Logistics information systems: An analysis of software solutions for supply chain co-ordination

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Abstract
Purpose – To review the development of software applications and their functionalities/benefits in relation to supply chain management and present scenarios on future development.

Design/methodology/approach – A range of recently published academic and non-academic pieces of work that can be classified as pertinent to the area in question. These sources employ both theoretical and practical views on the topic of supply chain co-ordination software and related functionalities and resulted benefits.

Findings – There is a significant overlap regarding the functionalities of software applications and the trend of convergence is about to intensify. At the same time the need for real time information will become crucial, putting emphasis on flexible IT-systems that can deal with large amounts of data and are easy to interconnect. In turn this will lead to the growing importance of system integration software and the process of creating standards.

Research limitations/implications – As a result of continuous development and convergence of IT-solutions and turbulent business environment more applied research will be needed in the area of product configuration, RFID-technology, standards in relation to interoperability of software applications (EAI technologies). This scrutiny is based only on written resources and no consultants or manager interviews were employed. Therefore the views of companies are not presented on the issues covered.

Practical implications – The selection of the appropriate software solutions for a company will need more time, expertise and money and the role of suppliers of software packages will become more significant.

Originality/value – This scrutiny stipulates the way the functionalities of software applications evolve with overlap one another and thus helps both researchers and companies to gain a clearer view on the development of supply chain software applications.

Keywords Distribution management, Computer software, Supply chain management

Paper type General review

1. Introduction
Supply chain management (SCM) is an integrative philosophy to manage the total flows of a distribution channel from suppliers level to production, distribution and the ultimately the end customer (Houlihan, 1987; Cooper et al., 1997; Simchi-Levi et al., 2000; Tam et al., 2002, p. 28). The aim is to achieve goals related to total system performance rather than optimisation of a single phase in a logistics chain. Typically the goals for SCM are to increase productivity by reducing total inventory level and cycle time for orders. To achieve these objectives business processes pertaining to material handling, information processing and capital control need to be optimised in relation to the limited resources. In a longer perspective, the customers should see the benefits, which result in the increase in customer satisfaction, market share and ultimately profits (Stevens, 1989). Figure 1 illustrates an example of supply chain. First-tier suppliers are the first part of the system. The next stage, production, is a
central hub in many cases. Production feeds wholesale inventories, which are connected to retail level. There are many companies involved in each category in global complex supply chain networks. Additionally, transportation takes place between each stage.

The development projects related to supply chain management have been related with performance measurement, architecture design for supply chains and productivity improvements. Different kinds of frameworks have been introduced. For example, supply chain operations reference (SCOR) model aims for a standardised approach for developing and benchmarking different types of chains. Collaborative supply chain planning is another attempt to emphasise the cooperation between network entities for achieving global optimum (see, e.g. Chandra and Kumar, 2001, p. 292; Holmström et al., 2002; Fisher et al., 2000).

The technology progress in information technology and the increasing use of Internet in everyday business has created possibilities for software based supply chain management. There are several developers originating from different schools such as ERP, application integration and mathematical supply chain optimisation. Still the basic objectives remained the same: to lower inventory levels and enhance customer service via improved agility of manufacturing (Spahis and Constantinides, 2003, p. 677) This paper investigates the range of software applications vendors, their products functionalities with regard to SCM, the ways of integration of different software applications and the future trends of development of the software applications in these sectors. The ultimate objective is to grasp a picture about the state of development in the software markets linked to the management of supply chains. First the categories of software applications will be presented and after that each sector of SCM will be considered with a view of forthcoming automation prospects. In the end of this scrutiny topics will be outlined open to further research.

2. Aspects for classification of SCM software applications
All the software applications of SCM are ready-made package – applications usually targeted for dealing with a certain set of tasks, e.g. for tracking product related information during the transportation process. These ready made package-software applications are mass-customised products ignoring the specific requirements of a certain business sector and so they are quite problematic. Many companies thus use mix of packages software applications to manage their business. According to a classification SCM-related software applications can be divided into two groups: intra-firm and inter-firm applications.

