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A Measurement Model for Web-enabled Supply Chain Integration

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Abstract

Recent developments in supply chain management information systems have greatly increased the ability of firms to integrate processes, systems, and information with their supply chain partners. Despite the apparent benefits of web-enabled supply chain integration, its further study and application is hindered by the lack of an empirically supported model for classifying the varying levels of supply chain integration that are now possible using e-business technologies. This paper presents findings from a multiple case study used to explore web-enabled supply chain integration and identify potential questionnaire measures for further study. The questionnaire findings were corroborated by rich qualitative evidence from the five manufacturers studied, but highlighted several issues in measuring integration in web-enabled supply chains. In contrast to well-publicized examples such as Dell Computer, the cases studied exhibited a very modest level of supply chain integration, despite each having large investments in supply chain partnerships. This discrepancy highlights the need to measure supply chain integration using empirically-supported models such as the one described, rather than relying on managerial assumptions about how integrated a firm is with its supply chain partners.

Keywords: e-business, supply chain integration, measurement model, multiple case study

1   Introduction

Recent developments in web-enabled supply chain management information systems (SCM IS) have greatly increased the ability of firms to integrate processes, systems, and information with their supply chain partners. Although supply chain integration appears to benefit many organizations (Lee, 2000; Reddy and Reddy, 2001), existing models for measuring the level of supply chain integration lack theoretical and empirical support (Brennan and McNichols, 2004). This paper presents preliminary findings from a multiple case study used to explore web-enabled supply chain integration and identify potential questionnaire measures. The next section describes the level of supply chain integration construct and its theoretical foundations. The following sections describe the

research methodology and findings. The final section discusses the implications of the findings for research and practice.

2   Research Model and Theoretical Foundations

Several studies have highlighted the benefits of using e-business technologies and SCM IS to support integration of the customers and suppliers in a supply chain (Mentzer et al., 2000; Riggins and Mukhopadhyay, 1994; Shah et al., 2002). No satisfactory models were found for measuring the level of supply chain integration for a firm, although the related concept of supply chain maturity is used by some practitioners (Supply-Chain Council Inc., 2005). There are several limitations of the existing consultant-developed supply chain maturity models, the greatest being lack of publicly-available evidence which provides empirical support for the models. Furthermore, the concept of "maturity" incorrectly implies that organizations progress through the stages sequentially and that higher levels of integration are desirable in all cases. While this may be true for many supply chains, for extremely fragmented supply chains (such as the construction industry) where tight coordination between suppliers and customers would hinder flexibility to the degree that performance suffers, higher levels of integration are not always a desirable goal (Dubois and Gadde, 2000).

This paper integrates and improves upon the two dominant supply chain maturity models (Moncrieff and Stonich, 2001; Roloff et al., 2001) by avoiding the problems of the "maturity" concept and making the operationalization of the various levels more clear. This paper defines the level of supply chain integration as the degree to which the processes, systems, and strategies used in a supply chain are jointly coordinated among the partners in a supply chain.

The information systems (IS) literature contains similar models of interorganizational integration that inform but do not specifically address supply chain integration. Venkatraman (1991) describes five levels of business transformation that are made possible through information technology (IT) implementation. These include: Localized Exploitation; Internal Integration; Business Process Redesign; Business Network Redesign; and Business Scope Redefinition. Similarly, Robey and Sales (1994) applies Thompson's (1967) theory of interdependence to interorganizational systems using the levels of pooled, sequential, and reciprocal dependency.

Poirier and Bauer (2001) describe four levels of supply chain maturity that could be used to measure supply chain integration although their text provides little guidance on operationalization and the terminology is not well defined. Moncrieff and Stonich (2001) also present a four-level supply chain maturity model; however, their "External Integration" level does not differentiate between sequential dependencies (i.e., *linked* organizations) and pooled dependencies (i.e., *integrated* organizations). Furthermore, as it is a proprietary model developed by consultants, there are no publicly available studies which examine the validity of the questionnaire items. To address these shortcomings, this paper presents a new typology informed by the aforementioned studies (see Table 1). In order to maximize the differentiability between the level of supply chain integration, the typology uses five levels as shown in the table and a terminology that is simple, precise, and agrees with industry standard terms such as those of the Supply Chain Council's (2005) SCOR Model.

