Indian Journal of Science and Technology, *Vol 9(30), DOI: 10.17485/ijst/2016/v9i30/99063, August 2016*
ISSN (Print) : 0974-6846
ISSN (Online) : 0974-5645

An Investigation on the benefits of ICT deployment in Supply Chain Management (SCM)

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Abstract

Objective: The objective of the paper is to investigate the influence of deployment of Information and Communication Technology (ICT) tools in a supply chain context. Methods/Analysis: The influence of deployment of ICT in Supply Chain Management (SCM) is studied using System Dynamics (SD) methodology using the tool, Causal Loop Diagram (CLD) using software Vensim. Findings: SCM discipline is grappled with dynamic and operational changes and challenges and this unpredictability can be understood better using SD. ICT capabilities fundamentally improve supply chain integration and performance. ICT adoption for SCM improves collaboration, workflow and decision-making which lead to cost savings; improved operational efficiency and inventory visibility. One process in SCM namely inventory control is described using SD. Introduction of a parameter, ICT capability dramatically changes the context and gives rise to new positive feedback loops Novelty/Improvements: The paper uses CLD for ICT influence on SCM process of inventory control. This can be extended for all supply chain management processes in both planning and execution. Case studies with the influence of specific ICT tools like RFID, Cloud, Social Media, Business Analytics, Mobile technology and Multi-agent systems are also possibilities for extending the study. Supply chain managers can deliberate on decisions, strategy, issues and policy by developing scenarios using SD tools and software packages. However the research limitation is that this is a simulation in a specific supply chain context. Generalization of this scenario may not be possible

Keywords: Causal Loop Diagram (CLD), Information and Communication Technology (ICT), Inventory, Supply Chain Management (SCM) ICT, System Dynamics (SD)

1. Introduction

Cutting-edge ICT tools aid drive enable smoothen and expedite enterprise transactions and operations. ICT adoption and deployment across various processes and links in the supply chain has become a determinant of competitive advantage for enterprises. Deployment of various ICT-based tools and applications like Business Analytics, Cloud and inventory management systems in supply chain planning and execution processes have resulted in better transparency, visibility, resilience, adaptability, dialogue, adaptability and decision-making for enterprises. This is not only within the enterprise intranet but also within the extranet consisting of their partners and suppliers.

2. Benefits of ICT Deployment in SCM

ICT deployment for SCM results in a shift from the linkage between physical processes such as inventory, warehouse or shipping to information-based processes across supply chain operations. ICT deployment significantly improves supply chain process integration, which leads to better enterprise performance Accessing actionable knowledge in a suitable manner as also managing

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dialogue and coordination among various stakeholders are other benefits. This greatly increases the ability of the enterprise to respond to market dynamics.

In 1994, an early study done on 1993 automobile suppliers with respect to *Electronic Data Interchange* (EDI) usage for Just in Time shipments demonstrated encouraging outcomes. EDI application dramatically brought a reduction in the shipment errors thereby brining about substantial savings for the EDI-enabled enterprises[1]. ICT deployment facilitates better dialogue, Integration and collaboration between various activities, processes and stakeholders in the supply chain, both upstream and downstream operations. Seamless access to the information as also the visibility and transparency of the information increases the efficiency of different supply chain processes. Deployment of ICT for various processes can bring about spectacular improvements in efficiency. Auto-ID technologies such as bar coding and RFID have rendered inventory management effective and brought about inventory visibility and transparency; transportation management systems have optimized routes for shippers; Internet-enabled services have brought about better communication, collaboration and dialogue among various stakeholders[2].

Cisco estimated savings of US $500 million leveraging web-services for its supply chain integration. Major suppliers of Wal-Mart such as Proctor & Gamble (P&G) have direct access to Point of Sale (POS) information from Wal-Mart retail outlets[3]. By migrating placing of orders to an online application, Intel could eliminate hundred of order clerk positions[4]. Celestica, one of the world's largest electronic manufacturing services companies, has applied a web-based ICT tool to manage its network of suppliers across the globe. Thereby, the company could improve its customer-responsiveness, primarily helping its customer, Dell to maintain its delivery promise to end-users[5].

