher the integration the higher the propensity to act collectively in a uniform manner and adhere to common policies. Integration is the quality of the state of collaboration existing among supply chain members that are required to achieve unity of efforts by demand environment. Integration enables the value creation and transfer process, right from the supplier to the end customer to operate as a seamless chain along which information, knowledge, equipment and physical assets flow as if water.
Adaptation / adapted	<b>Yes</b> (only one definition) main point is to <i>fit</i> with others and with environment	The changes require adaptations by companies to fit the characteristics of supply chains in dynamic environments and require internal and external fit (adaptation to SC and adaptation to the dynamics of the environment). Companies and supply chains have to anticipate changes happening in the market domain and the domain of technology.
Lean / leanness	<b>Yes</b> Main objective is <i>reduce waste and cost</i>	Lean is about doing more with less. The underlying theme in lean thinking is to produce more or do more with fewer resources while giving the end customer exactly what he or she wants. The rational behind going lean centres on waste removal both inside and between companies and cost reduction. A lean supply chain seeks to reduce waste (or non-value added activities to the total supply chain flow and to the products moving within the supply chain) found anywhere in the channel network. Lean supply chains are dedicated to the continuous improvement of people and processes throughout the extended supply chain, which means a great focus on inter-organisational relationships.
Flexibility / flexible	<b>No</b> In some papers flexibility is a goal, a performance metric for SCM, in others it is a characteristic of supply chains, But common main	Flexibility refers to a supply chain’s responsiveness to the consistent and changing needs of its users. Supply chain flexibility is to be seen as an ability to deal with change (certain or uncertain), by judiciously providing and exploiting controllable options dynamically with little penalty in time, effort, cost or performance. Flexibility includes both the degree of flexibility in the supply chain process itself and the product or service provided. Dimensions of flexibility include (1) range of states the SC can adopt; (2) cost of moving from one state to another; and (3) time

Abstract preview

	aspect of flexibility is to be able to <i>change rapidly</i>	required to move from one state to another. Flexibility is composed of two types: offering flexibility (the ability of a supply chain linkage to support changes in product or service offerings produced in conjunction with current partners, in response to changes in the business environment) and partnering flexibility (the ease of changing supply chain partners, in response to changes in the business environment). Supply chain flexibility is the ability of supply chain partners to restructure their operations, align their strategies, and share the responsibility to respond rapidly to customers' demand at each link of the chain, to produce a variety of products in the quantities, costs, and qualities that customers expect, while still maintaining high performance.
Adaptability / adaptable	To be able to <i>change in a radical way</i>	Adaptability refers to a willingness to reshape supply chains when necessary, without ties to legacy issues or the way the chain has been operated previously.
Agile / agility	<b>Yes</b> Main point is being both <i>reactive and proactive to unpredictable change</i> .	Agile supply chain requires the capability to survive and prosper in a competitive environment of continuous and unpredictable change by reacting quickly and effectively to changing markets, driven by customer-designed products and services. Agility in a supply chain is the ability of the supply chain as a whole and its members to rapidly align the network and its operations to dynamic and turbulent requirements of customers. Agility of a supply chain is the ability to respond to, and create new windows of opportunity in a turbulent market environment driven by individualized customer requirements cost effectively and rapidly. There are two main factors within the concept of agility: responding to changes in proper ways and due time, and taking advantage of changes as opportunities. Agility is a business-wide capability that embraces organizational structures, information systems, logistics processes and in particular, mindsets

We can conclude that there is a consensus even if definitions seem different at the outset and define concepts with different scopes and include different layers. This synthesis shows that even if each concept has a clear focus there are overlaps between the concepts. It explains why there are so many relationships between concepts (discussed in §.3.2).

The synthetic definitions provided in table 6 point out that combining integration and flexibility requires coordination of activities, resources and organisations. This is similar to the basic elements of the ARA-model constituting activity links, actors bonds and resource ties (e.g. Håkansson and Snehota 1995). The definitions also point out the importance of, on the one hand, the collaboration among supply chain members and the necessary and continuous efforts that must be undertaken in this respect, and on the other hand, the partnering flexibility to be able to provide and exploit controllable options dynamically with little penalty in time, effort, cost or performance. Hence, an important question is to develop close relationships with your partners while simultaneously keeping some kind of flexibility. In the IMP-literature, one response to this potential 'trade-off' would be that it is only together with your partners that you can develop this kind of flexibility. Dubois and Gadde (2002), for example, discuss this point as the balancing between tight couplings in the permanent network while loosening up in the temporary. Another point in the definitions of integration and flexibility is the different scopes involved: chains, network(s) and their relations with the 'environment' to which they have to adapt. Finally, and most important for our research focus on project-based supply chains, they point out the temporary nature of integrated and flexible supply chains that need to dynamically restructure themselves. Thus, means to combine flexibility and integration in 'classic' supply chains would probably be convenient also for project-based supply chains.