	Level 1 Functional Focus	Level 2 Internal Integration	Level 3 Linked Network	Level 4 Integrated Network	Level 5 Optimized Network
Observable Patterns	Discrete processes managed at the department level. Performance measured at the functional level.	Company-wide processes managed at both functional and cross-functional process levels. Performance measured at the company, process, and diagnostic levels.	Core processes managed internally; info sharing with external partners. Outsourcing of non-core processes. Metrics defined by one firm. Joint performance monitoring and correction with partners.	End-to-end process mgmt., coordination, & collaboration with external partners. Alignment of business objectives and processes of each partner Joint metrics definition, monitoring, and correction with external partners.	Standardized, modular processes coordinated in real-time and executed by most capable partners. Standardized performance metrics monitored and corrected jointly at the company, process, and diagnostic levels.
Term used in Moncrieff and Stonich (2001)	Functional Focus	Internal Integration	External Integration		Cross-Enterprise Collaboration
Term used in Poirier and Bauer (2001)	Internal Supply Chain Optimization		Network Formation	Value Chain Constellation	Full Network Connectivity

Table 1: The Five Levels of Supply Chain Integration Developed for this Study

3 Research Methods

To further explore the proposed level of supply chain integration construct, a multiple case study was conducted using organizations that had deployed web-enabled SCM IS. The cases consisted of four manufacturers in the electronics sector and one manufacturer in the energy sector (McLaren, 2004). Focusing on manufacturers primarily from a single industry facilitated comparison and theoretical replication among similar firms, while reducing extraneous phenomena and cross-industry differences (Weill and Olson, 1989; Dess, 1990; Yin, 2003). Inclusion of Case A (an integrated energy production and distribution company) allowed for comparison and contrast with a different industry and a more internally integrated supply chain.

A 15-item questionnaire (available upon request) and a shorter 4-item questionnaire (see Appendix A) were adapted from practitioner studies that surveyed and benchmarked the level of supply chain integration several industries (Moncrieff and Stonich, 2001; Supply-Chain Council Inc., 2005). Although these non-peer-reviewed studies helped ground the investigations in prior experience (Eisenhardt, 1989), care was taken to fully explore the operationalizations and

triangulate the findings using qualitative evidence and more rigorously documented research methods.

The level of supply chain integration was measured for each dimension by having respondents from each case choose the statement that best describes their case's current situation. Each statement corresponded to the Functional Focus, Internal Integration, Linked Network, and Integrated Network levels of supply chain integration proposed in Table 1[1], although these were not identified by name to avoid self-responding biases (Dillman, 1978). The respondents were senior business managers who were familiar with the organization's supply chain strategies, processes, and systems and who had worked in the organization a minimum of two years.

The widely-used SCOR model describing five supply chain process groups: Overall, Plan, Source, Make, and Deliver (Supply-Chain Council Inc., 2005). The 15-item questionnaire was adapted from Moncrieff and Stonich (2001) and covered the 15 dimensions of these four process groups. These dimensions include:

- <u>Overall</u>: Supply Chain Strategy; Supply Chain Performance Management; Supply Chain Processes; Supply Chain Organization
- <u>Plan</u>: Demand Planning; Supply Planning
- <u>Source</u>: Source Strategy; Commodity and Spend Management; Supplier Development and Management; Sourcing Organization and Infrastructure
- <u>Make</u>: Make Strategy; Production Scheduling; Inventory Management
- <u>Deliver</u>: Deliver Process Management; Order Management, Logistics and Invoicing

The overall level of supply chain integration was determined by the level that was chosen most frequently across each of the dimensions. A four-item questionnaire was also used to determine whether the four dimensions of the Overall process group were a sufficient indicator of level of supply chain integration or whether the additional 11 items from the Plan, Source, Make, and Deliver process groups were necessary for proper measurement.

