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A knowledge chain management framework to support integrated decisions in global supply chains

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Knowledge management has been identified as a key enabler to achieve organisation's value chain competitiveness. It, however, has been facing fresh challenges in a global supply chain setting. This paper proposes a global knowledge chain management (GKCM) framework that identifies and prioritises critical knowledge that a global supply chain can focus on to support integrated decisions. The framework explores three types of global context knowledge, namely global market knowledge, global capacity knowledge and global supply network configuration knowledge. Empirical study has been undertaken within the manufacturing industry to evaluate the GKCM framework. Analytic network process has been explored as a key method to assess the importance of the global knowledge constructs from supply chain managers' perspectives. A key contribution of the paper is that it advances existing knowledge chain management approaches within one organisation and its local supply chain to include the global context knowledge applicable to global manufacturing settings, and highlights how the GKCM framework can support global supply chain integrated decisions.

Keywords: knowledge chain management; global supply chains; integrated decisions; critical knowledge identification and prioritisation

1. Introduction

Global supply chains are now the approach of choice for most large companies, as the expansion of local supply chains into global supply chains has opened access not only to new markets but also new sources of supply (Crandall, Crandall, and Chen 2010). Management decisions in global supply chains face the challenges of complexity and uncertainty resulting from various internal and external factors, whether they are governmental, geo-economic or cultural. In practice, the global operation of many supply chains remains disintegrated, disconnected and non-spontaneous. It is important to understand the relevance of those factors and their impact on the operation of a global supply chain. The Sixth Annual Global Survey of Supply Chain Progress identified 10 dimensions for global supply chain performance. At the top of the dimensions list is the true integration of the whole supply chain, including customers and suppliers (Wang and Chan 2010; Schubert and Legner 2011).

Despite the fact that a vast amount of literature exists on knowledge management (KM) for supply chain management, in general, only a limited amount of literature has extended the discussion of KM to the context of global supply chains (Liu and Young 2004; Schubert and

Legner 2011). Literature has acknowledged the importance of knowledge sharing and transfer within global supply chains, whilst identifying a number of associated challenges. The first challenge is its complexity. Knowledge sharing and transfer is not only complicated by cultural differences, but also influenced by market structure, and organisational similarities and dissimilarities (Myers and Cheung 2008). Secondly, there is the issue of sustainability of knowledge sharing and transfer in global supply chains. Contributing factors to sustainability include management fit, market fit, resource fit, shared identity, relational capital and flexibility (Cheung and Myers 2008). A third challenge is to determine how much value knowledge sharing/transfer is provided to the partners within a global supply chain (Verma and Tiwari 2009). To address the common issue behind these three challenges, a global supply chain has to focus on the critical knowledge that is valuable and durable enough to offer a sustainable, competitive advantage, justify the costs of retaining and transferring it, and simplifying the KM effort and process, so that the knowledge flowing across the global supply chain partners can be smooth and swift enough to increase the supply chain's response time to global market. It is believed that KM only creates value when it enables the

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creation and flow of truly critical knowledge (O'Dell and Hubert 2011).

This paper is concerned with effective KM for global supply chains, and will focus on identifying and prioritising global supply chain's critical knowledge to enable global supply chain integration. In addition, through this integrated approach, the prioritised critical knowledge will be used for collaborative decision making between supply chain partners in balancing the supply side capacity and the demand side market requirements, in order to achieve optimal overall supply chain performance.

The following section reviews related work, followed by Section 3 on a conceptual global knowledge chain management (GKCM) model. Sections 4 and 5 discuss methodology and the empirical study. Finally Section 6 draws conclusions.

2. Related work

This section reviews related work in KM, knowledge flow and knowledge chain management (KCM) which can potentially contribute to the success of global supply chain integration.

2.1. KM, knowledge flow and knowledge chain

It has been recognised that the major competitiveness of a corporation lies in its knowledge and therefore KM has become a critical issue (Harding et al. 2006). There are three main knowledge models widely used in business decision-making: stage-focused model, spectrum-focused model and knowledge conversion model. The stage-focused model defines the KM life cycle as comprising four explicit stages: knowledge creation, retention, sharing/transfer and application (Raisinghani and Meade 2005; Cheng, Hwang, and Raghu 2010). The spectrum-focused model defines KM as a series of continuous activities with knowledge exploitation (knowledge sharing and transfer) and exploration (knowledge creation and learning) at the two end-points of a continuum, rather than identified as strict categories (Marra, Ho, and Edwards 2011). The third model is called tacit-explicit knowledge conversion model. The knowledge conversion model emphasises that knowledge can be either tacit or explicit. However, the status of knowledge being tacit or explicit is not static, i.e. knowledge can be converted between each form through appropriate processes under certain situations (Nonaka 1994; Samuel et al. 2011).

