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To cite this article: David L. Olson (2018) View of IJPR contributions to knowledge management in supply chains, International Journal of Production Research, 56:1-2, 733-742, DOI: [10.1080/00207543.2017.1398427](https://doi.org/10.1080/00207543.2017.1398427)

To link to this article: <https://doi.org/10.1080/00207543.2017.1398427>



Published online: 13 Nov 2017.



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View of IJPR contributions to knowledge management in supply chains

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(Received 2 June 2017; accepted 19 October 2017)

Knowledge management can be viewed as the ability to identify, store and retrieve knowledge. This paper presents a view of four perspectives of IJPR papers related to knowledge management, focusing on the specific perspectives related to information systems, computer software and analytics support of supply chain management. IJPR publications since 2006 that used these key terms are included in a primitive network analysis of these papers. A dichotomy of knowledge management into information systems versus quantitative analysis is detected, with some minimal overlap. This analysis elaborates the evolution of both analytics and information systems in knowledge management. The network is also viewed from specific relation to three fields considered important now and in the near future: sustainability, multiple criteria decision-making and supply chain risk management. The intent is to identify a view of the state-of-the-art of IJPR published research related to knowledge management in supply chains.

Keywords: supply chain collaboration; knowledge management; business analytics; business information system; networks

1. Introduction

Olson (2016) and Olson and Wu (2017b) described knowledge management to be the broad field including identification, acquisition, storage and retrieval of information to aid decision-making. These four functions are processes of knowledge management. Identification requires focusing on the information important in supporting organisational decision-making, selecting the best available measures to support these decisions. Knowledge acquisition involves getting the data providing these measures, which can involve aggregating data from internal systems such as ERP, extracting data from governmental or commercial sources for data external to the organisation and even conducting research to obtain more specific data. Storage is usually an information systems or information technology task, supplemented by individual databases. And what is entered into storage needs to be retrievable.

Knowledge management (KM) today is characterised by the existence of big data (Chae and Olson 2013). The advent of i-phones and other hand-held devices has led to an explosion in data. Our culture has become obsessed with sharing many details about ourselves. Some of this self-centred desire to share everything about ourselves with the world has been found useful to many retail organisations. There also is a great deal of useful information generated from e-business activity. Thus, we have big data, too massive to store on a single server, too unstructured to fit within standard spreadsheet formats, continuously generated, with little structure (Davenport 2014). This big data explosion has had highly important impact on knowledge management, offering many opportunities to business organisations and to identity thieves.

Knowledge management (KM) is process-oriented, thinking in terms of how knowledge can be acquired, as well as tools to aid decision-making. Rothberg and Erickson's (2005) framework defined data as observation, which when put into context becomes information, which in turn can be processed by human understanding to become knowledge. Big data can be a source used to generate insights, innovation and business value by providing real-time measures of performance, more timely analyses based on more complete data, and can lead to sounder decisions (Manyika et al. 2011).

Knowledge management is important in many areas, to include production. Hedbweg et al. (2017) looked at the relationship of specific manufacturing knowledge in terms of product characteristics, seeking better understanding of what knowledge would be the most important. In the context of supply chain management, Cerchione and Esposito (2016) described the KM process to consist of knowledge creation, storage, transfer and sharing. Liu et al. (2013) focused on lean supply chain management in terms of knowledge layers (know what, know why, know-how and know who with), to seek ways to eliminate waste in a system.

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This paper presents a supply chain frame of reference of knowledge management in supply chain management, to include evolution of the field. The author has been involved in some papers in *IJPR* involving supply chain research. Some have involved analytic approaches to forecasting (Flores, Olson, and Pearce 1993, 1994), vendor selection (Wu and Olson 2008, 2010) and inventory control (Swenseth and Olson 2016). Others have had a supply chain software focus (Olson, Chae, and Sheu 2012; Chae, Olson, and Sheu 2014; Chae et al. 2014). Papers in the 1990s predate the interest in knowledge management, although of course they included application of analysis to improve business (specifically supply chain) decision-making. Knowledge management interest arose in the twenty first century with strains of interest in the information system aspects as well as focus on analytics. The aim of the paper is to review *IJPR* publications over the past decade related to knowledge management with focus on the author's publications related to information systems software and analytic support (decision support systems and data mining). There are of course many other aspects of interest to others, but the aim here is more limited. It focuses on information systems (computer software and big data) as well as analytic support. *IJPR* publications 2006–2016 that used these key terms are evaluated. A primitive network analysis of these papers is conducted. This analysis elaborates the evolution of both analytics and information systems in knowledge management. The intent is to identify a view of the state-of-the-art of *IJPR* published research related to knowledge management in supply chains. The network is also viewed from specific relation to three fields of personal interest: sustainability, multiple criteria decision-making and supply chain risk management.

