



THE HONG KONG
POLYTECHNIC UNIVERSITY

香港理工大學

Pao Yue-kong Library

包玉剛圖書館

Copyright Undertaking

This thesis is protected by copyright, with all rights reserved.

By reading and using the thesis, the reader understands and agrees to the following terms:

1. The reader will abide by the rules and legal ordinances governing copyright regarding the use of the thesis.
2. The reader will use the thesis for the purpose of research or private study only and not for distribution or further reproduction or any other purpose.
3. The reader agrees to indemnify and hold the University harmless from and against any loss, damage, cost, liability or expenses arising from copyright infringement or unauthorized usage.

If you have reasons to believe that any materials in this thesis are deemed not suitable to be distributed in this form, or a copyright owner having difficulty with the material being included in our database, please contact lbsys@polyu.edu.hk providing details. The Library will look into your claim and consider taking remedial action upon receipt of the written requests.

A VIRTUAL WAREHOUSE SYSTEM FOR PRODUCTION LOGISTICS

A Dissertation

by

Fung Sui Hei

A Thesis Submitted in Partial Fulfillment of the
Requirements for the Degree of Master of Philosophy

May, 2006

The Hong Kong Polytechnic University
Department of Industrial and Systems Engineering



Pao Yue-kong Library
PolyU · Hong Kong

CERTIFICATE OF ORIGINALITY

I hereby declare that this thesis is my own work and that, to the best of my knowledge and belief, it reproduces no material previously published or written, nor material that has been accepted for the award of any other degree or diploma, except where due acknowledgement has been made in the text.

_____ (Signed)

Fung Sui Hei (Name of student)

Abstract

Traditional inventory planning is inadequate to handle the effects of variability, non-linear relations, and other abrupt factors on product demand. It is difficult for a manufacturer to keep inventory at a level that can cope with disruptive fluctuations. Nevertheless, the profitability of an enterprise greatly depends on a healthy inventory holding. Such a situation is dependent on the know-how, experience, and quality of the planners. Manufacturers often find it difficult to manage inventory when there are abrupt changes in demand, specifically if the production capacity is limited, or if the stock volume of the raw material is low and work-in-process (WIP) is scanty. Production logistics, a highly complex process concerned with the movement, storage and control of inventory provides useful research opportunities.

To support production logistic activities to meet the requirements from marketing affiliates, suppliers, and customers, a virtual warehousing approach is proposed for manufacturing enterprises. The WIP inventory is originally built for different customers as per demand forecasts. A certain volume of stock will be stored as a buffer to fulfill unexpected changes in demand. The distribution activities conducted at the upstream end of the supply chain before product differentiation is one of significant areas that can be successfully handled using the virtual warehousing approach. The customization process takes place after some key demand information about specific needs or requirements is revealed. Just-in-time delivery resulting from this practice can have the effect of postponing assembly activities. WIP inventory on the final customer order is then assembled for product customization at the global upstream facility and shuttled promptly to downstream distribution centers.

In order to prove the viability of the concept of virtual warehousing, a prototype of a virtual warehouse system (VWS) has been built and trial implemented in a manufacturing enterprise, Schick Asia Limited. With the simulation module in the VWS, the inventory plan is fine tuned to handle the effects of variability, non-linear relations, and other abrupt factors. Rapid changes of demand orders impact the fine tuning of the master plan and the stability of production in Schick. When supply chain events occur and result in shortages in WIP of shaving products, an advisory module in the VWS can also act as an advisor for decision making regarding the WIP inventory allocation. Human decisions on inventory swapping from one production belt to another are different case by case, so this system has been built using various information technologies such as knowledge-based systems. After the implementation of the VWS for selected WIP components in the company, the inventory level for the key components has greatly decreased while the overall customer service level has significantly increased.

The inventory visibility offered in the VWS helps the planners to monitor the supply chain, and enables them to offer reliable advice in order to fine tune the supply plan. It directly contributes to the stabilization of the production plan. Whenever unexpected events occur, VWS supports the planner to take curative action with the assistance of decision analytics and reliable functionality. With the application of VWS, the process of planning as well as the loosening of production constraints can minimize the overall inventory level across the supply chain among different parties, and finally lower the cost in the manufacturing enterprise, as happens in Schick.