When the KM models and methods are applied to a supply chain context, knowledge flow has become a focal point for many researchers (Hult et al. 2006; Samuel et al. 2011). A study based on German MNCs identified key characteristics of knowledge flows which include different firm-specific and country-specific variables, such as the cultural distance between the

subsidiary and the home country of the MNCs (Holtbrugge and Berg 2004). By distinguishing knowledge inflows and outflows, a knowledge inventory model was defined originating from the analogy of physical goods inventory (Mackinnon 2005; Cheng, Hwang, and Raghu 2010). The knowledge inventory model offers insights into the types of knowledge inflows and outflows, and cost and benefits to holding knowledge in the knowledge inventory. It demonstrates that organisations and supply chains should only hold the critical knowledge that is crucial for the success of their business. Holding any unimportant or unnecessary knowledge is a type of waste because of the holding and set-up costs associated with the knowledge.

There are several collaborative decision-making approaches combining KM and supply chain management. Lyons et al. (2012) revealed how binding individual operational capabilities and collective knowledge can be used to manage the challenges of product variety across collaborative networks. Hernandez et al. (2012) presented a collaborative network platform for multi-site production, where mass customisation decision-making process was facilitated in collaborative supply chain networks and collaborative dynamic decision-making for supplier selection. It is quite evident that these studies which discuss the collaborative decision-making in various contexts have not covered the global KM dimension. Therefore, this paper helps to address this particular shortfall in the supply chain management literature.

Knowledge chains are established through knowledge flowing among people, departments and organisations. In supply chain context, the term knowledge chain is more associated with the network for knowledge flow. Knowledge flowing through the knowledge chain can be personal, group and corporation knowledge. A knowledge chain can be considered as an interactive, ordered and recycling system. The main aim of managing knowledge chains is to convert the scattered, non-systematic knowledge into coherent, systematic knowledge. Key benefits include reducing the restriction of knowledge constrained by organisation's policy and promoting the core competitiveness of the whole supply chain (Gu, Li, and Wang 2005). Different types of knowledge chains have been discussed including customer knowledge chains (concerning customer knowledge acquiring, mining, sharing, transferring and innovating), technical knowledge chains and organisational knowledge chains (concerning supply side knowledge in providing and delivering goods and service to customers) (Li 2009).

2.2. Knowledge chain management

The concept of KCM is relatively new and was only coined at the outset of the twenty-first century (Holsapple and Singh 2000; 2001). The KCM concept is

developed based on knowledge flow, transfer and diffusion inside and between enterprises to achieve added value and competitiveness. The evolution of KCM theory has been represented by a series of known models. The earliest KCM model defined by Holsapple and Singh (2000) is probably one of the most influential KM frameworks via a Delphi study. This framework identifies five major knowledge manipulation activities and four managerial influences on the conduct of KM, which are known as the five primary and four secondary constructs in the Holsapple and Singh's KCM model. The five primary KM activities are knowledge acquisition, selection, generation, internalisation and externalisation. The four secondary activities are leadership, co-ordination, control and measurement (Holsapple and Singh 2001; Tseng 2009). Key contributions of the KCM model include not only establishing the connection between KM activities and organisational competitiveness, but also identifying organisational learning (i.e. inputs from the environment into an organisation's knowledge inventory) and projection (i.e. organisational knowledge being released into the environment) as important determinants of an organisation's viability and success in a competitive environment. Since then, a number of new KCM models have been proposed over the last decade, most of which are based on the modification of Holsapple and Singh's work. Soon after Holsapple and Singh's KCM model was published, Shin, Holden, and Schidt (2001) synthesised a knowledge chain model consisting of four activities: knowledge creation, storage, distribution and application. The model by Shin, Holden and Schidt seems to be focused on the primary knowledge activities originated from the Holsapple and Singh's KCM model. In the same year, the KCM model proposed by Wu and Liu (2001) substantially extended Holsapple and Singh's model. Wu and Liu's model not only re-organised the primary knowledge activities into three main activities (knowledge acquisition, knowledge application and knowledge creation), but also identified sub-activities for all the three main activities. Similarly, the model further extended the four secondary knowledge activities by defining sub-activities (Wu and Liu 2001).