From the data management point-of-view of supply chains software, applications can be grouped into two classes: transactional and analytical software applications. Transactional software applications are engaged with acquiring, processing and communicating raw data about the firm's past and current supply network operations. This group of software build up POS systems, general ledger systems, quarterly sales reports, e-commerce systems, etc. Analytical software applications deal with developing and applying systems for evaluating and disseminating decisions models based on supply chain decision databases. For instance, one can mention

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**Figure 1.**
An example of supply chain structure

- Supplier
- Production
- Wholesale
- Retail
- Customer
production scheduling systems, forecasting systems, or supply chain optimisation systems. There are six different dimensions differentiating these two classes of software (Shapiro, 2002, pp. 7-9):

1. The time-frame addressed: past and present (transactional)/future (analytical).
2. Purpose: reporting (transactional)/forecasting and decision making (analytical).
4. Nature of databases: raw and lightly transformed objective data (transactional)/raw, moderately and heavily transformed data that is both objective and judgemental (analytical).
5. Response time for queries: real-time (transactional)/real-time and batch processing.
6. Implications to business process reengineering: substitute for, or eliminate inefficient human effort (transactional)/improve managerial decision making (analytical).

From the process point-of-view of supply chains there are two main types of SCM software: planning applications and execution applications. The former group of applications use advanced algorithms to determine the best way to fill an order. The latter group of applications track the physical status of goods, the management of materials, and financial information involving all parties. Some SCM software applications are based on open-data models that support the sharing of data both inside and outside the enterprise. This ideal extended-enterprise model contains key suppliers, manufacturers, and end-customers of a specific firm. This shared data may reside in diverse database systems, or data warehouses at several different sites and companies. By sharing this data, key supplier and customers in the supply chain, SCM applications have the potential to improve the time-to-market of products, reduce costs, and allow all parties in the supply chain to better manage current resources for the future needs (Infoscaler, 2001).

Transactional and execution SCM software applications are usually for operational level and serve short-term needs while analytical and planning software packages – such as advanced planning and scheduling systems – fuel strategic and tactical level operations of further future (Figure 2). The different types of classification framework are related to actual functionality of the software. It seems that the software types are overlapping and coming closer to each other in different functionalities. In software selection for an enterprise, sometimes very different types of applications may compete with each other.

3. SCM software
3.1 Warehouse and transport management systems (WMS/TMS)
WMS systems are providing real time views on material flows within the warehouse, i.e. tracking and keeping note of the movement and storage of material within a warehouse facilitating the optimal use of space, labour, and equipments (ARC News, 2004; Piasecky, 2003). From the managers point-of-view this means that a WMS enables to optimise transactions to and from warehouse operators, recognise problem areas and major shifts in activity levels and patterns, while making it possible
continuously determine performance indicators, such as productivity, shipping and inventory accuracy, warehouse order cycle time, and storage density (Frazelle, 2002; Lee, 2002).

Typically WMS systems are well connected to material handling automation and transportation systems. Some WMS systems also include a route planning functionality that makes them related with the TMS systems. Some of the large suppliers of these software products are, amongst others, Marc Global Services, PeopleSoft, SSA Global, Microsoft Business Solutions, Oracle Corporation, JD Edwards, and PULSE Logistics Systems. Table I lists some key functionality of WMS systems and the claimed benefits of using the software.

Transportation management systems (TMS) are software applications that facilitate the procurement of transportation services, the short-term planning and optimisation of transportation activities, and the execution of transportation plans with continuous analysis and collaboration (ARC News, 2004; Rider, 2003, p. 62). They typically provide route planning, transportation control features and advanced

<table>
<thead>
<tr>
<th>Functionality</th>
<th>Claimed benefits</th>
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<tbody>
<tr>
<td><strong>Inventory management</strong></td>
<td>Maintain items, groups, orders</td>
</tr>
<tr>
<td><strong>Order flow</strong></td>
<td>Retrieval orders</td>
</tr>
<tr>
<td></td>
<td>Storage orders</td>
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<td>Track and trace</td>
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**Table I.** Functionality and benefits for WMS

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reporting. These software packages also automate the work of traffic controllers and provide a systematic way to generate documents and labels. Table II presents the functionality provided by typical TMS systems and the claimed benefits for business.

3.2 Enterprise resource planning systems (ERP)
ERP is a business management system made up from a collection of applications that integrates all facets – marketing, finance, human resources, sales, manufacturing, logistics, etc. – of the company into a common database (Hsu and Chen, 2004; p. 42; O’Leary, 2002, pp. 27-28; Al-Mashari, 2003, p. 23; Chang et al., 2002, p. 3).