Twenty-four out of the 38 papers mention (and define) other concepts (from one to three per paper) that are directly related to the question of combining integration and flexibility. Table 7 provides the list of these other defined concepts and where definitions can be found in the papers. These additional concepts have to be kept in mind when thinking about integrated/flexible supply chains. We notice that the most frequent 'related

concepts' are linked together: leagile supply chains (lean *and* agile), use of decoupling points and postponement to improve responsiveness.

Table 7: Other key concepts – synthesis from flexibility/integration papers

Related concept	No. of papers defining it	Reference(s) with page number for definition
Decoupling point	10	Agarwal et al. (2006, p.212), Christopher (2000, p.41 and 42), Duclos et al. (2003, p.450), Mason-Jones et al. (2000, p.4065), Mohammed et al. (2008, p.351), Naim and Barlow (2003, p.595), Oloruntoba and Gray (2006, p.118), Reichhart and Holweg (2007, p.1158), Stratton and Warburton (2003, p.189), Towill and Christopher (2002, p.300).
Leagile /leagility	6	Agarwal et al. (2006, p.212 and 222), Duclos et al. (2003, p.450), Goldsby et al. (2006, p.61), Mason-Jones et al. (2000, p.4065), Naim and Barlow (2003, p.596).
Postponement	5	Christopher (2000, p.41-42), Goldsby et al. (2006, p.62), Oloruntoba and Gray (2006, p.118), Stratton and Warburton (2003, p.189), Towill and Christopher (2002, p.303).
Responsiveness	5	Dekkers and Van Luttervelt, (2006, p.9), Gunasekaran et al. (2008, p.551), Jain et al. (2008, p.6654), Reichhart and Holweg (2007, p.1148 à 1149), Wang et al. (2006, p.54)
Complex Adaptive System	3	Choi et al. (2001, p.352), Surana et al. (2005, p.4238), Pathak et al. (2007, p.550 and 562)
Adaptivity	2	Hülsmann et al. (2008, p.17), Pathak et al. (2007, p.549)
Robustness	2	Hülsmann et al. (2008 p.21), Choi et al. (2001, p.360)
Virtual enterprise	2	Gunasekaran and Ngai (2004, p.273 and 278), Kim et al.(2006, p.204 and 206)
Modularization	1	Howard and Squire (2007).
Interoperability	1	Kim et al. (2006, p.204)
Connectivity	1	Jain et al. (2008 p.6656)
Stability	1	Hülsmann et al. (2008, p.17)
Changeability	1	Dekkers and Van Luttervelt (2006, p.9)
Alignment	1	Ketchen and Hult (2007, p.574)
Information visibility	1	Wang and Wei (2007, p.648, p.651 and p.652)

### 3.2. Links between the concepts

Most papers (27) explicitly link at least two of the integration/flexibility concepts (only two papers don't mention any link). Five types of links could be identified in the papers:

- **Combination:** e.g. “an effective and efficient value chain should be *flexible, lean and agile*” (Mohammed et al., 2008, p.338), “*leanness* and *agility* can sometimes be combined with the strategic use of a decoupling point, thereby capitalizing on the benefits of both paradigms” (Mason-Jones et al., 2000, p.4065);
- **Causality:** e.g. “the *integration* of supply chain is critical to the success of a global, responsive and *agile* humanitarian supply chain” (Oloruntoba and Gray, 2006, p.118), “Key to providing *agile* response is *flexibility* throughout the supply chain” (Goldsby et al., 2006, p.60);
- **Similarity:** e.g. “companies must understand that *flexible* supply chains will outperform those that are less *agile*” (Duclos et al., 2003, p.455)
- **Trade-off:** e.g. “there has been a tendency to suggest that these approaches [*lean and agile*] are mutually exclusive and represent conflict paradigms” (Towill and Christopher, 2002, p.300), “an increase in *integration* reduces *flexibility* and vice versa” (White et al., 2005, p.400);
- **Stepwise:** e.g. “It has been suggested [...] that *agility* is the next step after *leanness*” (Mason-Jones et al., 2000, p.4064).

Focusing on the causal links mentioned between the six concepts with an overview provided in table 8, we can conclude that most papers consider integration concepts to impact flexibility concepts, but also the reverse is suggested. Moreover there are important causal links inside the groups of integration / flexibility concepts.

