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Increasing Value Generation using a Hierarchical Simulation-Based SCOR Framework

John Crowe[1] and Amr Arisha[2]

Abstract

We are part of extraordinary times, global recession coupled with increased competition; high costs and decreasing demand have changed the dynamics of supply chain management (SCM). In response, many organizations have fast-tracked changes to corporate-level strategies to reduce costs and maintain profit margins and have not considered the long-term impact these decisions have on more operational-level SCM activities. This has resulted in a renewed focus on customer value and the economic and behavioral systems of the supply chain, or more accurately, the value chain. The Supply Chain Operations Reference (SCOR) model increases the integration organizations have within their supply chains and increases alignment between different hierarchical strategies. Simulation techniques, in particular discrete-event simulation (DES) and system dynamics (SD) are proven techniques in improving SCM corporate and operational decision making processes. This paper presents a framework that integrates SCOR with DES-SD modeling approaches in order to improve the performance of inventory management in a leading tire distribution center in Ireland. This integration shows an effective method to evaluate order strategies, enhance throughput and increase value generation within supply chain networks.

Keywords: *Supply Chain Management, Value Chain, SCOR, Simulation, System Dynamics*

1. Introduction

This is an era marked by an unprecedented global recession and a high level of uncertainty within markets. Coupled with cost reduction pressures and rapidly changing customer requirements, strategic management has evolved requiring more agile planning and lean control techniques. Through this evolution, there is recognition of the need for decision-making tools and new approaches to the arrangement of the supply chain (SC) that optimizes value, both for the customer and supply chain partners. The variations in product-orders, multi-suppliers, and parallel processes have increased the level of risk in SC's and make SC management (SCM) a major challenge. To complicate planning activities further, increased global competitiveness and innovations in technology have decreased the life cycle of many products. Demand uncertainty, in particular, has become an increasingly important factor. To accurately hedge against demand uncertainty, efficient inventory management controls are needed in SC operations.

SCM is a vast management concept, with many interpretations and definitions. Although the concept itself was only introduced in early 1980 by Oliver and Webber, cited in Jüttner et al. (2007), it was not until the mid 1990's that it came to prominence globally. SCM can be defined as the strategic management of upstream (suppliers) and downstream (customers) relationships in order to create enhanced value to the final consumer at less cost to the SC as a whole (Christopher, 1998). At its basic level, a SC is made up of multiple actors, multiple flows of items, information, and finances, and is sometimes described as looking like an 'uprooted tree' (Lambert and Pohlen, 2001). The end goal of SCM is value creation, both for end consumers; in the form of reliable high quality products and pre/after-sales services, and for SC partners; in the form of increased turnover and profits (Mentzer et al., 2001, Mentzer, 2004, Murman, 2002). Such value creation in the SC is more commonly known as the value chain (VC).

1.1 Value Chain Improvement

In recent years, decision makers have realized that competition is no longer enterprise versus enterprise, but SC versus SC (Li et al., 2005, Christopher, 2000), or more appropriately, VC versus VC. In addition, the global recession has disturbed the fundamental concepts of international business. To keep competitive, organizations have had to drastically revise and implement cost cutting strategies to their VC operations to sustain profits. This is not an easy task. VCs are very dynamic, and each network node has its own customers' and suppliers' management strategies, partnerships, demand arrival process and demand forecast methods,

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inventory control policies and item mixtures (Longo and Mirabelli, 2008), with many challenges to overcome including; complexity, uncertainty, risk, visibility, collaboration, cost and sustainability to name a few. The dynamic and complex nature of VC systems imply that there is very high probability that cost driven decisions to change VC strategies will fail with huge financial consequences (Tobail et al., 2011). Pitta, Franzak, and Little (2004) state that other decisions other than cost need to be considered to add value to the VC. They are: relationships, interactivity, customer retention, and customization. Analytical models such as mathematical programming are very useful tools in understanding SC dynamics. This is noted by Hae and Han (2000), who add that when an analytic solution cannot give measurable performance indicators simulation should be used. Simulation offers a more thorough, measurable analysis of the systems data including the examination of parameter variability, operational uncertainty, and the accurate estimation of probability distributions that statistically fit the data sets (Arisha and Young, 2004).

To be truly sustainable and value adding, organizations need to transcend the boundaries of their own SC operations and develop relationships with their suppliers' suppliers and their customers' customers (Barratt, 2004). For this reason, business process orientation concepts of reengineering, benchmarking and process measurement have been integrated into a cross-functional framework commonly known as a process reference models. With regards to SCM, the most commonly used models are the Supply Chain Councils (SCC) Supply Chain Operations Reference (SCOR) model and the Council of Supply Chain Management Professionals' SCM Process Standards. The objective of this paper is develop a hierarchical simulation-based framework integrated with the benefits of using process reference models such as SCOR in managing sustainable, competitive VC's. To achieve this, Section 2 will give a background overview of the SCOR model, generally and from the perpective of VC. This is followed by a detailed discussion on integrating SD and DES into a hybrid simultion model for value gernation in hierarchiacal systems such as in VC's in Section 3. Section 4 gives a profile of the case study industry; tire distribution, and the case study company. Data collected on this company will then be used in Section 5 to build an accurate SD-DES simuation model of the TDC system that will be analyzed in Section 6 before conslusions and future work are discussed in Section 7.

