How risk and uncertainty is used in Supply Chain Management: a literature study

A literature study and a preliminary model

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Document Version
Final published version

Publication date:
2004

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Working Paper No. 02/2004
March, first edition
ISSN 1398-9480

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Keywords *Supply Chain Management, Risk Management, Supply Chain Risk Management*

Abstract *To comply with Supply Chain Management dogma companies have cut their inventories to a minimum, lead times have been shortened, new suppliers have been chosen and the customer portfolio has been reduced. All of these activities impose a great deal of risk on the firms, jeopardizing the survival of entire supply chains. In this article the author intends to investigate and document the use and meaning of Risk and Uncertainty within journals publishing material on Supply Chain Management and Logistics. Subsequently suggestions for further research are proposed – the integration of Risk Management into the discipline of Supply Chain Design.*

Introduction

Risk Management (RM) is traditionally a term used in the world of finance to describe the vulnerability of investments, justify hedging policies and document the need for insurance (Borge, 2001). The development of the risk measures and management tools available today is well documented in the book "Against the Gods" (Bernstein, 2001). Bernstein describes how 16th and 17th century mathematicians like Bernouilly, de Moivre, Pascal and Fermat developed the mathematical and statistical foundation for financial risk management, primarily from an interest in various types of gambling. Further developments such as portfolio management (Markowitz, 1952) and real options (Black & Scholes, 1973) are spin-offs from these contributions.

Since the introduction of Supply Chain Management (SCM) (Oliver & Webber, 1982), companies have reduced inventory, shortened lead times, outsourced non-core activities, and segmented the customer portfolios. Concurrently product life cycles have become shorter, supply chains have become longer and demands from customers have increased significantly in terms of quality, agility and customisation (Schary & Skjoett-Larsen, 2001). This has left companies more vulnerable to disturbances in the product flow, competency flaws in product development and competition

between networks, to name but a few risks. The leaner supply chain has definitely increased profitability, but has at the same time introduced a need to better manage the flow of products, the development of relationships and the procedures to design the company's network.

The objective of this paper is to document an extensive literature study on risk and uncertainty within SCM. The literature study is the first step in a research project on risk as a criterion for supply chain design and management.

After introducing the working definition of SCM, a list of relevant journals is presented, and the search method is described. The identified contributions are classified according to orientation in the supply chain, predominant themes, and theoretical and methodological foundation. Based on the literature study, issues in supply chain integration is discussed.

Similar to other literature studies (Bechtel & Jayaram, 1997), the intended audience falls in two categories: experienced researchers interested in the field looking for research opportunities and the new researchers (e.g. doctoral students) entering the fields of (Business) RM and SCM. Practitioners might benefit from this study in terms of a higher awareness of the importance of identifying, assessing and managing the risks inherent in the cooperation in a supply chain, integrating processes across the boundaries of the individual company.

Supply Chain Management

Originally, Oliver and Webber (1982) explained the difference between logistics and SCM by the holistic view and strategic nature of SCM, aiming at integrating companies in a system creating a more robust business model. As they point out, the aim is to balance resources and

> *"that an integrated systems strategy that reduces the level of business vulnerability is developed and implemented" (Oliver & Webber, 1982, p. 66)*

To Stevens (1989) the integration of activities is a prerequisite for SCM. He defines four levels of integration, only the latter being SCM, see Figure 1 below.