Section 2 reviews literature related to knowledge management from the perspectives of information systems, computer software support, data management and analytics. The methodology used is covered in Section 3, along with discussion of data management and analytics in the context of supply chain knowledge management. Section 4 presents the bulk of paper topics to include the network of clusters. Section 5 is a summary.

2. Literature review

Information systems provide decision-makers with inputs, and analytics gives decision makers tools to make sense of how these inputs can be used (Olson 2016). Information systems aspects of knowledge identification, acquisition, sharing and distribution are important. Knowledge identification was addressed in *IJPR* by Irani, Sharif, and Love (2007), who presented a case involving knowledge drivers and constructs that were used in a manufacturing environment to develop knowledge maps. Knowledge acquisition has been addressed in five *IJPR* papers, to include system proposals by Choudhary et al. (2011), as well as an empirical study by Yang (2013). Knowledge development was a key focus of four *IJPR* papers, including an ontological framework addressing what, how, why and who by Wu et al. (2014). Knowledge sharing and distribution is more commonly studied in *IJPR*, with search revealing 12 papers, including an ontology for manufacturing by Lin et al. (2011). Knowledge retention and utilisation was empirically studied by Migdadi and Abu Zaid (2016). While these process-focused views are useful, we will look at perspectives of knowledge management from the orthogonal frames of information systems and analytics.

2.1 Knowledge management from the IS perspective

Gunasekaran and Ngai (2007) presented a framework for knowledge management in supply chains from the aspect of information technologies. Criteria were evaluated in terms of supply chain function, to include design and engineering, production, distribution and information technology. In our search, while no *IJPR* papers with keywords of knowledge management in combination with storage were found, knowledge management has been thoroughly examined in the information systems (IS) field. Supply chain organisations, especially need to utilise such tools to survive in the face of global competition, constantly learning and adapting to rapidly changing conditions. Knowledge management is often proposed as a key for building competency in this environment (Wang, Klein, and James 2007). From the IS perspective, knowledge can be defined as information plus the causal links that help to make sense of this information, and as a process establishing and articulating these links (Savary 1999; McGinnis and Huang 2007).

2.2 Computer system support to knowledge management

In the 1970s and 1980s, there was a great deal of interest in decision support systems, computer systems applied to support business decision-making (Keen and Scott Morton 1978; Sprague and Carlson 1982; Olson and Courtney 1992; Turban, Sharda, and Delen 2014). Personal computers were used to provide analytic tools for specific problems. Executive support systems were extensions on this theme marketed with the aim of providing dedicated service to top executives who were expected to want key data at their fingertips. A more successful commercial application was online

analytic processing, database spreadsheet software capable of generating reports using selected dimensions such as time, area, product, department, customers or other key variables.

The above applications were more information system-focused. Statisticians and artificial intelligence researchers were participants in the emerging field of data mining, seeking interesting patterns in large scale data. The quantitative aspect of this field is business analytics. The professional society INFORMS (Institute for Operations Research and Management Sciences) has taken the buzzword 'business analytics' as its marketing theme, with some valid justification. Quantitative analysis of business data applied to organisational decision-making is a valuable effort, growing in popularity so rapidly that most business colleges are moving to revise their curricula to include greater emphasis on this focus.

2.3 The data management perspective

We live in an environment driven by data (Olson 2016; Olson and Wu 2017b). Schoenherr, Griffith, and Chandra (2014) gave a supply chain knowledge management process from the perspective of data management, consisting of acquiring data, converting it into appropriate form, applying it (through knowledge aiding decision-making) and protecting it (data security). There have been many studies of supply chain data management, to include quality control aspects (Foster, Wallin, and Ogden 2011; Kumar and Schmitz 2011) and information sharing (Ma et al. 2013).

Three aspects of big data found important are volume, velocity and variety (Waller and Fawcett 2013).

