RESEARCH IN LOGISTICS & PRODUCTION

# THE SUPPLY CHAIN IN CLOUD COMPUTING

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**Abstract** Firstly, the paper presents the definition and evolution of supply chains. On the other hand, it details the use of mobile solutions in the supply chain and the characteristics, models and forms of cloud computing. Based on these, the paper describes the IT technical approach of cloud supply chains, and it presents the electronic freight and warehouse exchanges as a type of hybrid cloud supply chains. Moreover, the paper contains the new challenges and opportunities of cloud supply chains.

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## 1. INTRODUCTION

The Supply Chain (SC) (also referred to as the net of connections) is nothing but an expanded system within each link (enterprise) constitutes a separate subsystem. In (Ganeshan & Harrison, 1995), (Brown & Wilson, 2005) and (Lee & Billington, 1995) there is defined the Supply Chain as a network of places. Supply chain – a set of three or more companies directly linked by one or more of the up-stream and down-stream flows of products, services, finances, and information from a source to a customer (Mentzer, 2001). A Supply Chain is the alignment of firms that bring products or services to market (Lambert, Stock & Ellraml, 1998). Supply Chain Management is "the systemic, strategic coordination of the traditional business functions and the tactic across these business functions within a particular company and across businesses within the Supply Chain, for the purposes of improving the long-term performance of the individual companies and the Supply Chain as a whole" (Mentzer, Dewitt, Keebler, Min, Nix, Smith & Zachariaz, 2001). The Supply Chain is a metastructure. The metastructure is an intermediate form between a single enterprise (microstructure) and global economy (Grzybowska, 2010). It is understandable, since the enterprises do not exist in isolation from the environment in which they function: the organizations do not act in isolation and their survival is often dependent upon effective interactions with the environment (Robbins & Decenzo, 2001). This integration should be based on close and partner cooperation (Nizard, 1991).

**Table 1** The evolution of Supply Chain (Emmett, Crocker, 2006)

| Attribute | Functional Supply Chain to the 1980s | Responsive Supply Chain the 1990s | Adaptive Supply Chain the 2000s |
|---|---|---|---|
| Integration focus | Over the wall<br>Reactive/quick fixes<br>Monopoly suppliers | Transactional<br>Responsive<br>Competition is suppliers | Collaboration<br>Decision/proactive<br>Joined-up networks of enterprises |
| Customer focus | Customer can wait 'you will get it when we can send it' | Customer wants it soon 'you will have it when you want it' | Customer wants it now you will get it' |
| Organisation focus | Departmental and ring fencing | Intra-enterprise 'internal' involvement | Extended enterprise involvement |
| Product positioning | Make to stock | Assemble to order | Make to order |
| | Decentralized stock holding | Centralised stock holding | Minimal stock holding |
| Management approach | Store then deliver | Collect and cross dock | Whatever is needed |
| Technology focus | Hierarchical | Command and control | Collaborative |
| | Point solution | ERP | Web connected |
| Time focus for the business | Weeks to months | Days to weeks | Real time |
| Performance focus | Cost | Cost and service | Revenue and profit |
| Collaboration | Low | Medium | High levels |
| Response time | Static | Medium | Dynamic |

The systemic understanding of the enterprises operating in the Supply Chain is also the starting point and the basis for designing effective Supply Chain which would be characterized by more effective competitiveness and meeting of recipients' and consumers' expectations. The systemic approach is the skill to see the problem as a whole as well as the relations that connect individual elements (enterprises) thereof and the permanence of changes that take place over time. Supply Chain Management (SCM) has become an important management paradigm (Lee, Padmanbhan & Whang, 1997).

One may characterize three specific stages of Supply Chain development from the functional, through the reactive to those of an adaptive nature. This development is, inter alia, the result of change of relationships (dependencies and connections) that take place between the enterprises in the Supply Chain. Key characteristics and relationships in the Supply Chain are shown on Table 1.

In functional Supply Chains, repeatable and routine operations are carried out. The approach towards business partners is antagonistic and changing. Business partners cooperating in the Supply Chain apply the following rule: if I win, you have to lose. The risk of enterprise and cooperation is transferred to the business partner. As a result of all the above, the cooperation is not lasting long.