The basic structure of most ERP’s reminds the others. Figure 3 describes typical modules in ERP systems. The names of software modules may vary, but they all have similar functionality. From an information management point-of-view, the information flows from the upper part of the picture downwards:

- Production master schedule inputs sales orders and forecasts. In case of complex products, the products may be configured prior to taking the sales order in. Order entry and promise system may be connected if all required information is stored in the system.
- MPS generates schedule, whereas materials requirements planning creates purchasing orders for suppliers and production orders for plants based on MPS, capacity, bill-of-materials, and inventory records.
- Inventory statuses are updated based on shipments and receiving of parts, components and finished products.
- Financial control follows the real process. Invoices are sent to customers, employees are paid according to payroll accounting and suppliers are paid with regards to received goods and services. Financial records end up with bookkeeping, which creates the balance sheet as well as profit/loss statement for the fiscal period.

Each part of the software is connected to each other and every piece of information should be stored in only one place. Duplicate records are avoided by linking the information in the single database. In many cases these information systems are

<table>
<thead>
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<tbody>
<tr>
<td>Optimise delivery routes for retailers</td>
<td>Improve processes, drive savings and manage more business without increasing resources</td>
</tr>
<tr>
<td>Operational transportation control: booking,</td>
<td>Improve operational costs in collecting goods from suppliers and delivering to distribution centres. Improved utilisation of fleet</td>
</tr>
<tr>
<td>labelling and document printing, track and trace</td>
<td></td>
</tr>
<tr>
<td>Transportation business control: load tendering</td>
<td>Reduced costs; improved invoicing and tendering system</td>
</tr>
<tr>
<td>Route planning</td>
<td>More precise scheduling; managing scale, constraints, and seasonal fluctuations of its operations</td>
</tr>
<tr>
<td>Real time information</td>
<td>Streamlining reporting and analysis procedures: to achieve real-time inventory information</td>
</tr>
</tbody>
</table>

Table II. Functionality and benefits for TMS
Figure 3.
General structure of ERP system

required to support multiply currencies and languages, specific industries, and an ability to customise without programming as well (O'Leary, 2002, p. 28). Currently, the leading vendors of ERP software applications include SAP, Oracle, BAAN, PeopleSoft, and JD Edwards. Table III summarises the core functionalities and benefits stemming from ERPs.
## Functionality and benefits for ERP

### 3.3 Supply chain management software applications

Supply chain management software applications focus on optimisation of future planning and scheduling activities of inter-enterprise material flow related processes, such as procurement, production, transport, distribution and sales (Kovacs and Paganelli, 2003, pp. 167-168). These advanced planning and scheduling systems employ optimisation technologies of linear programming, heuristics programming, genetic programming and constraint-based programming (Miller, 2003; Van Eck, 2003). High data loads and demanding analysis requirements put robust data storage and processing capabilities into a critical position in these applications. Another application field of SCM optimisation software is advanced planning and scheduling systems, which help scheduling and order promising in large networks. The main functionalities and benefits are listed in Table IV.

The leading SCM software solutions are the following companies:

- i2;
- Aspen Technology;
- SAP APO;
- Oracle;
- Manugistics;

### Table III.

<table>
<thead>
<tr>
<th>Functionality</th>
<th>Claimed benefits</th>
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<tr>
<td>Integrated material handling, human resources and finance control</td>
<td>Integration and standardisation of processes: improved customer service (?)</td>
</tr>
<tr>
<td>Multi-site, multi-languages, multi-user systems</td>
<td>Distributed responsibility, despite information transparency. “bring the organisations’ people, systems and processes together”</td>
</tr>
<tr>
<td>Integration of data storage</td>
<td>Cost savings: each customer or address is entered only once in the system</td>
</tr>
<tr>
<td>Advanced reporting features</td>
<td>Evaluation of customers, products, suppliers etc. Tracking back the habits of doing business and to get more control on the complex system</td>
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### Table IV.

<table>
<thead>
<tr>
<th>Functionality</th>
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<tbody>
<tr>
<td>Supply chain inventory and lot size optimisation</td>
<td>Cycle-time reduction (Grackin and Gilmore, 2004; Miller, 2003; Novak, 2002; Donovan, 2001)</td>
</tr>
<tr>
<td>Available-to-promise/capable-to-promise calculations</td>
<td>Service level gains (Grackin and Gilmore, 2004; Novak, 2002; Donovan, 2001; Layden, 1998)</td>
</tr>
<tr>
<td>Inventory and transportation optimisation; order decoupling point definition</td>
<td>Inventory cost reduction (Grackin and Gilmore, 2004; Miller, 2003; APS Insight, 2001; Donovan, 2001; Layden, 1998; McLaren et al., 2002)</td>
</tr>
<tr>
<td>Reduced inventory points. Merge-in-transit – planning for orders</td>
<td>Process cost reduction (Grackin and Gilmore, 2004; TACTIC, 1996; Salmi, 2004; Van Eck, 2003; Novak, 2002; Donovan, 2001)</td>
</tr>
<tr>
<td>Material flow analysis</td>
<td>Product cost reduction (Salmi, 2004; Van Eck, 2003; APS Insight, 2001; Layden, 1998)</td>
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- Logility;
- E3;
- Escalate;
- Optum; and
- Provia Software.

