

## DECISION SUPPORT TOOL - SUPPLY CHAIN

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### ABSTRACT

We present a currently developed Decision Support Tool - Supply Chain (DST-SC). This is specialized domain oriented tool, which is an extension of the general purpose, UML-RT Hybrid Simulation kernel of AnyLogic by XJ Technologies. DST-SC allows high degree of flexibility with respect to the supply chain functionality being modeled, has the ability to handle large complex problems, and offers highly reusable model components, offering at the same time ease of use by non-experts in simulation. Typical features of DST-SC are interoperability with third party software (DB, GIS, PPS), platform-independence as well as potential for concurrent use by a geographically distributed group.

### 1 INTRODUCTION

Supply chain management (SCM) is the continuous, active organization and mobilization of resources in order to ensure adequate information and material flow in the economy in general and for each economic agent (e.g., enterprise, client) in particular. More precisely SCM integrates “a set of approaches utilized to efficiently integrate suppliers and clients (comprised of stores, retailers, wholesalers, warehouses, carrier and manufacturers) so merchandise is produced and distributed at the right quantities, to the right locations, and at the right time, in order to minimize system wide costs while satisfying service level requests” (Mayer 2000).

Due to the high complexity of the present day logistic requirements a variety of computerized (real time) SCM support systems are being developed and offered on the market. These are mostly database-centric (distributed) applications, which allow an immediate overview and control of the state of a subset of nodes in the chain. However the principal deficiency of these systems is their inability to predict the complex interactions of incoming requests with the current states and parameters (request response times, etc.) of the chain nodes. A SCM performance can only be

appropriately predicted and assessed by employing simulation methods, which have a long standing tradition in the dynamic analysis of production and logistics processes.

Despite the high added value that the application of simulation solutions is bringing, the market penetration of these is so far still very low in general (e.g., in Germany and in Austria with less than 10 %) and in SCM in particular. The reason for the low level of employment of the simulation-centric applications lies on the one hand in the insufficient number of the trained experts and on the other on the unsatisfactory degree of practical usability (inadequate interoperability with existing IT infrastructures and substantial deficits in user friendliness) of existing SCM simulation tools (Zeigler, Kim, and Buckley 1999).

The objective of the DST-SC developed in cooperation between ARC Seibersdorf research and XJ Technologies as a specialized, domain oriented tool, based on AnyLogic by XJ Technologies is to overcome the restrictions of the available SCM simulation applications regarding user comfort and functionality. The goal is building upon the typical AnyLogic features (UML based standard architecture, platform independence and intrinsic potential for interoperability) to establish a simulation-centric SC platform, which unifies flexibility with respect to integration in a variety of user infrastructures responsible for data collection with efficiency and predicting power of an analysis, based on simulation technology.

### 2 METHODOLOGY. BASIC DST-SC ARCHITECTURE

Supply chain management is the planning and optimization of the information and material flows within the supplying chain. A distribution system consists of two levels (Thaler 2001):

- on the information level incoming orders are processed, purchase orders are issued and purchase order forms are passed on,

- on the level of the physical material flow the transport of the commodities takes place via the logistics chain.

That is, the information level triggers the physical flow of material. The response of the system depends on the nodes-states and each node-state is being transformed by the material flow (Figure 1). Supply chain managers (typically responsible for a sub-set of nodes in the chain) can vary the strategies for system reaction or even define each particular reaction, thus modifying the overall performance of the chain.

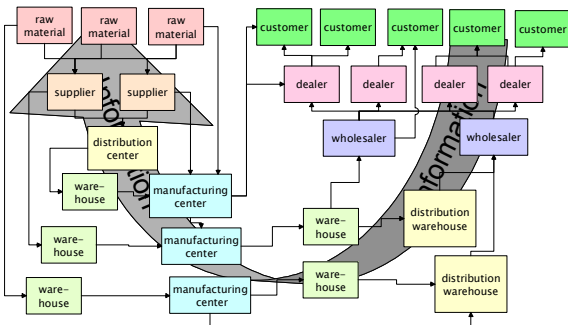


Figure 1: Schematic Representation of a Supply Chain

Optimization of supply chain performance was traditionally based on the expected order flow and potential subsystem failures, which led to more or less rigid plans and strategies. The emerging supply chain information infrastructures provide managers with (near to) real-time knowledge of the current state of the system. This requires corresponding dynamic response and coordination to enable optimal control of the chain. At this point the dynamic forecast of the system reaction to a particular action of the manager becomes essential. To assess and compare the impacts of alternative decisions an appropriate metrics for evaluating the performance of the supply chain is further required (Ball et al. 2000).

The developed DST-SC provides a supply chain manager with a tool that focuses on the dynamic forecast-assessment-optimization segment of SCM. It allows rapidly and straightforwardly to represent, examine and optimize different strategies, either trying out various possibilities one after the other or in a semi automatic regime.

