A SIMULATION-BASED BPR SUPPORT SYSTEM FOR SUPPLY CHAIN MANAGEMENT

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Modern manufacturing enterprises must collaborate with a large number of suppliers to design and produce their products. Management of these supply chains is crucial. This paper proposes a simulation-based, supply chain management system, which supports the implementation of BPR in an integrated system environment. The scope of the BPR includes management processes for production and operations within the supply chain. This paper describes the process analysis, models, and simulation methodologies. It also discusses a supply chain integration methodology.

1. Introduction

The manufacture of complex products such as automobiles, airplanes and computers takes place in global supply chains. Member enterprises are required to cooperate with their business partners in the chain, including vendors, retailers, and distributors. These enterprises must review continually their strategies and restructure to simplify their business procedures and fabrication processes. This restructuring frequently involves fundamental decisions regarding those activities that really do need to take place internally, but in full collaboration with business partners. In making these decisions, each enterprise must develop a flexible management system to survive in today's competitive market. The designers of these systems can face a situation in which they have to re-design process flows to meet requirements in the target supply chain. Membership in a supply chain often requires a company to change its business practices, to introduce a new production process, to modify its organizational structure, to alter its management style, to add new performance measures, and to open up its information systems. A systematic approach is required to implement such concepts as these.

Supply Chain Management (SCM) is the management of material and information flows both within and between chain members, such as vendors, manufacturing plants, and distribution centers. SCM is currently one area that has received a great deal of attention in the worldwide business community. In the United States alone, logistics costs account for approximately 30% of the cost-of-goods sold in an average manufacturing firm [1]. The potential saving for a reduction in these costs cannot be ignored. One way to reduce these costs would be to reduce customer service. Another would be to improve the overall performance of the supply chain. Such improvements can increase company profitability. The

Yankee Group, a Boston-based consulting firm, did a study of 1,000 European firms. The study showed that supply-chain costs, which are included in the logistics costs, are estimated at 10 percent of the revenues of most companies. The study further showed that some leading companies have logistics costs more than 36 % below the average. Those companies realized nearly a 4 % increase in net profit margin [2].

Some of the earliest work in supply chain logistics is related to the QR (Quick Response) manufacturing concept in apparel industry. The initial studies showed that the time to go from raw material to finished goods was 66 weeks, and that 40 weeks of that time were spent in warehouses or in transit. QR incorporates marketing information on promotion, discounts, and forecasts into the manufacturing and distribution plan. QR is a partnership in which retailers and suppliers work together to respond more quickly to customer needs by sharing information. After that study, industry has changed to adopt the UPC code by the grocery industry and electronic data interchange (EDI) standards. Retailers began to install POS (point-of-sales) systems to transfer sales information rapidly to distributors and manufacturers [3].

In 1992, the Efficient Consumer Response (ECR) Working group ran an industry task force for the grocery industry. The objective of this group was to identify opportunities to make the grocery supply chain more competitive [4]. There were two main results of this study. First, the group identified a set of best practices (over and above EDI and POS), which, if implemented, could substantially improve overall performance of the supply chain. Through implementation of the best practices, the working group projected an overall reduction in supply chain inventory of 37 % leading to cost reductions in the range of $24 billion to $30 billion. Second, espoused the concept of Continuous Replenishment (CR). CR is a move away from <u>pushing</u> product from inventory holding areas to <u>pulling</u> products onto grocery shelves based on consumer demand [5]. Computers forward point-of-purchase transactions to the manufacturer, allowing them to keep the retailer replenished and balanced, in a just-in-time manner [6].

Hammer and Champy, and Porter have the popularized the use of Business Process Re-engineering (BPR) as a way of improving the performance of a supply chain [7, 8]. It is easy to see that, as management philosophies, BPR and SCM have a great deal in common. Specifically, both approaches analyze the value-added implications of all business-related activities. Evans et al. present the similarities between BPR and SCM more rigorously [9]. They classified SCM planning problems into 3 hierarchical levels: strategic, tactical, and operational. They claimed that the distinguishing characteristic of these three levels is the time horizon - strategic planning has the longest and operational planning has the shortest [1]. The authors showed that the methodologies of BPR are effective for solving strategic planning problems. In Berry et al., some of the same authors describe the use of BPR to address strategic planning problems within an electronic products supply chain [10].

O'Sullivan and Geringer [11] present an important concept in the SCM, the notion of a natural vs. contrived value chain. The natural value chain is "a conceptual ideal of the necessary value chain activities", while a contrived value chain is "an imperfect implementation of the natural value chain." The authors outlined an approach for defining the natural value chain and stress the importance of keeping this natural chain in mind when reengineering the actual, "contrived chain". BPR is said to be a method to reform "Contrived value chain" to "Natural value Chain".