2. Supply Chain Operations Reference Model

The concepts of the VC or SCM are not recent additions to management philosophy. Many experts including Michael Porter and W. Edwards Deming have created process frameworks that embrace whole system value creation (Bolstorff and Rosenbaum, 2007). The purpose of the SCOR model is to provide the ability to describe process architecture in a way that makes sense to key SC partners and give a better understanding of whole system value creation. It is especially useful for describing value/demand/supply chains that cut across multiple departments and organizations, providing a common language for managing such processes (SCC, 2010). The SCOR model contains four main sections: (1) Performance: Standard metrics to measure process performance: (2) Processes: Standard descriptions of management processes and a framework of process relationships; (3) Practices: Management practices that produce best-in-class performance; and (4) People: Training and skills requirements aligned with processes, best practices, and metrics. The foundations of the framework developed in this paper are built on the first two sections of the SCOR model, performance metrics and processes. The SCOR Performance section is separated into two hierarchical groups: (1) strategic and qualitative performance attributes such as; responsiveness, reliability, agility, cost and asset management; and (2) operational and quantitative performance metrics such as on-time delivery, average cycle time, invoice accuracy etc. Performance metrics are used to quantify and measure the higher-level strategic attributes.

The SCOR Process section is the core SCM knowledge base for the development of the hierarchical simulation-based framework, and is divided into three hierarchical levels. Zhou et al. (2011) summarize each level very efficiently. Level 1 consists of five strategic supply chain processes: Plan (P), Source (S), Make (M), Deliver (D), and Return (R). Level 2 of the SCOR model describes core processes. Level 3 specifies the best operational practices of each process. The P component includes the processes that balance aggregate demand and supply to develop a course of action which best meets sourcing, production, and delivery requirements. The S component includes the processes that procure goods and services to meet planned or actual demand. The M component is comprised of the processes that transform product to a finished state to meet planned or actual demand. The D component includes all processes which provide finished goods and services to meet planned or actual demand. The R component includes all processes that provide accurate returns of unwanted and poor quality finished goods, product recalls and equipment.

3. Comparison of System Dynamics and Discrete-Event Simulation

As noted earlier, simulation is a widely used analytical modeling technique within the field of SCM. Two of the most-established approaches are that of SD and DES (Pidd, 2004). System dynamics methodology is best suited to problems associated with continuous processes where feedback significantly affects the behavior of a system, producing dynamic changes in system behavior. SD is a system thinking approach to modeling that is not data-driven, targeting executive-level decision makers (Rabelo et al., 2007). DES models, in contrast, are better at providing a detailed analysis of systems involving linear processes and modeling discrete changes in system behavior (Sweetser, 1999). DES is mostly applied at operational-levels for planning and scheduling activities (Venkateswaran et al., 2004). A very accurate review of the fundamental differences between SD and DES is given by Lane (2000); Table 1 presents an overview of these differences.

Table 1. Fundamental differences between SD and DES (Lane, 2000)

	System Dynamics	**Discrete-Event Simulation**
Perspective	Holistic; emphasis on dynamic complexity	Analytic; emphasis on detail complexity
Resolution of models	Homogenized entities, continuous policy pressures, and emergent behavior	Individual entities, attributes, decision, and events
Data sources	Broadly drawn	Primarily numerical
Problems studied	Strategic	Operational
Model elements	Physical, tangible, judgmental, information links	Physical, tangible, and some informational
Human agents	Executive policy implementers	Decision makers
Model outputs	Understanding behavior, location of key performance indicators, effective policy levers	detailed performance measures across a range of parameters, decision rules, and scenarios

3.1 Why integrate SD and DES modeling?

When modeling a complex system, it is sometimes very difficult to define the boundaries of a model that appears to be a closed loop with its external environments (Brailsford et al., 2010). This is often the case with hierarchical levels of the VC. Similar kinds of uncertainties occur at different hierarchical levels of organizations, yet they are nearly always handled independently at each level. Integrating SD and DES can be very effective in studying the impact interaction between each level has on the system (Venkateswaran et al., 2004). Hybrid simulation integrating both SD and DES can create valuable synergies. By integrating each technique hierarchically, "both paradigms symbiotically enhance each other's capabilities and mitigate limitations by sharing information" (Chahal and Eldabi, 2008), which is very attractive to VC managers. The hierarchical nature of a hybrid SD-DES simulation model can support VC decision-making process by being able to combine the aggregate and strategic aspects of the system with the very detailed operational-levels, in a way that recognizes the different needs along the management hierarchy (Rabelo et al., 2005).

