

Logistics Design and Modelling - A Simulation Perspective

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Executive Summary

Market and customer pressures will drive changes in the way the process industry currently does business. Customers are increasingly demanding greater reliability of products at lower total cost. Changes in public policy are likely to require plans for increased security throughout the process industry. Meanwhile, infrastructure constraints and threats from new, more agile entrants will challenge the way industry players currently approach both asset optimization and customer relationships. In order to position themselves to benefit from these changes, logistics operations need to balance product reliability with asset utilization more evenly. This will require a shift in mindset. Moreover, the process industry will need to change deep seated ways of working to achieve executional excellence and organizational flexibility.

Simulation is the process of modelling an existing or future system and observing the behaviour of this system over time to identify and understand the factors that control the system and predict future behaviour. The value of simulation-based tools is that they give the user the ability to examine alternative designs, decisions, and plans, and allow for testing the effect of those alternatives without experimenting in a real environment, which is often cost prohibitive or altogether infeasible.

This white paper discusses an overview of logistics, logistics in the process industry, simulation of logistics systems in the process industry, an approach for simulation and a detailed discussion on a case study for logistics simulation of a process industry.

1. Logistics Overview



Logistics is defined as a business planning framework for the management of material, service, information and capital flows. It includes the increasingly complex information, communication and control systems required in today's business environment.

Logistics encompasses the business functions of transportation, distribution, warehousing, material handling, and inventory management, and interfaces closely with manufacturing and marketing. Logistics supply chains (also called logistics systems or logistics networks) arise in numerous business segments and government functions, including: manufacturing firms, retailing firms, food producers and distributors, the military, transportation carriers (such as trucking and railroad companies), service companies, postal delivery, utilities, petroleum pipelines, and public transportation, among others.

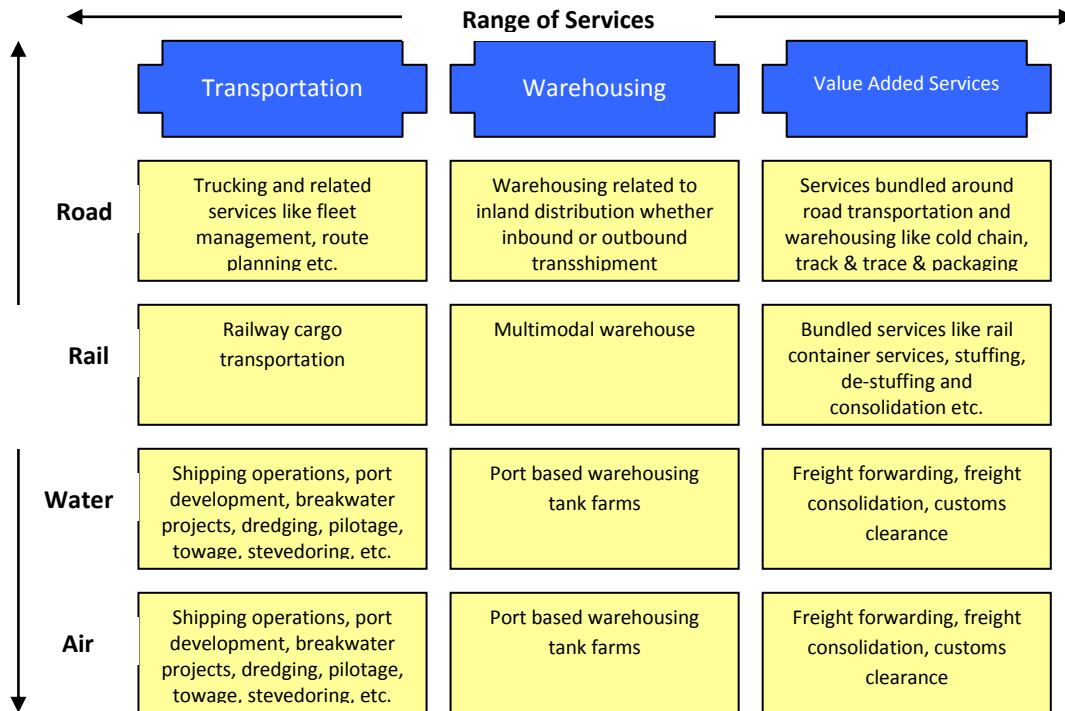


2. Significance of Logistics

Logistics management is one of the critical activities of businesses and forms the crux of entire dealings. In the highly competitive world of today, a quality Logistics management service keeps your company ahead of your competitors and gives you the extra edge needed to stay ahead. It is important to understand the requirement of clients first and then act accordingly. No two clients are the same and thus the entire procedure of planning, execution and processing completely differs from one customer to another. Premium Logistics management service providers take every step after great research and planning, keeping in mind the core of business of clients and their respective needs. One needs to constantly update the procedures and functioning of Logistics management services to be on a par with the changing business scenario. Continuous growth, competitive prices and planned execution are some of the features of a good Logistics management service. It also includes superior warehousing, transportation, and Logistics solutions tailor-made to meet customers unique supply chain needs.