The reactivity of the links composing the Supply Chain is interpreted as a relatively constant intensity of reacting to external signals (resulting from the environment in which the Supply Chains functions) and internal signals which come from other links of the Supply Chain and from the enterprise itself. The enterprises thus function on the basis of action-reaction rule. They accommodate their own as well as mutual needs and expectations. These actions are both of reactive nature, forced by the business partner and adaptive, carried out at own initiative of the enterprise. As a result of reactivity of the Supply Chain, a relative synergy of joint actions of enterprises takes place. Considerable support and facility for maintaining the reactivity of a Supply Chain is implemented in ERP-class IT systems and in other telecommunication technologies. The available resources of cooperating enterprises are appointed to specific goals. Selection of both the resources and business partners is oriented on competitiveness goals set out (Grzybowska, 2009).

A mutual interdependency and cooperation on strategic level occurs between the enterprises. Business partners are allowed to cooperate in creating joint strategy of the supply chain. The nature of the development of adaptive SCs are to make joint decisions based on partnership principles, taking of actions that serve integration of enterprises as well as integrating processes carried out within the scope of the Supply Chain. The goal thereof is to increase efficiency of flow in the Supply Chain and improvement of competitiveness of all participants of the Supply Chain. Adaptive Supply Chain networks possess the flexibility to continually morph and respond to the environment in near real time without compromising on operational and financial efficiencies. These networks seamlessly connect supply, planning, manufacturing, and distribution operations to critical enterprise applications and provide near real-time visibility across the supply network, thereby enabling rapid decision making and optimal execution (SAP, 2003).

In order to make Adaptive Supply Chain even more efficient and adaptive to market requirements, the authors propose a new solution based on Cloud Computing. In cloud computing, the user's computer may contain almost no software or data (only an operating system and a web browser). The provider's cloud computing services form the cloud. These services are provided via an Internet connection within one or more of the next layers: application, platform and infrastructure (Marincas & Voicila, 2004). The application of SC concept in the context of cloud computing is innovative and opens a new research field (Lindner, Galan, Chapman, Calyman, Henriksson & Elmroth, 2010). Lindner et al. present definition of Cloud Supply Chain (CSC). It is two or more parties linked by the provision of cloud services, related information and funds. The Supply Chain represents a network of interconnected businesses in the cloud computing area.

Figure 1 is part of an exploration on moving from the old methods of running our businesses (in the 20th century) – including business models, processes, and technologies – to the new (the 21st century) (Hincliffer, 2011). Characteristics of CSC:

- Primary goal: Supply Chain demand at the lowest level of costs and respond quickly to demand,
- Product design strategy: Create modularity to allow individual setting while maximizing the performance of services,
- Pricing strategy: Lower margins, as high competition an comparable products,
- Manufacturing strategy: High utilization while flexible reaction on demand,
- Inventory strategy: Optimize of buffer for unpredicted demand, and best utilization,
- Lead time strategy: Strong Service Level Agreement (SLA) for ad-hoc provision,
- Supplier strategy: Select on complex optimum speed, cost, and flexibility,
- Transportation strategy: Implement highly responsive and low cost modes.

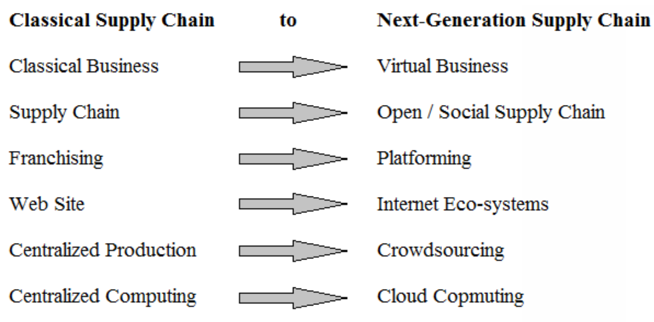


**Fig. 1** Moving from Classical to Next-Generation: Cloud Supply Chain (Hincliffer, 2011)

## 2. MIGRATION OF SUPPLY CHAINS TO THE CLOUD

Mobile SCM (mSCM) integrates software applications with mobile devices (e.g. cell phones, personal digital assistants, tablets, on-board computers, Fig. 2) to give users the flexibility to operate in a wireless environment at any location. Mobile de-vices are connected to the company's computer server via wireless technology infra-structure such as GSM/3G, Wi-Fi capable equipment or trough modern satellite providers (e.g. Inmarsat BGAN). These enable users to share data across functions and along the supply chain without the need for fixed wired connections for exchange of real time information. In the early stages of mobile communication short message service (SMS) software applications were used to access company databases, nowadays service oriented architecture (SOA) is preferred with standardized XML (Extensible Markup Language) communication (Teck-Yong, 2006).