3.2 Synergizing SCOR with SD-DES Model

The SCOR model can be a powerful value management and decision-making tool. Once a complex management process such as SCM is captured in standard process reference model form, it can be measured, managed, and controlled (SCC, 2010). However, Bolstorff and Rosenbaum (2007) quite cleverly state that "*for all its strengths and potential, the SCOR model is still just a noun-a-series (or glossary) of definitions for processes, metrics and leading practices*". They continue by saying that simply having the dictionary is not enough and to change the nouns into verbs, effective management, business process engineering and problem-solving techniques are needed. Integrating SCOR with simulation has been used very effectively, especially DES to achieve this (Venkateswaran et al., 2004, Persson, 2011, Jin et al., 2006). Despite the huge potential in using a hybrid SD-DES driven SCOR model, there has been no record of it in literature. This alone is a key reason for synergizing SCOR with SD-DES modeling in this paper.

4. CASE STUDY – Tire Distribution Industry

Intensive global competition, reductions in brand loyalty, increasing tire life spans, high costs of raw materials, and decreasing demand due to recession have reduced tire distributors' profit margins. Market variety creates a high demand on several categories of tires which vary in size and type. Tire supply and manufacturing is seen as a much easier process than other automotive components, as it needs a relatively small number of commodity raw materials such as natural and synthetic rubbers. Nevertheless, its distribution network is considered complex as a direct result of globalization. The case studied in this paper focuses on the order processing system at a leading brand name tire distribution center (TDC) in Dublin, Ireland. To add value for customers, SC strategies were revised in order to provide short order cycle times with a minimum of incurred cost. TDC is an Irish-based distribution center for one of the biggest brand names in the global tire market. It supplies tires for a wide variety of customers ranged between individual customers to large-scale companies which in turn impact the variety of customer orders regarding item quantities and types. In order to keep customer satisfaction high, the company's response to its customers has to be fast, accurate, on-time, with low costs. The company also provides the proper capacity of equipment, labor and storage spaces to prevent operations bottlenecks and improve item flow. However, many SC and operational challenges have arisen that prompted the company to think about applying a process reference model to their SC structure. SCOR has been recommended as a reference guide for TDC to follow to increase SC transparency, visibility, collaboration and effectiveness along their VC.

4.1 TDC Problem Definition

The diversity in customer types causes a wide variation in the customer demand regarding to tire quantities and types. To maintain customer loyalty and value, the company aims to respond speedily to customers' demands in an accurate manner with the least possible cost, following the SCM strategy of responsiveness. The company mainly faces challenges in ordering accuracy. Monthly forecasting plans are generated based on extensive analysis of the market conditions, competitors' positions, future customer contracts and stock keeping unit (SKU) consumption rates. Applying such a process for more than 200 different SKUs requires considerable time and effort, particularly when one considers that 75% of all orders received in 2011 were for 10 SKU's or under (Figure 1). In an attempt to cope with these challenges, the company decided to increase the lot sizes of its replenishment orders and regularly schedule them in longer time intervals. Although this policy has prevented stock-out situations and reduced item unavailability rates (a key requirement of a responsive SC), this has resulted in considerably long order cycle times as well as high inventory costs.

Figure 1. TDC customer order frequency distribution for 2011

5. PROPOSED FRAMEWORK

Structuring, planning, collaborating, analyzing and improving are all key factors in managing a successful VC. The powerful analytical and mitigating benefits both SD and DES have in understanding and aligning the hierarchical levels of the VC are evident. The hierarchical simulation-based framework developed in this paper is illustrated in Figure 2. It incorporates the structure, knowledge base and SCM expertise of the SCOR model with the analysis and evaluating strengths of SD-DES simulation. TDC data will be used to describe the framework in more detail.

