ABSTRACT
Nowadays, the concept of modeling the supply chain represents an important revolution and new approach to the development and evaluation of the complex supply chain systems.

The proposed conceptual modeling approach especially tailored for describing the most important and active supply chain business processes and activities; it provides a systematic approach for generating executable model definitions from high-level modeling design. That captures effectively the complexity of the supply chain through depicting the internal supply chain business processes and activities structure, relationships, conversations, and commitments. Those provide starting point for developing the details of the supply chain models and implementations to satisfy the multiple objectives and requirements.

KEY WORDS
Supply Chain Modeling, SCOR, UCM, Simulation

1. Introduction
Despite the great emphasis given in the last decade on the need for companies to smooth their physical boundaries in favours of more integrated perspective, simulation based heuristics is a method by which a comprehensive integrated supply chain model can be analyzed by considering both its strategic and operational elements. Nowadays, the concept of modeling the supply chain represents an important revolution and new approach to the development and evaluation of the complex supply chain systems.

Supply chain systems are collections of autonomous components that interact or work together to perform tasks that satisfy their end customer goals. Several supply chain-modeling methodologies were proposed such as Petri nets & coloured Petri net [1,2], Conceptual models[3,4], Supply Chain Process Reference Model SCOR [5,6,7].

Each of the above models has it is strong and weak points, and each included features which are tailored for a specific application domain.

Our aim contribution in this paper is presenting our modular and reusable conceptual framework considering several real life logistic activities and previous related developed models, through showing and discussing the behavior of different supply chain entities on a realistic serial distribution supply chain and how they operate subject to different sets of constrains and objectives according to SCOR model. However, those entities are highly interdependent when it comes to improve the performance of the supply chain in terms of objectives such as delivery time, order picking processes, order fulfillment strategies and cost minimization. As a result, the modeling concept of main supply chain components and related entities were discussed in sections 2 and 3 presenting the combination of the UCM and the SCOR model in developing the conceptual framework of modeling supply chain network.

The use case map (UCM) [8] notation method supported by supply chain operations reference SCOR Ver. 6.1 2004 assist in developing the supply chain simulation model discussed in this paper. Both methods are able to captures and describe the most shared elements in the supply chain, such as cooperation and interaction, organizational design, communication, collaboration, and coordination.

The Use Case Map (UCM) notation method supported by Supply Chain Operations Reference SCOR ver. 6.1[9,10] and proposed conceptual modeling framework was adopted and assist us in developing the Logistical Distribution Network Simulation Tool (LDNST) [11,12]. Both methods are able to captures and describe the most shared elements in the supply chain, such as cooperation and interaction, organizational design, communication, collaboration, and coordination.

The proposed conceptual modeling approach using UCM and SCOR level 1 and 2, that especially tailored for
describing the most important and active supply chain business processes and activities; it provides a systematic approach for generating a supply chain simulation model definitions from high-level modeling design. That captures effectively the complexity of the supply chain through depicting the internal supply chain business processes and activities structure, relationships, conversations, and commitments. Therefore, the contribution of this paper is presenting some theoretical and practical operational modeling logics that were considered in the development of the (LDNST) tool, and detailed operational elements proposed in SCORE 6.1 model level 3 and 4 were not discussed in this paper.

A real life supply chain simulation model of a European-German supply chain firm motivated this paper work that the developed simulation model used in assisting and evaluating several shipment replenishment policies and different supply chain configurations [11,12], the logistics supply chain managers in evaluating the distribution supply chain performance measures.

2. Supply Chain System Objects and Components

A supply chain objects library proposed by Biswas and Narahari (2004) [13] was considered, and a detailed description and classification of various library objects was summarized at the end of this paper. They classified the objects into two categories:

- Structural objects and
- Policy objects.

The structural objects are the physical entities of supply chain networks. The physical structure of the supply chain networks is modelled using these classes. Physically the supply chain network is composed of plants, warehouses, distributors, retailers, suppliers, customers, orders, and vehicles. The policy objects embed business logic, which is used to control the flow of products and information through the network, such as inventory policy, order management policy, demand planning policy, supply planning policy and distribution policy.

The set of structural objects is used in conjunction with the policy objects to build the object models of a supply chain. These models are used to provide customized inputs for various decision problems to be studied.

The policy objects describe the protocols used in procurement, manufacturing, transportation, and distribution of material within the supply chain. For example, a structural object such as "Warehouse" can be composed with a policy object such as "Inventory Policy" to describe different types of warehouse management and replenishment schemes [13].

Those structural objects integrated with predefined policies will be used to construct the high-level supply chain system utilizing the UCM conceptual visualization aids.