The optimisation type of approach has been used widely in complex networks, where the central control is difficult to organise without data and communication systems. Typical application industries include the telecommunications and the automotive industry, where suppliers and component factories are geographically distributed in a large area and the scheduling requirements are hard.

3.4 Enterprise application integration software

Enterprise application integration (EAI) can be defined as follows:

EAI is the unrestricted sharing of data and business processes throughout the networked applications or data sources in an organization (Webopedia, 2004).

In practice this means that software applications within an enterprise are sharing information among other external systems, such as an information system in another enterprise. EAI brings the interaction between systems and allows the business process to be automated also when the information flows between the organisations. The four categories of EAI are:

1. Linking and replication database systems.
2. Linking applications: using and sharing information between enterprises.
3. Data warehousing: reporting and analysis of data combined from several sources.
4. Common virtual system: the system and the information appear as a unified application although the data may be stored and distributed in the enterprise network.

Thus an EAI system consists of at least five parts:
1. A data-interchange format.
2. Server architecture.
3. Programmatic methods.
4. Message queuing systems.
5. Transaction monitors.

There are many services an EAI system can provide, these are amongst others: security management, protocol management, data mapping, etc. These services define the functionality and the flow of data in the application. This way firms can benefit from EAI through end-to-end visibility and control of business operations. Herein control improves interactions with partners and customers, increases the ability to respond for changes in the business environment, enables to exploit better market opportunities, and disseminates more efficiently captured knowledge to relevant partners (Infoscaler, 2001).
Figure 4 illustrates the architecture for an EAI application. The data is stored in a database system in the lowest level. The business logic layer, which may be based on application server or messaging broker platform, is connected to database via a standard interface. The business logic of the software handles the messaging to external data systems and verifies that everything has been sent will be delivered as well. Also the messaging server typically handles the ensuring the security of the connection. The communication layer defines the format of messages for different partners. Some customers/suppliers may use EDI type of communication protocol, which some use XML-based systems. In the end the message is carried in a communication network, which today is the internet. The messages may be in pure text format, XML-type of formatting or binary messages.

Additional reasons for employing EAI software might be to respond the ever-increasing mergers and acquisitions, to scale with the e-business needs, to reduce redundancy, or to increase competency by reducing the time taken in transmitting information. Straight benefits are the ability to automate business processes across the enterprise and existing boundaries, increased value of information by the reduction of duplicated data. In addition costs are cut when creating one interface per application in case of upgrades or modifications (Infoscaler, 2001). At the moment, the major EAI vendors are IBM, Microsoft, Vitria Technology Inc., Software AG, BEA Systems Inc., SeeBeyond Technology Corporation, and TIBCO Systems Inc. In Table V a synopsis is given about the functionalities and the claimed benefits in relation to EAI.
4. Discussion on future trends
As companies and other commercial organisations are always seeking ways of reducing costs, increasing revenues and improving productivity figures, and IT software solutions offer increasingly a powerful method to achieve these goals, one can argue that in the future SCM, ERP, WMS/TMS software applications sooner or later will merge. According to this scenario EAI software will be at the heart of this development (Roch, 2002, p. 36). Already nowadays, one can notice that for example SAP has developed software capable of functioning as a WMS or TMS and SAP APO-solutions are targeted toward SCM optimisation problems. On the other hand, the complexity and unpredictable nature of turbulent business environment force companies to employ more science-based inter-disciplinary oriented approaches in building their new infrastructure (Rosenblum, 2004).

ERP-systems will develop toward facilitating value chain participation with the possibility of having a targeted version of the ERP package for a specific sector/segment. Processes will be externally connected, and the architecture will be web-based, open and componentised and thus both external and internal publications and subscriptions of data will be possible.