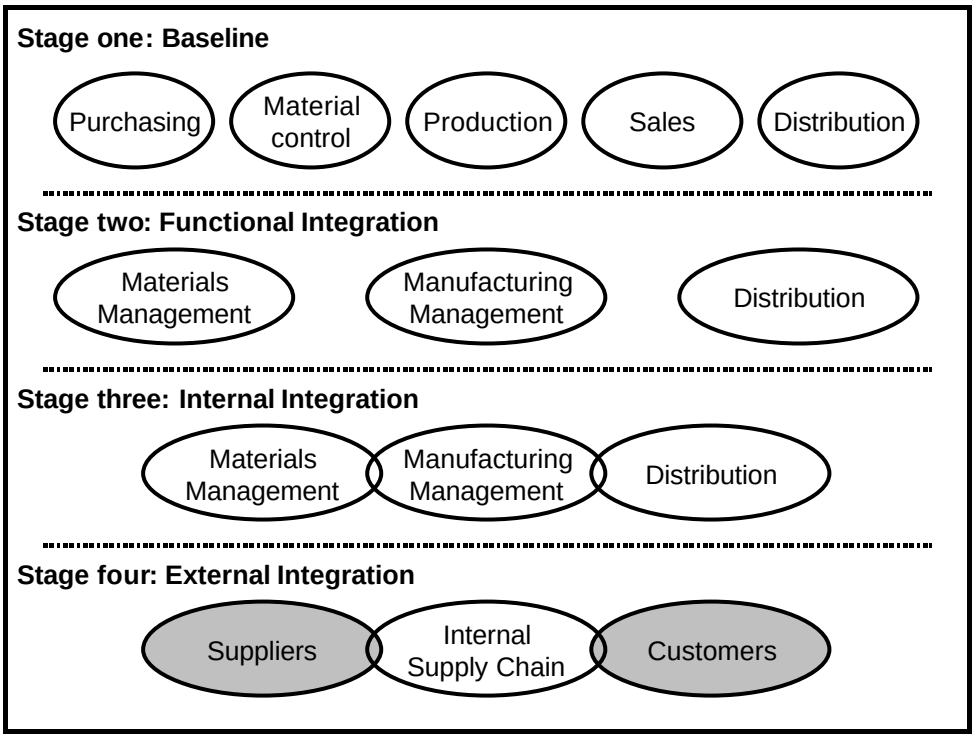

Figure 1: The Integration Model (Stevens, 1989)

In Cooper & Ellram (1993) SCM is defined as

> *"…an integrative philosophy to manage the total flow of a distribution channel from the supplier to the ultimate user." (Cooper & Ellram, 1993)*

While this definition more or less equates SCM with the traditional logistics concept, Handfield & Nichols (1999) define supply chains as encompassing

> *"…all activities associated with the flow and transformation of goods from the raw materials stage, through to the end users, as well as the associated information flows. Material and information flow both up and down the supply chain. … [SCM is] the integration of these activities through supply chain relationships, to achieve a sustainable competitive advantage." (Handfield & Nichols, 1999)*

To Mentzer et al. (2001) a supply chain is

> *"a set of three or more entities (organizations or individuals) directly involved in the upstream and downstream flows of products, services, finances, and/or information from a source to a customer." (Mentzer et al., 2001)*

Mentzer and his colleagues distinguish between a "direct supply chain", an "extended supply chain", and an "ultimate supply chain". The direct chain encompasses the focal company, a

supplier and a customer. The extended chain includes suppliers' suppliers and customers' customers, and the ultimate chain includes all the organizations involved, e.g. third-party logistics providers, financial services providers and providers of management services. They go on and classify the various definitions of SCM into three categories: a management philosophy, an implementation of a management philosophy and a set of management processes.

Harland (1996) divides the definitions into: management of supply relationships, management of inter-business chains, and management of inter-business networks.

Although definitions of SCM vary, they all have three things in common: (1) the focus on the efficient flow of materials, finances and information between firms in the chain/network, (2) the process orientation of the participating firms and (3) the integration of processes across company boundaries. Figure 2 illustrates the author's view of the supply chain.

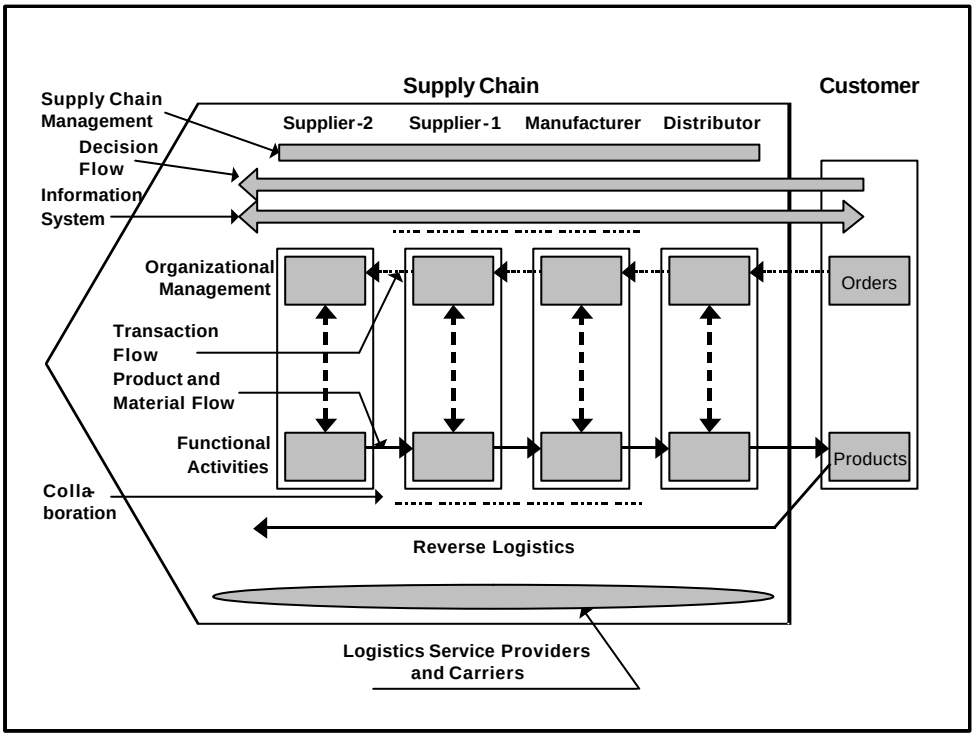

Figure 2: The Global Supply Chain (Schary & Skjoett-Larsen, 2001, p. 39)

The integration with suppliers and customers come with a price: increased risk. The overall cost reduction obtained through the adjustment of processes across organizational boundaries, the resources invested in integrating socially through frequent interaction and modification of IT (and other) systems to support commonality in reporting is countered by an increase in the risks, e.g. the

risk of opportunistic behaviour of supply chain partners, increased transparency in operations and vulnerability due to the reliance on fewer suppliers etc.