It is quite common for an individual company to be a member of several supply chains, concurrently. Each time a company joins a new chain, it must determine if its current management system suits the specific needs of the new chain. Changes may be needed in both its strategic business management practices and its performance measures. Different methods may be needed to evaluate new product introduction, to examine required organizational changes, and to modify existing information systems. This chapter proposes Business Process Re-engineering models, together with simulation models, to address many of these changes. Companies can use BPR models to recognize critical problem areas, and simulation to measure the impact of possible changes in those areas [12]. The chapter includes a description of the process analysis, models, simulation methodologies, and a supply chain integration methodology.

2. Business Process Models for Supply Chain Management

As noted above, planning problems can be classified into three hierarchical levels - strategic, tactical, and operational – based on the time horizon (See [5], pp.32-35). Strategic planning considers issues such as the way companies do business, the introduction of a new production process, the organizational structure, business management practices, performance measures, and the information system. During its lifetime, an individual company may belong to many different supply chains, some concurrently. Consequently, it must examine its planning process on a regular basis. Changes to that process involves controversial decisions that impact the entire company, including the work force, and must be done very carefully [13].

Strategic planning is also done in a supply chain. It occurs in three macro-scale stages: procurement, production, and distribution. Each of these stages may be implemented in facilities from different companies simultaneously. This implies that the supply chain for a particular product frequently crosses both functional and corporate boundaries. The implication of this is, as Fawcett points out [14], that knowledge of value-added activities gets distributed in such a way that no one, including top management, has a complete picture of the all activities in the chain. Consequently, models to analyze strategic planning for the supply chain must be able to represent the business processes within each company in the chain. It must also capture the constraints needed to coordinate activities across the chain [14].

The model proposed here is a set of network models representing business process flows and information flows in supply chain management. Individual process in the network exchanges information and shares the resources as necessary. Information sharing can reduce waste and efficiency at both member sites and across the entire chain. The model must represent both a specification of information exchange and sharing mechanisms among all of the members of the chain. The model must also represent both the frequent patterns of exchanging information and mechanism of information transfer. Such mechanisms must be dependent on autonomous and distributed form to realize loosely connection among suppliers in the chain. Because, individual companies has it own unique manufacturing capabilities, information capabilities, and system resources.

The business process model is basically composed of a set of functional models, which are performed activities and relationships among them. While there are many activities in suppliers companies, the typical primitive operational activities are countable. This common set of activities forms the basis for a coherent production and operations management plan for the supply chain. Each of these operational activities contains a sequence of primitive activities. A primitive activity consumes both time and information/material resources. Some examples are: generate, dispose, assemble, branch, batch, unbatch, merge, split, join, transform, copy, assign, seize resources, and, release resources. Both network flow and activity cycle diagrams are used to represent each business process flow. Each individual process can have its own internal decomposition into sub-processes. The information is tightly coupled with the descriptions of the business process models. It is because all of business activities get materials and information, process them to add value, and put out them to take over the next process.

We have developed a collection of formal models using OMT methodology [15]. These models describe the entities (objects), which provide complete and detail definitions for each of flows. They also identify all of the relationships that exist among these entities. The modeling method used here is based on our previous research [16,17]. The concrete procedures are summarized as follows:

1. Extract "instances" of information objects in manufacturing enterprises: These instances are the documents that flow among individual business process activities. Fig.1 shows the business documents flow analysis.
2. Abstract the above "instances" to define class hierarchy model: In this process, the relation among the above instances is the important key to define "class". According as concept of either super-ordinate / subordinate or relevance, these instances are classified into several groups. The objects that own the same attribute belong to the same "class".
3. Adjust the relations among the sub-classes to define a framework of business process:

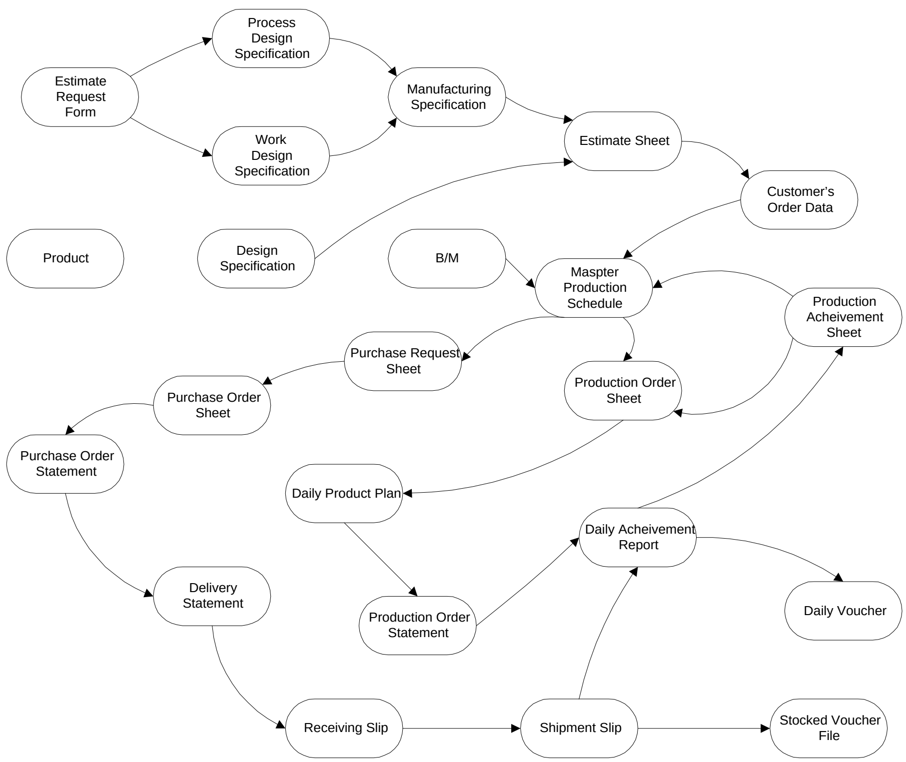

Figure.1 Business document flow analysis

Figure.2 shows the business process model at the strategic level operations of supply chain. The modeling notation of this is equivalent to "data-flow model" of OMT method. The circle nodes and the rectangle nodes represent business processes and actors, respectively. The node described by parallel lines represents a data store (database). Individual arc corresponds to the "information class", which details are defined in class hierarchy models. These models describe the timing requirement of information transfer among inner and inter factories. Some information can be stored in a relational or object database with specific pieces transmitted in response to specific queries. Some information must be stored and transmitted using messages in "real-time". These requirements give a solution to the questions regarding storage options. These determinations can also specify the details of file formats, database structures, and message protocols.

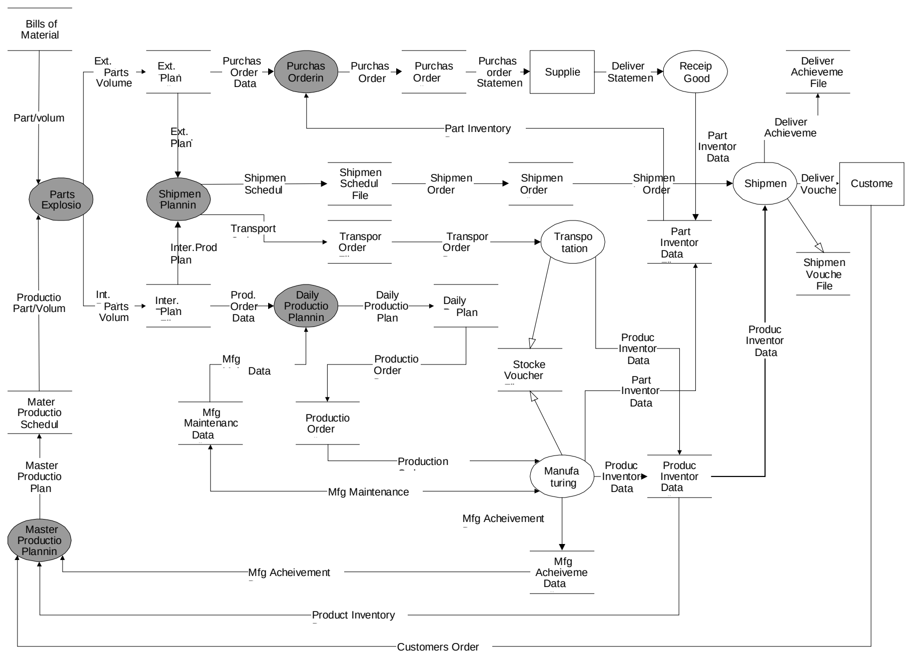

Figure.2 Business process model at strategic level

3. Virtual Supply Chain System

3.1 Hierarchical structured simulation model

Here, we propose a hierarchical simulation system, called "Virtual Supply Chain Management System (VSCMS)". The tasks of the simulation are to simulate 1) the business processes and activities in the chain, 2) the individual suppliers (factories) activities according as the orders, which are generated in the chain and 3) the transactions occurred at manufacturing processes in the chain. These simulations provide all of the activities in the chain process behaviors controlled by the production orders and daily schedules. These are basically stored as simulation logs and accessible by the decision-makers of management when they needs.