Acknowledgements

I would like to express my sincere thanks to the Research Committee of the Hong Kong Polytechnic University, the Innovation and Technology Commission of the Government of HKSAR, and Schick Asia Ltd. for their financial support for this research work. Many thanks are also due to Catherine Wong, C.K. Leung, Masada Li and Angus Ng for their helpful advice and technical support of the research project.

The project documented in this dissertation was completed under the enthusiastic guidance of my academic supervisor, Dr. Benny Cheung, to whom I would like to express my gratitude. Without his encouragement and advice, this research work would not have been feasible.

I am also indebted to my co-supervisors, including Prof. W.B. Lee and Dr S.K. Kwok, for giving me tremendous insights, support and inspiration. I also benefited from many valuable and practical discussions with my colleague, Terry Chow, C.M. Tam, Samuel Fung, and Andrew Chung, in the company.

Special thanks go to Prof. Thomas Wong from the Faculty of Health and Social Sciences for taking care of me during my tutor duty in the Chengde Hall, and to C.W. Jo for his thoughtful aid to my research work and for his companionship.

Last but not least, I would like to take opportunity to thank teaching company associates, Ann Yim and T.F. Kong, for assisting me with the methodology of this research, and sharing numerous experiences with me while we were conducting research.

Table of Contents

Abstract	i
Acknowledgements	iii
Table of Contents	iv
List of Figures	viii
List of Tables	x
Chapter 1 Introduction	1
1.1 OVERVIEW.....	1
1.2 INDUSTRIAL BACKGROUND	1
1.3 FORMULATION OF RESEARCH PROBLEM.....	2
1.4 PROJECT INITIATIVE	3
1.5 RESEARCH SCOPE.....	4
1.6 OBJECTIVES.....	4
1.7 ORGANIZATION OF REPORT	5
Chapter 2 Literature Review	6
2.1 PRODUCTION LOGISTICS.....	6
2.1.1 <i>Inventory Planning</i>	7
2.1.1.1 Vendor managed inventory (VMI).....	9
2.1.1.2 Collaborative Planning, Forecasting, and Replenishment (CPFR).....	10
2.1.1.3 Virtual Warehousing (VW).....	11
2.1.1.4 Summary of Inventory Management Approaches: Demand for Enhancement of Virtual Warehousing in Inventory Management.....	13
2.1.2 <i>Production Strategies</i>	14
2.1.2.1 Make-to-stock (MTS).....	14
2.1.2.2 Make-to-order (MTO).....	15
2.1.2.3 Assemble-to-order (ATO).....	15
2.1.2.4 Just-in-time (JIT).....	16
2.1.2.5 Summary of Production Strategies: Demand for a Production Constraint Loosening Tool in Order Fulfillment	17
2.2 INFORMATION TECHNOLOGY SUPPORTING PRODUCTION LOGISTICS.....	18
2.2.1 <i>Information Technology Frameworks</i>	19
2.2.1.1 Material Requirements Planning (MRP).....	19
2.2.1.2 Manufacturing Resource Planning (MRPII)	19
2.2.1.3 Enterprise Resource Planning (ERP)	20
2.2.1.4 Advanced Planning and Scheduling (APS).....	21
2.2.1.5 Distribution Requirements Planning (DRP).....	22
2.2.1.6 Summary of Information Technology Frameworks: Demand for Simulation Model in APS and ERP	23