- Volume is an important aspect of knowledge management, as streams of data arrive in real time from cash registers. Large organisations such as Walmart have found it worthwhile to capture this information, aggregate it, providing capability to generate customer profiles to enable real-time marketing opportunities custom tailored to milk the maximum revenue stream from each source. This information can also be used to manage inventories, and to deal with vendors.
- Velocity is important to enable real-time response. One of the most voluminous types of data is the weather data generated by satellites, streamed back to earth-bound computers, which need to process this information and feed useful information to weather reporters throughout the world. Military operations also have high-velocity information that needs to be made sense of to enable rapid decisions concerning targeting and other military applications. Retail business also needs to be able to operate in real-time, which requires high-velocity capabilities.
- Variety is important in many applications. Social media generate data useful to retail businesses. This social media data consist of many data formats, to include networks of links, photographic data, movie data, etc. The medical industry has become a major part of the global economy, with even more complex data formats, to include MRI data, DNA data and ever-evolving new format types.

The importance of data management is exemplified by Amazon, who prospers by understanding what their customers want, and delivering content in effective ways. Walmart has also been very successful, using electronic means to gather sales in real time, storing 65 weeks of data in massive data warehouse systems that they intensively mine to support inventory, pricing, transportation and other decisions related to their business. Data management also is found in governmental operations. The National Weather Service has collected unbelievable quantities of information related to weather, harnessing high-end computing power to improve weather prediction. NASA has developed a knowledge base of physical relationships enabling space activities (Olson 2016; Olson and Wu 2017b).

2.4 The analytics perspective

The analytics perspective of supply chain knowledge management involves various forms of management science, which has been around since the Second World War, and in the field of inventory management, longer than that. Zimmer, Fröhling, and Schultmann (2016) gave a recent review of model use in the specific aspect of sustainability. There have been many applications of models to many supply chain decisions, to include sustainability (Sarkis 2003) and risk management (Ivanov et al. 2016).

Davenport (2013) reviewed three eras of analytics. In the first, business intelligence, focused on computer systems such as decision support systems harnessing custom-selected data and models. In the early twenty-first century, big data generated from internet and social media provided a second focus. Davenport saw a third era involving a data-enriched environment with online real-time analysis.

The Internet of Things provides an additional source of big data. Just as people can communicate through text, e-mail and other forms of communication, machines communicate with each other (Kellmerit and Obodovski 2013). In the healthcare industry, Fitbits and other personal monitoring devices generate data that could conceivably link to personal physicians. The problem physicians would have coping with this potential flood of data is thought provoking.

How people ever survived until 2010 is truly a wonder. Out of massive quantum amounts of data, only a minuscule bit is germane. Of course, signals are sent only when critical limits are reached, but if the system scales up to include the majority of the billions of people inhabiting the earth, it would seem that some means of management of data volume would grow in importance. But related applications include vending machine signals monitored for stock replenishment, home electricity monitoring and automobile signals to dealers and mechanics concerning engine problems. Some insurance firms already market their ability to attach devices to cars to identify good drivers, a euphemism for detection of bad driving so that they can cancel policies more likely to call for claims.

3. Supply chain knowledge management

Supply chain management involves requirements to keep on top of key knowledge. Understanding, monitoring and control of operations at all stages of supply chains, to include sourcing, logistics, production and retail delivery to customers is important. We will consider the two aspects of data management as well as analytics based on Olson (2016) and Olson and Wu (2017b).

3.1 Data management in supply chains

Use of all of these data requires increased data storage, the next link in knowledge management. It also is supported by a new data environment, allowing release from the old statistical reliance on sampling, because masses of data usually use population data and preclude the need for sampling. This also leads to a change in emphasis from hypothesis generation and testing to more reliance on pattern recognition supported by machine learning. A prime example of what can be accomplished is customer relationship management, where every detail of company interaction with each customer can be stored and recalled to analyse for likely interest in other company products, or management of their credit, all designed to optimise company revenue from every customer.

The dictionary definition of knowledge is the expertise obtained through experience or education leading to understanding of a subject. Knowledge acquisition refers to the processes of perception, learning and reasoning to capture, structure and represent knowledge from all sources for the purpose of storing, sharing and implementing this knowledge. Our current age has seen the emergence of viewing knowledge as those things that can lead to improvement of our society.