These three kinds of simulation construct a hierarchical structure. The top layer's ("Chain") simulation is composed of the objects representing individual suppliers such as vendor's factories, warehouses, distributors, and so on. These objects are controlled by "Virtual Suppliers Manager (VSM)", The middles layer's

("Factory") simulation is a factory simulation, which posses processes, transporters, and buffers. The final layer's ("Process") one is, what we call, a cell simulation, which posses equipment like NC machines, or robots, and controller. Individual simulation exchanges the transactions with its upper and lower layers. Individual simulation is corresponded with the SCM hierarchical layers: "Strategic", "Tactical", and "Operation". (Figure.3)

The "Chain" simulation handles the highest level interactions between the factories that make up the chain. The "Chain" simulation constructs a network of suppliers linked each other with the global transportation facilities. This layer also posses a process simulator other than factory simulator of members in chain. The process simulator is called as "VSM" (Virtual Suppliers Manager). VSM is a simulator that simulates business process activities in supply chain management. The activities are defined in the business process models described in the previous section. VSM also owns data entry points form demand information server and data entry points to factory simulator. It uses these entry points to get/put information or data, and generates orders for production or transportation orders to suppliers. In some cases, a particular factory communicates with another factories or transporters in direct.

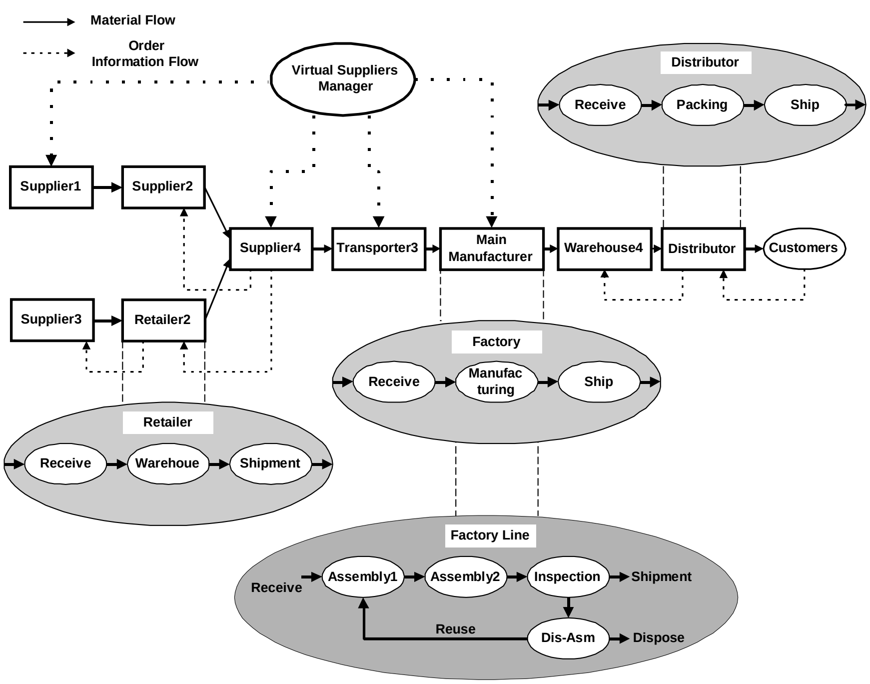

Figure.3 Hierarchical structured simulation model

The “Chain” simulation connects suppliers in “PUSH” mode or “PULL” mode. When “PUSH” mode is chosen, the factory works according as the orders generated in VSM (“PUSH” mode), and when “PULL” mode is chosen, the factory works according as the orders generated in their down-stream factories (“PULL” mode). VSM generates production orders whenever it is needed, and sends them to the factories in the chain. The details of behavior of VSM will be described in the next section.

The materials usually flow from up-stream to down-stream if the factory has no rework. Material-flow model is a set of the descriptions and rules that include the materials handling paths in the chain. Material-flows invoke when the materials enter in the specific process (“Entrance”), or transportation between factories. The mechanism descriptions how to invoke material flow is called “Logistics model”. Logistics models deal primarily with material flows at the “Chain” level. At this level, the transfer means the long distance transportation by trucks, rails, boats, planes, and others. The “Logistics” model includes order planning, warehouse operation planning, transportation planning, and inventory planning among them. The fundamental modeling approaches is based on “Hybrid PUSH-PULL” system.

“Factory” simulation handles the factory levels interactions in the chain including warehouses, retailers, and distributors. These simulation construct networks of processes linked each other with the plant transportation facilities. Factories include, at least, more than one material processing line. These lines include multiple manufacturing cells, parts buffers, material entry processes, shipment processes, and the in-line transporter like AGV. The inspection process is often included in them for the purpose of the product quality management. The general feature is similar to the traditional manufacturing line simulation. The difference with them is that the activities at several particular processes (manufacturing, shipment, transport, and material entry) are controlled by the orders from the VSM.

The “Cell” layer’s simulations make up the lowest level. These are usually control logic simulations. The input is the physical transaction control rules of a particular machine or resource, such as NC machines or robot control program. The output is, for example, machine performance or part quality.