Table 8: Number of papers including causality between concepts

Causal (b) link a->b (a)	Integrat*	adapt*	lean*	flexib*	adaptab*	agil*
integrat*		[X] <sup>3</sup>	[8] [12] [19] [20] [21] [28]	[20] [25] [31] [33] [35] [38] [40]		[3] [8] [9] [12] [19] [20] [27] [28] [33] [38] [39]
adapt*				[31]		
lean*	[1]			[20] [28]		[9] [29] [39]
flexib*	[23]				[38]	[3] [9] [11] [19] [20] [29] [32] [33] [39]
adaptab*						
agil*	[28]			[24] [28] [37] [39]	[39]	

Figure 1 provides a mapping of the multiple and complex relationships including causality and trade-off, illustrating that the concepts are interrelated and must be jointly considered for the purpose of studying integrated/flexible supply chains.

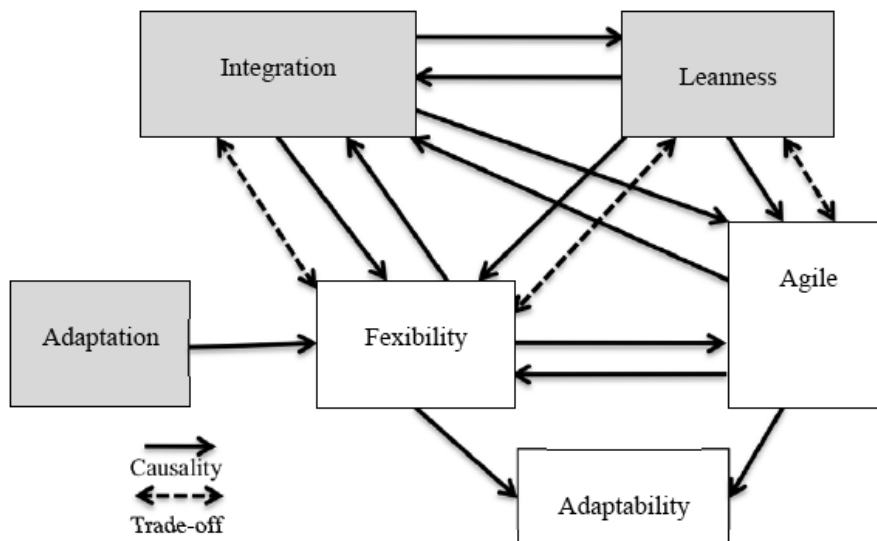


Figure 1: Links between concepts – synthesis from flexibility/integration papers

### 3.3. Means for flexibility and integration in prior research – a synthesis

Since we have demonstrated that it is necessary to combine integration and flexibility to face changing and uncertain environments, which may suggest that ‘classic’ supply chains behave in a similar vein as the project-based, what are the means to do it? Most papers (26 out of 38) explicitly mention means – or enablers – that permit to combine integration and flexibility (only two papers don’t mention any mean). Very few papers, however, (exceptions including Wang and Wei, 2007; Gunasekaran et al., 2008) put the question

<sup>3</sup> Each figure [X] means that the paper [X] mentions explicitly or implicitly that for example in this box, more integration leads to more adaptation. See appendix for correspondence between No.[X] and papers.

of means at the core of the research. Analysis of the means/enablers explicitly or implicitly mentioned in the integration/flexibility papers gives a list of different types of means as shown in table 9.