This wide range of risks points toward an integration of risk into the models/theories used when performing SCM: operating/managing the company and its supply chain partners and developing the network. These issues will be dealt with in later contributions.

Research methodology

The literature study performed is based on a list of relevant journals identified as a compromise between other literature studies performed within the field (Zsidisin, 2003) and evaluations of the usefulness of journals (Gibson & Hanna, 2003). The journals investigated fall in three categories, listed in Table 1 below. Since "Supply Chain Risk" is not an established term, the analysis has been performed by reading through the abstracts of all issues available to the author, looking for articles dealing with Vulnerability, Uncertainty and Risk. The inclusion of an article in the study is based on the subjective choice made by the author.

After analysing the list of relevant journals, the quality of this search is tested by performing a cross-database search using the phrase "Logistics" or "Supply Chain" and combining that with "Vulnerability", "Uncertainty" or "Risk"[1]. These six combinations are tested in all available e-databases: ABI/INFORM, Business Source Premier, EMERALD, JSTOR and Science Direct. The number of relevant hits will determine the "completeness" of the list of relevant journals mentioned above.

The final step in the analysis is to identify themes, defined as a collection of at least three articles focusing on the same problem or phenomenon. The articles are grouped according to the problem investigated or phenomenon described. The process is repeated until as many articles as possible belong to at least one theme, and the themes themselves are constant. Between iterations the themes identified are evaluated and themes are potentially redefined or merged with other themes. The method is very subjective, but is deemed acceptable as a means to describe trends in the published material. The analysis is performed first with each of the three journal categories and then for the entire collection of articles. The purpose of this analysis is to document if the use of risk and uncertainty within the three sub-disciplines differ, and subsequently if there are any themes that cut across the journal categories.

[1] Alternatively in one step using the expression "('logistics' OR 'supply chain') AND ('vulnerability' OR 'uncertainty' OR 'risk')".

Table 1: List of relevant journals

Journal Name	Abbrev.	Period investigated
Logistics		
European Journal of Purchasing and Supply Management [2]	EJPSM	1994 [vol 1] – 2002 [vol 8]
International Journal of Logistics Management	IJLM	1990 [vol 1] – 2002 [vol 13]
International Journal of Logistics: Research and Application	IJL-RA	1999 [vol 2] – 2002 [vol 5] [3]
International Journal of Physical Distribution & Logistics Management	IJPDLM	1994 [vol 24] – 2003 [vol 33]
International Journal of Purchasing and Materials Management [4]	IJPMM	1985 [vol 21] – 1998 [vol 34]
Journal of Business Logistics	JBL	1978 [vol 1] – 2003 [vol 24]
Journal of Purchasing and Supply Management [5]	JPSM	2003 [vol 9] – 2003 [vol 9]
Journal of Supply Chain Management [6]	JSCM	1999 [vol 35] – 2003 [vol 39]
Supply Chain Management: An International Journal	SCM-IJ	1996 [vol 1] – 2003 [vol 8]
Supply Chain Management Review	SCMR	2000 [vol 4] – 2003 [vol 7]
Operations Management		
Interfaces	I	1971 [vol 1] – 2002 [vol 32]
International Journal of Production Economics	IJPE	1991 [vol 22] – 2003 [vol 85]
International Journal of Operations & Production Management	IJOPM	1980 [vol 1] – 2003 [vol 23]
Journal of Operations Management	JOM	1980 [vol 1] – 2003 [vol 21]
Management		
California Management Review	CMR	1980 [vol 22] – 2003 [vol 45]
Decision Science	DS	1985 [vol 16] – 2002 [vol 33]
European Management Journal	EMJ	1982 [vol 1] – 2003 [vol 21]
Harvard Business Review	HBR	1990 [vol 68] – 2003 [vol 81]
Industrial Marketing Management	IMM	1985 [vol 14] – 2003 [vol 32]
Journal of Occupational Behaviour [7]	JOCB	1980 [vol 1] – 1987 [vol 8]
Journal of Organizational Behavior [8]	JORB	1988 [vol 9] – 2003 [vol 24]
Scandinavian Journal of Management	SJM	1988 [vol 4] – 2003 [vol 19]
Sloan Management Review	SMR	1970 [vol 12] – 2000 [vol 42]

Results

The results of the literature study are presented in the following section. Each of the articles is classified according to orientation (Supply, Internal, Demand and/or Network) and strategic level (Strategy and/or Operational), and the explicit use of theory/framework is listed as well. The chosen categorizations are determined with the implicit structure of a supply chain and the standard structure of an academic article in mind. Some of the contributions might not "fit" the categories, and these will be identified with the symbol '-'.