3.2 Virtual Suppliers Manager

Virtual Suppliers Manager (VSM) simulates the business processes and activities in the chain. VSM is a virtual organization, which manages all of business activities and information flows in the supply chain. The simulation model is derived from business process model of the supply chain management in the previous section. While other layers’ simulations present physical activities of factory, VSM mainly simulates the flows of business activities, which give orders to factories at the lower layer in the scoped chain. These simulated activities include demand receiving, production ordering, transportation ordering, purchase ordering, shipment ordering, and activity cost estimation.

Some processes of VSM are linked with the plant schedulers that give production orders to the individual plant. The entrance process and the exit process in the chain are also liked with VSM. It can get and put all data of ordering activities, when it needs. According as the predefined planning tables or rules, it sends orders of production, transportation, purchase, and shipment to the individual suppliers. The input data to VSM is the delivery orders from customers, on the while, the output is the process order to the individual suppliers' factories, warehouses, transporters, and distributors.

The main simulation facility of VSM is to provide individual suppliers with such orders according as the "PUSH" ordering mechanism. The details of this scenario can be described as follows:

1. Predicts customers' demand volume in the next phased term by using the past log data of demand and production, and builds "Master Production Schedule"(MPS). MPS is an anticipated build schedule for those items assigned to the master scheduler. The master scheduler maintains this schedule, and in turn, it becomes a set of planning numbers that drives material requirements planning.
2. Calculates the each part volume required in individual factory. It represents what the company plans to produce expressed in specific configuration, quantities, and dates. This stage is the simulation of the part explosion using a BOM (Bill Of Material) table. In this mechanism, the synchronization of suppliers is performed in schedule-driven. At this time, it uses the suppliers/part table, which shows parts name and its supplier.
3. Gives the production orders to individual supplier. The order information transaction flows from VSM to suppliers, and the materials flow from up-stream factory to down-stream factory.

Although the master production schedule is not a sales forecast that represents a statement of demand, it must take into account the forecast, the production plan, and other important considerations such as backlog, availability of material, availability of resource capacity, and management policies and goals. In other words, this process is a typical prediction-based planning. VSM plays a role of prime contractor such "PUSH" system in the suppliers' chain.

"PULL" system is the contrast with the above "PUSH" system. A typical "PULL" system is a Kanban system. Each station has a collection of input and output buffers. A station will pull inventory from up-stream stations whenever its input buffer becomes too low. A station will receive a request for new production orders when the WIP level in its output buffer is too low. In this case, the prime contractor will pull inventory from suppliers whenever it is needed. The "PULL" system can be defined as a buffer-driven system. This scenario can also be extended to a supply chain environment. Part suppliers or distributors individually define the replenishment point on the inventories. When the input material volume becomes lower than the predefined stock level, the suppliers independently make orders to their up-stream suppliers. The up-stream suppliers who received the orders generate their own production orders. Materials flow from up-stream to down-stream, while the order information transactions flow from down-stream to up-stream.

In practical production management, some particular supplier's factories receive production orders not from the central control system (VSM) but from their down-stream's factory in direct. In other words, some suppliers' factories or field warehouses use replenishment points to control input part inventories. When the rest volume of input parts undergoes to predefined replenishment point, the factory independently publishes production orders of fixed volume. These suppliers re-stock inventory whenever it becomes too low. We define this scenario as "hybrid PUSH-PULL" system.

VSM provide such "hybrid PUSH-PULL" system environment to represent manufacturing logistics in supply chain. This facility can give a good solution to the "PULL factory selection problem", which is often difficult choice at practical operations planning. The solution impacts not only material flow, as we have seen, but also the information flow (and the communications infrastructure needed to support that flow) between the prime contractor and suppliers.

3.3 Business Process Planning using VSM

VSM is a business process simulation to support supply chain managers in designing and reengineering the operational processes. VSM simulation enables designers and analysts to observe the work flows within a service process in their entirely. The business process simulation pre-estimate not only the ordering process flows but prediction of physical behavior in supply chain. Such pre-estimation helps designers' decision making in the re-engineering project. At the problem finding phase, designers can try various business scenarios in the computer to find a cause problem. At the situation understanding phase, they will be able to try the business situation, and find its potential problems. At the data analysis phase, simulation might find why the observed phenomenon had occurred in a scenario. At the final phase, the analyzed data in detail by process simulation will be a trigger to generate a final solution of the process planning problem.

BPR is a paradigm that many businesses need to radically change the organizational structure of business process and the policies and methods by which the process operates in order to achieve significant improvement. Process reengineering emphasizes the overall improvement of a process with respect to its quality, cost, and efficiency. If it fails, the damage to the company will be huge. All designer and practitioner must do the justification to the proposed plan.