The functional roles of ICT in SCM have been outlined in figure 1[6]. ICT has an impact on SCM in three dimensions, i.e transaction execution, collaboration & coordination and decision-support.

ICT adoption improves collaboration, workflow and decision-making. Another study highlights benefits such as cost savings; improved operational efficiency, inventory visibility & control; quality, reliability and accuracy of information; improved communication, collaboration and customer-connect and innovation and differentiation of products or services[7]. Many of the buzz words in SCM such as Vendor Managed Inventory, Point of Sale, Collaborative Planning, Forecasting and Replenishment and *Engino Robotics Platform* (ERP) stem from ICT usage.

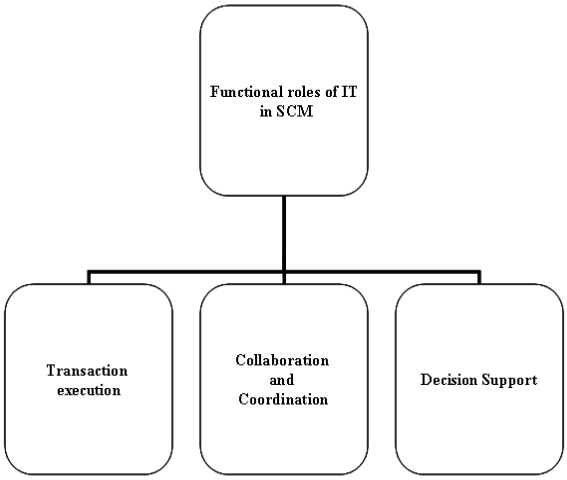

Figure 1. Functional Roles of ICT in SCM

In spite of the wide-ranging benefits of ICT deployment in SCM, enterprises face challenges such as lack of supply chain coordination through ICT or lack of capabilities for their suppliers or trading partners to align with them. It becomes all the more important for enterprises to leverage ICT to make supply chain coordination more successful[8]. Other challenges include people and change management, legacy applications and disconnected enterprise systems[9].

3. System Dynamics (SD)

SD is an inter-disciplinary perspective based on systems thinking, non-linear dynamics and feedback loops to study structure, performance and behavior of complex and dynamic systems. SD origins are from Industrial Dynamics research at MIT in 1956 led by Professor Jay Wright Forrester. System Dynamics uses techniques and conceptual tools like Causal Loop Diagrams (CLD) and Stock Flow Diagrams (SFD) for modeling and simulations. These simulations and models help us to understand various abstractions and views also the behavioral patterns with respect to the interaction of variables and attributes of the system[10]. The basic premise is that systems tend to be dynamic and unpredictable due to its building blocks and structure as also causal relationships between these blocks or attributes.

System Dynamics throws light on the exchanges between the flows of information, cash, orders, supplies, staff and equipment in any enterprise or country[11]. SD has made inroads into various disciplines like management, strategy, policy, economics, healthcare, communication systems, social and biological systems, software engineering and electrical engineering. Some examples of application areas could include studying the spread of an infectious disease epidemic or a nose-diving stock market crash, introduction of i-pod and the effect on Sony walkman sales, etc. We get a holistic view and strategic perspective of the system as also is able to interpret the system over a period of time. Enterprises can look inwards and place the lens on themselves to understand themselves better as also devise new strategies to survive and thrive in the complex and competitive business environment. One great advantage of this technique is the ability to measure and model intangible variables or factors, which were hitherto not quantifiable. The reasons for policy resistance can be analyzed and addressed. For example, we sometimes perform actions to solve a problem, but these backfire on us. An interesting observation is that use of ICT tools for paperless office in some cases has actually increased per capita consumption of paper. Of course many of these things are beyond our control and the actions we perform bring about side effects. CLD help us understand the interactions between variables using feedback loops while SFD help us understand the status of a variable of interest at any given point of time and its traversal and transformation in the flow. In CLD, we are able to classify loops as positive and self-reinforcing or negative and self-correcting. Positive loops are generally at an unstable equilibrium while negative loops tend to denote that the system is trying to reconfigure and goal-seek itself to an equilibrium state after a disruption. CLD gives us a working model with an idea of the causal relationships in the system, while SFD gives us an idea about the state and rate variables.