The comparison between the modes and range of services highlights the simulation significance in logistics (Figure 1).

Figure 1. Simulation Significance in Logistics



3. Simulation of Logistics Systems

More than in the past, companies which are not able to introduce concrete logistics design and periodically revise their logistics strategies and, accordingly, modify their organizational processes seriously risk to losing their competitive edge.



In the industrial area, simulation has been mainly used for decades as an important support for production engineers in validating new lay-out choices and correct sizing of a production plant. Nowadays, simulation knowledge is considered one of the most important competencies to acquire and develop within modern enterprises in different processes such as inbound and outbound logistics, asset strategy, resource allocation, transportation, storage, business, marketing, manufacturing, etc. Within the visions for 2k-enterprises, simulation is considered one of the most relevant key success factors for companies' survival, thanks to its predictable features.

Several organizations consider simulation as an essential decision support system. In particular, as per the topic of this white paper, logistics design and modelling is a typical environment where simulation can be considered a useful device. In fact, it is quite evident to find out how, by using simulation technology, it is possible to reproduce and to test different decision-making alternatives upon more likely foreseeable scenarios, in order to ascertain in advance the optimal level and robustness of any given strategy.

4. Literature Review

A literature review in the domain of the simulation of logistics systems is detailed: The work of Jennings et al (2000) detailed some of the basic principles surrounding the movement of food and commodities into areas where assistance is required. The authors developed a response model expressed in terms of the selection of transport modes and networks required for effective delivery of assistance to refugees. Pettit and Beresford (2005) expanded the earlier Jennings model with the purpose of developing a better understanding of emergency logistics needs by splitting a specific emergency into different stages or phases. In developing simulation models for emergency logistics, the use of Monte Carlo simulation can be selected to simulate the output of any logistics response model. Monte Carlo simulation is a computerised mathematical technique that allows people to take into account risks in quantitative analysis and decision making (Mooney, 1997).

Computer Simulation in Logistics

Simulation models in logistics represent an attempt to replicate mathematically the functional relationships between the logistical activities of facility location, transportation, inventory, order processing and material movement. The usefulness of this replication is realized by experimentation and analysis through manipulation of the simulation model. This allows the manager to study the effects of different managerial policies and environmental conditions upon the logistics system without any manipulation of actual logistical operations (Bowersox et al 1973).

From a management and research perspective there are many benefits to the use of computer simulation in logistics. For example, the effects of certain decisions can be evaluated before implementation and systems of great complexity can be reduced to a more simple structure for ease in understanding. However, there are also certain problems associated with simulation in logistics: 1) the simulation models may be too complex for managerial use; 2) there may be little resemblance between the actual system and the model; and 3) the simulation model may be limited in its abilities to analyse the system. Any simulation model designed for analysis for business situations should meet certain criteria (Baskar et al 1973). A possible list of such criteria includes the following:

- (1) Minimum of data input.
- (2) Ease of data input.
- (3) Ease of updating.
- (4) Ease of use.
- (5) Ease of understanding.
- (6) Minimum of outside help.
- (7) Minimum of computer cost.
- (8) Rapid turnaround.
- (9) Transferrable software package (hardware compatibility).
- (10) Model a wide range of corporate systems.
- (11) Model a wide range of environmental factors.
- (12) Quantitative analysis.
- (13) Readable, informative reports.
- (14) Educational potential.

The first eight criteria deal with the ease of use of the computer model. The last six criteria deal with its flexibility in application to a variety of business situations. One computer simulation technique which meets most of the above criteria and seems quite suited to logistical problems is the Graphical Evaluation and Review Technique [GERT] (Prister 1966). Though GERT has experienced many previous managerial applications, it has not previously been utilised in the area of logistics.

Weigel and Cao (1999) applied GIS in conjunction with Operations Research [OR] techniques to solve technician dispatching and home delivery problems at Sears, Roebuck and Company. Sears used a vehicle routing and scheduling system based on a geographic information system to run its delivery and home service fleets more efficiently. Although the problems to be solved can be modelled as vehicle routing problems with time windows [VRPTW] (Solomon, 1987), the size of the problems and, thus, practical complexity make these problems of both theoretical and practical interest. The authors constructed a series of algorithms, including an algorithm to build the origin and destination matrix, an algorithm to assign resources, and finally algorithms to perform sequencing and route improvement. The combination of GIS and OR techniques improved the Sears technician dispatching and home delivery business. It (i) reduced driving times by 6%, (ii) increased the number of service

orders each technician completed per day by 3%, (iii) reduced overtime by 15%, (iv) helped to consolidate routing offices from 46 to 22, and (v) achieved annual savings of \$9 million. The success of this application also suggested a promising link between GIS and OR techniques. It also helped ESRI, the GIS consultant for the project develop ArcLogistics, a low-cost PC-based routing-and-scheduling application that brings high-end functionality to small organizations who were previously unable to afford this technology.