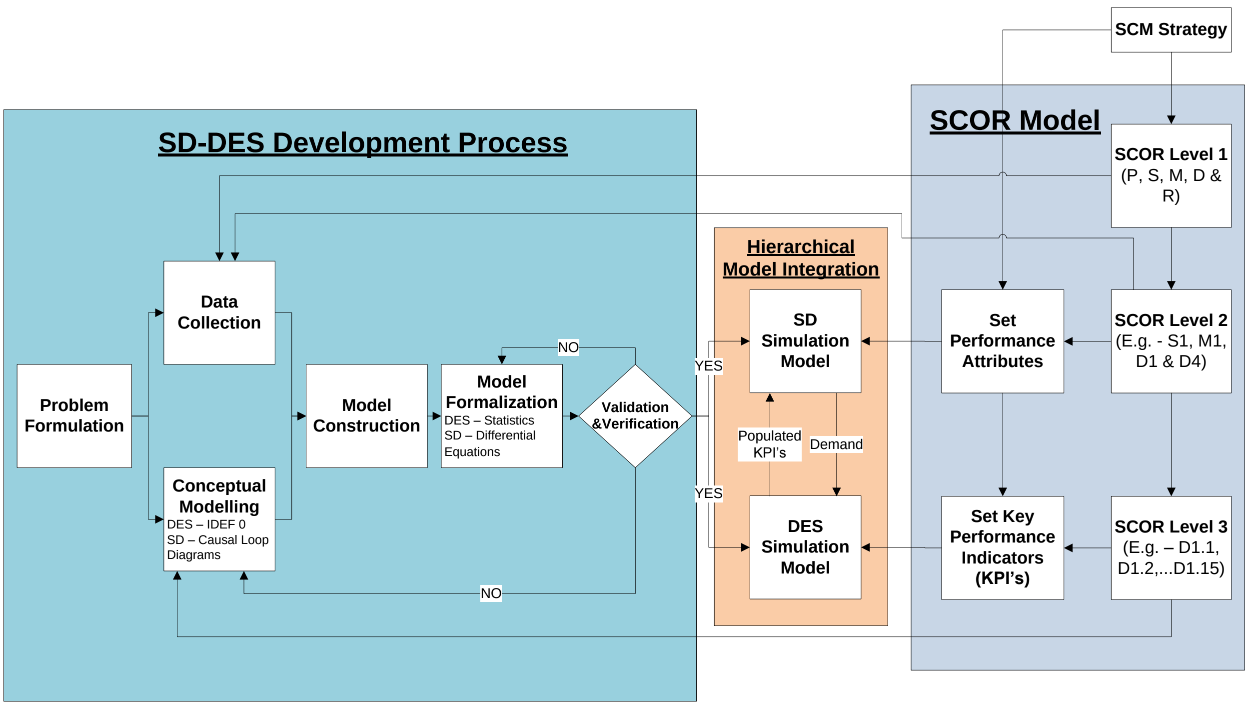

Figure 2. Hierarchical Simulation-Based SCOR Framework

5.1 SCOR Model

According to the SCOR process, SCM is defined by five key integrated processes; PLAN (P), SOURCE (S), MAKE (M), DELIVER (D), and RETURN (R). There are four strategic hierarchical process levels; this paper focuses on the first three levels of TDC's SCOR model.

5.1.1 TDC SCOR Level 1

SCOR Level 1 processes are the core management processes that are put in place to achieve the overall SC strategy of an organization. TDC's VC strategy is that of agility and responsiveness in the distribution of tires to several customer categories in the Irish market. For this reason, the company follows the SCOR SC model which is inventory driven, has high fill rates and short turnarounds, and is called Make-to-Stock (MTS). As a distribution service provider the company's core strategic value management processes center on PLAN, SOURCE and DELIVER, (and RETURN which is beyond the scope of this paper).

5.1.2 TDC SCOR Level 2

SCOR Level 2 categorizes and configures the sub-processes of Level 1. Using a thread diagram Figure 3 shows the TDC VC from a SCOR perspective, focusing on the Level 1 category most important to the company, PLAN and DELIVER. In the TDC SCOR model, thread diagrams are relationship maps that focus on the material flow (D, R), material strategy (M, S) and planning processes (P) (Bolstorff and Rosenbaum, 2007). The TDC SCOR thread process focuses on the material flow (D), material strategy (M, S) and planning processes (P). The thread diagram disaggregates the MTS model further into level 2 processes, which are explained in Table 2.

Table 2. TDC SCOR Level 2 Processes

Level 2 Process	Code	Core Activity
Plan Source	**P2**	Aggregate Planning
Plan Make	**P3**	Aggregate Planning
Plan Deliver	**P4**	Aggregate Planning
Source Stocked Product	**S1**	Procurement
Source Make-to-Order Product	**S2**	Procurement
Make-to-Stock	**M1**	Production Planning
Make-to-Order	**M2**	Production Planning
Deliver Stocked Product	**D1**	Distribution Planning
Deliver Make-to-Order Product	**D2**	Distribution Planning
Deliver Retail Product	**D3**	Distribution Planning

There are two main inputs to the process, first, the source of supply from TDC's regular supplier, which produces and holds product in stock for customers such as TDC to order periodically. The regular supplier sources raw material to produce tires (S1), makes-to-stock for future customer orders (M1) and distributes customer orders to TDC within a lead time of 10 days (D1). Supplier number two is a backup supplier TDC uses when there are shortages in supplier 1 inventory, peaks in demand, or when an expedited order is needed. Although the lead time is 3 days less than the regular supplier, the backup supplier works under a make-to-order plan, a more expensive order process.

TDC's procurement department executes the S1 and S2 processes, while D1 (deliver to motor shop/repair garage) and D4 (deliver to retailer) are generic warehouse functions that receive, store, pick, load and deliver, along with information and capital flows. P2, P3 and P4 are the planning activities that support the movement of material and information along TDC's SC. SD modeling will be used to recreate the planning, sourcing and, distribution functions represented in Level 2.