The proposed model (shown in Fig.1), for an example, includes all of the modeling primitives of the business process flows that generate process orders (manufacturing orders, shipment orders, and etc.) to individual factories. Process planners can use and modify them to pre-estimate the impact when the process structure is changed. The examples are:

1. Suppose that all of factories in the chain uses common database for purchase ordering process, what impacts occur on total lead time in the chain?
2. Suppose that two processes of internal and external production planning are linked together, what impacts occur on the total productivity in the chain?
3. Suppose that all factories and distributors works on PULL-mode, all of planning processes will be extremely simplified. While, all factories always keep balanced inventory, and require distributed inventory management system. Which is better?

The model and simulation of VSM enables managers to gain insight that will help them control the current complex operational process flows. The insight and the process analysis will help to identify areas that need reengineering and to predict the quantitative impact of reengineering efforts.

4. Toward the integrated Supply Chain

4.1 Decision making processes in SCM

The support system must provide methodologies to solve such optimization problems in supply chain management.

Utilization of simulation is effective to get solutions to the most of the above problems. In addition to that, we are designing and implementing a generic system optimizer linked with simulation. Some of them use experimental design methods to find optimal solutions on it. Typically, the objective functions in these formulations take into account several performance measures including: cost estimation, lead-time, highest utilization of resources, throughput performance, and due date. This results in a multi-objective optimization problem with multiple variables. Generally, this will be a NP complete problem, for which optimal solutions will be hard to find. The practical solution will be to find semi-optimized solutions quickly in cooperative work of various skilled planners.

We discussed, in the previous section, the strategic level's problems and solutions by using the proposed simulation system. Here, we summarize the tactical level's problems and solutions. These are also significant problems to make decisions on the supply chain management. Examples include:

- Material selection: Which material is the best to choose for various products?
- Location selection: Which supplier is the best to produce and distribute?
- Inventory planning: Where and how many inventories should be stored?
- Load planning: How workload handled by each supplier?
- Capacity planning: How much production capacity do suppliers need to meet demand?

- Production scheduling: When and what suppliers should produce and associated due dates?
- Distribution planning: When and how much volume of end products or component parts should be transported?
- Logistics planning: Which supplier should operate in PULL mode?
- Fixed period or fixed volume?
- The determination of number, location, capacity, and type of manufacturing plants and warehouses to be used;
- The set of suppliers to be selected;
- The transportation channels to be used;
- The amount of raw materials and products to ship among suppliers, plants, warehouses, and customers;
- The amount of raw materials, intermediate products, and finished goods to hold at various locations in inventory;

Many of literature report the solutions to the above problems by using mixed integer programming (MIP) (for examples, see [25]). We can find lots of research reports applying MIP to SCM planning problems, such as location selection and suppliers-distributors network optimization. As an example using other than MIP, we can see application of applied stochastic model by queuing theory [26]. It is needless to say that such traditional mathematical programming methods are very useful to find the solution. However, simulation can nevertheless provide more detail solution. This is because simulation makes clear not only such static characters but also dynamic behaviors in system by using the dynamic trace data.

4.2 Sharing data across the chain

VSM (the supply chain simulation in strategic level) uses huge volume of production data of suppliers distributed in the chain. The data used in simulations must be gathered in rapidly to shorten BPR process cycles. Successful SCM requires a sharing information facilities as well as simulation support. The initial design has been completed, and the implementation is going on. This section describes the design outline and the fundamental technique used there. Furthermore, we discuss the particular problems in supply chain management.

Information management within the test-bed will be carried out using three data driver sub-systems.

1. The **Production Data Driver** receives tactical operational data from suppliers and translates it to meet the format specifications of the target software applications (simulator and optimizer). Most of them are operations management application like partial modules of commercial ERP packages.

2. The **Demand Data Driver** receives demands data from retailers or distributors. The data is partially reformed to parameters of simulator and optimizer, and partially used to the demand prediction.
3. The **Communication Server** provides the data access methods and utilities, which the above drivers use.

One of the keys to the successful implementation is the timely and accurate exchange of information across the software applications in the system. There are two barriers that must be overcome:

1. **Data security problem**: The companies participating in a particular supply chain are independent and frequently compete against one another. They may not want to share information with their competitors, so security control will be a significant issue in such an environment.
2. **Application interface problem**: Each company has a different set of software applications and business practices. The information produced by the software in one company cannot be processed directly by the software in another company.

These will lead to both semantic interoperability and code interoperability. The former means that two applications cannot process each other's data because they do not understand the internal organization of each other's data. The latter is that two applications cannot make use of each other's functionality because they cannot invoke each other's resources. Furthermore, each company's software applications may be complex and require extensive training to be used correctly. The solution to these problems requires not only the careful development of models but also careful choice of interface protocols. The technology used to exchange that information must be cost-effective, reliable, and hardware independent. In the test-bed system implementation, we are examining the following four methods for exchanging large amounts of information.