Besides the categorizations mentioned above, attention is given the use of or reference to RM. The identification, assessment and management of risks are of primary interest in this study; contributions that fall within this domain will receive special attention, and will be described in

[2] The journal changed name to "Journal of Purchasing and Supply Management" in 2003.
[3] Last 12 months available as abstracts only.
[4] The journal changed name to "Journal of Supply Chain Management" in 1999.
[5] Previously "European Journal of Purchasing and Supply Management".
[6] Previously "International Journal of Purchasing and Materials Management".
[7] The journal changed name to "Journal of Organizational Behavior" in 1988.
[8] Previously "Journal of Occupational Behaviour".

further detail. Finally, the underlying themes will be analysed, first for each category of journal, and subsequently for all articles collectively.

Logistics and SCM journals

The search in logistics and SCM journals resulted in 36 matches. Categorizing the contributions according to the orientation revealed a distinct over-representation on the upstream side, and a surprising lack of focus on the network level. The majority of contributions are dealing with operational issues, especially the journals "International Journal of Logistics: Research and Application", "International Journal of Physical Distribution & Logistics Management" and "Journal of Business Logistics". In contrast, the journal "Supply Chain Management Review" has only articles with strategic orientation.

Explicit use of theory is almost absent, although an important exception is Svensson (2000; 2001; 2002a; 2002b; 2002c; 2002d), who is using marketing channels in all his contributions. Other examples of explicit use of theory are the articles "Proactive Supply Management: The Management of Risk" (Smeltzer & Siferd, 1998), "An Agency Theory Investigation of Supply Risk Management" (Zsidisin & Ellram, 2003) and "Effectively managing vertical supply relationships: a risk management model for outsourcing" (Lonsdale, 1999), using resource-based theory and transaction cost economics, agency theory, and resource-based theory, respectively. Finally, there are a few articles using modelling.

As for explicit references to RM, only three articles could be identified: "Risk in supply networks" (Harland, Brenchley, & Walker, 2003), "Effectively managing vertical supply relationships: a risk management model for outsourcing" (Lonsdale, 1999) and "Purchasing organization involvement in risk assessments, contingency plans, and risk management: an exploratory study" (Zsidisin, Panelli, & Upton, 2000). As indicated by the titles, all three articles deal with the supply side of the network only. Albeit SCM is about inter-organizational business processes and fulfilment of the customer demand, there is a lack of focus on the customer side.

Of the six articles dealing with activities internal to the company, two are dealing with demand uncertainty and inventory management, two are concerned with planning of operations, and the last two are dealing with demand uncertainty and facility location analysis and strategic planning, respectively. Table 2 below shows the articles found, their orientation, strategic level and explicit theories referenced.

Table 2: Classification of articles published in SCM/Logistics journals

Journal	Article	Orientation				Level		Explicit Theory
		S	I	D	N	S	O	
EJPSM	1. Ottesen & Gronhaug, 2002	✓				✓		None
IJLM	2. Ho & Carter, 1994		✓				✓	None
	3. Sheffi, 2001	✓		✓		✓		Utility
IJL-RA	4. Svensson, 2001	✓		✓			✓	Marketing Channels
	5. Svensson, 2002b	✓		✓			✓	Marketing Channels
IJPDLM	6. Boronico & Bland, 1996		✓				✓	Modeling
	7. Koutsoukis et al., 2000	✓	✓	✓			✓	Modeling
	8. Svensson, 2000	✓					✓	Marketing Channels
	9. Svensson, 2002a	✓		✓			✓	Marketing Channels
	10. Svensson, 2002c	✓		✓			✓	Marketing Channels
	11. van der Horst & Beulens, 2002	✓					✓	None
	12. Wilding, 1998 *	✓		✓			✓	None
IJPMM	13. Carter, Vickery, & D'Itri, 1993 *	✓					✓	Modeling
	14. Pilling & Zhang, 1992 *	✓				✓	✓	None
	15. Smeltzer & Siferd, 1998	✓					✓	TCE, RBT
	16. Templin & Noffsinger, 1994	✓					✓	None
	17. Tullous & Munson, 1991	✓					✓	None
JBL	18. Copacino & Lapide, 1984 *	✓		✓			✓	None
	19. Lau, 1989		✓				✓	None
	20. Menachof, 1996	-	-	-	-		✓	None
	21. Meshkat & Ballou, 1996		✓				✓	None
	22. Schwarz & Wenig, 2000	✓		✓			✓	None
	23. Speh & Wagenheim, 1978			✓			✓	None
	24. Vidal & Goetschalkx, 2000				✓		✓	Modeling
	25. Wood, 1985 *	-	-	-	-		✓	None
	26. Zinszer, 1983		✓				✓	None
JPSM	27. Harland, Brenchley, & Walker, 2003	✓		✓		✓	✓	None
JSCM	28. Zsidisin, 2003	✓					✓	None
	29. Zsidisin & Ellram, 2003	✓				✓		Agency Theory
SCM-IJ	30. Lonsdale, 1999	✓				✓	✓	RBT
	31. Svensson, 2002	✓		✓		✓	✓	Marketing Channels
	32. Zsidisin, Panelli, & Upton, 2000	✓				✓	✓	None
SCMR	33. Geary, Childerhouse, & Towill, 2002 *	✓		✓		✓		None
	34. Lee & Wolfe, 2003	✓		✓		✓		TQM
	35. Martha & Subbakrishna, 2002	✓				✓		None
	36. Simchi-Levi, Snyder, & Watson, 2002	✓				✓		None