Table 9: Means / enablers to combine flexibility/integration in supply chains

Means / enablers	No. of papers	Papers mentioning the means / enablers
Information system (IS) Incl.: Information processing and sharing, information visibility, transparency, free flow of information.	27	All papers except: Barlow and Feng (2007), Choi et al. (2001), Dekkers and Van Luttervelt (2006), Duclos et al. (2003), Hertz (2001), Naim and Barlow (2003), Pathak et al. (2007), Reichhart and Holweg (2007), Tang and Tomlin (2008)
Partnership: Incl: alliances, collaboration, long-term relationships, joint teams, collaborative working, joint problem-solving and decision-making, incentives and contracts, dialogue	21	All papers except: Barlow and Feng (2007), Choi et al. (2001), Dekkers and Van Luttervelt (2006), Duclos et al. (2003), Gates (2004), Goldsby et al. (2006), Gunasekaran and Ngai, (2004), Mason-Jones et al. (2000), Oloruntoba and Gray (2006), Pathak et al. (2007), Quesada et al. (2008), Siau and Tian (2004), Surana et al. (2005), Wadhwa and Saxena (2007), Wadhwa et al. (2008)
Information technology (IT) Such as EDI, ERP, e-business technologies (e.g. extranet)	16	Barlow and Feng (2007, p.294), Christopher (2000, p.42), Dekkers and Van Luttervelt (2006, p.20), Gunasekaran and Ngai (2004), Gunasekaran et al. (2008), Jain et al. (2008, p.6654), Kumar et al. (2006, p.309), Mason-Jones et al. (2000, p.4067-4069), Mohammed et al. (2008, p.340), Reichhart and Holweg (2007, p.1157), Siau and Tian (2004, p.67), Surana et al. (2005, p.4236), Towill and Christopher (2002), Wang and Wei (2007), Wang et al. (2006), Yusuf et al. (2004, p.381)
<i>Standardization (for IS, IT, product design, business interface, process, policies)</i>	11	Choi et al. (2001, p.360), Christopher (2000, p.42), Gosain et al. (2004, p.33), Gunasekaran and Ngai, (2004, p.288), Hertz (2001, p.243), Hülsmann et al. (2008, p.18), Siau and Tian (2004, p.68), Stonebraker and Afifi (2004, p.1138), Surana et al. (2005, p.4242), Wadhwa and Saxena (2007, p.438), White et al. (2005, p.399).
<i>Knowledge management and development</i>	9	Gates (2004, p.513), Gosain et al. (2004, p.28-29), Gunasekaran et al. (2008, p.551), Hertz (2001, p.243), Jain et al. (2008, p.6657), Kumar et al. (2006, p.309), Towill and Christopher (2002, p.301), Wadhwa and Saxena (2007, p.437), Wang and Wei (2007, p.654).
<i>Modularization - modular design</i>	7	Choi et al. (2001, p.362), Christopher (2000, p.42), Duclos et al. (2003, p.452), Gosain et al. (2004, p.28-29), Howard and Squire (2007, p.1196), Reichhart and Holweg (2007, p.1158), Surana et al. (2005, p.4242)
<i>Network structure</i>	5	Proximity: Goldsby et al. (2006, p.60); short/narrow: Hertz (2001, p.250); Hülsmann et al. (2008 p.19), Reichhart and Holweg (2007, p.1156), number of nodes, use of intermediaries: Tang and Tomlin (2008, p.15)
Trust	3	Gates (2004, p.513), Towill and Christopher (2002, p.301), Wang and Wei (2007, p.665).
Culture - shared values and beliefs	3	Gates (2004, p.513), Gunasekaran et al. (2008, p.553), Ketchen and Hult (2007, p.574)

It can be noticed that some means to combine integration and flexibility are ‘well-known’ classical SCM enablers: information systems and technologies, partnership between supply chain members, trust and culture, the latter in particular also related to the IMP-approach. These means are also classical for project-based supply chains, e.g. use of ICT (Vordijk, 1999; Dainty et al., 2001a), use of standards and modular design (e.g. Elliman and Orange, 2000; Vordijk et al., 2006) and co-ordinated working and development of close relationships (e.g. Nicolini et al., 2001; Saad et al. 2002, Dubois and Gadde 2002). Four enablers would be considered as being less classical and off mainstream: standardization, modularization, network structure and knowledge management. Considering plug-in and plug-out issues in integrated/flexible supply chains, and in particular in project-based supply chains and networks, the remaining discussion is focused on standardization

and modularization which can also be ‘root’ enablers for flexible/integrated IS/IT, innovative network structure and partnerships. This is in line with other literature in general (e.g. Fredriksson and Gadde, 2005; Fabbe-Costes et al., 2006) and in project-based industries particularly (e.g. Dubois and Gadde, 2002; de Waard and Kramer, 2008), pointing out the importance of standards and modular design.

### 3.4. Results from standardization and modular design focus and propositions for integrated and flexible project-based supply chains

Three papers were identified in the systematic search on modularity/standards in project based logistics/supply chains. Gibb and Isack (2003) present a study on pre-assembly in the building industry suggesting modular building as increasing the level of pre-assembly. They conclude that main advantages most frequently seen by clients include shorter project time, better quality and low cost, whereas others pointed out poor quality, late deliveries and sometimes higher cost than conventional on-site assembly as disadvantages. Pryke (2005) discusses the use of building specifications’ standardization to reduce risk and the need for high levels of information exchange relating to design during the production phase. Santiago et al (2008), using concepts such as design for manufacture and assembly and lean construction, propose that modular products can be developed for their assembly by robotics systems onsite. Hence, modular design of building components combined with automatisisation on the building site can increase efficiency.