One of the four secondary activities is knowledge measurement, which involves the valuation of knowledge resources and knowledge processors (Holsapple and Singh 2001). Zhang and Zhou (2006) enhanced the knowledge measurement by proposing a KCM measurement and improvement model. The model considered five maturity levels for an enterprise's KCM and 48 performance indicators to quantitatively evaluate the importance of KCM to an enterprise's overall performance (Zhang and Zhou 2006). The five maturity levels are people and organisational level, content level, flow procedures level, technology level and supply chain

level. The model for the first time explicitly distinguished KCM at organisational and supply chain levels. Soon after, a conceptual model solely focused on KCM in supply chains was proposed (Khadivar et al. 2007). This supply chain oriented KCM model recognises the importance of different partners in a supply chain to collaborate in joint creation, transfer and application of knowledge. The model also highlights the knowledge flow between the supply chain partners. Another contribution of Khadivar et al.'s work is that customer knowledge was identified as one of the most important knowledge sources in a supply chain, in contrast to most previous literature which is limited to product-related and process-related knowledge types. The inclusion of customer knowledge in the KCM model is echoed by a more recently reported KCM framework (Tseng 2009). This newest KCM model further added supplier and competitor knowledge alongside customer knowledge.

2.3. Research gap

Based on the analysis of the related work, there is a clear gap in the literature. That is, even though a number of knowledge chain models have been defined to guide KM activities in the scope of an organisation or in the generic context of supply chains, there is no existing KCM model developed and suited for the KM in the context of global supply chain integration. There is an urgent need to clearly identify critical knowledge essential to the global supply chain in order to enable 'just-enough knowledge' to flow through the supply chain to improve 'time-to-decision'. In addition, just as supply chains must at times remove physical items from inventory, maintain, update and keep them up to date with customer's needs, a global supply chain must also constantly maintain and update its knowledge inventory. In order to do so efficiently and effectively, the knowledge inventory needs to be kept as 'lean' as possible, i.e. to only hold the most critical knowledge. It is this 'lean' and 'critical knowledge' thinking that motivates the authors' work reported in this paper.

3. A conceptual model for GKCM

Existing literature has extensively discussed the knowledge types and knowledge flowing requirements within supply chains; this paper will focus on the context knowledge that highlights the global nature of international supply chains. The features of global supply chains require new dimensions for the integrated decision-making process, i.e. to simultaneously consider the exploration and exploitation of both the demand side global market knowledge and supply side global capacity and global supply network configuration knowledge.

3.1. Global market knowledge

The twenty-first century marketing has largely moved away from traditional mass-marketing and broad market segmentation to a more customer-centred approach (Crandall, Crandall, and Chen 2010; Liu, Kasturiratne, and Moizer 2012). It is thus important for global businesses to build up an extensive market knowledge base. Business decision-makers can then use the global market knowledge to better understand the changes in markets as a source of opportunity, primarily to forecast market demand and determine which markets to enter, to identify potential customers and their preferences in relation to products and services, to invent new distribution channels, and to develop an effective overall competitive positioning (Tseng 2009). The global market knowledge includes knowledge for, from and about markets in relation to customers, competitors and complementors.

3.2. Global capacity knowledge

The global capacity knowledge is about how to manage global demand (aggregated demand from different markets), especially under uncertainty (i.e. with demand fluctuations). Three capacity strategies to cope with the demand fluctuation have been explored: level capacity, chase demand and manage demand. In the context of global supply chains, demand fluctuation is much more significant than that of a company with access to local resources and local markets only. Global capacity strategies also closely depend on manufacturing strategies that supply chain participants have adopted, for example, make-to-stock, assemble-to-order, make-to-order or engineer-to-order (Crandall, Crandall, and Chen 2010). Therefore, global capacity knowledge will provide the decision-makers with the knowledge about supply chain's global capacity including capacity measure, constraints and balancing in order to support the global capacity strategy decisions.