Classifying the articles based on problem/subject/theme reveals a certain degree of overlap, as even after a couple of iterations, the articles still "belong" to more themes. Accepting the ambiguity of the themes supports the notion of uncertainty/risk as an underlying theme in many areas.

The most predominant themes are "Vulnerability in physical flows" and "Supply Management", the former dominated by Svensson, the latter characterized by many contributors. These two are predominant in the sense that the theme was defined in the first iteration, while the theme "Improving Techniques for Operations" is the result of several iterations. Of the 36 articles, 30 were assigned to the five themes identified. The remaining six articles do not "fit" the themes identified (marked '*' in the table), and since there is no commonality between the six, they are kept unassigned until the re-analysis of the total portfolio of articles later.

Table 3 below shows the identified themes and the articles assigned to them.

Table 3: Themes identified in SCM/Logistics journals

Theme	Article No
Improving Techniques for Operations	2, 6-7, 11, 19-22, 24, 26, 30
Risk Management	27, 30, 32
Securing the Supply Chain	3, 34-36
Supply Management	1, 6, 15-17, 28-29, 32
Vulnerability in Physical Flows	4-5, 8-10, 23, 31

Operations Management journals

The search in the four OM journals resulted in 44 matches, of which almost all are focusing on operational issues. Also the method used is quite uniform, as the vast majority of articles use mathematical modelling. Of the few articles not using mathematical modelling, only one, "Strategic Sourcing, Vertical Integration, and Transaction Cost" (Walker, 1988), makes explicit references to theory, namely resource-based theory and transaction cost economics.

The orientation of the articles within this category differs from the previous category and shows more diversification, as more articles have internal orientation (22) than upstream (16) or downstream (12). Two articles, "A dynamic game model for distribution problems with non-stochastic uncertainty" (Blanchini, Rinaldi, & Ukovich, 1996) and "Simulation of supply chain behaviour and performance in an uncertain environment" (Petrovic, 2001), are oriented towards the network level.

Within this category only partial contributions to risk management in supply chains have been identified. All five articles identified, "Purchasing, Risk and Logistics: A Neglected Combination?" (Wright, 1980), "A methodology for the vulnerability analysis of just-in-time production systems" (Albino & Garavelli, 1995), "Risk analysis and assessment in network environments: A dyadic case study" (Hallikas, Virolainen, & Tuominen, 2002), "Profit and risk evaluation in customer driven engineering and manufacturing" (Muntslag, 1994), and "Market vulnerability in process industries" (Zaidman, 1994) focus on assessment, not identification or management of risks.

Other themes emerging from the analysis are identical to the previous category despite our attempts to "disregard" the themes previously identified. Of the five themes identified in the previous category, three are reused and no new ones are added. The hit rate assigning articles to themes is similar to the previous category, as 36 of the 44 articles are assigned. Assigning more articles to fewer categories call for a further subdivision of the three categories, but attempts on this has been unsuccessful. As for the previous category, the remaining articles do not represent any

commonality, and cover issues as diverse as e.g. safety in rail transportation of dangerous commodities (Swoveland, 1987) and risks incurring in companies producing highly seasonal products (Vörös, 1999).

All the articles are classified in Table 4 and assigned themes in Table 5.