2.2.2 Planning Support System (PSS)	24
2.2.2.1 Artificial Neural Networks (ANNs).....	25
2.2.2.2 Expert Systems.....	26
2.2.2.3 Knowledge-based Decision Supporting Systems.....	26
2.2.2.4 Summary of Planning Support Systems: Demand for a Knowledge-based System in Inventory Decision Support.....	27
Chapter 3 Virtual Warehousing	29
3.1 THEORETICAL BACKGROUND OF VW.....	29
3.1.1 Connotation of Virtual in the Proposed Concept.....	30
3.2 ELEMENTS OF VIRTUAL WAREHOUSING.....	31
3.3 ILLUSTRATION OF VIRTUAL WAREHOUSING.....	32
3.3.1 Postponement.....	32
3.3.2 Make for Assembly.....	33
3.3.3 Inventory Allocation.....	34
3.4 CHARACTERISTICS OF VW FOR ADOPTION TO EFFICIENT SCM.....	35
Chapter 4 Design of VWS.....	37
4.1 DESIGN REQUIREMENTS	37
4.1.1 Enhancement in Supply Chain Planning.....	38
4.1.2 Enhancement in APS and ERP.....	40
4.1.3 Enhancement in Order Fulfillment	41
4.1.4 Enhancement in Inventory Decision Support.....	42
4.1.5 Assumptions on VWS.....	43
4.1.6 Data Requirements.....	44
4.2 ARCHITECTURE OF THE VWS.....	45
4.2.1 Inventory Planning Module.....	45
4.2.2 Inventory Allocation Module.....	46
Chapter 5 Development of VWS.....	50
5.1 SYSTEMS OVERVIEW AND DATA FLOW	50
5.2 SIMULATION MODULE FOR THE DETERMINATION OF THE INITIAL INVENTORY PARAMETERS AND INVENTORY PLAN SETTING	52
5.2.1 The Function List of the Simulation Module.....	52
5.2.2 Formulation of the Distribution Resource Planning Table	53
5.2.3 Inventory Indicator and Stock Level Alarm	54
5.2.4 Multi-objective Optimization.....	56
5.2.5 Searching for the Global Optimal Inventory Setting	57
5.3 ADVISORY MODULE FOR THE DETERMINATION OF PRODUCTION SCHEDULES CONTROL AND INVENTORY ALLOCATION	57
5.3.1 A Function List for the Advisory Module.....	59
5.3.2 Formulation of a Daily Distribution Resource Planning Table	60
5.3.3 Input of Case	62
5.3.4 Case Searching & Similarity Analysis	62
5.3.5 Case Retrieval	64

5.3.6 Case Indexing and Solution Reasoning.....	64
5.3.6.1 Action Transformation in Solution Reasoning.....	65
5.3.6.2 Action Substitution in Solution Reasoning.....	68
5.3.7 Case Adaptation.....	68
5.4 DATA REPORTING.....	70
Chapter 6 Case Study	71
6.1 COMPANY BACKGROUND.....	71
6.1.1 Company Products.....	71
6.1.2 Master Scheduling.....	72
6.1.3 Distribution Channels.....	73
6.1.4 Production Lead Time.....	74
6.2 BUSINESS ANALYSIS AND PROBLEM IDENTIFICATION.....	75
6.2.1 Suffering in Business Model.....	75
6.2.2 Suffering in the Supply Chain Model.....	76
6.2.3 Suffering in the Manufacturing Model.....	77
6.3 VIRTUAL WAREHOUSING IN CASE COMPANY.....	78
6.3.1 Business Adjustments to the Virtual Warehousing Approach.....	78
6.3.2 System Development for Virtual Warehousing Approach.....	79
6.4 IMPLEMENTATION OF VWS.....	80
6.4.1 Process Overview.....	80
6.4.2 System Overview.....	82
6.4.3 Data Flow.....	84
6.5 ILLUSTRATION OF THE OPERATIONS OF VWS.....	87
6.5.1 Initiation into the System.....	87
6.5.2 Determination of Initial Inventory Parameters and Inventory Plan Settings for Production Logistics in the Simulation Module.....	88
6.5.3 Determination of Production Constraint Resolving and Inventory Allocation for Production Logistics in Advisory Module.....	91
Chapter 7 Results and Discussion.....	95
7.1 ORDER PROMISING IN VIRTUAL WAREHOUSE SYSTEM.....	95
7.2 DETERMINATION OF THE INITIAL INVENTORY PARAMETERS AND THE INVENTORY PLAN SETTING FOR THE PRODUCTION LOGISTICS IN THE SIMULATION MODULE.....	96
7.3 DETERMINATION OF PRODUCTION CONSTRAINT RESOLVING AND INVENTORY ALLOCATION FOR PRODUCTION LOGISTICS IN THE ADVISORY MODULE.....	97
7.4 REAL LIFE EXAMPLES OF THE BEST USE OF THE SIMULATION MODULE.....	98
7.4.1 Scenario 1 – Oil Crisis.....	98
7.4.2 Scenario 2 – New Product Phase-in.....	99
7.5 SELECTION OF THE DEVELOPMENT METHOD.....	100
7.6 VALIDATION OF VWS.....	101
7.7 BENEFITS AND SIGNIFICANCE.....	102
Chapter 8 Conclusion	105
Chapter 9 Suggestions for Further Work.....	109