3.3. Global supply network configuration knowledge

This type of knowledge is concerned with the shape and integration of the global supply network, location of operations in the supply chain network (Childe 2011),

roles of each participant (dominant or weak partners), responsibilities of participants (Crandall, Crandall, and Chen 2010), joining or leaving the supply network (procedure and consequences), network re-configuration (to cope with the dynamics of other participants joining and leaving). Typical modes for participants to enter a global supply network include exporting, licensing, franchising, off-shore outsourcing, joint venture and wholly-owned subsidiaries (Needle 2010).

This paper, therefore, proposes a GKCM framework to extend the existing knowledge chain model defined in the literature to include three new knowledge dimensions in order to support integrated decision-making in global manufacturing. Together with the five primary and four secondary KM activities for organisational learning and projection, the GKCM also includes global market knowledge, global capacity knowledge and global supply network configuration knowledge. The aim of the GKCM model is to achieve global competitiveness in supply chains, as shown in Figure 1.

A great deal of literature has discussed supply chain integration through the study of material, information, funds and human capital flows (Hernandez et al. 2008). This paper, however, is focused on knowledge flow through global supply chains by exploring the inter-relationships between the three global context knowledge dimensions. Figure 2 illustrates the key inter-relationships between the three knowledge types, which enable the smooth flow of knowledge to support global supply chain integration. Supply chain integration allows a smooth flow of knowledge in order to support collaborative decision-making between the supply chain partners who are responsible for key supply chain activities, particularly the activities of source, make, deliver, use and return that have been defined by the Supply Chain Council SCOR model (Crandall, Crandall, and Chen 2010). The knowledge requirements include both supply side (global supply network configuration knowledge and global capacity knowledge) and demand side knowledge (global market knowledge). The global supply network configuration knowledge represents the organisational knowledge aspect, and the global capacity knowledge represents the aspect of capability knowledge. Important types of collaborative decisions in the global

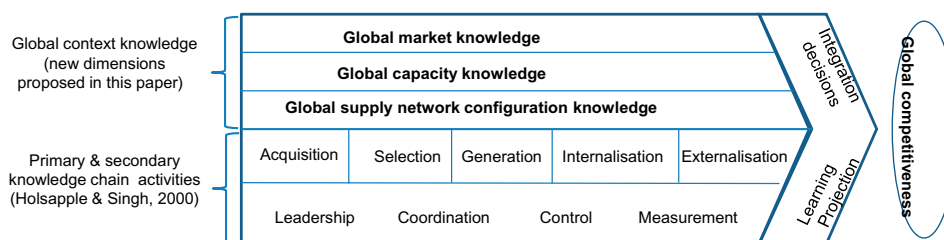


Figure 1. GKCM model.