To determine if the findings using the questionnaire measures were corroborated by other evidence, interview transcripts and archival documents were also gathered from the case participants (see Appendix B). The qualitative analysis looked for patterns in the evidence that most closely matched one of the above levels of supply chain integration. For example, if review of a case indicated their internal units were well integrated but there were few linkages with external partners, they would be inferred to be at Level 2 – Internal Integration.

4 Preliminary Findings

Although results from a statistically significant sample were not obtained, the two questionnaire measures were pilot tested using two respondents from each case who also participated in in-depth interviews (conducted at least two weeks after the questionnaires were completed to reduce response bias).

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[1] The Optimized Network level was not included in the measure since a wider study did not find any firms that consistently operated at that level (Moncrieff and Stonich, 2001). Any such firms would be considered Level 4.

Preliminary results summarizing the 15-item questionnaire for measuring the level of supply chain integration for Cases A-E are shown in Table 2: . The level of supply chain integration determined using the 4-item questionnaire was within a few decimal points with the level determined from the 15-item measure. However, this discrepancy combined with the findings from the interviews below suggests the 15-item measure will be more reliable and descriptive in most cases.

Case	Average (Range) of Level of Supply Chain Integration for the Four Overall Dimensions (1=at Functional Focus level, 4=at Integrated Network level)				Average (Range) of the Four Overall Dimensions
	Supply Chain Strategy	Supply Chain Performance Management	Supply Chain Processes	Supply Chain Organization	
A	2.5 (1)	2.0 (0)	2.5 (1)	2.5 (1)	2.4 (0.2)
B	4.0 (0)	2.5 (1)	2.0 (0)	3.0 (0)	2.9 (0.2)
C	3.0 (0)	2.0 (0)	2.0 (0)	2.0 (0)	2.3 (0.0)
D	1.5 (1)	3.5 (1)	1.5 (1)	3.0 (0)	2.4 (0.2)
E	3.0 (0)	1.5 (1)	1.5 (1)	3.0 (0)	2.3 (0.0)

Table 2: Overall Level of Supply Chain Integration for each Case

As can be seen from Table 2: , the overall level of supply chain integration for each case varied between 2.3 and 2.9. Therefore, the level of supply chain integration for each case was somewhere between Internal Integration (Level 2) and Linked Networks (Level 3).

Coding and analysis of interview transcripts and archival documents were used to identify patterns in the texts (Eisenhardt, 1989) and determine the level of integration between the case and its supply chain partners. The purpose of this analysis was to triangulate the findings from the questionnaire measures and to further explore the level of supply chain integration construct.

Pattern matching analyses (Yin, 2003) determined which of the five levels of supply chain integration best described the case: Functional Focus, Internal Integration, Linked Network, Integrated Network, or Optimized Network. As outlined in Table 1, cases at different levels of supply chain integration would exhibit different patterns of information sharing, process management, performance management, and decision-making within its organization and between its supply chain partners. Generally, higher levels of integration exhibit more collaborative information sharing, management, and decision-making patterns.

For example, analysis of the texts suggested Case A focused primarily on internal integration but had linked some systems and processes with key suppliers. Most of their integration efforts were aimed at improving *internal* information sharing to reduce costs and improve decision-making. Interview respondents highlighted how Case A had implemented a centralized ERP, which was felt to improve information sharing and decision-making within the organization:

> *Since we've moved to the [new ERP], I think our information sharing is a lot more robust and accessible so that you can go and do analyses without having to go to someone else for that information.*

Based on this evidence, Case A was inferred to be at least at the Internal Integration level.

The texts were examined further to determine if there was evidence that Case A had formed linked networks with its customers and suppliers. Although there was some evidence of this, most patterns exhibited in the transcripts and documents indicated that overall, Case A was at Level 2 and could be considered to be at Level 3 for only a few processes and supplier relationships. Most of the external information exchange involved incorporation of supplier information into Case A1's systems for procurement of indirect supplies, rather than sharing information or collaborating with its suppliers.