5. Logistics Simulation in the Process Industry

Although simulation of logistic systems in the process industry has a long lasting tradition it was always difficult to establish the methodology there. The awareness of simulation in logistics in the process industry was not strong enough and obviously the challenges in this industry were elsewhere but the situation is changing and logistics and production aspects are last resorts where money can be saved.

On the other hand, simulation has always had difficulties being applied correctly in the process industries such as: the food industry, chemical industry, pharmaceutical industry, animal care etc. The difficulties are based on the discrete nature of the methodology where liquids or powder is pouring through tanks, silos and tubes and is finally filled in silos, big bags or sacks and transported and stored in barrels and pallets. An additional complexity is due to the fact that, because of flexibility in operations, control rules tend to be very complicated. Furthermore, many systems' performances are dependent on the scheduling of processes, equipments, tools, resources, etc.

Simulation has always had difficulties being applied correctly in the process industries. The potentials, however, are considerable

The potentials, however, are considerable. The range of assets has to be standardized, inventory levels have to be decreased, control rules have to be standardized, product quantities have to be harmonized along the logistic chain and production facilities have to be utilized as much as possible.

The process industry is adding complexity to the simulation studies because it covers nearly all manufacturing aspects and adds process-based needs to the investigations. If it were possible to appropriately fulfill the requirements of the process industry some other application areas such as traffic or mass production (e.g. cigarettes, the textile industry) could follow and benefit from the developments.

6. Basic Investigations in the Process Industry

For a sample, the design of a production system in the process industry has to face the same questions as all others application fields. The basic questions might be:

CRITICAL FACTORS

Stochastic features
Exchange rate fluctuation
Suppliers' reliability
Reliability of transportation channels
Lead times
Stochastic facility fixed costs
Stochastic demand
Uncertainty of market prices
Political environment
Stochastic customer service level
Taxation and cash flow features
Taxes and duties
Modelling of profit repatriation
Duty drawback and duty relief
Modelling of transfer prices
Non-international features
Selection of manufacturing technology
Product differentiation by country
Bill of materials (BOM) constraints
Impact of economies of scale
Excess capacity determination
Financial decisions
Infrastructure modelling
Cash flow modelling
Information flow modelling
Global supply chain coordination
Modelling of competitors' actions
Modelling of alliances
Trade barriers
Quotas
Local content
Offset requirements
Subsidies

- Investigations of buffer capacities
- Determination of no. of facilities & units
- Effects of changing production steps
- Determination of the sequence of orders
- Evaluation of lot sizes
- Elaboration of routing rules through the system
- Optimization of productivity according to maximum capacities of flexibility as a reaction on demand structure
- Allocation of personnel to tasks (qualification, shift models, operation rules)
- Design of warehouses for intermediate and finished goods.
- Investigation of production concepts (dedicated production lines, push and pull principles, batch versus continuous, etc.)
- Detection of bottlenecks
- Influence of product lines on overall performance of the system
- Definition of capacities along logistic chain
- Distribution planning and routing
- Investigations on the supply chains (from the raw materials to the customers)
- Evaluation of different maintenance strategies
- Testing improvement proposals for improvement of the line availability

7. A Few Simulation Challenges Confront the Process Industry

The following examples are limited to the application of simulation for the production process of process industry. Of course distribution problems and supply activities for raw materials including trucks and trains might have a significant relevance, and will be considered as a special case in the later section.

Simulation for the Production of Paint Powder

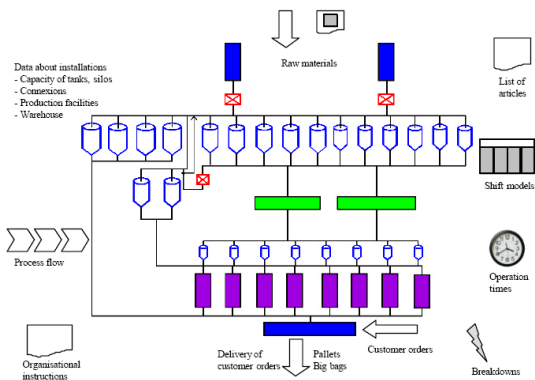
The complete production process of a production plant for paint powder consists of a number of different production and storing steps. The numbers of finished goods in the storage are the result of different product designs made from only a few starting products and different product packages.

Process in the Food Industry

In mashed potato production, the treatment of the potatoes is the first step of the three step production process; when finished, it is dried and filled into the bunkers. In the second step, the different sorts of mashed potatoes are mixed with spices and pumped into silos in front of the packaging area. After packaging, the finished containers are put into delivery storage.

A Few Simulation Challenges for the Examples

- Are the silos big enough for the realization of the production program?
- How strong is the utilization of the packaging depending on the production program?
- What products can be handled by the installation?
- Which batch sizes are useful?
- Which investments should have priority?
- Where are the bottlenecks in the whole process chain?