5.1.3TDC SCOR Level 3

Level 3 processes describe the steps performed to execute the processes of Level 2. The sequence in which these processes are executed influences the performance of the Level 2 processes and the overall VC. The example used in this framework is that of TDC D1, or delivered stocked item to customer. Figure 4 shows the hierarchical breakdown of level 2 process D1 into its level 3 sub-processes, D1.1 to D1.15. These are generic activities within any distribution function of any organization, ranging from process customer order inquiry, to storage, order picking and invoicing. DES modeling will be used to create this operational level view of TDC's SC.

5.2Data Collection

One of the key factors that affect the quality of the simulation results is the input data (Ismail et al., 2010). System understanding and process analysis using qualitative and quantitative data collection methods were used in the analysis stage through the collection of TDC primary data. Several field visits, interviews, ERP data collection and process analysis sessions were conducted in order to frame an understanding about the main parameters and generate a list of SCM activities of the studied SC. Secondary data collection in the form of a review of current literature supports the process analysis phase.

Data required for the SD model development was mainly to gain a strategic level understanding of the internal and external influences on the behavior of TDC's more-strategic Level 1 and 2 SCOR processes. This was done using interviews with senior management and focus groups. A more-tactical, operational level of data collection was introduced to collect data for Level 3 process D1.

5.3 Conceptual Models

Conceptual modeling is a presentation of the sequences of system processes, procedures and resources and shows the relationship between a system's objects, such as customers and products, and their status during the systems process (Mahfouz et al., 2010). Many modeling methods have been developed, studied, and reviewed by academic experts (Aguilar-Savén, 2004, Shen et al., 2004). To develop the hierarchical simulation-based framework, it was important to choose the best fit conceptual models for each simulation technique used.

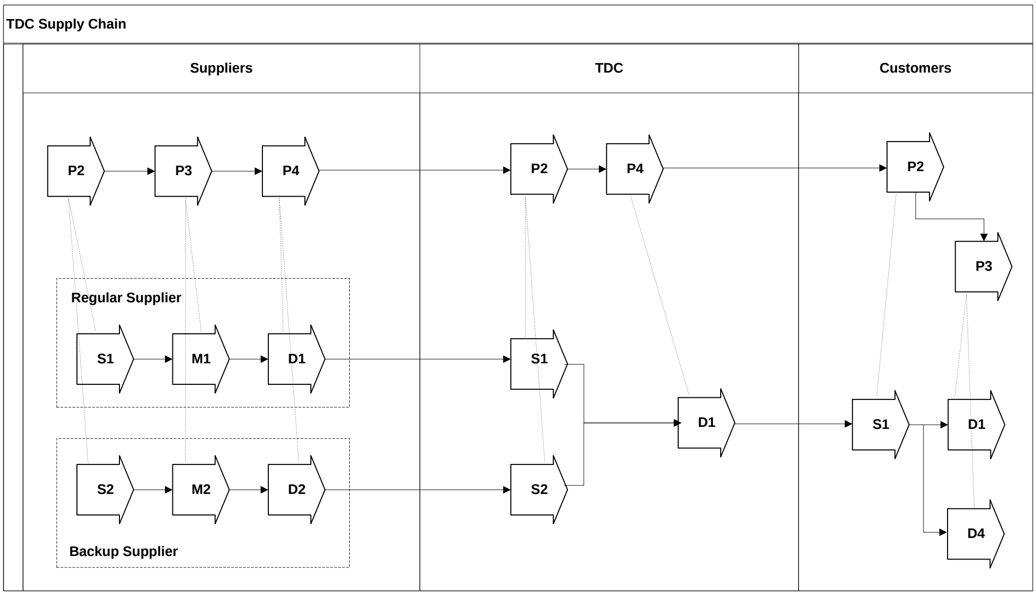

Figure 3. Thread diagram of TDC SC – SCOR Level 2.