> *For [indirect supplies] we use our procurement systems a lot. We try to standardize across all our operating units so we can get into higher volume, longer-term relationships with one larger supplier... We try to move our purchase orders electronically across to them and make it more efficient.*

However, there did appear to be a recent trend towards more collaboration and sharing of information and benefits with strategic suppliers that indicates Case A may soon reach a higher level of supply chain integration:

> *I think traditionally we've had more of the upper hand in the relationship because of our volume, because we're a big customer. But I think we look to our suppliers for ideas on how to reduce cost... To be more efficient you have to share more information in order to get out some of that slack in the system... A good example is the contract trucking [suppliers].*

The qualitative analyses highlighted the difficulty of determining a case's overall level of supply chain integration when the firm may be at very different levels for different processes, relationships, or product lines. Case B had several ERP, EDI, and web-based SCM IS, suggesting internal and external integration were both important to Case B. However, the presence of multiple non-integrated ERP systems across the corporation suggested internal coordination was not been fully realized in all areas. Furthermore, a respondent for Case B noted the supply chain strategies were not highly coordinated between business units across the firm:

> *We may have an excellent SCM solution as a corporation, [but it is] only deployed in certain geographies...Siloing can be an issue, forcing each business unit to have a separate supply chain strategy with little coordination.*

Thus, Case B appeared to be at the internal integration level for most of its processes and businesses, but at lower or higher levels for others. Although similarly ambiguous patterns were found in the evidence for the other cases, an attempt to identify the overall level of supply chain integration for each case was made as shown in Table 3.

The rich qualitative data also produced some additional interesting findings related to supply chain integration. For example, the importance of supply chain integration appeared to differ among the cases and between business units in the firms. A respondent for Case D suggested the use of sophisticated SCM IS to facilitate tighter supply chain integration was not a priority in their business unit. This was attributed to the high-margin, low volume nature of the products produced:

For the company, [SCM IS are] very important [for products where] we sell a lot of units. But [for the Case D business unit], sales of units aren't as high. It's a very high-end product... To generate a lot of income, we don't have to sell all that many units. So I'm not sure that the distribution and logistics systems need to be as good as maybe other business units... I would say our business unit isn't as reliant on [SCM IS].

Case	Level of Supply Chain Integration	Example Evidence
A	Level 2: Internal Integration (approaching Level 3 in some areas)	- Implemented ERP gave improved access to information "*without having to go to someone else.*" - Supplier information incorporated into procurement systems, but little sharing of Case A's information with customers or suppliers.
B	Level 2: Internal Integration (approaching Level 3 in some areas)	- Usage of multiple non-integrated ERP systems across firm suggests internal integration is incomplete; however, some external sharing of information using EDI and web-based portals. - "*There is not strong external and even cross-functional representation*" in supply chain decision-making.
C	Level 2: Internal Integration (approaching Level 3 in some areas)	- ERP system facilitated information sharing across functional areas, but not widely used to share information externally. - Strong cross-functional representation for supply chain decision-making, with some involvement of external partners.
D	Level 2: Internal Integration (approaching Level 3 in some areas)	- ERP and other SCM IS used to integrate information internally, although "*not integrated very well.*" - Information sharing was unidirectional (given to suppliers) rather than collaborative and not in electronic formats. - Management and decision-making not jointly performed with partners.
E	Level 2: Internal Integration (approaching Level 3 in some areas)	- Two separate SCM IS used for supply and demand-side processes, respectively, with some integration. - Some external integration; however, information exchanged mostly limited to product requirements and purchase orders rather than order forecasting.

Table 3: Level of Supply Chain Integration from Qualitative Analyses

This may also be because Case D outsourced many of its supply chain management processes to contract manufacturers (including Case B) who then managed the operational data. Although one might expect these transactions would require sophisticated SCM IS, much of the information sharing between Case D and its suppliers was via non-integrated phone and fax communications. A respondent suggested this was because Case D's power over their contract manufacturers allowed them to offload the responsibility of managing the transactions to the manufacturer:

We use contract manufacturers almost exclusively. [Sophisticated SCM IS] probably are more useful to our contractors. We shift off all the responsibility to the contract manufacturers and they must use their systems. We basically tell our contract manufacturers how to build something and what parts to buy and who to buy them from and what price that they should pay for it... A lot of it is old-fashioned phone/fax because like I said, the quantities are lower.