Knowledge discovery involves the process of obtaining knowledge, which of course can be accomplished in many ways. Some learn by observing, others by theorising, yet others by listening to authority. Almost all of us learn in different combinations of these methods, synthesising different, often conflicting bits of data to develop our own view of the world. Knowledge management takes knowledge no matter how it is discovered and provides a system to provide support to organisational decision-making.

In a more specific sense, knowledge discovery involves finding interesting patterns from data stored in large databases through use of computer analysis. In this context, the term interesting implies non-trivial, implicit, previously unknown, easily understood, useful and actionable knowledge. Information is defined as the patterns, correlations, rules or relationships in data providing knowledge useful in decision-making.

3.2 Supply chain analytics

There are many applications of quantitative analysis, falling within the overall framework of the term business analytics. Analytics has been around since statistics became widespread. Business analytics involves four types of analytic tools. Descriptive analytics focus on reports. Statistics are a big part of that. Descriptive models are an example of unsupervised learning, where algorithms such as clustering may identify relationships without user direction. They don't predict some target value, but rather try to provide clues to data structure, relationships and connectedness. Predictive analytics offer forecasting capability. They are directed in the sense that a target is defined. This can be a continuous variable to forecast. They also apply to categorical output, especially classification modelling that applies models to suggest better ways of doing things, to include identification of the most likely customer profiles to send marketing materials, or to flag suspicious insurance claims, or many other applications. Diagnostic analytics includes automatic control systems. This is especially useful in mechanical or chemical environments where speed and safety considerations make it attractive to replace human monitors with automated systems as much as possible. It can lead to some problems, such as bringing stock markets to their knees for short periods (until humans can regain control). Prescriptive analytics includes optimisation models, which can lead to improving systems. Data mining includes descriptive and predictive modelling.

Knowledge management in supply chains includes a number of components. This paper considers performance management resources, information systems, sources of data and analytic tools. Each of these has different functions, with different tools available for knowledge management support. Table 1 presents this paper's view of supply chain knowledge management:

4. IJPR supply chain knowledge management network analysis

Chircu et al. (2016) applied a form of text mining to view business analytics as applied in supply chain operations. They reviewed some 194 academic papers along with 431 industry articles, and generated clusters of papers. In their academic papers, they identified three major clusters: Enterprise resource planning system development, data warehouse approach and business intelligence analysis and decision support. Here, our purpose is not to replicate that study, but we do take their idea of searching the EBSCO database using key words for *IJPR* papers, and use this to identify papers in terms of supply chain software, business analytics and data support. We focused on the period 2006–2016 as more current reflections of knowledge management applied to supply chain research. There are older publications in *IJPR* related to knowledge management, but the focus tended to be more on topics such as expert systems, production planning. The 2006 cut-off was selected, admittedly arbitrarily, to represent a clearer focus on the use of software and analytics to aid supply chain decision-making. In the 2006–2016 period, 84 papers were obtained. The abstracts and key words were analysed to categorise topics and overlaps. There is an admitted degree of personal subjectivity involved, but the intent is to identify a view of the state-of-the-art of *IJPR* published research related to knowledge management in supply chains.

In the software cluster, focus was given to the terms:

- Supply chain software
- MRP
- ERP
- BPR (process mining)

We searched for data terms:

- Data management
- Database
- Big Data

The analytics cluster was represented by:

- Business intelligence
- Analytics
- Decision support systems
- Data mining

The EBSCO search engine was used to identify papers by cluster. Figure 1 shows these counts within each topic, as well as link counts to other terms.

Table 1. A view of knowledge management.

KM component	Functional	Elaboration
Performance management resources	How things are done (tacit knowledge; BPR)	Process control Six Sigma
Information systems	Databases, reports, decision support	Cloud computing
Data sources	ERP & related systems External sources Big data	RFID Government publications Social media
Analytics	Descriptive analysis Data mining	Classification Prediction Clustering Link analysis Text mining
	Operations research	Mathematical programming Stochastic modelling Monte Carlo simulation

4.1 Sustainability applications

Supply chain sustainability is very important, and has received a great deal of attention. In Table 2, the key terms under which sustainability papers appeared were analytics (10 papers) and DSS (6 papers). Of the 10 analytics papers addressing sustainability issues, 1 applied mathematical programming, while the other 9 all applied either analytic hierarchy process (AHP) or its variant, analytic network processing (ANP). Of the six DSS-related papers that referred to sustainability terms, two applied AHP and one expert systems to model standard supply chain problems. Koh et al. (2013) focused on a DSS for carbon dioxide mitigation, while Li (2013) applied simulation modelling to sustainable manufacturing. Kumar et al. (2015) developed a DSS based on a taxonomy which was empirically replicated, and analysed through cluster analysis. These *IJPR* papers demonstrate strong interest in sustainability features, to include consideration of multiple, conflicting objectives. Zimmer, Fröhling, and Schultmann (2016) reviewed 143 papers published between 1997 and 2014 involving supply chain sustainability, supporting the predominance of AHP/ANP as well as fuzzy modelling, with social matters underrepresented.