- WWW - The World Wide Web encapsulates communications protocols to organize and access data across the Internet [18].
- PART 21 - An international standard that provides a standard physical file structure that is easily produced an d consumed by multiple applications [19].
- CORBA - The Common Request Object Broker allows applications to use each other's resources by supporting message call between objects through a network [20]. IDL is a language to define application interface.
- EDI - Electronic Data Interchange provides a collection of forms for the electronic exchange of a wide variety of business and manufacturing data [21].

4.3 A system architecture for SCM

As discussed above, we are implementing the test-bed of "Virtual Supply Chain Management". The proposed system is a simulation-based test-bed system. The system focuses on both BPR and DSS for production and operations management within the supply chain. The kernel of this system is the hierarchical simulation system described previously. Since suppliers can be distributed across the globe, communicating information and transporting material can be costly and time consuming. Therefore, the proposed architecture must support communication protocols to allow world wide information transfer. The main modules in this architecture are (See Figure. 4):

- Simulation kernel (including simulation models libraries)
- Supply-chain Management data Server
- Production Management Decision Support
- Suppliers Management Knowledge Data Base

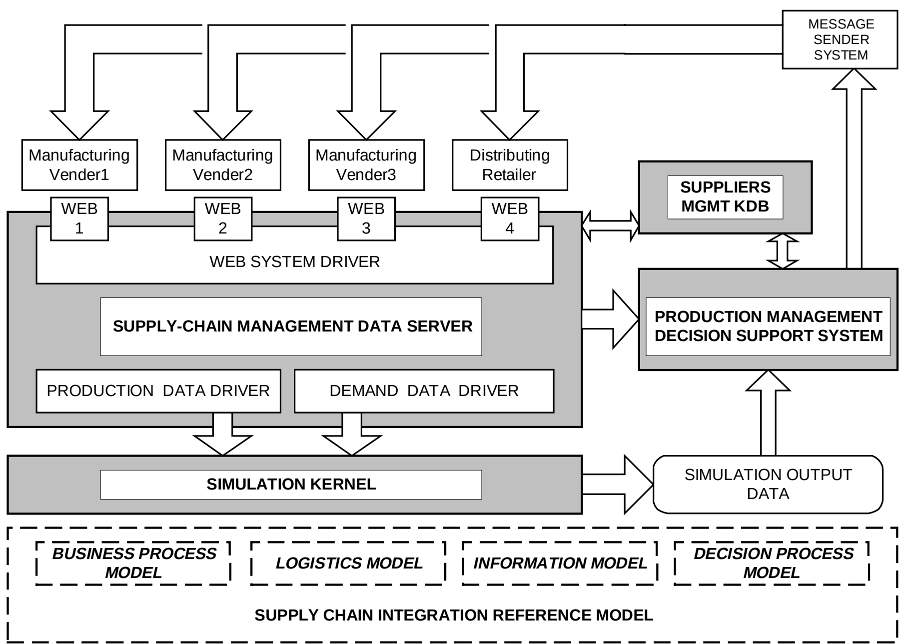

Figure.4 System Architecture of Virtual Supply Chain Management System

5. CONCLUDING REMARKS

Every enterprise system implementation must repeat the following system life cycle: (1) Decision of business goals; (2) Business processes design; (3) System implementation; and (4) Measurement of the performed system. Efficient supply chain will require a powerful support system at the individual stage. If the system could be pre-estimated before the actual implementation, these processes will be rapidly performed. Especially, in the case of the supply chain, the management of multiple suppliers is becoming critical to an enterprise's success.

The objectives of the integration test-bed systems are three items to achieve successes in supply chain management.

1. The system implementation to synchronize operations to the demands change,
2. A thorough understanding of the business processes and BPR practices at these suppliers, and
3. Performance prediction of the supply chain system.

Among them, the increased demand from marketing activities may have a significant impact on the supply chain. The increase in demand creates a disturbance at a particular node in the supply chain [22]. For instance, a trade deal increases demand from the distributor back to the manufacturing plant. The disturbance may have little affect on the entire supply chain if the node has the ability to absorb the disturbance through safety inventory. When the increase in demand exceeds available inventory, the disturbance is passed upstream to other links in the supply chain. The disturbance is especially significant at two extreme situations:

- When the demand increase due to the promotion activity strains the supply chain's capability to produce at the new level. The temporary increase in demand may be met through building inventory in slack periods or by activities such as overtime production.
- When predictions of the impact of the promotion activity are in accurate. For instance, a retail-advertising program is expected to increase demand by 5 percent for three weeks, and instead prompts a 10 percent increase. This unplanned demand exceeds the forecast, the supply chain must react in the short term to provide product.