It appeared that Case D's power over their suppliers meant that the relationship does not need to be collaborative in order to gain low prices and keep costs under control:

> *Unfortunately for our suppliers, our company holds all the cards. It's probably one of the biggest customers... Sometimes we'll say [to our suppliers] 'you're competitor is 20% cheaper'. And they'll say, 'we're unable to meet that price'. And we'll say, 'okay, we're going to chop off your orders by 30% now'. And they have to take that. It can backfire, but ... they are forced to eat inventory as a sign of goodwill, business-relationship-wise. And it's unfair to them, but... I think they realize that the [money] they make from our company over the long haul certainly compensates for any short term inventory eating that they have to do.*

As can be seen in the preceding, the qualitative data provided rich findings at a detailed level that were well corroborated by the findings from the 15-item questionnaire measure. Agreement with the shorter 4-item questionnaire was also satisfactory, although there is stronger support for using the 15-item questionnaire since the level of integration may vary sufficiently across the Plan, Source, Make, and Deliver processes in each case. Although the 15-item questionnaire measure appeared to have good reliability and face validity when compared with the qualitative evidence, a statistically significant sample should be analyzed before widespread adoption of these measures.

5 Discussion and Further Research

This paper presents preliminary findings from a multiple case study used to explore web-enabled supply chain integration and identify potential questionnaire measures. The questionnaire findings were corroborated by rich qualitative evidence from the five manufacturers studied although analysis of evidence from a larger sample is required. The purpose of this investigation was: to explore the level of supply chain integration construct and its dimensions and to determine the feasibility of measuring a case's level of supply chain integration.

By integrating the preliminary work of several studies (Moncrieff and Stonich, 2001; Poirier and Bauer, 2001; Supply-Chain Council Inc., 2005), this study proposed the level of integration of a supply chain could be modelled as five stages or levels. These levels are: Functional Focus, Internal Integration, Linked Network, Integrated Network, and Optimized Network.

A 15-item measure was adapted from studies my Moncrieff and Stonich (2001) and the Supply-Chain Council (2005) and used to assess the level of supply chain integration of a case's overall supply chain, as well as for each of the Plan, Make, and Deliver process areas of the supply chain. The measure assessed four dimensions of the supply chain including supply chain strategy, performance management, processes, and decision-making.

Results of both the questionnaire measures and the qualitative analyses indicated each case had only a moderate level of supply chain integration — somewhere between the Internal Integration and Linked Networks stage. This finding agrees with preliminary studies of supply chain integration in several other industries (e.g., Roloff et al., 2001) that have not found many examples of highly differentiated levels of supply chain integration at present, despite the existence of

widely-publicized outliers like Dell Computer's highly integrated supply chain (Reddy and Reddy, 2001; Chopra and Meindl, 2001). In contrast to well-publicized examples such as Dell Computer, the cases studied exhibited a very modest level of supply chain integration, despite each having large investments in supply chain partnerships. This discrepancy highlights the need to measure supply chain integration using empirically-supported models such as the one described, rather than relying on managerial assumptions about how integrated a firm is with its supply chain partners.

As e-business technologies mature, it is expected that firms will be further differentiated in their level of supply chain integration making the proper conceptualization and measurement of this construct even more important for conducting research and guiding practice. The research model and results described in this study are a first step towards developing more detailed measures of supply chain integration for tomorrow's increasingly dynamic web-enabled supply chains.

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Appendix A – Level of Supply Chain Integration Questionnaire

Notes: The following measure is adapted primarily from Moncrieff and Stonich (2001) following the frameworks of Supply-Chain Council Inc. (2005).

In the instrument used in this study, the number of the description was replaced with letters to reduce the tendency to self-report a higher number (Dillman, 1978). Levels 1, 2, 3, and 4 represent the Functional Focus, Internal Integration, Linked Network, and Integrated Network levels of supply chain integration, respectively. Level 5, which is Optimized Network, is not included in the measure since in a much wider study no firms were found that currently consistently operate at that level. In this measure, any such firms would therefore be identified as Level 4 companies.