Publication Arising from the Thesis	112
References	113
Appendix A Program Source Code of System Algorithm.....	A-1
Appendix B Templates of Upload Data Files.....	B-1
Appendix C Procedures of Source Data Download	C-1
Appendix D User Manual of System Installation.....	D-1

List of Figures

Figure 1.1 Conventional Material Flow.	2
Figure 2.1 Existing systems network for production logistics.....	24
Figure 3.1 Inventory decentralization and overstock in the conventional approach.....	30
Figure 3.2 Virtual Warehousing.....	31
Figure 3.3 Virtual warehousing concept chart.....	32
Figure 3.4 Postponement of customization timing.....	33
Figure 3.5 Inventory centralization and postponement of differentiation.....	33
Figure 3.6 A timeline illustrated the decisions of inventory swapping.....	35
Figure 4.1 Function modules.....	38
Figure 4.2 VW system integrated with logistics information systems.....	40
Figure 4.3 Mechanism to loosen production constraints adopted in VWS.....	41
Figure 4.4 A schematic diagram of knowledge-based system applied in VWS.....	42
Figure 4.5 A schematic diagram of data flow.....	44
Figure 4.6 Mock-up interface.....	47
Figure 5.1 The direction and type of information transmitted across three parties.	50
Figure 5.2 Conceptual interfaces to acquire data from MRPII system.	51
Figure 5.3 Process flow chart of advisory module.....	58
Figure 5.4 Daily Table of Distribution Resource Planning.....	61
Figure 5.5 Action date timeline in the transformation of solution reasoning.....	66
Figure 6.1 Components of a shaving product.....	72
Figure 6.2 Bill of distribution.....	74
Figure 6.3 Lead Time.....	75
Figure 6.4 Operations in supply chain planning in Schick.....	81
Figure 6.5 The information flow and processes between information systems in Schick	83
Figure 6.6 Overview of related data in the information systems co-coordinated with VWS.....	86
Figure 6.7 Flow chart of data transformation in the data warehouse for VWS.....	87
Figure 6.8 Users log-in interface of VWS.....	87
Figure 6.9 The list of WIP being the inventory planning key.....	88

Figure 6.10 The master supply chain plan generated by the APS system.	89
Figure 6.11 Inventory plan on a common component in the simulation module.....	89
Figure 6.12 Snapshot of the inventory plan for next 6 months in simulation module.	90
Figure 6.13 Inventory allocation with problem input in advisory module.....	91
Figure 6.14 Snapshot of the most suggested solutions to reallocating resources.	92
Figure 6.15 One less strongly suggested solutions to deal with a supply chain event.....	92
Figure 6.16 Results of a case retrieval after similarity analysis on supply chain events. .	93
Figure 6.17 Snapshot to input final decision reacting on supply chain event.....	94
Figure 9.1 Enhanced virtual warehousing among distribution facilities.....	109

List of Tables

Table 5.1	Standard Table of Distribution Resource Planning.....	53
Table 5.2	Daily DRP Table Elements	60
Table 5.3	Five features of a problem with their corresponding weights.....	63
Table 5.4	Similarity table of initial l, p	64
Table 5.5	Daily DRP Table Elements (II).....	70
Table 6.1	Scheduling Levels	73
Table 7.1	Results of the performance evaluation of the VWS.....	102

Chapter 1 Introduction

1.1 Overview

Around the world, most companies of any appreciable size are engaged in a certain effort intended to improve the processes that take place from one end of the supply chain to the other. To manage their supply chains, the companies align the processes of upstream and downstream supply chain partners so that they can deliver superior products to the end customer (Oliver and Webber, 1982) while minimizing waste. This is called supply chain management (SCM). And logistics is the task of coordinating material flow, information flow, and flow of funds across the supply chain (Christopher, 1998). The competitiveness of the supply chain is supported by logistics in production to meet customer demand through supplying what is needed, when it is needed, at low cost. This is defined as production logistics (Curran et al., 1998).