When it concerns the analysis of the overall set of papers we analyzed for this research, there are some interesting conclusions to be drawn.

First, even if ‘there is consensus among several researchers that standardization and product modularity are conceptually inseparable’ (Jacobs et al., 2008, p.1048), table 9 and 10 show that only four of the integration/flexibility reviewed papers combine them explicitly.

Table 10: Combining modularization and standardization in integration/flexibility papers

Mean mentioned		Standardization	
		NO	YES
Modular Design	NO		<b>7 papers</b> = Gunasekaran and Ngai (2004), Hertz (2001), Hülsmann et al. (2008), Siau and Tian (2004), Stonebraker and Afifi (2004), Wadwha and Saxena (2007), White et al (2005)
	YES	<b>3 papers</b> = Duclos et al (2003), Howard and Squire (2007), Reichart and Holweg (2007)	<b>4 papers</b> = Choi et al (2001), Christopher (2000), Gosain et al. (2004), Surana et al. (2005)

Hellström and Wikström (2005) discuss the importance of flexibility through modularity structures in project-based industries saying that ‘there seems to be lack of conceptual understanding of how to deal with modularity in project business’ because ‘Most literature [...] seems to focus on high volume goods’ (p.393). They also link the two concepts: ‘A key driver behind modularity is the pursuit of scale economies through standardization of both products and production’ (p.394). Hence, it seems that particularly in project-based industries, an understanding of modularization and standardization suggest viewing them jointly.

*Proposition 1: Flexible and integrated project-based supply chains require modular design and use of standardization to be seen in combination.*

Second, whereas standardization concerns organizational and physical elements ranging from technology and product design to processes, business interfaces and policies, modular design concerns mostly physical elements in terms of modularization of products. Pekkarinen and Ulkuniemi (2008), however, present an interesting study on modularity in services. They refer to a general theory defining modularity as the degree to which the components of a system can be separated and recombined to create a variety of configurations without losing in functionality (Schilling 2000). Referring to Sundbo (1994) and to existing service operations literature, they suggest that ‘Platform thinking can be used to identify and use the shared, i.e. modular, structure and logic of activities and customer offerings in service production’ (ibid. p.85). A conceptual model for modular services based on four dimensions of modularity including services (i.e. output), processes (i.e. production), organization (e.g. sub-contracting) and customer interface (i.e. identify needs and manage

relationship) is developed. Also Mason and Lalwani (2008) focus on the service industry discussing how modularization and standardization of components in transport and warehousing allows parallel supply chains to be combined so that economies of scope can be better realized. Reporting on a study of modularity in construction supply chains, Vordijk et al (2006) uses Fine's (1998, 2005) concept of supply chain modularity on construction, and define it as 'who does what' and how the different actors interact with each other. They conclude that hybrid governance forms, i.e. between market and hierarchy, must be specified when determining supply chain modularity. Hence, it seems that a perspective involving both organizational and physical elements can improve the understanding of modular design as a means for combined integration and flexibility of supply chains, particularly those within more service and project-based industries.

*Proposition 2: Flexible and integrated project-based supply chains require modular design and standardization of both organizational and physical elements.*

Third, even if standards are viewed as important, few in-depth studies have been reported in logistics and SCM (Fabbe-Costes et al., 2006). The concept has attracted more attention within technology development in terms of for example 'increasing returns' and 'lock-in effects' (Arthur 1989), 'dominant design' (Suàrez and Utterback 1995) and 'basic technology' (Håkansson and Waluszewski 2002). In this literature, standards are discussed as a basis for technological development, for example, in the design of new products or technologies and for allowing for large economies of scale (David, 1987). Another research stream is more concerned with standards as a coordination mechanism because '[they] possess some qualities that can affect the ease with which they travel between and within organizations and organizational fields' (Brunsson and Jacobsson, 2000, p.9), creating a common language between the adopters, and reducing the transaction costs (Tassey, 2000). Particularly interesting is the concept of compatibility or interoperability which is also described as a 'standardized interface', i.e. the standard itself is the connection between two or more elements that don't need to adapt to each other but only need to plug into the standard that is the interface. This is in line with Sanchez and Mahoney (1996) who say that modularity is an example of architectural innovation that enables greater flexibility without changing its components. This latter paper, as well as Schilling (2000), are within general management. This suggests that taking a step back into such literature, logistics/SCM can widen its understanding of the use of standards for the plug-in/plug-out on a more organisational level in the supply chains.