Table 4: Classification of articles published in Operations Management journals

Journal	Article	Orientation				Level		Explicit Theory
		S	I	D	N	S	O	
I	37. Swoveland, 1987 *	-	-	-	-		✓	None
	38. Walker, 1988	✓				✓		RBT, TCE
IJOPM	39. Baker, 1986		✓				✓	None
	40. Callarman & Hamrin, 1984		✓	✓			✓	Modeling
	41. Newman, Hanna, & Maffei, 1993	✓					✓	None
	42. Wright, 1980	✓				✓		None
IJPE	43. Albino & Garavelli, 1995	✓		✓			✓	Modeling
	44. Bartezzaghi & Verganti, 1995			✓			✓	Modeling
	45. Bartezzaghi, Verganti,& Zotteri, 1999		✓				✓	Modeling
	46. Blanchini, Rinaldi, & Ukovich, 1996				✓		✓	Modeling
	47. Dolgui & Ould-Louly, 2002		✓				✓	Modeling
	48. Gong & Sun, 1995		✓				✓	Modeling
	49. Gupta, Gerchak, & Buzacott, 1992		✓			✓	✓	Modeling
	50. Güllü, Önol, & Erkip, 1999	✓					✓	Modeling
	51. Hallikas, Virolainen, & Tuominen, 2002	✓		✓		✓		None
	52. Jang & Liu, 1993		✓	✓		✓	✓	Modeling
	53. Jeunet & Jonard, 2000	✓					✓	Modeling
	54. Johansen, 1999			✓			✓	Modeling
	55. Kelle & Miller, 2001	✓				✓	✓	Modeling
	56. Korpela et al., 2002			✓		✓		Modeling
	57. Lau, Lau, & Willett, 2000 *			✓			✓	Modeling
	58. Matsuura, Tsubone, & Kataoka, 1995		✓				✓	Modeling
	59. Muntslag, 1994		✓				✓	Modeling
	60. Murthy & Ma, 1991 *		✓				✓	None
	61. Petrovic, 2001 *				✓		✓	Modeling
	62. Petrovic & Petrovic, 2001	✓					✓	Modeling
	63. Tang & Grubbström, 2002		✓				✓	Modeling
	64. van der Vaart, de Vries, & Wijngaard, 1996	✓					✓	None
	65. van Dorp & Duffey , 1999		✓				✓	Monte Carlo
	66. Vörös, 1999 *		✓				✓	Modeling
	67. Wenig, 1999			✓			✓	Modeling
	68. Zaidman, 1994			✓		✓	✓	Modeling
	69. Zimmer, 2002	✓					✓	Modeling
	70. Zäpfel, 1996		✓				✓	Modeling
JOM	71. Callen & Sarath, 1995 *		✓				✓	Modeling
	72. Denzler, Boe, & Duplaga, 1987		✓				✓	Modeling
	73. Etienne, 1987	✓	✓				✓	Modeling
	74. Hill & Vollmann, 1986	✓					✓	Modeling
	75. Kadipasaoglu & Sridharan, 1995	✓	✓				✓	Modeling
	76. Lewis, 2003 *		✓	✓			✓	None
	77. Pagell & Krause, 1999 *	✓	✓	✓			✓	None
	78. Schmitt, 1984		✓				✓	Modeling
	79. Treleven & Schweikhart, 1988	✓				✓		None
	80. Zhao & Lee, 1993		✓				✓	Modeling

Table 5: Themes identified in OM journals

Theme	Article No
Improving Techniques for Operations	39-41, 44-50, 52-54, 56, 58, 62-65, 67, 70, 72-73, 75, 78, 80
Risk Management	42-43, 51, 59, 68
Supply Management	38, 42, 55, 64, 69, 74, 79

Management journals

The search in the selected management journals resulted in 43 matches, see Table 6 below.