Cloud computing is a model for enabling ubiquitous, convenient, on-demand net-work access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and re-leased with minimal management effort or service provider interaction. According to NIST specification (National Institute of Standards and Technology, U.S. Department of Commerce) cloud model is composed of three service models (Software as a Service /SaaS/, Platform as a Service /PaaS/, Infrastructure as a Service /IaaS/), and four deployment models (Private-, Community-, Public- and Hybrid Cloud), (Mell & Grance 2011). Figure 2 shows the overview of cloud computing.

Before migrating enterprise Supply Chain to the cloud numerous assumptions must be analysed. Implementation of new technologies requires high level IT culture and developed IT infrastructure. As cloud computing is a new area of IT technologies preparation is needed in key areas such as standardization technology, virtualization technology, data management technology, platform management technology in supply chain information collaboration (Chen & Ma Yan, 2011).

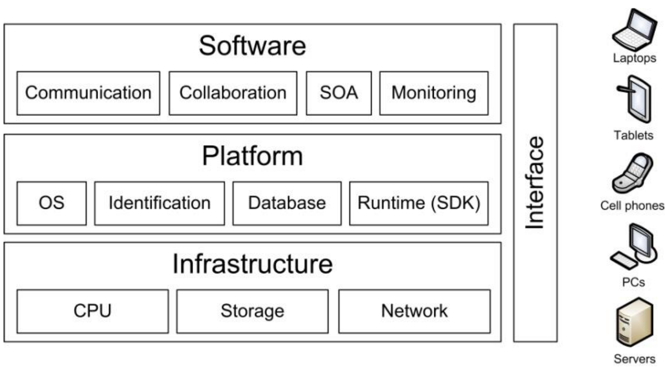


**Fig. 2** Diagram showing overview of cloud computing

Regarding to the dynamic changing computational and storage demand the Cloud computing service providers (e.g. Amazon EC2, Microsoft Azure) use virtualization technologies to maintain resources mainly for load balancing and management purposes. Hardware virtualization refers to the creation of virtual appliances such as computers, storage and network devices. In this case a hypervisor is installed on the physical hardware. The hypervisor runs the virtual entities and manages the hardware resources such as CPUs, memory, hard disks and I/O devices.

Cloud service providers provide classical data storage and database as virtual machine image (e.g. Oracle Database 11g Enterprise Edition) or as a service (e.g. Amazon Relational Database Service or Microsoft SQL Azure) within the cloud. The ad-vantages of these services are scalability, high availability, reliability compared to the traditional solutions. These factors are highly important as the key element of the Supply Chain Management is information. With high quality services and reliable data communication techniques this goal can be achieved.

One of the most challenging questions in Supply Chain Management is data exchange between service providers. The traditional ways of changing data is Electronic Data Interchange (EDI), which is a structured electronic data transmission standard between computer systems. This standard was developed in 1996 and it is capable of computer-to-computer communication over computer network (e.g. VAN, BBS). As it was developed for point-to-point communication the current state of EDI is not able to grant the present need of business-agile enterprises. Collaboration of companies nowadays is a key factor and the dynamic interchange of information is a need.

Along with the development of information technology, internet data transmission became secure, scalable and standard for data communication. Compared to the EDI internet transmission cost is far lower, the enterprise only need to open a SOA based web service without having to acquire additional equipment and increase the professional management staff. In the supply chain management the mode of information collaboration and information service object is also constantly changing, the supply chain members may quit and also new members may join at any time.

As mentioned before collaboration and data exchange between companies within the whole supply chain is a common need in logistics. Such as traditional point-to-point EDI is no more acceptable for the market. The existing ERP and CRM systems are capable for the communication through its standards (e.g. SOA), developed in early 2000s, but a centralized solution not exists on the market, which can reduce supply chain information distortion, accelerate information transmission speed and accuracy, and improve the overall competitiveness of supply chain’s role. With an integrated cloud service application such as electronic freight and warehouse exchange a controlled collaboration can be achieved within the whole supply chain (Subsection 2).