3. Designing a High-Level Supply Chain Model

Developing and understanding complex systems is not easy to achieve by traditional systems that concentrate on low level details. The main goal of the use of a high level view is to understand the entire supply chain and its structure without referring to any implementation details. The Use-Case Maps supported by SCOR 6.1 level 1 and 2, which are suitable for high-level visual representations and particularly a starting point for generating more detailed visual descriptions, because of their ability to simplify and successfully depict the design of complex systems and to provide a powerful visual notation for a review and detailed analysis of the design.

Selected UCM notation presented in Table 1; these notations with SCOR model level 1 [10] help to visualize, think about and explain the overall behaviour of a whole supply chain system. It describes scenarios in terms of causal relationships between responsibilities. It also emphasizes the most relevant, interesting and critical functionalities of the system, where the details will be considered according to SCOR 6.1 model.

Table 1: Basic UCM Symbols [8]

<table>
<thead>
<tr>
<th>UCM Notation</th>
<th>Notation Explanation</th>
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<tbody>
<tr>
<td>Start End Path</td>
<td>Path: Represents flow of events in the system, path, connects start points, stubs, responsibilities, forks, and end points of UCM. The start-point represents preconditions. The end-point represents post-conditions.</td>
</tr>
<tr>
<td>Do something Responsibility point</td>
<td>Represents the functions to be accomplished by the system at that point of the path.</td>
</tr>
<tr>
<td>Or Fork</td>
<td>Or Fork: An OR fork means the path proceeds in only one out of two or more directions.</td>
</tr>
<tr>
<td>Or Join</td>
<td>Or Join: it means two or more paths merged it in one single path.</td>
</tr>
</tbody>
</table>
And Fork: it means that a single path is distributed at the same time into many concurrent paths.

And Join: it means that several concurrent Paths merged at the same time into a single path.

Static stub: associated with one plug-in (Sub UCM) as task to be achieved by the system, used as decomposition of complex maps.

Dynamic stub: associated with several plug-ins, whose selection can be determined at run-time according to selection policy (often described with preconditions). It is also possible to select multiple plug-ins at once (sequentially or parallel).

Wait point: Path a waits for an event from path b.

Structural object: component representing a Supply chain Structural object.

### 3.1 Generalized Proposed Serial supply Chain Model Scenarios

In this section we will describe the proposed high-level supply chain structure and objects of a five-echelon serial supply chain system utilizing the UCM and SCOR model and show how the proposed modeling approach is able to capture real supply chain components based activities and different system scenarios in visual views. The following scenarios represent interactions between some important supply chain components and functions. Examples of interactions shown are end customer components with a distribution center, distribution center with central warehouse components, and central warehouse production plants with suppliers. By tracing application scenarios the high-level model is derived.

This modeling approach maintains the most important steps such as: 1) Identify scenarios and major components involved in the supply chain. 2) Identify roles for each component. 3) Identify pre-conditions and post-conditions to each scenario. 4) Identify responsibilities and constraints for each component in a scenario. 5) Identify sub scenarios and replace them with stubs.

#### 3.1.1 End Customer (Retailers)-Distribution Center Scenarios

The retailers/end customer scenarios describe the flow of material and information between the end demand point and distribution center (bottom-up approach), the customer order pre condition state is ready for processing (customer made an order it contains several multi products). The scenarios starts when the data from the SAP/ERP system is retrieved and the checking of the demand order quantities through product available inventory positions (IP) has been performed, where the inventory positions are represented by the following:

\[
\text{Product Inventory Position (IP)} = \text{Available On Hand Inventory (OH)} - \text{Demand Quantity (D)} + \text{In-Transit Quantity (T)}
\]

The scenarios start with the check of the static demand stub, which hides the detailed information of the checking demand request process (see stub 1) in Figure 1. The checking demand stub request may result in three post conditions. Such as: satisfy the whole order from the existing inventory, a partial order may be satisfied and the rest will be back ordered or the whole order will be treated as a lost sales order. Therefore, the Check Demand Request stub 1 is represented as a static stub. Figure 2 illustrates the plug-ins for the Check Demand Request stub.

![Figure 1: End customer (Retailers)-Distribution Center Scenario](image)

**Preconditions:**
- Customer Order Issued and Received.

**Post conditions:**
- Order satisfied
- Open orders (backorder)
- Lost Sales Record

![Figure 2: Plug-ins for Check Demand Request Stub](image)
After checking demand, the paths lead to the generating of replenishment order from the distribution center components; in the event that the required demand could not be satisfied from the existing on hand inventory, then the distribution center verifies the replenishment order based on a pull principle; then the path leads to an or-fork immediately after the order is verified indicating alternative scenario paths. One path leads to refuse the replenishments order request, e.g. because those ordered products are not stocked in this location (wrong information flow, product inventory allocation strategy). Then the path continues to the result stub to inform the model that the order request will be submitted to an other distribution center (error message). These scenarios will be utilized later in case of multi-echelon supply chains. The other path leads to accept the replenishment request and the path proceeds to the distribution center to check product availability (check demand) stub, according to the inventory management control policy. The distribution center checks whether the demand stub has the same outgoing ports b and c.