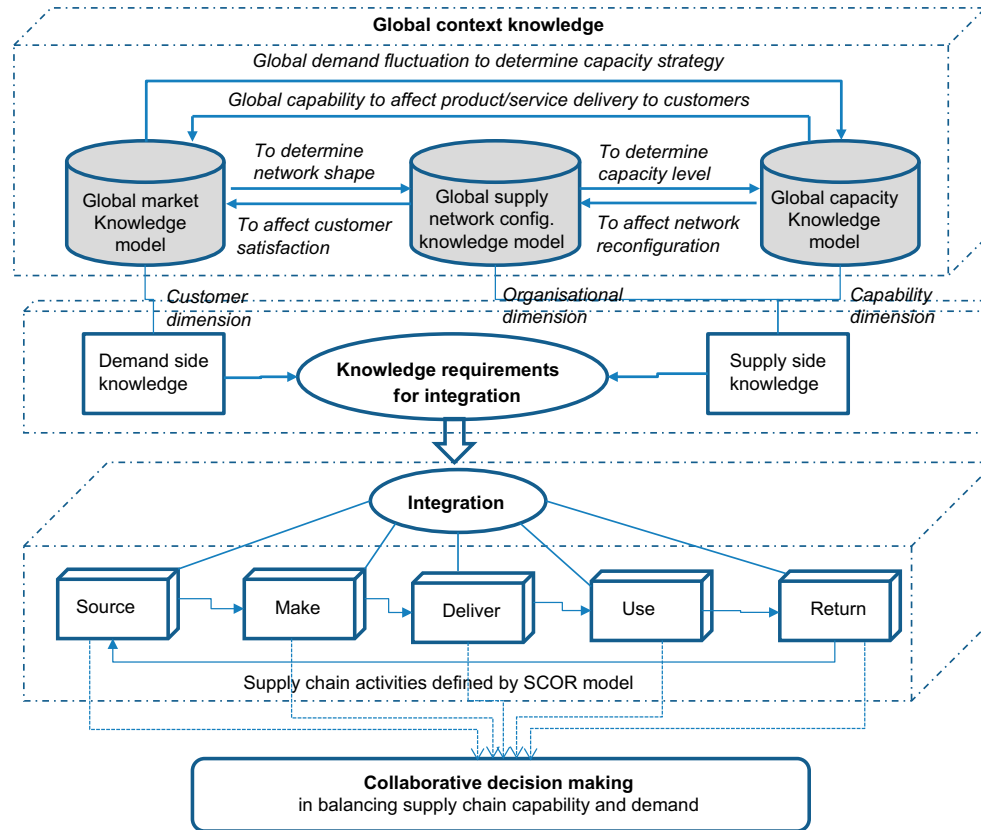


Figure 2. Knowledge integration to support collaborative decision-making between supply chain activities.

supply chain context include the supply network shape decisions and supply network capacity decisions. Collaborative decision-making on supply network takes in the network configuration knowledge, which in turn is based on global market knowledge. The global capacity knowledge will provide direct input to the collaborative decision-making in supply network capability. The integration of the three types of knowledge (i.e. global market knowledge, configuration knowledge and capacity knowledge) along with the global supply chain will ensure the essential support for the collaborative decision-making between supply chain partners, in balancing the supply side capacity with the demand side market requirements, to achieve optimal overall supply chain performance.

4. Research methodology

The objective of this study is to identify and prioritise the critical knowledge constructs in a global supply chain context. As there are few existing studies that show how a supply chain can transform such knowledge to improve its integrated decisions and to enhance its global competitiveness by analysing the knowledge chains, this study is considered as highly explorative.

Therefore, the research methodology for this study comprises two purposeful components: in-depth interviews combined with an analytic network process (ANP) for data collection and analysis.

In-depth interviews were considered appropriate based on the exploratory nature of the study. In-depth interviews can provide the researchers with the opportunity to probe participants' answers, especially where the researchers want the interviewees to explain or build on their responses. Supply chain and operations managers, as potential interviewees, tend to use words and ideas in a particular way, especially when they deal with cross country/culture global supply chains. The opportunity to probe these meanings through in-depth interviews can add significance and depth to the data obtained. The companies solicited for the empirical study operate at an international level with a global manufacturing focus in the automotive sector. Participants in the interviews were supply chain managers. All the individuals who were interviewed have direct or partial responsibility for international supply chain functioning and regularly make global supply chain decisions.

Data collection and analysis incorporated the ANP proposed by Saaty and Vargas (2006), in order to prioritise the core knowledge constructs based on how

important supply chain managers think the knowledge elements in supporting their decision-making practices. ANP is a well-known method which can offer pairwise comparisons by taking account of expert judgements to derive priority scales. Along with the development of dedicated software tools such as Super Decisions[®], to facilitate ANP implementation, the efficiency issue is greatly alleviated. ANP is therefore widely used in business management including supply chain decision-making (Raisinghani and Meade 2005).

The interview questions were composed of two main parts: part one focused on identifying the critical knowledge elements in the three global context knowledge types (market, capacity and network configuration); part two asked participants to prioritise the knowledge elements by quantifying the comparative importance they value the knowledge elements in terms of its contribution to supply chain integration decisions. A pilot study was undertaken with six supply chain professionals in order to refine the interview questions. In total, over 40 supply chain and operations managers from the automotive industry took part in the in-depth interview process. Based on the data collected from the interviews, knowledge constructs that are critical to automotive global supply chain integration decisions have been identified, and prioritised using the ANP. Pairwise comparisons and calculation of overall priorities have been conducted with the facilitation from the dedicated software Super Decisions[®]. The key reason to have selected the automotive industry for the empirical study is based on the fact that vehicles are one of the most complex products and that the industry provides mature supply chains with a global nature. The evolution of the automotive global supply chains from the traditional tier-based model to modern integrator-based model has been discussed in the authors' previous publication (Liu, Young, and Ding 2011). Empirical results from the authors' recent research on KCM are presented in the next section.