- How the material waste in the different process steps can influence the output and how the waste could be reduced?
- What is the optimum inventory level on the input storage?
- What planning and control principles should be used in different process steps?
- When is each order expected to complete?
- Which orders are expected to be late?
- Which operations are expected to cause orders to be late?
- Which production facilities are expected to be bottlenecks and when will there be bottlenecks?
- How much overtime would be needed to maintain the production schedule to meet demand?
- What is the impact of this new order on the existing schedule?
- What impact will this expedited order have?
- What is the next sequence of jobs within production facility to meet the plan?

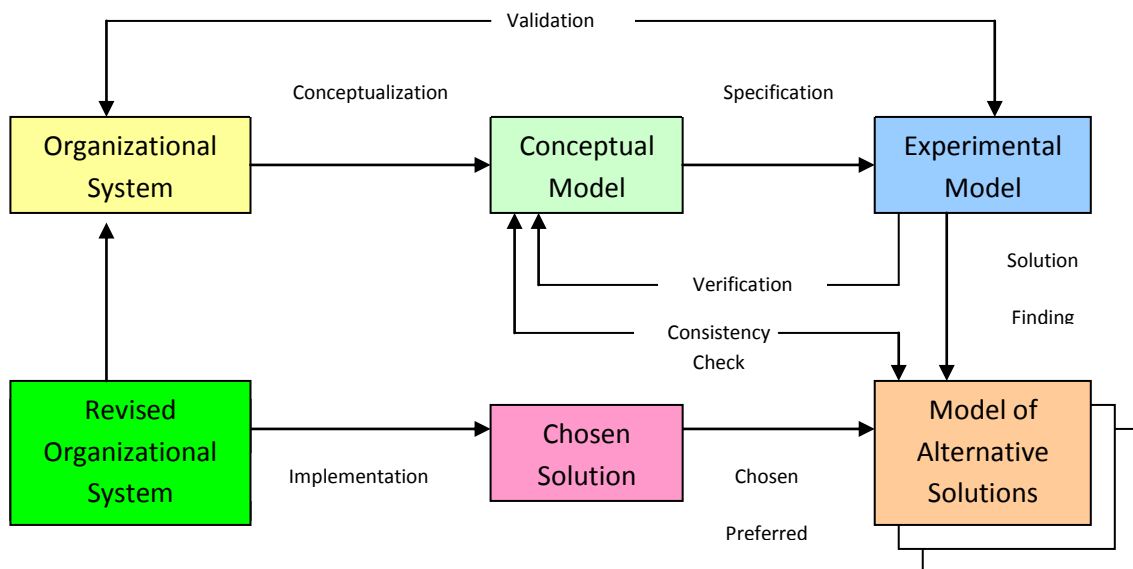
8. Model Based Strategy for Simulation

A supply chain refers to the flow of materials, information, and services, from the raw material suppliers through factories and warehouses to the end customers. A supply chain includes the organizations and processes that create and deliver these products, information and services to the end customer. The most important reasons for the increasing attention and practice of supply chain management are the possibilities that technology enhancement have generated. Simulation is often applied as a powerful tool for solving supply chain logistics problems. However, in contrast to modelling processes related to only one organization, supply chain modelling entails additional difficulties since it involves different organizations. A key barrier to full supply chain management has been the cost of communication with, and coordination among, the many independent suppliers in each supply chain. Building a detailed model of the supply chain does not pose a problem when the chain involves only a single organization. In contrast, not many participating organizations are willing to share detailed model information when the chain crosses the organization boundaries. In order to cater for this, each organization can design and develop its own simulation model, thereby encapsulating the internal information. The task is then to couple the independently designed and developed simulation models in order to analyze the simulated supply chain as a whole. Therefore simulation coupling plays an important role in supply chain projects involving different organizations

and this leads to the requirement for a well designed standard implementation framework for coupling the constituent simulation models. Simulation can interpret reality in order to understand and control it as consisting of various systems. A system is defined as ‘a set of two or more interrelated elements of any kind’. A model is a representation of such a system. A model is an abstraction of a system in the sense that it is less complicated than reality and hence it can be more easily used for manipulation. If an organization tries to achieve goals, decisions must be made taking into account various courses of actions. Managing organizations involves decision making and decision making entails problem solving. In this, view managers are problem owners, and they tend to solve these problems through a decision making process.

The model based problem solving strategy is detailed in Figure 2.