The sequence of steps in SD is as follows:

- Study and analysis of the system
- Representing the system using CLD
- Representing the system using SFD
- Building the systems model
- Testing various assumptions
- Perform simulations
- Presenting the policy recommendations

User-friendly SD simulation packages with friendly *Graphical User Interface* (GUI) like Stella, I-think, Vensim and Powersim have contributed to the steady usage of this exciting technique.

4. System Dynamics in SCM

Despite the spectacular advancements and innovation derived by ICT deployment, the SCM discipline is grappled with dynamic and operational changes and challenges in real-time. This is primarily because of the fact that there are several stakeholders – partners and suppliers, who are autonomous or semi-autonomous and unpredictable with the added complexity of interactions between these actors. Each of these actors has objectives and is constrained in their own way. It would be thereby be worthwhile to investigate SCM from a SD perspective[12]. One popular definition of supply chain management[13] is "a system whose constituent parts include material suppliers, production facilities, distribution services, and customers linked together via the feed-forward flow of materials and the feedback flow of information." SD focuses on these feedback loops in sourcing, production and distribution to study structure, behaviour and performance of the systems. SD can be used to classify principal variables of supply chain performance as positive and self-reinforcing or negative & self-correcting. In other words, we are able to identify the variables which enable or inhibit supply chain performance. A SCM context consists of various dynamic stake-holders and SD can be used to effectively study the complex and dynamic nature of SCM[14].

SFD technique is used to describe the supply chain as an extended enterprise consisting of its network of interconnected suppliers, warehouses, shippers, distributors and retailers. The SFD tracks the process workflow of transformation of inputs to value-added outputs and the various aspects governing these workflows. Invariably, these workflows have feedback systems and loops making SD an excellent modelling technique. SD could aid decision-points with regard to all aspects with regards to plant, inventory and warehouse location, workflow and operations. Other activities that could be influenced include MRP, sales and distribution planning, forward and reverse logistics, supply-chain integration, outsourcing and procurement strategies.

SD has been used in various SCM contexts in manufacturing and production for over five decades[15]. At MIT, during the SD early days, this research group applied this simulation technique for SCM. The supply chain was

modelled as 6 interacting flow systems, namely the supplies, cash, information, orders, human resources and equipment with four tiers namely plant, store, distributor and merchant. The group led by Forrester studied the impact of inventory fluctuations, demand magnification, distributed control and ICT deployment for SCM process[16]. Figure 2 depicts such a supply chain setting with entities such as warehouses, retailers, factories and warehouses.