4.2 Multiple criteria modelling support

The European emphasis on the triple bottom line naturally leads to consideration of multiple criteria. Hollos, Blome, and Foerstl (2012) surveyed West European firms in regard to sustainable supplier cooperation, finding general positive effects of cooperation across the three key factors of social, conservation and economic performance. Tsai and Hung (2009) applied fuzzy goal programming to a green supply chain model.

Unlike in the sustainability-focused papers, papers applying multiple criteria were found in data or information system articles (admittedly a small number). In the topic area of supply chain software, Wong and Fang (2010) applied utility theory in discussing supply chain negotiation, offering a DSS-like system for support. Cruz (2013) gave a multiple criteria model to support supply chain risk analysis involving corporate social responsibility. Shukla and Kiridena (2016) applied rough set analysis in the context of distributed manufacturing supply chains. In the topic area of ERP,

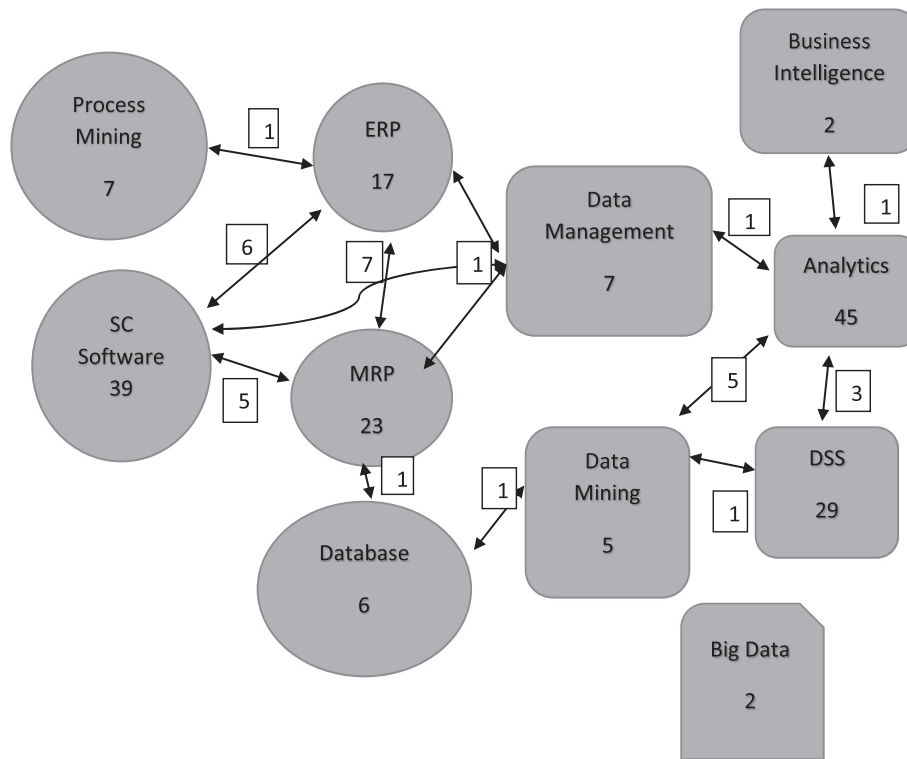


Figure 1. Term network.

Table 2. References to terms of interest.

Key term	Total papers	Sustainability	MCDM	Supply chain risk
SC software	39	0	3	2
MRP	23	0	0	0
ERP	17	0	1	0
Analytics	45	10	25	6
DSS	29	6	4	3
Data mining	5	0	1	0
Business intelligence	2	0	0	1
Big data	2	0	0	0

Zandi (2014) proposed coordination of ERP modules and processes through a linear programming multidimensional analysis of preference.

On the analytic side, there are many multiple criteria studies, with 25 appearing in our Analytics category, and another 4 in DSS. There was also a rough set model presented applying clustering of suppliers using rough set theory offered by Parmar et al. (2010).