## 3. A HYBRID CLOUD SUPPLY CHAIN MODEL: ELECTRONIC FREIGHT AND WAREHOUSE EXCHANGE

The electronic freight and warehouse exchange facilitates a forum for logistics service providers to advertise their service supply, such as transport and storage on the worldwide web; whereas customers can choose the offer, which best suits their needs. The cloud structure of the electronic freight and warehouse exchange is shown by Figure 3 (Kovács, 2010). The freight and warehouse exchange (cloud computing service provider) offers the following main services (Kovács, 2011):

- e-commerce toolbar (agile information and communication techniques): (1) advertising and searching in a simple catalogue (freight/storage tasks/capacities), (2) automatic offer sending (based on individual settings), (3) tenders/auctions (just for freight/warehouse tasks),
- multi-criteria decision supporting algorithms (choose the best offer),
- optimization algorithms (optimize the logistics processes),
- other functions (e.g. statistics, blacklists, data maintenance, etc.).

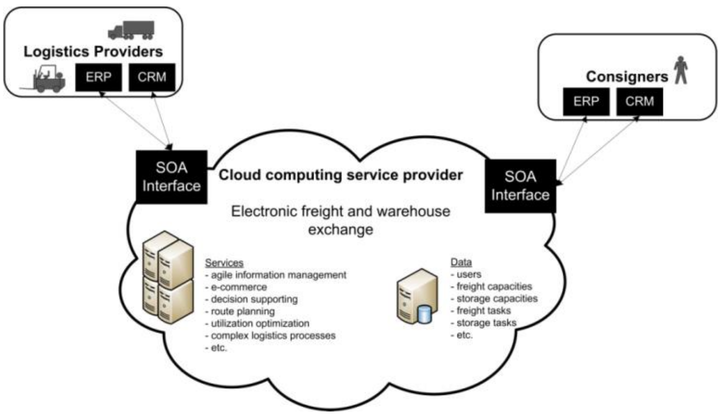


**Fig. 3** The cloud model of electronic freight and warehouse exchanges.

The electronic freight and warehouse exchange has three participants: consigners, logistics providers, and the cloud computing service provider. The aims of the electronic freight and warehouse exchange: to advertise freight/storage capacities/tasks, to choose suitable offers based on e-commerce methods and complex optimum criteria, to support complex logistics processes (e.g. combined transport, city logistics, etc.).

In these exchanges there are lots of optimization opportunities, e.g. in case of freight and warehouse exchanges, we have to define a complex objective function. On a part of the total transport route, the freight tasks are transmitted together and then with the help of a combi terminal the freight tasks are transferred (multimodal transportation with rail/river) (Kovács & Grzybowska, 2011). These problems can be solved by ACO (ant colony optimization), which is an optimizing algorithm developed by M. Dorigo (2004) based on the modeling of the ants' social behaviour. In the electronic freight and ware-house exchange similar problem emerges as the ants' search for food: the target is the agile performance of freight/storage tasks offering the higher profit.

The role of freight and warehouse exchanges in complex logistics problems (city logistics, combined transportation) may be viewed as the route planning systems of companies (e.g. wholesalers): the processes (e.g. tours, utilization) can be optimized by handling demands and capacities in one system. Moreover, through the coordination they are able to establish collecting-distributing routes, to organize back haul, and through this to reduce the number of vehicles. In this way, support of complex logistics problems (city logistics, combined transportation) will be possible. In other words, freight and warehouse exchanges is one of the "simplest", but still the most efficient way of optimizing complex logistics processes. Moreover, the freight and warehouse exchanges can be an excellent example of cloud supply chains.

## 4. NEW CHALLENGES CLOUD SUPPLY CHAIN – THE BASIS FOR CREATING A NEW EXISTENCE NEXT-GENERATION

Modern times (globalization, specialization and the use of World Wide Web) – create the hybrid SCM 2.0 (Supply Chain Management 2.0). This is the subsequent development phase of SC intended to increase its effectiveness in the exchange of information and cooperation between the participants of SC (Grzybowska, 2010).