*Proposition 3: Going into general management and technology development literature on modular design and standardization should help to build and innovative research platform for the study of flexible and integrated project-based supply chains.*

Finally, the study by de Waard and Kramer (2008) nicely links all these elements together. Based on a military mission as an example of temporary organizing, they show the 'need [for] a parent organization that functions as a stable platform from which repeatedly effective temporary, or project organizations, can be mobilized' (p.537). The parent organization must constitute suitable modules, ready-made building blocks made available for the temporary organization, hence demonstrating the use of modular design. Accordingly, the coupling and de-coupling apply also to organizational aspects such as business processes and systems. Based on Baldwin and Clark (1997), they develop their model formed by *architecture* (which modules will be part of the system and what are their functions), *interfaces* (how the modules will interact) and *standards* (allows the mixing and matching of modules into different configurations and still achieve synthesis). They conclude with two contradicting types of flexibility: composition and that 'a more modularly built parent organization can better deal with the dilemma of balancing [them]'. (p.544). The fourth proposition therefore relates to the issue of temporary and permanent networks (see also Dubois and Gadde, 2002).

*Proposition 4: An innovative approach to flexible and integrated project-based supply chains is to view different parts as a permanent network and other parts (i.e. the projects) as temporary organizations where modular design and standards can be used for different degrees of (tight vs. loose) couplings.*

Particularly in project-based industries such as construction, event and disaster management, links between temporary projects and more permanent structures, standards and modularity have been discussed as solutions for obtaining customisation (through flexibility) and cost reductions (through integration) (e.g. Gibb, 2001; Hellström and Wikström, 2005; Vordijk et al, 2006; de Waard and Kramer, 2008). Project logistics (e.g. Modig, 2006) and relations between temporary and permanent networks (Dubois and Gadde, 2002; Jahre and Heigh, 2008) are interesting perspectives as is project marketing (e.g. Skaates and Tikkanen, 2003; Cova and Salle, 2005; Crespín and Salle, 2003). In the latter perspective, it is the importance of business relationships

particularly between sellers and buyers of projects that is in focus. Interestingly this links back to one of the articles identified in the review on flexibility and integration as discussed above. Howard and Squire (2007) focus on the relationship between modularization and supply relationships. Based on previous inconclusive literature which says that: (1) Modularization makes buyers and suppliers move towards greater collaboration in order to co-develop products and; (2) The standardization of interfaces due to the effects of modularization suggests introducing a “black box” approach to component design with arm’s length relationships, they pose the following research question: ‘Under what conditions does modularity lead to increasing collaboration?’ Their findings provide support for the notion that product modularization will lead to greater levels of buyer-supplier collaboration, but that this relationship is mediated by relationship specific assets and information sharing. Hence, even if more research on this particular issue is necessary, we suggest a proposition linking business relationships and use of modular design/standardization.

*Proposition 5: Modular design and standardisation lead to closer business relationships among the actors involved in the temporary as well as in the permanent network in project-based industries.*

Howard and Squire (2007) suggest further studies of the tiered supply chain, linking it to the concept of system sourcing which can be linked to project marketing (e.g. Skaates and Tikkanen 2003, Cova and Salle 2005). Here the project is seen as embedded ‘in the wider context of project business’ (Cova and Salle 2005, p.355) and the goal is ‘to build and maintain relationships in-between two projects with key customers and stakeholders.’ Projects are defined as a complex transaction concerning a package of products, services and works, designed specifically to realize in a certain period of time a specific asset for a client (Cova and Holstius, 1993). A related term introduced in Cova and Salle (2007) is ‘solution marketing’ which combines integration of technical functions with integration of services around products ‘so as to facilitate the use of these products...’(p.141). Four capabilities are keys to develop a solution approach; system integration, operational service, business consulting and financing capabilities. It is claimed that since solution marketing has no pre-fixed offer and no systematic demand in literal terms, it is the interaction between customers and solution providers that is the foundation (p.143). They suggest that the concept of ‘solution marketing’ is a combination of systems selling and project marketing, both strongly related to the industrial network paradigm (Owusu and Welch, 2007). In systems selling the idea is to develop a basic modular system of components that can be easily configured and reconfigured for a variety of customer needs so that the cost advantages of producing standardized product components with high flexibility in system design (Mattson 1973). Davies et al. (2007) also relate this to integrated solutions stating ‘the importance of developing standardized ‘solutions-ready’ components that can be combined and recombined at much lower cost than solutions comprised entirely of customized components’. They discuss the role of the systems integrator suggesting that ‘the trend towards modularity and open standards in industries has increased possibilities for firms to specialize in component supply and/or systems integration’ (p.188). Such solutions are becoming more popular, not only in the construction industry, but also in humanitarian disaster response (Jahre and Heigh, 2008). This suggests a final proposition concerning the role of ‘integrator’ that should develop in project-based supply chains (a role that has been discussed in the specific context of the logistics service industry).