Figure 2. Model Based Problem Solving Strategy for Simulation

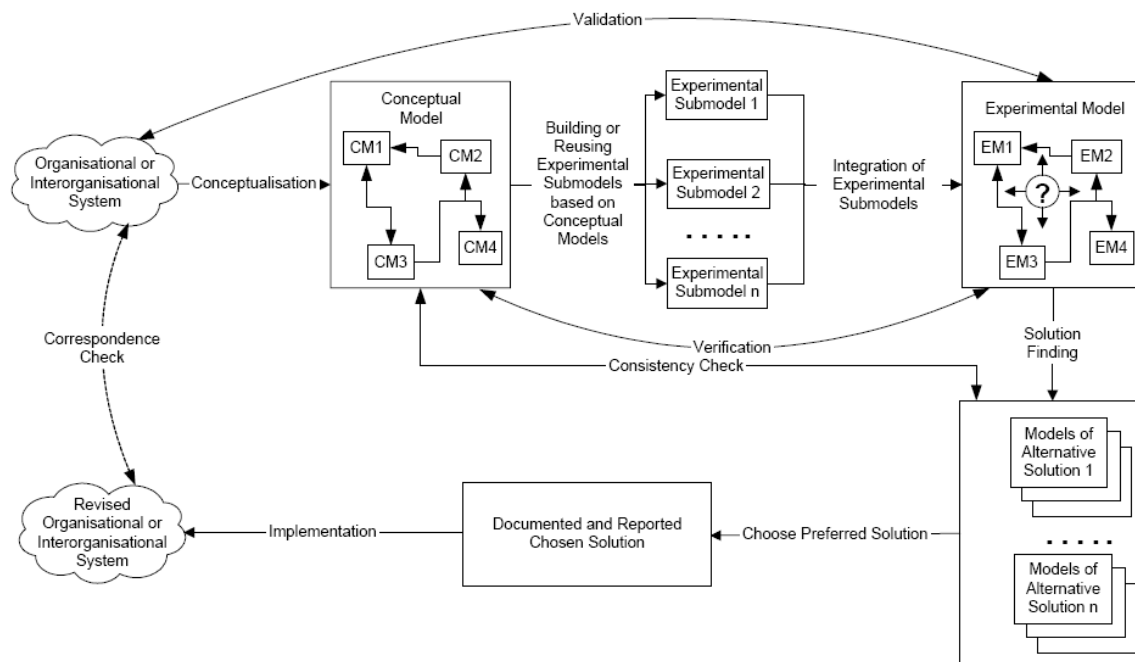


9. Distributed Model-Based Strategy for Simulation in Logistics

Experimental models aim to provide alternative solutions for the problem stated through experimentations. Modellers can choose to design one single, compact model referred to as a monolithic model that incorporates all the functionality needed for the experimentation. However,

they could also decide to design and develop a collection of sub-models that focus on sub-problems that are interrelated and, by integrating them, they form the whole experimental model which is intended to solve the main problem. We refer to a collection of interrelated sub-models as a modular or distributed model. The experimental model can be a distributed one. For this reason, the general model-based problem solving strategy will be extended based on distributed models. Not only the experimentation model can be distributed, but the conceptual model as well, by constructing it as a set of several conceptual sub-models. Now that several sub-models are designed, in order to get the final experimental model, the sub-models have to be integrated. Therefore, this strategy additionally comprises an integration phase and extends the specification step of the problem solving strategy. This is explained in Figure 3.

Figure 3. Distributed Model-based Problem Solving Strategy for Simulation



10. Simulation Design Components

Simulation design components provide the distributed services required to accomplish the role of the backbone for Simulation Backbone Architecture. There are four important simulation design components: Run Control, Time Manager, Logging and Visualization. Additionally, there is a need for a kind of Scenario Object that specifies the scenario for a simulation execution.

Run Control Technical Component

The Run Control technical component is the main controller in the Simulation Backbone Architecture. It communicates directly with all technical and functional components. Run Control is the only technical component that has direct access to the Scenario Object, that includes relevant information about the execution, participating components, public and private variables, and so on.

Back Bone Time Manager

Time management plays an important role in simulation. It aims to synchronize simulation time among different simulation components. The technical group's responsibility was to design and develop a component that accomplishes this time synchronization. The component that was designed for this purpose is called the Backbone Time Manager.

Logging Component

In a simulation system where many components interact over the backbone, a data log can be used to check and analyze the performance and correctness of the system and subsystems. In a data log information can be recorded about the running system, such as output data, statistics, model errors, and warnings. This component is called as Logging Component.