The following instructions preceded the instrument:

> "For the following items, please circle the description that best matches your organization for the given supply chain dimension.
>
> Please respond according to the CURRENT state of your organization, rather than the *desired* state.
>
> Responses are confidential; respondent and organization names WILL NOT BE DISCLOSED.
>
> If you have any difficulties responding to any of the questions, please provide your comments so that we may improve the questionnaire."

1. For our Supply Chain Strategy:

    (a) Each department or business unit has a separate supply chain strategy. There is little coordination of strategies across enterprise or supply chain.
    (b) A formal enterprise-wide supply chain management strategy exists but there is no formal strategy for external partners.
    (c) A formal enterprise-wide supply chain management strategy exists including an internally developed formal strategy for external partners.
    (d) A Formal supply chain-wide supply chain management strategy exists that was jointly developed with external supply chain partners.

2. For managing the Performance of our supply chain:

    (a) Supply chain performance is measured predominantly at functional / departmental level.
    (b) Supply chain performance is measured predominantly at the company, process, and diagnostic levels.
    (c) Supply chain performance metrics are defined internally and there is joint performance monitoring and correction with external partners.
    (d) Supply chain performance metrics are jointly defined, monitored, and corrected with external partners.

3. For managing the business Processes in our supply chain:

  (a) Processes tend to be managed within discrete departments or functions. There is little cross-functional or inter-enterprise process management.
  (b) Processes are often company-wide and are managed at both the functional and cross-functional process levels. There is little inter-enterprise process management with supply chain partners.
  (c) Core processes are managed internally. Outsourcing is used for most non-core processes. Information is frequently shared with external partners.
  (d) End-to-end process management, coordination, and collaboration with strategic partners is used for most processes. Alignment of business objectives and processes is done with each strategic partner.

4. For high level Decisions regarding our supply chain, major decisions are usually made by a committee:

  (a) Without representatives from each of our production, finance, logistics, and information technology areas.
  (b) With representatives from each of our production, finance, logistics, and information technology areas, but without external partners.
  (c) With representatives from each of our production, finance, logistics, and information technology areas, and external partners (who may observe and provide input, but do not have a final say in decisions).
  (d) With representatives from each of our production, finance, logistics, and information technology areas, and external partners (who usually have a final say in decisions).

The 15-item questionnaire contained additional items for each of the eleven dimensions of the SCOR Plan, Source, Make, and Deliver processes (Supply-Chain Council Inc., 2005).

Appendix B – Excerpt from Interview Protocol

Sources of Data:

  -Web site documentation (e.g., supplier/customer portals, electronic markets, EDI)
  -Financial Reports, letters to shareholders, investor communications, etc.
  -Previous case reports, interviews, newspaper and magazine articles.
  -Strategic Plans (if not confidential)
  -Organizational charts (for reporting structure for supply chain management group)
  -Senior Managers
  -Consultants who have worked for company

Sample Questions:

1) <u>How important is optimizing the performance of the firm's supply chain to the overall performance of the firm?</u>
  PROBES:
- Who is responsible for supply chain coordination in the firm?
- What metrics are gathered for measuring supply chain performance?

2) <u>Are there significant differences in the level of supply chain integration between the Plan, Make, Source, and Deliver supply chain processes? If so, describe them.</u>

3) <u>How important is internal and external integration to your supply chain performance?</u>
  PROBES:
- Who is involved in decisions regarding integration/coordination?
- What metrics are gathered for measuring integration effectiveness?
- How important is having sustainable long-term relationships or shared benefits?

4) <u>How closely integrated is the unit with other members of its supply chain?</u>
  PROBES:
- What is the current focus of integration efforts? What information, processes, and systems are involved?
- Has internal integration been achieved? How? Benefits and problems?
- Has external integration been achieved? How? Benefits and problems?
- How are decisions made between business units or supply chain partners? Are decisions made jointly or dictated by one party?
- How are performance of and benefits to the partner measured? Who defines and measures the metrics?
- To what degree is outsourcing used? How are outsourced processes managed?
- How formal and inclusive is the strategic planning for the supply chain? Is there a strategic plan? Who creates it? How useful is it?

5) <u>What is the desired level of integration with other members of the supply chain?</u>
  PROBES:
- What improvements will be made this year? Next Year? In five years?
- How easy will it be to achieve these improvements?