*Proposition 6: Use of modular design and open standardisation in project-based industries leads to the potential development of ‘integrators’ in flexible and integrated project-based supply chains.*

#### **4. CONCLUDING REMARKS**

Results provide an innovative starting point for discussions concerning practical ways to combine flexibility-adaptability-agility/integration-adaptation-leanness in project-based supply chains and for the purpose of identifying resources and capabilities that permit flexible and integrated project-based supply chains. The paper links these concepts from SCM to the concept of project marking developed within the industrial network approach. Definitions of integration and flexibility and related concepts in the context of supply chain management (i.e. for inter-organisation supply chains, not only ‘manufacturing’), have been provided. Additional concepts have been reviewed and the relationships identified illustrate the necessity of including them for the purpose of understanding innovative supply chains that are more and more similar to project-based supply chains. A list of means/enablers divided into classical and more recent has been provided as basis for further research. Hence, a research platform based on a wide range of concepts has been provided. Considering plug-in and plug-out issues in integrated/flexible supply chains, and in particular in project-based supply chains, a deliberate choice was made in this paper to focus on two of the nine means/enablers identified in the review. Discussion of standardization and modularization as means to build flexible and

integrated supply chains leads us to suggest six propositions for further research. Our research is a starting point for further research as well as for practical purposes.

The results suggest avenues for further research. In particular we suggest that the next step is to go more deeply into the project marketing literature concerning discussions on systems selling versus systems integration and links between temporary and permanent networks. Considering the lack of research concerning the organisational aspects of modular design and since the use of standards and modular design and its links with business relationships is somewhat inconclusive, we would recommend further research to study business relationships as discussed in relation to the fifth proposition. Linking project marketing with project-based logistics is one research area where more conceptual development based on empirical research could contribute to both research streams. This is also related to trade-offs between adaptability and adaptations: 'Adaptations among firms [that] are normally undertaken in order to increase the flexibility in the joint operations of the two companies... induce rigidity by reducing the individual firm's flexibility when it comes to changes of business partner' (Fredriksson and Gadde, 2005, p.704). Finally, the concepts of system selling, systems integration and project marketing seem a promising avenue for further research into construction and humanitarian disaster response with a potential change in actors' roles in such integrated and flexible supply chains.

A limitation of our literature review is that we have included only already published papers. Knowing the leadtimes in many journals, it is difficult to argue that such an approach gives the most updated and recent research trends. Hence, additional reviews for example of conference proceedings and other 'work-in-progress' could complement the review presented here. However, rather than expanding the literature basis of our paper, we suggest to confront results and propositions to in-depth case studies that could help to enrich and prioritize the research agenda.

Our final point is that even if we have chosen to focus on project-based industries, our propositions may also be useful for permanent supply chains in traditional industries because they are facing challenges of changing demands which require resilience (Fredriksson and Gadde (2005, p.703). This concept of resilience (Christopher and Peck 2004), related to risk management in supply chains, needs to be included in further research to improve knowledge about flexible and integrated supply chains and that could be interesting in the context of project-based industries.

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Abstract preview

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\*Yusuf, Y. Y., Gunasekaran, A., Adeleye, E.O. and Sivayoganathan, K. (2004), "Agile supply chain capabilities: Determinants of competitive objectives", *European Journal of Operational Research*, Vol. 159 No. 2, pp. 379-392.