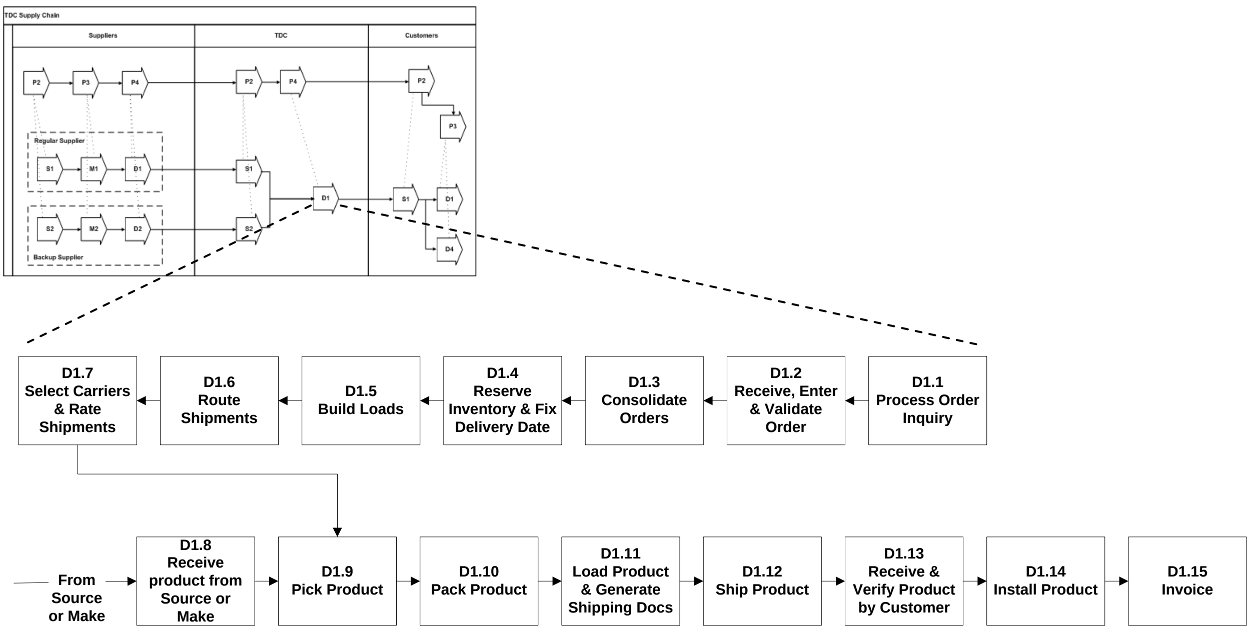

Figure 4. Deliver stocked product (D1) - SCOR Level 3 process.

5.3.1Conceptual Model of TDC SCOR Level 2 Processes

As illustrated in the thread diagram in Figure 3 and Table 2, Level 2 processes at TDC are at a high hierarchical level, incorporating senior management decision-making processes. The type of simulation modeling technique used to recreate this process will directly influence the choice of conceptual model used. Using SD suggests that the objective of the simulation model is to study and understand the underlying behavior of TDC SC and the influencing factors (feedback mechanisms) each parameter, decision and performance measure have on each other.

The causal loop diagram depicted in Figure 5 shows the feedback processes that affect the customer order process and inventory accumulation at TDC. The diagram is formed of two types of feedback loops: balancing feedback loops and reinforcing feedback loops. An example of a balancing loop is the loop connecting the inventory and ship to customer processes. The + inventory and – shipments explain that whatever happens to inventory, the opposite or negative happens to shipments. That is, if shipments increase then inventory decreases. An example of a reinforcing loop is that between forecasted orders and inventory. The + inventory and + forecasted orders show that the same behavior occurs in this relationship, that is if forecasted supplier orders increase, inventory in TDC's warehouse increases. The behaviors depicted in the feedback loops are the core blueprints for building SD models.

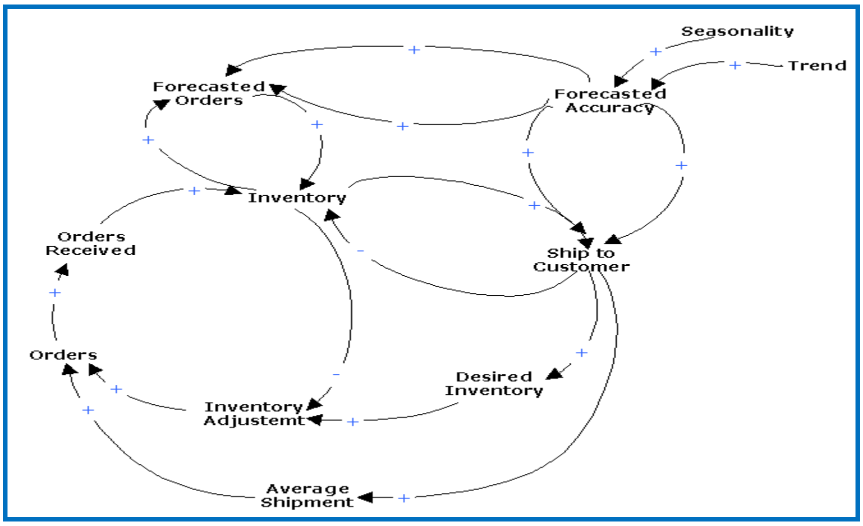

Figure 5. Causal Loop Diagram of TDC SCOR Level 2 Process

5.3.2 Conceptual Model of TDC SCOR Level 3 Processes

Figure 4 in Section 5.1.3 clearly maps the process requirements for TDC's Level 3 process D1. In this process view of D1, information, resource, and material flows are represented, making it a complex process to model and capture all details needed to create an accurate 'As Is' simulation. Taking into account the complexity of the D1 system and its multiple input, output, controls, and mechanisms, integrated definition for functional modeling (IDEF0) is a perfect match for modeling such intricate systems (Mahfouz et al., 2011). IDEF0 allows users to understand the sequence of system functions. An activity block which is the basic unit for IDEF0 describes the main function of the process using ICOMs (Input, Control, Output and Mechanism), which are represented by horizontal and vertical arrows, as illustrated in Figure 6. Each activity block shown in Figure 6 incorporates SCOR Level 3 processes D1.1–D1.15. For example, activity block A1, customer order management, depicts D1 sub-processes D1.1, D1.2, and D1.3. The hierarchical nature of IDEF0 means that all activity blocks can be filtered down another level to gain more detail for the simulation model-building phase.