DCT-SC communicates with the user through a graphic user interface and implements a set of object-oriented class libraries on top of an AnyLogic-based general-purpose simulation platform (Figure 2). To facilitate the management of complex models it is also possible to design on demand dedicated model libraries comprising complicated supply chains.

The typical interoperation of a user with DST-SC involves: definition of a particular supply chain scenario, caring out of simulation runs, result analysis and iterative

(semiautomatic) optimization. To define a scenario the user selects the individual classes necessary for a particular Supply Chain Model from the library, creates model objects using drag-and-drop methods and graphically arranges the objects on the model editor. Further he defines the individual information paths and the physical routes of transportation thus establishing information flow / material distribution channels. Parameterizing the individual objects and assigning routes to information / material flow types takes place in pull down menus or semi automatically through a database containing standard model parameters. In the course of the simulation the individual stocks, delivery times and delivery costs are computed.

Different supply chain strategies can be analyzed by changing the parameters of individual components or by modifying the flow channels. By setting a number of well defined constraints and fixing an objective function / cost functional one can automatically modify the model definition and look for system performance optima.

The Tool implements interfaces for real time communication with other software applications, and in particular enables interoperation with databases (JDBC/ODBC interoperability) and Production Planning Systems (PPS).

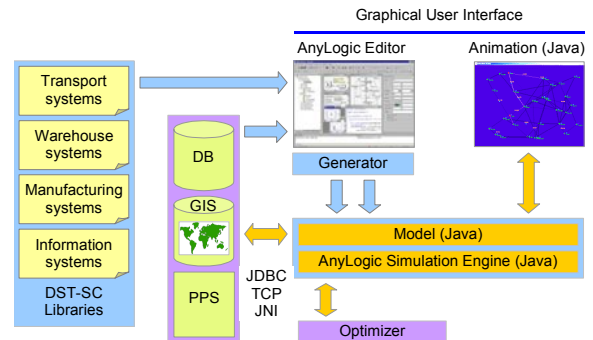


Figure 2: Structure of the Decision Support Tool – Supply Chain

Thus the DST-SC can be put to use in a number of specific application domains. On the one hand it can be employed in an “off line” mode as an effective instrument for testing strategies and/or training supply management skills in a variety of operation regimes. Simultaneously its capacity to interoperate with SCM information infrastructures and the inbuilt mechanisms for dynamic optimization opens the door for integrating it as a simulation backbone in a comprehensive SCM information system for real-time operational control.

A particular advantage of DST-SC is its potential for enabling a geographically distributed collaboration of users. This feature is due to the fact that the AnyLogic DST-SC kernel supports the distributed simulation standard HLA. (In general the AnyLogic Java HLA module communicates with the simulation engine through a dedicated interface and enables coherent interoperation with other

AnyLogic simulation models, as well with models of arbitrary origin complying with the HLA standard.) Thus DST-SC permits to operate the simulation of supply chain models over the Internet, so that the members of a geographically distributed group can accomplish necessary parameterization (each in his field of responsibility). As a consequence the effects of the separate actions on the entire supply chain performance can be analyzed in real time conditions, which adds further insights indicating proper choice of strategies.

### 3 DST-SC INTERNAL FUNCTIONALITY

The internal functionality of DST-SC is based on a uniform representation of the information and material flow through the system as well as on a universal underlying behavior of all supply chain nodes.

The basic class representing the flow is that of a Message class, which can belong to one of the following types:

- inquiry,
- response,
- reservation,
- order,
- delivery.

Each Message is parameterized by an ID, a precursor ID and an internal information table, which specifies uniquely the content, origin, quality, packaging art, etc. of the delivery or the delivery relevant information that is passed.

The universal functionality of a supply chain Node class involves manipulation of both messages and the internal database assigned to each object. The typical operations of a Node are:

1. receive message
2. register and save information table of received message in the DB
3. query DB
  - information table of message matches information in DB – GoTo 6.
  - information table of message does not match information in DB – GoTo 4.
4. create and send new message; register it in the DB
5. wait for an event (e.g., response to new message or time to elapse) and update the DB
6. create and send response message
7. update the DB

The universal functionality is further specified by internal Strategy properties, which fix the particular mode of reaction of a node to external messages.

On this basis a library of node classes is built, which provides a multiplicity of Supply Chain relevant objects

with different characteristics. It includes classes such as Customer, Dealer, Distributor, Distribution Center, Manufacturing Center, Raw Material Supplier, Warehouse, etc.