## 6. APPENDIX

n°	Article reference	Year	Nb us.	Use integrati.	Use abstrakt.	Use Learn?/Use health	Use abstrakt.	Use agly?/Nb. oim.	Def integratio.	Def abstrakt.	Def Lea.	Def feasibility?/Def abstrakt.	Def agly?/Link conce.	other conc.	Means to c.
29	Agarwal et al.	2006	5	YES	NO	YES	YES	YES	4	YES	YES	YES	YES	YES	Yes
41	Badlow and Feng	2007	2	YES	NO	YES	NO	NO	0	NO	NO	NO	NO	NO	Yes
16	Choi et al.	2001	4	YES	YES	NO	NO	YES	0	NO	NO	NO	Indirectly	YES	Yes
9	Christopher	2000	4	YES	NO	YES	NO	YES	3	YES	YES	NO	YES	YES	Yes
32	Dekkers and Van Lunsvelt	2006	5	YES	YES	YES	NO	YES	4	YES	NO	YES	YES	YES	Indirectly
26	Duclos et al.	2003	4	YES	NO	YES	NO	YES	3	NO	YES	YES	YES	YES	Yes
1	F. Farnet et Fowler	2006	3	YES	NO	YES	NO	NO	1	NO	YES	NO	NO	NO	NO
2	Gates	2004	4	YES	NO	NO	YES	YES	0	NO	NO	NO	NO	NO	Indirectly
59	Gobbly et al.	2006	4	YES	NO	YES	NO	YES	2	NO	YES	NO	YES	YES	Yes
22	Gossain et al.	2004	4	YES	YES	NO	YES	NO	1	NO	NO	YES	Indirectly	NO	Yes
37	Gunasakaran and Ngai	2004	6	YES	YES	YES	YES	YES	1	YES	NO	NO	YES	YES	Yes
33	Gunasakaran et al.	2008	5	YES	NO	YES	YES	YES	3	YES	YES	NO	YES	YES	Yes
21	Hertz	2001	5	YES	YES	YES	NO	YES	1	YES	NO	NO	NO	NO	Yes
34	Howard and Squire	2007	4	YES	YES	YES	NO	NO	1	YES	NO	NO	Indirectly	YES	Indirectly
6	Hillsman et al.	2008	3	NO	NO	YES	YES	YES	1	NO	NO	NO	YES	YES	Yes
38	Jain et al.	2008	5	YES	NO	YES	YES	YES	4	YES	YES	NO	YES	YES	Yes
24	Ketschen and Hilt	2007	3	NO	NO	NO	YES	YES	3	NO	NO	YES	YES	YES	Indirectly
6	Kim et al.	2006	3	YES	NO	NO	YES	NO	1	NO	NO	NO	Indirectly	YES	No
36	Kumar et al.	2006	4	YES	YES	NO	YES	NO	1	NO	NO	YES	NO	NO	Yes
10	Mason-Jones et al.	2000	3	YES	NO	YES	NO	YES	2	NO	YES	NO	YES	YES	Indirectly
20	Mohammed et al.	2008	5	YES	NO	YES	YES	YES	3	NO	YES	YES	YES	YES	Yes
8	Naim and Barlow	2000	5	YES	NO	YES	YES	YES	2	NO	YES	NO	YES	YES	Yes
3	Olonutoba and Gray	2006	4	YES	NO	YES	NO	YES	2	NO	YES	NO	YES	YES	Indirectly
15	Parabak et al.	2007	5	NO	YES	YES	YES	YES	0	NO	NO	NO	Indirectly	YES	Indirectly
25	Quasda et al.	2008	2	YES	NO	NO	YES	NO	2	YES	NO	YES	Yes	NO	Yes
36	Reichert and Hildweg	2007	5	YES	NO	YES	YES	YES	2	YES	NO	YES	Yes	YES	Yes
23	Sanz and Tian	2004	3	YES	NO	NO	YES	YES	1	YES	NO	NO	Indirectly	NO	Yes
53	Stonebraker and Alesi	2004	4	YES	NO	YES	NO	YES	1	YES	NO	NO	Yes	NO	Indirectly
12	Stanton and Warburton	2003	3	YES	NO	YES	NO	YES	2	NO	YES	NO	Yes	YES	Indirectly
17	Suzana et al.	2006	5	YES	YES	NO	YES	YES	0	NO	NO	NO	Indirectly	YES	Indirectly
7	Tang and Tomlin	2008	5	YES	NO	YES	YES	YES	1	NO	NO	NO	Yes	NO	Yes
11	Tovell and Christopher	2002	4	YES	NO	YES	NO	YES	2	NO	YES	NO	Yes	YES	Yes
30	Wadhwa and Saxena	2007	3	YES	NO	NO	YES	YES	1	NO	NO	YES	Yes	NO	Yes
40	Wadhwa et al.	2008	3	YES	NO	NO	YES	NO	1	NO	NO	YES	Indirectly	NO	Yes
31	Wang and Wei	2007	6	YES	YES	YES	YES	YES	2	YES	NO	NO	Yes	YES	Yes
36	Wang et al.	2006	6	YES	YES	YES	YES	YES	3	YES	NO	YES	NO	YES	Yes
27	White et al.	2006	3	YES	NO	NO	YES	NO	1	NO	NO	NO	Yes	NO	Yes
28	Yusuf et al.	2004	5	YES	NO	YES	YES	YES	3	YES	YES	NO	Yes	NO	Yes