Visualization Component

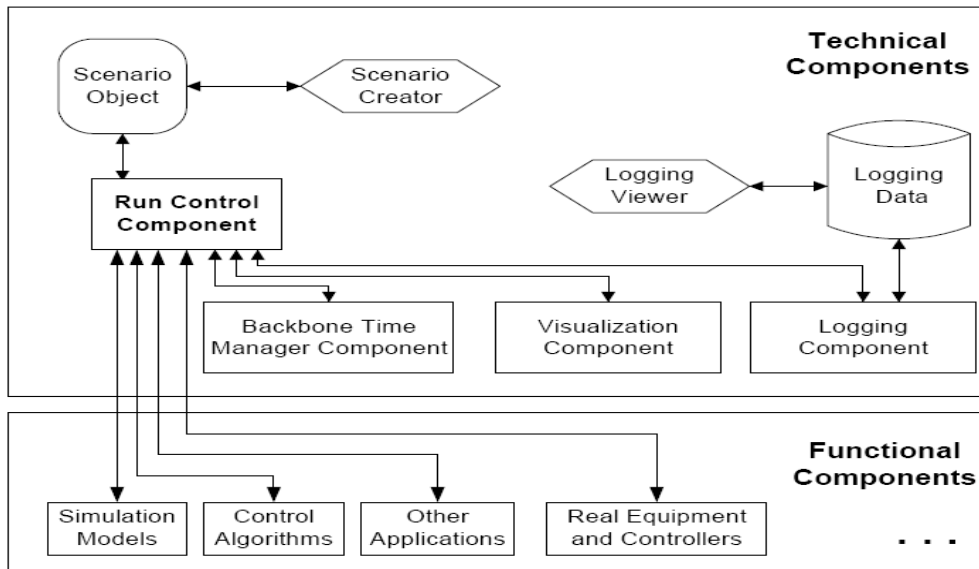
The aim of the Visualization Component is to present simulation results during and after the simulation run in the form of an animation. In this sense we can also refer to it as an animation component. This component should present as many instances of 2D or 3D viewing as necessary. There should be possibilities to animate the whole system on one screen or just part of it on different screens.

Scenario Object

Scenario Object defines a simulation run of a model. It is directly embedded in the Run Control component which in fact interprets the information provided by the Scenario Object.

The simulation backbone architecture is depicted in Figure 4.

Figure 4. Simulation Backbone Architecture



11. Simulation for Site Logistics – A Case

A leading oil company has selected a multi-billion dollar chemical company as its potential partner to engage in exclusive negotiations concerning a joint venture company to construct, own, and operate a world-scale chemicals and plastics production complex at the province of a leading oil company. This joint venture would encompass an array of world-scale facilities producing a very broad portfolio of plastics and chemical products. The following are its challenges as it plans to grow:

- Design and build a highly efficient and integrated site logistic assets and operations
- Optimize the capital investment for assets and resources
- To ensure that the integrated site logistics is designed and equipped to handle the expected product volumes
- To develop models based on a designed push production and distribution system

The proposed site logistics would be integrated with the existing refinery complex, which is one of the world's largest refinery complexes. When fully operational, the new petrochemical complex would be one of the largest plastics and chemicals production complexes in the world and be ideally situated to access most major world markets. The joint venture would produce an extensive and diversified slate of chemicals, and introduce new value chains and speciality products. The availability

of these chemicals would facilitate the development of downstream conversion industries and the further industrialization. With the above strategy in place, the company would like to focus on the stated objectives.

- Demonstrate how highly flexible simulation models can support strategic decision making and provide value to the business
- Design of dredge channel and berths for container and bulk ships
- Design of marine jetty
- Design of solids silos, packaging lines, and warehouse for export and local market
- Design of on-site centralized and decentralized liquid bulk truck loading racks and drumming

12. Strategic Decisions for the Case

The strategic decisions are based on various scenario analyses. The major scenario analyses are tank sizes, loading racks, liquid berths and drumming lines.

Decision on

- number of channels
- capacity of channel
- number of berths required
- number of loading racks
- number of manual loading arms
- number of hoses required
- tank size volume
- number of drumming lines
- drumming capacities
- number of palletizers and doors are the key outputs for integrated site logistics

13. Model Approach for the Case

The primed approach for simulation of integrated site logistics is follows:

- Exploration of objectives
- Input User interface design
- Model logic creation
- Development of Simulation Model
- Verification and Validation of Model
- Scenario analysis
- Training and documentation

The details are provided below:

Complete understanding of process requirement through

- Brainstorming discussions, Delphi analysis, group discussion, and focused group discussions

User Interface Design through

- Interactive support system with various inputs embedded in the model

Model logic creation by leveraging

- Simulation concepts and techniques

Development of Simulation Model based on

- System design approach

Verification and Validation of Model by

- Logic analysis, testing through sample datasets and sensitivity analysis of outputs

Scenario analysis through

- Brainstorming discussions, focused group discussions and expert opinion using interactive support system

Training and documentation by

- Proper manuals, procedures and Frequently Asked Questions with Answers

Various sensitivity analyses for scenario analysis:

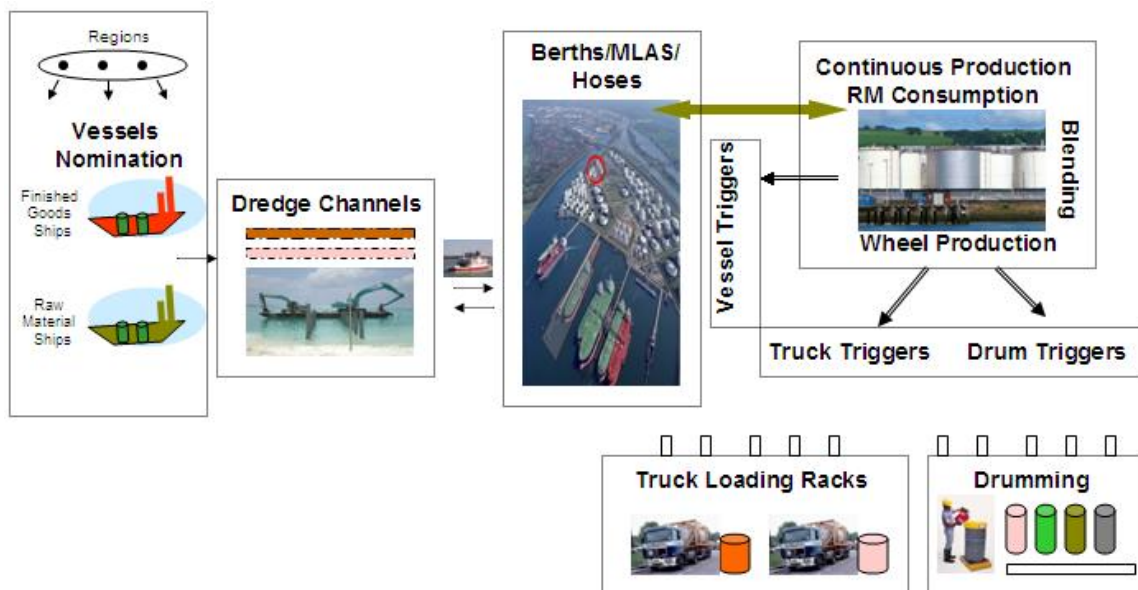
- Variations in quantities
- Variations in loading times
- Variation in frequency of arrivals
- Variation in production rates

Model design:

- Model to be designed to represent future material flow
- Model to be used for scenario analysis and testing prior to, during and after construction
- Model to provide broad range of functionality to test planning, transport logistics and site logistics operations

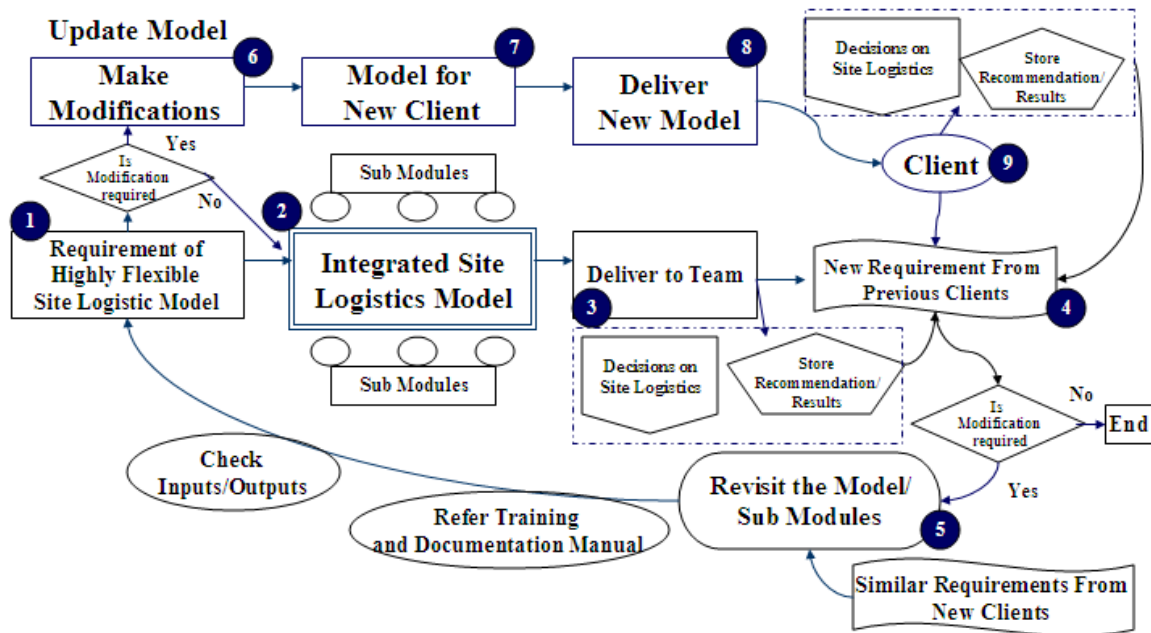
The overall model building blocks and process is depicted in Figure 5.

Figure 5. Model Building Blocks for the Case



The model control plan is detailed in Figure 6.