5.4 Simulation Models

The simulation models created for TDC SCOR processes are very detailed and extensive. The aim of this paper is to introduce a SC value generating framework integrating SCOR with SD-DES simulation; therefore it goes beyond the objectives of this paper to describe the simulation models in detail. An overview of the models is as follows.

5.4.1 SD Model

Based on the causal loop diagram, the SD model was built using four primary blocks: levels, flows, auxiliaries, and constants. Levels are accumulators that give a snapshot view of reality. Their values highlight how the system is doing at any given point in time. Flows are action variables, creating dynamics when they accumulate in levels. They feed levels with a rate of material or information flow. Auxiliaries are used to aid in the formulization of flow rates, level and other auxiliaries. They are algebraic computations used in conjunction with differential equations used in the model. Constants are similar to auxiliaries but remain static over the course of the simulation run. The inventory variable is the only level used in the model, while customer orders/shipments and forecasted supplier orders are flows. The remaining variables were used as auxiliaries and constants to construct the differential equations. The model was run for a period of 1 year, with multiple replications (warm up period showed 10 runs for each experiment is a statistically valid selection).

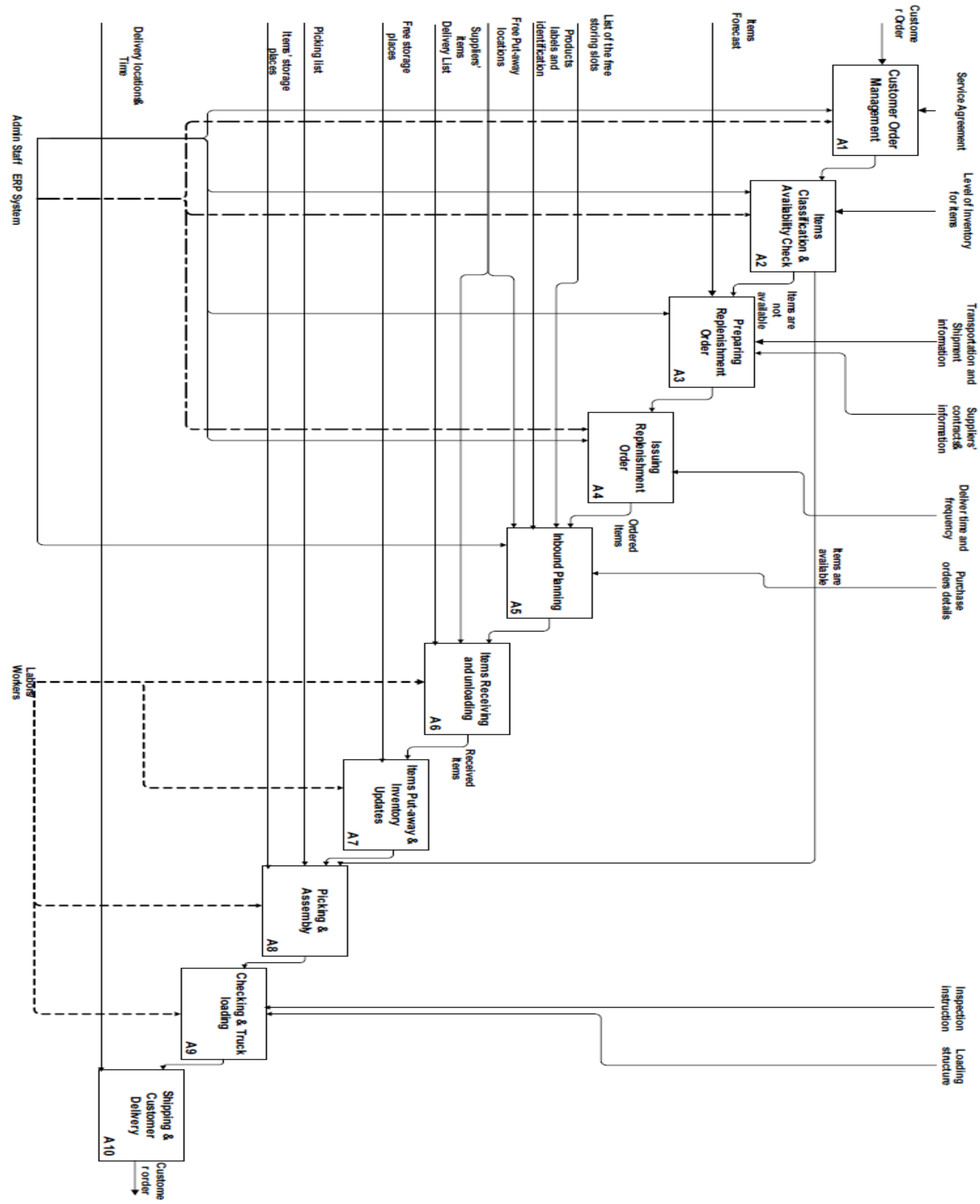

Figure 6. IDEF0 Model of TDC SCOR Level 3 Process D1

5.4.2 DES Model

A DES simulation model based on the IDEF0 conceptual model shown in Figure 6 was developed. The model assumptions are (1) no returnable items are modeled, (2) the resource availability rates are based on data collected from managers, and (3) the model focuses on the generic features (Figure 4 and 6) of the distribution activities. For the model to reach its steady-state condition, the warm-up period was found to be 2 weeks. Every simulation run represents one year of actual timing. Each experiment result is an average of 10 independent replications. The DES model of the distribution processes has used a generic simulation package and customized it with Java and XML technologies.

Excel sheets are the link between the two simulation models. Each model runs independently of each other and data is transferred via input and output Excel sheets generated by the SD and DES models. Forecasted demand created in the SD model is transferred to the DES model as customer order input. Cycle time, average inventory, and late jobs are the variables transferred back to the SD model to measure the SCOR performance attribute Responsiveness.

6. Results Discussion

The uncertain nature of customer demands and suppliers' lead time makes it difficult to select the best system process parameters that can achieve high level of customer satisfaction (i.e. short cycle time and no late orders) while achieving the goals set out in the VC. After discussions with TDC managers, it was agreed that to generate value through increased agility and responsiveness the models would run under four scenarios (Table 3): (1) base scenario- no change in current system; (2) scenario 1- change forecasting technique to triple exponential smoothing (Snyder and Shen, 2011) incorporating trend and seasonality in demand predictions; (3) scenario 2– Increase frequency of forklift maintenance to optimize order picking rate; and scenario 3 – Customers Segmentation, which is splitting customers into a Pareto grouping by their contribution to TDC sales.