Figure 5 illustrates how different software types are related with each other. Transportation management systems deal typically with the distribution side only. However, the new functionality in many software packages is extending to terminal operations and warehouse management. Also warehouse management systems do not optimise only picking and palletising but the transportation route building too. Many enterprise resource planning systems, such as SAP R/3, have already warehouse and

<table>
<thead>
<tr>
<th>Functionality</th>
<th>Claimed benefits</th>
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<tbody>
<tr>
<td>Integration to customers with web-based e-sales systems</td>
<td>Reduced sales order processing costs</td>
</tr>
<tr>
<td>Reduced interfaces in applications</td>
<td>Fast information exchange between organisations</td>
</tr>
<tr>
<td>Internet-based real time transactions</td>
<td>Reduction of duplicated data</td>
</tr>
<tr>
<td>Data compatibility and common formats</td>
<td>Improved visibility for management and operational supply chain control</td>
</tr>
<tr>
<td>Supply chain level reporting</td>
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**Table V.** Functionality and benefits for EAI systems

![Material flow diagram](image)

**Figure 5.** Software solutions for managing the supply chain
transportation-related modules integrated. The new challenges are in the integration side to other supply chain level systems. EAI platforms offer tools for systematic and standardised data exchanges. In practice, a lot of the functionality of the software packages are overlapping. This may result in a situation where a company has several software packages with same type of functionality, but this is used in only one. In the end, the basic question is whether to purchase an integrated complete ERP type of package or a set of different smaller software entities.

According to a study completed by Industry Canada, supply chain software applications are developing toward the future affected by the dimensions (Industry Canada et al., 2003):

- standardisation of data exchange between organisations is becoming more essential;
- sharing data masses to different companies in the supply chain; and
- internet-based platform software is replacing other types of architectures.

In the WMS/TMS sectors voice recognition technologies will make it possible to perform various operations simultaneously such as data collection and confirmation while continuing the process of order-picking. Supply chain event management systems let CEOs monitor their supply networks and collaborate with suppliers and customers to resolve unpredicted events wherein an SCEM system send an alert to the managers and all the partners about the upcoming event. Labour management systems will be able to tell how many people they need to accomplish a certain task or how long each task should take determining and monitoring real-time performance data for each employee. RFID technology development will lead to applications with larger memory capacities, wider reading ranges and faster processing capabilities. Barcodes will co-exist with RFID-technologies in the future, as barcodes will always be more cost-effective (Wyatt, 2002).

5. Conclusions
From the literature there evolves a number of concepts overlapping each other. Among these there are “supply chain”, “supply network” and “supplier web” with that of “value chain” and “value network”. The same can be said about “business logistics management” and “supply chain management”. As well “supply chain co-ordination” and “supply chain synchronisation” might include similar elements. “Advanced planning and scheduling systems” refer more or less to ERP-II systems and SCM software applications. On the e-commerce side of the business world, e-procurement hub and e-procurement portal seem to depict the same entity too. These descriptions make it difficult to obtain a clear picture about the functionalities and roles of each entity in the whole picture. On the other hand these configurations of words give a sign about the direction of development of contemporary business environment: the convergence of different technologies and the increasing emphasis of internet-based solutions affecting the business world. At the same time one can claim that these information systems and related business concept become more complex and more science-based. ERP systems increasingly include warehouse management systems and transport management systems whereas SCM software applications incorporate ERP functionalities whilst utilising internet technologies in uniform platform creation. As a consequence the integration of the different legacy and other information systems
becomes the core issue in terms of facilitating the functioning of the business models and software applications in question. EAI is thus in a key role at the heart of these systems. Problem number one in this regard is the creation of an appropriate standard which addresses data exchange syntax, the parameters of a middleware of enterprise integration and of legacy integration adapters in the context of mixture of enterprise information systems in use.

Albeit, the integration of different systems, there are several future challenges for the logistics software, which need more applied research for application implementations:

- Complex product structures require configuration tools for production planning. Products and parts may be standardised, but the variety is vast.
- Requirements for real-time information is increasing from data accuracy to material flow. New applications of RFID systems are presenting possibilities for automated real-time traceability processes.
- Evolving logistics network architectures require flexible IT systems that are easily interconnectable, but also fast to change whenever required.
- New advanced business uses will emerge, when real-time information on customer behaviour may be obtained. Knowledge and understanding of customer habits helps building powerful demand management systems for logistics management.

To put it in nutshell: advances in information and communications technology enable new possibilities for managing the supply chains. Key features are based on those properties that combine system integration with chain level view on the material flow.

References


Further reading