Below we outline the functionality of typical DST-SC objects. Figure 3 shows an example of two objects, defined on the basis of classes from the DST-SC library. In the object Dealer the order information is accepted. Due to the processing time there arises a delay before the information is forwarded further. This delay is described by a variable, which is assigned a particular value (parameter) in the course of model definition. The object Dealer communicates through an interface with the object Warehouse. Over this interface the order information is passed to the Warehouse. As soon as the information about the order reaches the Warehouse it is checked in a table (internal DB) whether the required commodity is in the Warehouse (commodity available). In case the commodity is available in the required quantity, it is subtracted from the table and material flow of the commodity to the object Dealer is initialized. In case the commodity is missing (or not available in sufficient quantity) a purchase order is triggered. As soon as the commodity leaves the Warehouse, the current stock level is examined. If the stock is below a certain fixed level, as defined in the order strategy, a purchase order is likewise triggered.

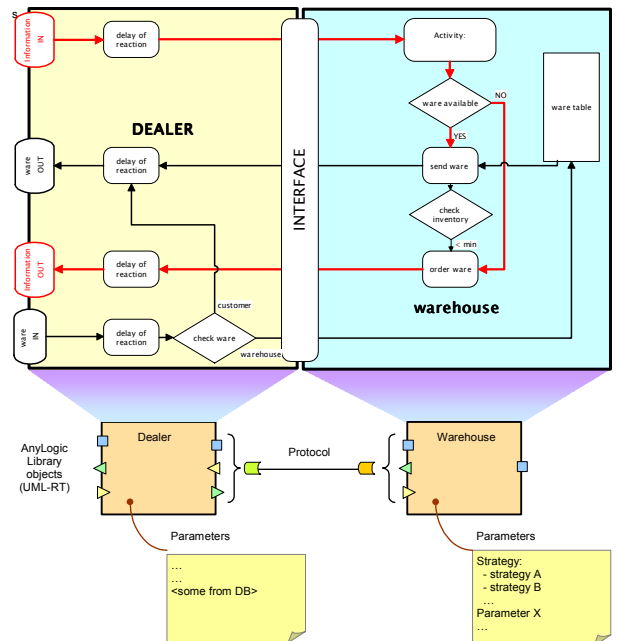


Figure 3: Example of two Objects as defined in the Library - Object Dealer and Object Warehouse

The object Warehouse can be characterized by selecting one from different order strategies:

- always a constant quantity, regardless of the demand,

- a constant quantity, as soon as a certain minimum of stock has fallen below a predefined level
- always exactly as much as would be necessary to ensure that the Warehouse stock is maximally filled,
- as soon as a certain minimum of stock has fallen below a predefined level exactly as much as would be necessary to ensure that the stock is maximally filled,
- according to the demand – always the sold quantity plus the backorders.

The user can also define independent strategies beyond the predefined ones by means of easy to use semantics.

The purchase-order lead date is also to be chosen by the user: Orders can either be submitted in regular intervals or the order strategy adapted to the Warehouse levels.

The commodity leaving the Warehouse is passed on over by the Dealer to a Customer (more generally the agent that issued the order).

On arrival of a commodity ordered by the Dealer it is determined whether it has to be directly passed on to a Customer, or it has to proceed further to the Warehouse for filling up the stock.

In addition to the universal Node classes described above additional specific class types are included, to model synchronized node-cluster behavior and transportation.

The universal nodes described above have individual strategies. To represent a cluster of synchronized nodes (e.g., a distributed enterprise) it is necessary to replace the individual strategy by a cluster strategy. To do so a Cluster Manager class is introduced. A node in a cluster possesses only a restricted strategy. It does not act on its own, but sends queries to and awaits orders from the Cluster Manager object, which controls and synchronizes the cluster.

To represent transportation, coordinates are assigned to the individual model objects in simulation space. An interconnected GIS system allows parameterizing the transportation Route class. The Route object parameters include length, type (normal road, motorway, railway, waterway, air connection) maximal allowed velocity, road pricing. Simultaneously Transport Enterprise objects are assigned to a geographic region. The Transport Enterprise class properties include number and type of vehicles such as:

- small truck,
- truck,
- train,
- ship,
- airplane.

The vehicles have capacity, average velocity (depending on route type), costs per time unit, etc. An interaction of Route and Transportation Enterprise objects establishes

the basis for modeling delivery transportation between supply chain nodes.

#### 4 THE UNDERLYING MODELLING AND SIMULATION TECHNOLOGY

The underlying modeling and simulation technology employed coincides with the one put to use in AnyLogic. In contrast to the traditional flow diagrams, hierarchical structure diagrams based on UML-RT (UML for Real Time - an extension to UML) constitute the foundation of the modeling language of DST-SC. These diagrams substantially facilitate the creation of well-organized models of any complexity. They enable encapsulation, explicit structural decomposition, clear separation of structure and behavior and great degree of reusability as well as many other features essential when modeling big-scale systems.

The block behavior specification is based on state charts (state machines), see (Borshchev et al. 2000). These describe object states (modes), the response to external or internal events and conditions and ensure event- and time ordering of operations. The behavioral specification through state charts is a particular advantage as compared to the usual stateless blocks and provides a solid framework for describing delays, timeouts, reactions to other block actions, etc. of any kind.

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