Table 6: Classification of articles published in Management journals

Journal	Article	Orientation				Level		Explicit Theory
		S	I	D	N	S	O	
CMR	81. Grabowski & Roberts, 1997 *	-	-	-	-	✓		None
	82. Johnson, 2001	✓		✓		✓		None
	83. Lee, 2002 *	✓		✓		✓		None
DS	84. Arcelus, Pakkala, & Srinivasan, 2002 *	✓					✓	Modeling
	85. Ballestero, 2002		✓				✓	Modeling
	86. Ballou & Pazer, 1987		✓				✓	None
	87. Christy & Kanet, 1988	✓	✓				✓	None
	88. Dillinger, Stein, & Mizzi, 1992	-	-	-	-		✓	None
	89. Ghosh & Ray, 1992	-	-	-	-		✓	None
	90. Ghosh & Ray, 1997	-	-	-	-		✓	None
	91. Ghosh, 1994	-	-	-	-		✓	None
	92. Graves & Ringuest, 1991	✓					✓	None
	93. Havlena & DeSarbo, 1991 *			✓			✓	None
	94. Krueger & Dickson, 1994	-	-	-	-	-	-	None
	95. Lee, 1997	-	-	-	-	-	-	Prospect theory; Modeling
	96. Lin & Krajewski, 1992		✓				✓	Modeling
	97. Marshall & Narasimhan, 1989	-	-	-	-	✓	✓	Decision theory
	98. Noori & Keller, 1986		✓				✓	None
	99. Sridharan & Berry, 1990		✓				✓	None
	100. Wedel & DeSarbo, 1993 *	-	-	-	-		✓	None
EMJ	101. Collis, 1992 *	-	-	-	-	✓		None
	102. Noy & Ellis, 2003 *	-	-	-	-	✓		None
HBR	103. Bernstein, 1996 *	-	-	-	-	-	-	None
	104. Fisher et al., 1994			✓			✓	None
	105. Hecht & Morici, 1993 *	-	-	-	-	-	-	None
	106. Sells, 1994 *	-	-	-	-	-	-	None
	107. Simons, 1999 *		✓			✓		None
	108. Watkins & Bazerman, 2003	✓		✓		✓		None
IMM	109. Bunn & Liu, 1996 *			✓			✓	None
	110. Henthorne, LaTour, & Williams, 1993 *		✓				✓	None
	111. Meldrum & Millman, 1991 *			✓		✓	✓	None
	112. Polk, Plank, & Reid, 1996 *			✓			✓	None
	113. Schill, 1985	✓		✓		✓		None
	114. Westbrook, 1996 *			✓			✓	None
JOCB	115. Clegg & Fitter, 1981 *		✓				✓	Organizational theory
JORB	None							
SJM	None							
SMR	116. Allaire & Firsirotsu, 1989 *		✓			✓		None
	117. Bowman, 1980 *	-	-	-	-	✓		None
	118. Bowman, 1982 *	-	-	-	-	✓		None
	119. Clemons, 1995 *		✓			✓		None

	120. Cozzolino, 1979	-	-	-	-	✓		None
	121. Hertz & Thomas, 1983		✓			✓		None
	122. Marsh & Swanson, 1984 *	-	-	-	-	✓		None
	123. Quelch, Neslin, & Olson, 1987 *			✓		✓		None

A relatively large proportion of the articles do not fit into the categories. Five articles do not fit neither the 'Orientation' nor the 'Level' classification, 18 articles do not fit 'Orientation'. Of the nine journals, two do not have any relevant articles. The distribution of strategic/operational is quite even over the group, but most journals have a bias. The journals "California Management Review", "European Management Journal" and "Sloan Management Review" have a strategic orientation, whereas "Decision Science" is focused towards operational issues. In contrast, there is no apparent emphasis on the supply chain orientation across journals. There are no articles in the 'Network' classification, but a quite mixed picture on the other three classifications, fewest in 'Supply'. Again the explicit use of theory is quite scarce; four articles are using modelling, and prospect theory and decision theory are referenced in one article each. Finally, the article in "Journal of Occupational Behavior" makes reference to organizational theory.

Also references to RM are quite scarce. In "Learning From Toys: Lessons In Managing Supply Chain Risk From The Toy Industry" (Johnson, 2001) only the management part is addressed, whereas the article "Decision and Risk Analysis in a New Product and Facilities Planning Problem" (Hertz & Thomas, 1983) is focusing on the analysis part. The article "Predictable Surprises: The Disasters You Should Have Seen Coming" (Watkins & Bazerman, 2003) is the only contribution dealing with all three phases: identification, assessment and management.

The analysis for themes revealed a new one, 'Risk Preference', as well as two already identified: 'Improving Techniques for Operations' and 'Risk Management'. The number of articles not assigned to a theme is quite high, 23. Table 7 below contains the themes identified and the articles assigned to them.

Table 7: Themes identified in Management journals

Theme	**Article No**
Improving Techniques for Operations	85-88, 92, 96-99, 104, 113, 120
Risk Management	82, 108, 121
Risk Preference	89-91, 94-95

Cross-database search

The cross-database search resulted in only 13 new articles, collected from as many as 10 journals. The author therefore concludes that the search in the listed journals is as complete as could be expected.

Table 8: Classification of articles published in other journals

Article	Orientation				Level		Explicit Theory
	S	I	D	N	S	O	
124. Agrawal & Seshadri, 2000	✓					✓	Modeling
125. Bensaou & Anderson, 1999	✓					✓	TCE
126. Bowersox, Stank, & Daugherty, 1999			✓			✓	None
127. Escudero et al., 1999		✓	✓			✓	Modeling
128. Grabowski & Roberts, 1999		✓			✓		None
129. Kouvelis & Milner, 2002	✓		✓		✓		Modeing
130. Nooteboom, Berger, & Noorderhaven, 1997	✓		✓		✓		TCE
131. Ritchie & Brindley, 2000	✓		✓		✓		None
132. Sabri & Beamon, 2000				✓	✓	✓	Modeling
133. Sharratt & Choong, 2002				✓		✓	None
134. Tsay, 1999			✓			✓	Modeling
135. van der Horst et al., 1998		✓	✓			✓	None
136. van Mieghem, 1999	✓					✓	Modeling

The articles show no apparent biases besides the normal scarcity of articles working on the network level. More than half the articles make explicit reference to theory; two articles make reference to transaction cost economics, other six are using modelling.