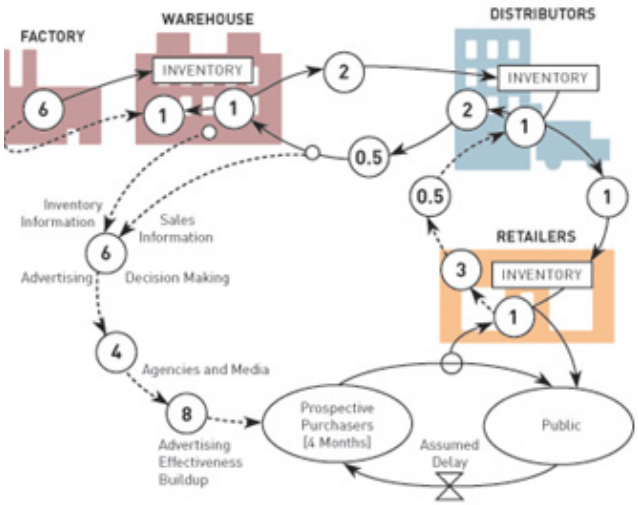

Figure 2: Modeling SD

SD was applied to understand the causal relationships between various elements and variables in SCM. Elements could be divided into structural such as supplier or factory and control such as supply and demand signals and information flow[17]. Modelling the structural and control actors help us in understanding the decision-making process which needs to be coherent. A typical situation could be the dilemma of an inventory manager. How should he balance the orders versus production and take decisions with respect to re-ordering or manufacturing.

After the initial investigations into SD for SCM, there was a lull till mid 1990s in terms of research with this trend gaining interest in recent times[18]. The popular SD textbook by Sterman has a couple of case studies with SD application in a reverse logistics context.

5. Causal Loop Diagram (CLD)

CLD is one of the popular tools of SD. It throws light on the actors and the inter-relationships between them based on the principle of causality, i.e. cause and effect. Arrows symbolize associations and are represented with a + or a — symbol. The + symbol alludes to the fact that a change in the source variable of the arrow will result in a positive change in the destination variable. The — symbol is the opposite. 'R' stands for reinforcing (positive) and 'B' stands for balancing (negative). Feedback represents a closed chain of causal relationships. Loops tend to be positive or negative. Positive loop means that the number of negative relationships is even (or zero). Negative loop has odd relationships. Negative loops stabilize the system towards equilibrium. Positive loops tend to disturb the equilibrium and contribute to instability. If a system has both kinds of loops, we look for the one that is dominant. In addition to the elements of actors of the system, we also identify the factors that these actors are influenced by. The changes brought about by the interactions of the elements with these factors are described and studied. A sample CLD is given in Figure 3[19], which describes the dynamics of a population with respect to birth, death and life expectancy.

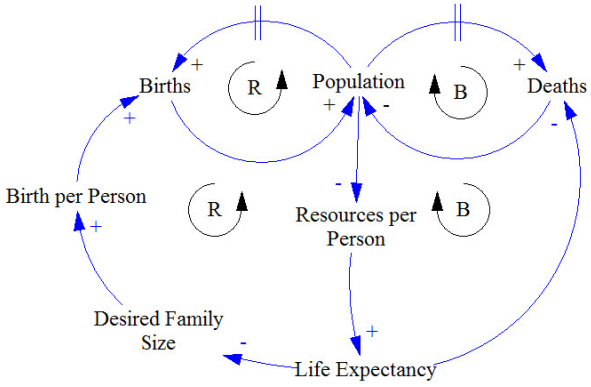

Figure 3. A sample CLD

6. CLD for Benefits of ICT Intervention for SCM

ICT intervention in SCM brings about a marked change and improvement in all processes of supply chain planning and execution. ICT tools and tackles impact planning, manufacturing and distribution as well. Here we see the impact of ICT deployment in processes such as inventory control. Figure 4 shows a CLD wherein we see the dynamics of inventory control with respect to inventory levels, shipments orders received and order placed.

B1 is a balancing feedback loop showing the causal relationship between orders received and inventory levels.

B2 is another balancing loop showing the relationship between inventory levels and shipments made.

R1 is a positive feedback loop showing the relationship between shipment, desired inventory, inventory adjustment and the placed orders.

R2 is a positive feedback loop showing the relationship between shipment, average shipment and orders[20].