The Cloud Supply Chain offers: (1) limitless flexibility: With access to millions of different pieces of software and databases, and the ability to combine them into customized services, users are better able to find the answers they need, share their ideas; (2) better reliability and security; (3) enhanced collaboration: By enabling online sharing of information and applications, the Cloud offers users new ways of working together; (4) portability: Users can access their data and tools wherever they can connect to the Internet; (5) simpler devices: With data and the software being stored in the Cloud, users do not need a powerful computer. They can interface using a cell phone, Personal Digital Assistant (Cavoukian, 2008) and (6) synchronization: The Cloud offer tools enable business units and multiple plants across an enterprise and SC to communicate with one another more effectively. Authors identified the barriers to adoption of SC in Cloud Computing; (7) standardization: So far, there are no clearly defined and widely adopted standards, though this would be beneficial to cloud computing customers and service developers (Höfer & Karagiannis, 2011). Standardization refers to the use of common APIs (Application Programming Interface) and architectures, as well as, technical standards (ANSI – American National Standards Institute or the ISO – International Organization for Standardization, or simply a commonly-used or familiar interface). The elements of the system are identified which are relevant to the problem:

- Cooperation and partner eco-system: The concept of an eco-system in the natural world hasn't changed. What has changed is our understanding of the potential that such a concept represents when applied to traditional business concepts of partnering. A partner eco-system's depends upon interdependence – it is a highly-collaborative and complexly-orchestrated. Cooperation and partner eco-system applied as parts of a business strategy, it creates a partnering environment where group strength drives improvements far greater than those that can be realized by any individual organization.
- Sharing information: The major challenge of the Cloud Supply Chain coordination is to find a global solution for the composite service. Therefore, we need to coordinate the flow of information and link the business processes under various constraints. The Cloud Supply Chain coordination leads to take the advantage of the web services standardized communication protocols. This simplifies communication among the firms in the Supply Chain, and thus facilitates collaboration (Mahdavi, Mohebbi, Zandakbari, Cho & Mahdavi-Amiri, 2009).
- Trust: Trust is a factor of the relationships. As pointed out by R. Hardin trust is a characteristic of interest (Hardin, 2009). Thus, trust means (Sztompka, 2007): (1) trusting others and assuming their reliability (unless proved otherwise), (2) treating trust put in oneself seriously and meeting other parties expectations (unless the trust proves unauthentic).

In a Supply Chain, trust is one of the key cooperation factors (e.g. trust that a supplier or a sub-contractor perform their duties according to specifications; trust that a supplier with which the enterprise did cooperate previously, will supply a product of a proper quality; trust that the customer will pay within agreed period of time and will not cause a payment gridlock, etc.). In such cases, trust is a mandatory condition of cooperation – it is like a grease that facilitates the cooperation of elements (Dasgupta, 1998). New developments include the offering of computer-business that are completely hosted in the Cloud. This will make portability easier, as the software can be resumed from a different location (Edwards, 2009). Also, it is less dependent on the user's hardware and less prone to piracy.

The effective management of the SC according to (Lehtonen, 2004) and (Chen & Paulraj, 2004) is based on the creation of a virtual organization by combining a number of commercial entities (for example the Cloud Supply Chain). These, in turn, supplement each other in pursuing a joint objective. In order to ensure the versatile success of the created alliances, it is purposeful that the Cloud Supply Chain be based on trust and the involvement of all parties of the Supply Chain.

## 5. CONCLUSION

The main advantage of the freight and warehouse system is, that a manifold optimum search tool is available in the electronic freight and warehouse exchanges. With the help of the mentioned methods by the filtering of local optimums, a solution can be found shortly, which to freight/storage capacities/tasks selects freight/storage capacities/tasks. There are a lot of optimization opportunities, from the decision making, to the route planning and utilization optimising. In addition, complex e-commerce methods (e.g. tender, auction) help the selection.

The role of freight and warehouse exchanges in complex logistics problems (city logistics, combined transportation) may be viewed as the route planning systems of companies (e.g. wholesalers): the processes (e.g. tours, utilization) can be optimized by handling demands and capacities in one system. Moreover, through the coordination they are able to establish collecting-distributing routes, to organize back haul, and through this to reduce the number of vehicles. In this way, support of complex logistics problems (city logistics, combined transportation) will be possible. In other words, freight and warehouse exchanges is one of the "simplest", but still the most efficient way of optimizing complex logistics processes. Moreover, the freight and warehouse exchanges can be an excellent example of Cloud Supply Chains.

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**Balázs Lénárt** is Assistant Lecturer at the Budapest University of Technology and Economics (Department of Transport Technology, Faculty of Transportation Engineering and Vehicle Engineering). His research subject is "Application of artificial intelligence in logistics system planning, prominently forecasting methods", also interested in decision supporting algorithms and optimization algorithms. He has published papers in journals such as Periodica Polytechnica Transportation Engineering and Lecture Notes in Computer Science.