Combining the themes from the previous sections, and performing the analysis on all the articles across journal categories reveal only one new theme; 'Supply Chain Design'.

Table 9: Themes identified in across journal categories

Theme	Article No	Count
Improving Techniques for Operations	2, 6-7, 11, 19-22, 24, 26, 30, 39-41, 44-50, 52-54, 56, 58, 62-65, 67, 70, 72-73, 75, 78, 80, 85-88, 92, 96-99, 104, 113, 120	49
Risk Management	27, 30, 32, 42-43, 51, 59, 68, 82, 108, 121	11
Risk Preference	89-91, 94-95	5
Securing the Supply Chain	3, 34-36	4
Supply Chain Design	11, 33, 107, 131, 135	5
Supply Management	1, 6, 15-17, 28-29, 32, 38, 42, 55, 64, 69, 74, 79	15
Vulnerability in Physical Flows	4-5, 8-10, 23, 31	7

Conclusion

Judging by the number of articles dealing with improvement of techniques in operations, risk and uncertainty is definitely dealt with on the operational level. A number of articles are dealing with the integration of uncertainty into the operational decision making process: the establishment of planning fences in MRP systems and the determination of planning horizons etc. These articles

have already had an impact, as most ERP systems today have these techniques built into their standard functionality. Surprisingly, though, is the lack of a thorough and complete integration of RM into the management and design of supply chains. The articles listed above in the theme 'Supply Chain Design' are a starting point, but there is still a long way to go.

Discussion

The literature study has revealed an absence of RM within SCM. Despite many efforts related to minimizing uncertainty, and assessing the vulnerability of the market and the internal operations, apparently risk has not been perceived as a parameter for supply chain design.

One way of minimizing the vulnerability of the supply chain is to build buffers in all interfaces to other companies, but doing so will cost the company dearly on holding costs in the short run and lack of information in the long run. And it might be argued that at least some of the relationships with the supply chain partners must be non-arms-length to classify as a supply chain member. So, if integrating with the other participants in the network is a characteristic determining the degree or type of supply chain management, how should one choose whom to integrate closely with, and whom should be held at arms length?

Supply Chain Integration

Lawrence & Lorsch (1986) define integration as

> *"the quality of the state of collaboration that exists among departments that are required to achieve unity of effort by the demands of the environment" (Lawrence & Lorsch, 1986)*

While this definition refers to integration internal to a firm or organization, the emphasis here goes beyond the firm and encompasses external entities that are players in a supply chain.

According to Bowersox, Closs, & Stank (1999) the integration objective can be formulated along six different lines: Customer integration, internal integration, material and service supplier integration, technology and planning integration, measurement integration, and relationship integration.

Similarly, Lee (2000) outlines three dimensions of supply chain integration: information integration, co-ordination and resource sharing, and organisational relationship linkage. Information integration refers to the sharing of information and knowledge among the members in the supply chain, including sales forecasts, production plans, inventory status and promotion plans. Co-ordination and resource sharing refers to the realignment of decisions and responsibility in the

supply chain. Organisational relationship linkages include communication channels between the members in the supply chain, performance measurement and sharing of common visions and objectives.

In previous research (Bagchi, Skjoett-Larsen, & Sørensen, 2003) the author has worked with a supply chain integration framework consisting of the following types of integration: process, social and information. Process integration is the co-development of processes or the adjustment of existing routines to match the routines of supply chain partners. Social integration is the contact, e.g. meetings, conferences, phone calls etc. Information integration describes the integration of automated systems, like EDI/XML, ERP-systems etc. The research has shown that the level of integration between European firms in supply chains is still quite low. This is supported by other researchers performing similar research (Bask & Juga, 2001;Fawcett & Magnan, 2002).

Arguments for not integrating closer are many. The fear of losing proprietary information on products and processes is a very real threat to many companies, as is the loss of competencies when outsourcing. The integration of administrative systems and processes might cause exit costs to rise, making the termination of the relationship more painful, thereby increasing the risk of competency and quality flaws from suppliers.

Choosing not to integrate closely has corresponding risks, including the loss of business opportunities, the lagging of technological knowledge, sub-optimality in all transactions due to their generic definition, etc.

Further research

The author intends to integrate RM into SCM by developing a methodology to assess the risk level of each participant in the supply chain and to manage it by altering the type and level of integration between the focal company and the individual partners. The goal of the methodology is to implement stability as a design objective alongside cost and lead time minimization and responsiveness.

Acknowledgements

The author would like to thank professor Tage Skjøtt-Larsen, Copenhagen Business School and two anonymous reviewers from IJPDLM for useful comments on an earlier version of this manuscript.

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