5. Empirical data analysis and findings

5.1. Identifying critical knowledge

The main objective of the first part of the interviews is to ask interviewees about 'what', i.e. what knowledge elements they think are most critical to global supply chain integration decisions. All knowledge elements from the interviewees were recorded in the 'critical knowledge elements list'. A knowledge classification scheme was devised to conduct the analysis of the data collected. The data analysis consists of three key steps. Step 1 is to develop a classification scheme, Step 2 to specify assignment criteria, and Step 3 to associate the knowledge elements with the classification scheme. The development of the classification scheme is guided by the GKCM

conceptual framework presented in Section 3. The classification scheme has two levels: a knowledge category level on the top and knowledge constructs on Level 2. The top level of the classification scheme has three knowledge categories: global market knowledge, global capacity knowledge and global supply network configuration knowledge. Each knowledge category then has a series of knowledge constructs on the second level. Following the development of the classification scheme, the next step is to specify assignment criteria/rules in order to determine what data units will be associated with which knowledge constructs. For example, a data unit will be associated with customer knowledge if it concerns knowledge about customer needs (e.g. do customers need a stylish car or an economical car), customer preferences (e.g. would customers put car styling ahead of fuel consumption efficiency), and customer profile (e.g. their income level to decide how likely they are to purchase a car). After the classification scheme and the assignment criteria have been devised, the next step is to assign relevant data units to the appropriate slots for knowledge elements and categories in the scheme. The frequency of knowledge elements identified by different interviewees is counted.

The results of the analysis of 40 interviews are summarised in Table 1. Critical knowledge constructs identified are shown in Column 2 in the Table. Column 3 contains the assignment criteria. The numbers in Column 4 represents the frequency, i.e. the number of interviewees out of the 40 identified the knowledge construct as critical. The higher the frequency count, the more interviewees have identified the knowledge construct as critical for global supply chain integration decisions. If a knowledge element has a frequency count of less than four (less than 10% interviewees identified it as critical) then it is considered as non-critical knowledge and therefore has been removed from the Table for the purpose of clarity. Based on the results shown in Table 1, customer knowledge has been identified as critical knowledge with a maximum score of 40, which indicates that all interviewees recognised the importance of customer knowledge in the decision-making process for global supply chain integration. There are another four knowledge constructs which have been identified as critical with high scores from interviewees. They are network shape knowledge (36), competitor knowledge (34), market specific regulatory knowledge (32) and network integration knowledge (33).

5.2. Prioritising critical knowledge

This section focuses on 'how' important of the identified critical knowledge, i.e. prioritising the critical knowledge by incorporating experts' judgement with relative comparisons of the critical knowledge. ANP method (Saaty

Table 1. Classification of critical knowledge identified through interviews.

Knowledge category	Critical knowledge constructs	Assignment criteria	Frequency
Global market knowledge	Customer knowledge	Customer needs, customer preferences, customer profile	40
	Competitor knowledge	Bench-marking, threat level, competitors' ability and marketing strategy	34
	Complementor knowledge	Complementators' product and service profile	8
	Market specific regulatory knowledge	End-of-life vehicle directives, vehicle safety regulations, vehicle emission control policy	32
Global capacity knowledge	Demand fluctuation knowledge	Demand statistics, market change patterns, market forecasting, market uncertainty factors	27
	Global capacity measure knowledge	Capacity aggregation, design capacity, effective capacity	23
	Global capacity constraints knowledge	Capacity ceiling and bottleneck	25
	Capacity strategy knowledge	Capacity leading strategy, capacity lagging strategy, alternative capacity plans (e.g. level capacity, chase demand, management demand)	18
Global supply network configuration knowledge	Capacity balancing knowledge	Capacity smoothing, capacity adjusting	11
	Network shape knowledge	Shape of immediate network, shape of downstream end of network, shape of upstream end of network, location decision method (e.g. centre-of-gravity method or weighted score method)	36
	Disintermediation knowledge	Bypassing some customers, bypassing some suppliers	21
	Co-opetition knowledge	Co-opetition strategies	10
	Network integration knowledge	Vertical integration, horizontal integration, backward integration, forward integration, balanced integration	33
	Network re-configuration knowledge	Dynamics of participants joining and leaving the network	18

and Vargas 2006) is explored for this purpose. A key step of exploring the ANP method in KCM is to develop an overall control network which clearly defines the KM criteria, alternative knowledge constructs and the relationships between them. Figure 3 shows the top level ANP-GKCM control network which defines five criteria for KM and the three knowledge categories and their bi-directional relationships represented by links, in the context of GKCM.