4.3 Supply chain risk analysis

There were a total of 11 papers in the supply chain knowledge management joint set (one overlapped business intelligence and analytics categories) in *IJPR*. Two of these were related to supply chain software. Datta and Christopher (2011) investigated information sharing and coordination effectiveness in reducing uncertainty within supply chains, focusing on the impact of unexpected large demand swings. The other paper in this category was Cruz's (2013) multiple criteria model involving corporate social responsibility, balancing profit and risk. There were no ERP or MRP papers involving supply chain risk management.

On the analytic side, there were nine papers relating to supply chain risk. Huang, Chou, and Chang (2009) provided a dynamic systems model of supply chain disaster management. Day (2014) used complex adaptive supply network framework to sort disaster relief literature. Yang and Fan (2016) in turn used control theory modelling and simulation to compare supply chain disruption strategies from the information system perspective. Zsidisin, Petkova, and Dam (2016) reviewed supply chain disruption impact on shareholder wealth, while Shi and Feng (2016) analysed supply contract potential value from the supplier perspective. Samvedi, Jain, and Chan (2013) used fuzzy AHP and TOPSIS models to create risk indices for supply chain situations, overlapping the multiple criteria literature.

Papers specifically using the term decision support systems involving supply chain risk management included Feng, D'Amours, and Beaugard (2010), who applied simulation models and performance analysis in make-to-order supply chains. Li and Amini (2012) offered an integrated supply chain configuration and new product diffusion model to consider demand dynamics. Finally, Micheli, Mogre, and Perego (2014) provided a quantitative DSS to select mitigation measures based on stochastic integer programming.

5. Summary

The primary purpose of knowledge management is to wade through all of this noise to pick out useful patterns. That is data mining in a nutshell (Olson 2016; Olson and Wu 2017b). Thus, knowledge management in supply chains is viewed as:

- Gathering appropriate data
 - Filtering out noise
- Storing data (DATABASE MANAGEMENT)
- Interpret data and model (DATA MINING)
 - Generate reports for repetitive operations
 - Provide data as inputs for special studies

This review of the state-of-the-art of *IJPR* published research related to knowledge management in supply chains indicates that descriptive modelling is usually applied to initial data analysis, where the intent is to gain initial understanding of the data, or to special kinds of data involving relationships or links between objects.

The papers of *IJPR* cover both the information processing and analytic sides of knowledge management. There are clearly fewer information system-related papers than journals designed specifically for what most call MIS, but the importance of tools to manage data, especially big data, are important enough to require some overlap. The number of MRP and ERP papers in *IJPR* was a bit surprising, but these are important topics that need to be considered when studying knowledge management. Overlaps aside, there is practically even balance between the broad categories of information system focus and analytics focus. Both are very important in supply chain management.

There are a number of important supply chain topics of study (Olson and Wu 2017a). These include inventory management, lean management and communication across supply chains. This paper focused on three similar topics: sustainability, multiple criteria analysis and risk management. Note that multiple criteria analysis is a tool, overlapping the other two focuses. The selection of these three topics reflects personal interest, and there is no implication that other areas are not as important. These focuses gravitated to the analytic side as opposed to the software side of knowledge management, as software is a tool applicable in general.

The methodology used in this paper is subjective, focusing on matters of interest to the author. However, the procedure can be applied by others to identify chains of interest in whatever topics they choose, and *IJPR* (and other journals) include an evolving number of topics, and fields such as knowledge management, supply chain management and business analytics continue to evolve (as they should). *IJPR* has played a valuable role in providing an outlet for study of the evolving field of production. Figure 1 and Table 2 in this paper give some view of the interlaced linkages of sub-topics within the three areas mentioned in this paragraph. In a broader context, *IJPR* publishes many papers applying specific tools to aid various aspects of managing manufacturing planning and control. At the date of writing, there are seven papers in the *IJPR* print queue of this nature. In terms of future research directions, this paper has focused on only a few aspects, biased by author interest. Future research will and should reflect new directions as new problems arise.

Knowledge management is a critical field in supply chain management literature. It is important to have tools to cope with the explosion in data generated by supply chain operators and their customers. This paper has tried to demonstrate the importance of both software tools and analytic tools in supply chain management.

Disclosure statement

No potential conflict of interest was reported by the author.

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