The parameter change in the forecasting technique in the SD model has had a significant impact on the SCOR Level 3 performance metrics chosen to represent VC responsiveness. Factoring seasonality and trend into the demand forecast has decreased order cycle time and average inventory by 47% and 14%, respectively. This suggests that the use of triple exponential smoothing has increased the forecasting accuracy of demand, resulting in increased availability of SKU's, less wait time for back orders, and higher inventory turnover. The large decrease in late jobs of 61% needs more investigation, but reflects the increased accuracy between forecasted and customer orders. On the other hand, management's suggestion that decreasing the probability of breakdowns through applying regular maintenance services in fixed intervals did not materialize, suggesting that equipment breakdowns do not have a significant impact on order fulfillment at present. If management implemented these measures using random estimates and experience alone, it would be a costly mistake to make. There were no significant changes in VC performance when the hybrid simulation was run under scenario 3, customer segmentation. Cycle time and average inventory remained static because order and supply rates remained the same as the base line; it was only the order fulfillment priority that changed. The number of late jobs increased by 30% as there was a delay in lowest priority customers receiving their orders. In terms of value generation, this increase was balanced by the on-time order fulfillment of customers with larger order volumes.

Table 3. Main effect of Level 2 Scenario change on Level 3 performance metrics

		Results		
	Process Parameter	**Cycle time (days)**	**No of Late Jobs**	**Average Inventory (All SKU's)**
Baseline –	No Changes	28.75	3.67	18020.07
Scenario 1 -	Change Forecasting Technique	15.34	1.42	15467.23
Scenario 2 -	Decrease Equipment Breakdowns by 50%	27.26	3.32	17547.34
Scenario 3 -	Customer Segmentation	27.67	4.78	18067.1

7. Conclusion

We are part of extraordinary times, where global recession coupled with increased competition, high costs and decreasing demand has changed the dynamics of supply chains. In response, many organizations fast-tracked changes to reduce costs and maintain profit margins, not considering the long-term impact these decisions have on operational-level SCM activities and overall value generation. The Supply Chain Operations Reference (SCOR) model increases the control organizations have on their VC's and increases alignment between different hierarchical strategies. Simulation techniques, in particular DES and SD are very effective in decreasing poor SCM corporate and operational decision making.

This paper presents a novel framework that integrates SCOR with SD-DES simulation modeling to improve the VC performance of hierarchical SCM decision-making with respect to inventory management and order processes. Using TDC as a case study, it was found that conceptual modeling techniques such as IDEF0 and causal loop diagrams complement the process modeling methods used by SCOR. The integration of SD and DES gives companies a powerful analytical tool to support the knowledge base gained by using SCOR. This integration appears to be an effective method to; evaluate order strategies and performance, enhance throughput rates, and increase value generation.

A full hierarchal SD-DES model of the entire SCOR reference model, using generic processes is a future research work. The next phases in the model advancement will include: the development of a performance index to assess and grade the success of using SCOR in any SC; and more in-depth collection of corporate-level data, evaluating the alternatives from the simulation results against other qualitative factors using analytic hierarchy process (AHP).

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