The five criteria for KM derived from the literature (Jashapara 2011; O'Dell and Hubert 2011) are: C_1 – immediate performance improvement (short term goals), assessed by measures such as repeated customer complaints resolved and sales (process) efficiency improved, for example closing a deal more quickly; C_2 – threats and assumptions about knowledge in the global supply chain's long term goals, i.e. core knowledge that needs to be captured and retained, and how an enhanced flow of knowledge across the global supply chain will improve the learning cycle for less experienced employees and partners; C_3 – value proposition to marketplace, i.e. does the global supply chain want to compete on the basis of customer knowledge and service, product development and time-to-market, or low cost, high-quality operations? C_4 – impending challenges that could stop

the global supply chain from meeting its strategic goals, i.e. to align with the supply chain's strategies; and C_5 – stakeholders' expectations from KM programmes, including KM strategy for all partners and flow of knowledge throughout the global supply chain. The three knowledge categories as discussed in previous sections are: K_1 – global market knowledge; K_2 – global capacity knowledge; and K_3 – global supply network configuration knowledge.

Under the guidance of the ANP-GKCM control network, the same 40 interviewees who participated in the critical knowledge identification were asked to make pairwise comparisons based on their judgement of the relative importance of different knowledge clusters with respect to the five criteria. In the pairwise comparison process, a ratio scoring system suggested by Saaty and Vargas (2006) has been employed. A judgment or comparison is the numerical representation of a relationship between two elements. Each judgment reflects the answers to two questions: which of the two elements is more important with respect to a higher level criterion, and how strongly, using the 1–9 scale where scale 9 means that one element is extremely important compared with the other, and scale 1 means that both elements have equal importance.

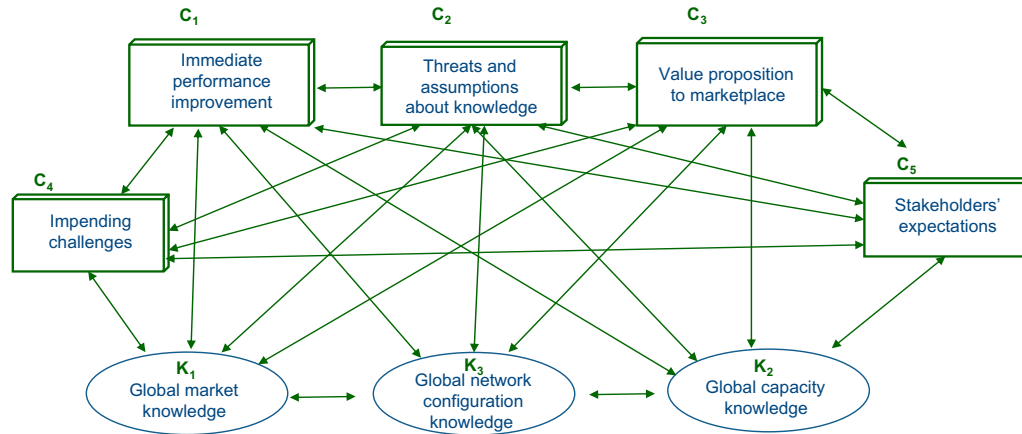


Figure 3. The ANP-GKCM control network.

Table 2. Super-matrix for the knowledge prioritising.

	C_1	C_2	C_3	C_4	C_5	K_1	K_2	K_3
C_1	0	0	0	0	0	0.43795	0.05373	0.04348
C_2	0	0	0	0	0	0.08759	0.35104	0.21348
C_3	0	0	0	0	0	0.14598	0.14598	0.17391
C_4	0	0	0	0	0	0.10949	0.10949	0.26067
C_5	0	0	0	0	0	0.21698	0.21896	0.30435
K_1	0.72187	0.07692	0.74468	0.74468	0.63158	0	0	0
K_2	0.17500	0.38401	0.14894	0.10638	0.21053	0	0	0
K_3	0.10312	0.53846	0.10638	0.14894	0.15789	0	0	0