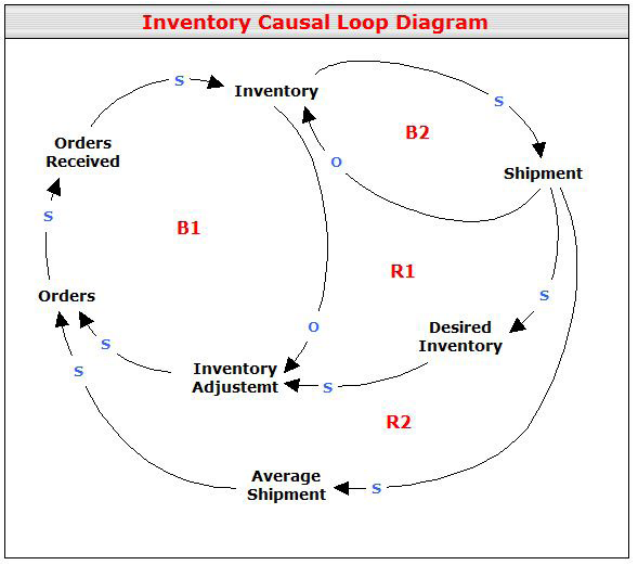

Figure 4. Inventory Control CLD

We introduce a variable, ICT Capability. The action of this variable is very wide and impactful[21] and affects three elements.

Using a tool like RFID[9,22], we are able to get better tracking of inventory at both storage and shipment levels. Using a tool like Decision Support Systems[23] or web services[24] or cloud[25] or analytics[26], we have better engagement with customers and better access to orders received and also visibility of shipments.

ICT capability positively impacts the following variables in the above-mentioned CLD:

- Orders Received
- Inventory
- Shipment

The CLD is redrawn using Vensim as shown in Figure 5 with the introduction of the ICT capability variable.

Now we have two more positive feedbacks R3 and R4

R3 is a positive feedback loop showing the relationship between ICT capability, orders and inventory

R4 is a positive feedback loop showing the relationship between ICT capability, shipment and inventory

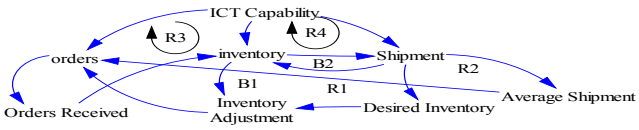

Figure 5. Modified Inventory Control CLD using Vensim

Similarly, for every process in supply chain management context, ICT capabilities influence various variables and control flows. From a managerial standpoint, the ICT advantage and impact on SCM processes as also its interplay with various actors and factors in the supply chain are highlighted and better understood so as to create business value for the enterprise. The ICT advantage can be extended by building various scenarios similar to financial time series prediction for stock market data[27]. Various supply chain scenarios like bullwhip effect[28] or designing the supply chain network using mathematical models[29] can be conceptualized analyzed and addressed using these techniques. The correlation between ICT competences which results in organizational competence[30] is also better understood.

7. Conclusion

Supply Chain Management discipline is grappled with dynamic and operational changes and challenges in real-time. This is primarily because of the fact that there are several stakeholders – partners and suppliers, who are autonomous or semi-autonomous and unpredictable with the added complexity of interactions between these actors. ICT adoption and deployment renders supply chains to transition from physical processes such as inventory, warehouse or shipping to information-based processes across supply chain operations.

System Dynamics is an excellent simulation and modeling technique based on systems thinking, non-linear dynamics and feedback loops to study structure, performance and behaviour of complex and dynamic systems. Causal Loop Diagram, one of the tools of SD is used to study the impact of ICT deployment on the the supply chain processes of inventory control. Using SD software package, Vensim, we are able to see that the introduction of an ICT capability variable in the CLDs dramatically changes the dynamics of the process with positive effects and new reinforcing or balancing loops being created. From a managerial standpoint, the ICT advantage and

impact on SCM processes as also its interplay with various actors and factors in the supply chain are highlighted and better understood so as to create business value for the enterprise. With better understanding of the workflow and processes, supply chain managers can deliberate on decisions, strategy, issues and policy by developing scenarios and extending the models using SD tools.

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