The strength of simulation-based system is that it has strength to analysis and diagnosis the dynamic behaviors in comparison with the numerical model [23]. Especially, Integration simulation with such models will be also useful to the BPR in supply chain. It will enable a system analysis of the dynamic behavior that is difficult in model-based approaches.

The final goal of the strategic planning of SCM should be summarized two keys of system implementation: "the shortest total business lead-time" and "synchronization of individual process". SCM systems implementation requires not only faster execution of these individual processes, but also concurrent execution of all of them. In the supply chain environment, this concurrent execution of business processes should be done across the entire chain. If successful, we will be able to realize the reduction in total lead-time prophesied in the literature [24].

References

1. Ballou,R.H., Business Logistics Management, Prentice-Hall, Englewood Cliff, NJ, 3rd edn., 1992
2. Davis,1995, “Sate of a New Art: Manufacturing and Trading Partners Learn as They Go.” Manufacturing Systems, August 1995
3. Mullin, T., 1994 “A New Frontier.” Stores, July, 1994
4. Kurt Salmon Associates, Inc., 1993, Efficient Consumer Response: Enhancing Consumer Value in the Grocery Industry. Food Marketing Institute, January,1993
5. The ECR Performance Measures Operating Committee, Performance Measurement, Applying Value Chain Analysis to the Grocery Industry. Joint Industry Project on Efficient Consumer Response, 1994
6. Garry, M. “ Is There Life After CRP?” Progressive Grocer, September, 1994
7. Hammer,M. and Champy, J., Reengineering the Corporation: A Manifesto for Business Revolution, Harper Business,1993
8. Porter, M.E., Competitive Advantage: Creating and Sustaining Superior Performance, Collier Macmillan, New York,1995
9. Evans, G.N., Towill, D.R., and Naim, M.M. “Business Process re-engineering the supply chain”, International Journal of Production Planning and Control 6/3,1995, 227-237
10. Berry, J., Naim,M.M., and Towill, D.R., “Business process re-engineering am electronic products supply chain”, IEE Proceedings –Science, Measurement and Technology 142/5, 1995, 395-403
11. O’Sullivan, L. and Geringer, J.M., “Hamessing the power of your value chain”, Long Range Planning 26/2,1993,59-68
12. Craspar.S., and C. Gray. “Manufacturing the Demand and Supply Chain: How to Make the Customer-Supplier Partnerships of the Future Work Today.” APICS 1995 International Conference Proceedings, October 1995
13. Stewart, T. A. 1993, “Reengineering: The hot new managing tool,” Fortune (August 23), pp. 40-45
14. Fawcett, S.E., “Using strategic assessment to increase the value-added capabilities of manufacturing and logistics”, Production and Inventory Management Journal (2nd Quarter 1995) 33-37
15. Booch, G. “Object-Oriented Analysis and Design 2nd Edition”, San Jose, Benjamin /Cummings Pub. Inc. (1994) .
16. Umeda, S. “A Reference Model for Manufacturing Enterprise System by using OMT method, ACM SIGGROUP Bulletin, 8,1, 54-57 (1997).
17. Umeda, S. “An object-oriented system model for manufacturing enterprise information system”, 395-400, Proc. of APMS, IFIP WG5.7 (1996).
18. Berners-Lee, T., Cailliau, R. , Luotonen, A. Frystyk Nielsen, H. and Secret, “A. The World-Wide Web”. Communications. ACM 37,8 (1994).

19. ISO/IS 10303-21, “Industrial automation systems and integration - Product Data Representation and Exchange - Part 21: Clear text encoding of exchange structure," ISO, 1 rue de Varambe, Case Postale 56, CH-1211 Geneva, Switzerland (1994).
20. OMG, “The common object request broker: Architecture and Specification ver. 2.0” (1995).
21. Banerjee, S. “EDI: characteristics of users and no-users’, Info. & Management., 26, 65-74 (1994).
22. Hadavi,C. “Tightening the Supply Chain Using Real-Time Information.” APICS—The Perfromance Advantage, January,1996
23. Mahmut Parlar, Z.Kevin Weng, Desinging a Firm’s Coordinated Manufacturing and Supply Decision with Short Product Life Cycles, Management Science, 43,10,1329-1344,1977,Oct.
24. Andrews, D.C., Stalick, S.K., “Business Re-engineering” Yourion Press (1994).
25. Geoffrion, A.M., and Grave, G.W., “Multicommodity distribution system design by Benders Decomposition,” Management Science, 20/5 (1974) 822-844
26. Cohen, M.A., and Lee, H.L. , “Strategic analysis of integrated production – distribution systems: Models and methods”, Operations Research, 36/2 (1988) 216-228
27. ANDRE I. KHURI, and John A. Cornell, Response Surfaces Design and Analyses, Mancel Dekker Inc., 1996