Synthesising all the pairwise comparison matrices developed, a super-matrix based on the vector weights is shown in Table 2, using the dedicated software Super Decisions[®]. This unlimited super-matrix must be transformed into a weighted super-matrix in order to obtain meaningful results. To do this, firstly the influence of the clusters on each other is determined, which generates an eigenvector of the influences. Then the un-weighted super-matrix is multiplied by the priority weights from the clusters, which yields the weighted super-matrix. The final step in the ANP analysis process is to stabilise the super-matrix. This step involves multiplying the weighted super-matrix by itself until the row values converge to the same value for each column of the matrix. At the end of this step, the limiting priorities of all the knowledge elements and clusters are computed. The elements and clusters with the highest global priority become apparent and are identified as the most critical knowledge. The final global priorities for criteria and knowledge clusters are calculated using Super Decisions[®].

The principal findings from the empirical data analysis include that:

- All participants have prioritised global market knowledge as the most critical knowledge and reported that they integrated global market

knowledge into their global supply chain decisions for integrating planning, sourcing, making, delivering and returning activities. Knowledge about customer needs and preferences has the highest calculated global priorities among all market knowledge elements.

- Over three quarters of the participants (78%) have prioritised the global capacity knowledge as critical in making global supply chain integration decisions. Within the global capacity knowledge, capacity measure knowledge and capacity constraint knowledge have the highest global priority.
- Less than half (44%) of the participants have prioritised global network configuration knowledge as critical knowledge in their supply chain integration decisions. Within this knowledge category, disintermediation (i.e. bypassing some suppliers) knowledge was considered significantly less important than network shape knowledge. The majority of the interviewees were mostly unaware of the co-opetition knowledge.
- There is a consensus view amongst the interviewees that integrating critical knowledge into their decision-making process can significantly improve the global supply chain overall performance.

6. Discussion and conclusions

This paper discussed a GKCM framework focusing on identifying and prioritising critical knowledge for global supply chain integration decisions. Three knowledge types have been addressed, i.e. the context knowledge about the global market, global capacity, and global network configuration. Inter-relationships between the knowledge types have been specified. A key contribution of this paper is the empirical demonstration that advances the knowledge chain model theorised in the literature stressing the KCM issue within one organisation (Holsapple and Singh 2001) and local supply chains (Khadivar et al. 2007), to include the context knowledge applicable to global manufacturing. Consequently, the extended GKCM framework can support global supply chain integration decisions. A key benefit of exploring critical knowledge for GKCM is that it enables 'just-enough knowledge' for the success of global operations through improved 'time-to-decision'. Ultimately, the prioritised knowledge and the integration of the knowledge types through the knowledge chain model can efficiently support the collaborative decision-making between various supply chain partners, specifically, in balancing the supply side capacity with the demand side market requirements.

Managerial implications include the recognition that context knowledge from both demand and supply sides is important for global supply chain management, especially in the integration of planning, sourcing, making, delivering and returning. It suggests that companies involved in global manufacturing should invest in obtaining global market, capacity and network configuration knowledge, identifying and prioritising the most critical knowledge, so that the supply chain wide KM strategy can be aligned with the global supply chain's overall performance objectives.

The limitations of the work are that: (1) the empirical study undertaken is restricted to companies in the automotive manufacturing sector, which makes it difficult to generalise the findings into other organisational settings such as the service industry; (2) the main instrument used for empirical data collection was in-depth interviews, which limited the scope of empirical study.

Future research will extend the work to include companies in wider manufacturing sectors, especially those belonging to more nascent, dynamic global supply chains. Exploratory research through observation of supply chain managers will also help to triangulate the empirical data for more precise and detailed knowledge about how the decision-makers integrate the critical knowledge with respect to global market, capacity and network configuration knowledge into their everyday work decision-making process. Further research will also investigate knowledge measurement efficiency and

mechanisms that can help to determine the optimal level of critical knowledge for a global knowledge inventory, if indeed an optimal level can be established. The proposed GKCM framework can be further consolidated if the global supply chain can determine the relative magnitude of input variables. For example, do particular critical knowledge elements exhibit relatively high or low knowledge subtractions (due to a dynamic environment characterised by outflows resulting from decay and obsolescence)? Within global supply chains it would be necessary to determine the amount of knowledge inflow, in particular, when and how much critical knowledge to order. In this circumstance, it will be useful to establish the pace of the knowledge subtraction and acquisition.

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