Figure 6. Model Control Plan



14. Business Benefits for the Case

The Chemical Company derived the following information from the model which is used for implementation:

- Stock out and overflow quantity implies sub optimal tank sizes. Input parameters such as vessel schedule need to be changed to minimize stock out and overflow.
- Percentage utilization of loading spots and desired loading at site implies requirement of additional / excess spots at site.
- Percentage utilization of drumming lines and desired drumming at site implies requirement of additional / excess drumming lines at site.
- Total waiting time for vessels implies
 - Requirement of dredge channel
 - Optimal / Sub optimal configuration of product compatibility at berths
 - MLA and Hose requirement at respective berths

15. Model Complexity in Simulation

Simulation helps to get answers about questions then some decisions have to be made. However, the modelling is very complicated and the usual problems are:

Credibility of the Result

The question is how to ensure the correctness of the control rules in the models and how long should simulation runs last? The complexity of the decisions which in real life is done by operators and in simulation models has to be done by algorithms is always critical because it depends on the modelling accuracy and the available information for the decision making. When investigating varying production schedules it is apparent that the time for simulation runs has to be enlarged. That leads to the point that efficient mechanisms are needed for evaluating large amounts of data.

Duration of a Simulation Study

Usually the duration of the studies depends on the availability of data and appropriate project management but this is not the only explanation. Individual control rules and production policies as well as strategies for treating products and using tanks and silos are hard to gain in one meeting. The availability of the operational data is an important data acquisition step which cannot be overestimated. In general these control rules do not exist in the document and depend on the individual experiences of the operators.

Search for Solutions

Simulation is an important tool for evaluating and proving concepts and for finding best practice designs in the logistic chain. The results of the simulation runs are very frequently difficult to understand and even more difficult to translate into new production concepts. The difficulty is a result of the combination of the use of all resources in the system in combination with efficient controls rules.

One of the most interesting problems seems to be the accuracy of the computations. The more accurately the values can be calculated, the more unrealistic the solution may be. If, for example, in a silo with a capacity of 5 t after a production 5 kg remain in real life nobody would care. Eventually

somebody would clean the silo, fill a sack or just ignore the quantity. In the simulation model the silo remains occupied and is not free for new products or lots. From this point of view, the simulation technology complicates the chemicals' world and reveals weak points whereas, in general, the simulation technology has its strengths.

16. Future Scope: Simulation in the Process Industry

Therefore the demands for further developments of discrete event simulation in the process industry have to be taken into consideration in that the general applicability has to be defined properly. Some important developments, however, should be:

- Definition and implementation of appropriate modelling elements such as building blocks, receipts, process flow descriptions etc. considering, at the same time, modelling accuracy demands. Here the appropriate modelling of products in the different production steps has to be looked at carefully.
- Much more than in other application fields appropriate control rules for the operation of the systems are needed. Some of these rules are used repeatedly in the models, some are obvious but difficult to describe and some are based on the requirements of the enterprise resource planning. In general, a systematic approach is needed for structuring this logic.
- Incorporation of scheduling algorithms and rules into the models and simulation tools: this part of the modelling has very much influence since the appropriate production schedule can prove the investment is worthwhile whereas an inappropriate schedule might prove exactly the opposite.
- Visualization and animation capabilities of the simulation tools in the process industry are very poor and have to be improved considerably. A pure application of 3D animation cannot help at all. New ideas about a combined visualization of control information and material flow are needed.

- A combination of simulation and general computational methods is needed. A rough calculation helps to define principal concepts and to check the correctness of simulation results. Experiences of a queuing network and other methods of operations research have to be incorporated into the simulation environments.
- Databases for relevant information about product properties are needed. The difference in calculations and decisions just by checking the volume and the weight of a product can spoil the models and control rules. The database can be extended for the definition of receipt, process flow restrictions etc.
- For finding new structures of chemical process a combination of optimization technology and computational methods (based on simple simulation models) should be developed. Investigation about applicability, quality of results and transferability to detailed models are especially needed.
- The use of the models in operations has to be considered right from the beginning of a simulation study. The tools of the future offer a more interactive decision. Thus a switching between manual influences and automatic event control has to be incorporated.

Demands from the process industry will lead to new modelling capabilities in the discrete event tools. They are different from the manufacturing world such as the automotive industry because chemical processes suffer from uncertainty and offer, at the same time, the chance to act with a certain freedom in a range of specifications.

Research programmes for the application of simulation in the process industry should take this into account. If these tasks cannot be fulfilled appropriately, the spreading of the application of discrete event simulation technology in the process industry will continue to be unsatisfactory but the potential for industry is high because this field of experience was not yet really estimated considered or extensively applied.

Conclusions for the increased acceptance of simulation in the industrial practice:

1. Many simulation models are too detailed – they are not built according to the real project goal setting and customer expectations.
2. The customers do not need simulation, they need solutions – in the acceptable (usually very short) time and quality.
3. Simulation specialists are often too focused on the simulation model and the required information. There is often not good contact with the real processes – analyses on the shop floor, observations, snap shots, interviews with production supervisors, etc.
4. Many simulation results stay on paper without implementation because of insufficient staff involvement into the project or because of wrong project timing.
5. Many simpler methods, which can bring considerable improvements in the short term, are, overlooked – eg. Value Stream Mapping.

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