The outgoing path from port b leads to satisfying the product replenishment order action followed by a second important business process based on SCOR Model called Order Picking Consolidation stub 2 (Levels 3 and 4). Figure 3 depicts the main activities and decisions made in the order picking and consolidation stub.

There are three plug-ins associated with the Order Picking Consolidation stub. Events and states with consolidating and aggregating the shipment size that forms the final customer shipment loads according to the following rules:

- Shipping only product full pallet type, and/or
- Manual Order-picking (eventually Negative Order-Picking Policy),
- Shipping mixed pallets consisting of several product types.

Then, after the order picking and consolidation process, the shipment order is transferred to the shipping and loaded to trucks to be transported to the demand location through transportation components. Those processes are according to SCOR blocks such as M2.2; M2.4; M2.5; D2.5; D2.6; D2.7; D2.8; D.9 [9]. When the post condition replenishment decision had done satisfy at port e. This leads to the shipment transportation components discussed later.

The transportation component starts by a transportation request, which is responsible for searching and preparing the required fleet size to perform the shipment transportation request. The transportation component has the possibility to manage and transport the whole shipment size by using a capacitated fleet size. The path e leads to the Preparation for the Transportation Request stub; three plug-ins are associated with that stub as illustrated in Figure 4. Three types of transportation offers are considered; the 3rd party transportation logistics provider (Common carrier), Private carrier, or Mixed carrier.

Figure 4: Stub 3 Plug-ins for Preparation Transportation Request Stub

Vehicle routing and scheduling were not considered in details in this paper; only one to one shipment trips were modelled. The path leads to completion of the shipment request and satisfies the precondition by the end customer or retailers outlets.

3.1.2 Distribution Center-Central Warehouse Scenarios

The regional Distribution center–Central warehouse scenario is similar to the previous end-customer distribution center scenario with little differences in the order-picking stub, which allows direct shipments to end customers without passing through the distribution center. Figure 5 illustrates the modified order-picking consolidation stub 2.1. Only product full palette are transported to distribution centers and mixed pallets in case of direct shipments to customers. This assumption will be ignored in distribution center operated under the cross docking concept.
3.1.3 Central Warehouse - Production Plants and Supplier Scenarios

Figure 6 shows the proposed basic conceptual scenarios between plant central warehouses, production facility and raw material suppliers, which represent the material management loop in the supply chain before the phase of distribution. This loop is designed under the push production principle; such that products are produced in production plants and stocked in plant central warehouses to satisfy downstream demand requirements (distribution center, retailers, and customers). The modelled scenario starts with the new production plan stub 4, which hides the detailed information of the production order request process. The production orders request stub 4 is illustrated in Figure 7, and it starts checking the production plan in the next planned period to confirm to the planned demand; the path leads to an or-fork immediately after the inventory position (IP) check responsibility, which results in two possible alternatives based on whether the product order was planned and scheduled and will be shipped or an urgently requested order will be issued and scheduled in the production plan; then the path leads to an extra production planning scenario.

It checks if raw material is available or a new request is issued to suppliers, then it reschedules the production plan according to the new adjustments.

Figure 5: Sub 2.1 Plug-ins for Order Picking and Consolidation Request Stub

A generalized proposed serial supply chain conceptual model is depicted in Figure 8 with associated model stubs. Two main types of transport components were considered: Inbound and Outbound, where outbound presents long haul and short-haul distribution transportation activities.

The Detailed policies and modeling aspects of Logistical Distribution Network Simulation Tool (LDNST) will be discussed in other research paper, which provide more detailed activities and capture the internal details of the supply chain business process, and their relationships are discussed considering the supply chain policies objects and strategies mentioned in Biswas and Narahari, 1999 [13].

4 Summary and Conclusion

In this paper, we present the development steps of a prototype serial supply chain model utilizing high-level notation method of Use Case Maps and the SCOR 6.1 supply chain process reference model levels 1 and 2. The developed prototype model is capable of providing a solution for modeling and constructing a practical supply chain simulation model, which is required to be flexible and to consider system dynamics, utilizing the visualized high-level model that helps us to understand, and define the behaviour of the supply chain components and the possibility of integrating the functions.

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References


Figure 8: The Generalized Conceptual Serial Supply Chain Scenarios using UCM and SCOR 6.1 Level 2 Modeling Methodology