1.2 Industrial Background

Conventionally, as shown in Figure 1.1, a network of inventory flows with several distribution centers serves wholesalers and retailers in its geographic territories. The stock movement develops into a supply chain network, like the branches of a tree, which support outlying downstream demanders. Each conventional distribution center plays the role of a breaking bulk hub whereby finished products are doled out to the retailers (Gattorna and Walters, 1996). The distributors individually take care of their own ordering and inventory control. They may suffer from the bullwhip effect (Lambert,

1998) and the abrupt change in demand. A lavish high stock level is the result of the uncertainty at their end.

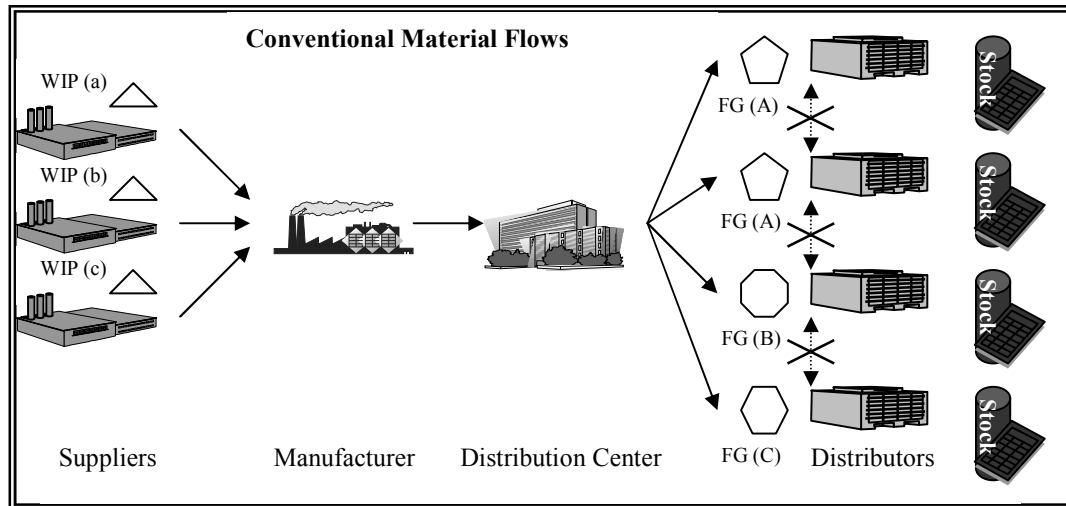


Figure 1.1 The accumulated stock (FG) at the downstream end is costly to cross-dock among distribution facilities due to product customization and the limitation of logistics information sharing.

Inventory flow is simply downward to the customers, and no cross-docking is taken place among distribution facilities. Slow moving items at a point cannot be directly swapped to another one that is out of sales. This results in damage to their market share. The accumulated stock is costly to inter-transfer among distributors (Fung et al., 2004). It results in somewhat slow moving inventory obsolescing downstream in the supply chain and needs to be written off in the account book, while somewhere else is out of stock causing shrinkage in their market segment.

1.3 Formulation of Research Problem

Application of SCM tools along with earlier re-engineering of processes based on ERP implementation has effectively reduced much of the inventory held in the supply chain.

As a result, parties across the supply chain can be viewed as highly susceptible to unexpected events such as an underestimated demand forecast. Leanness achieved in such circumstances results in the enterprise finding that there is insufficient inventory in the supply chain to meet customer demand (Institute of Logistics and Transport 2004). To anticipate and overcome this problem, a virtual warehousing (VW) approach is introduced to the supply chain planning in this research.

1.4 Project Initiative

This is a joint research project funded under a teaching company scheme. The project is jointly organized by the Hong Kong Polytechnic University, the Innovation and Technology Commission of the Government of the HKSAR, and the sponsor company namely, Schick Asia Limited. A teaching company associate (TCA) is appointed to make full use of the appropriate knowledge and skills in a real-life situation in which research takes place alongside the practical application and development of skills. The TCA in the scheme is required to work on an industrial-based project at their places of work under the joint supervision of their own industrial supervisors together with academic supervisors.

The sponsoring company of this project, Schick Asia Limited, provides the industrial environment and technical support for the TCA to collect data, implement and evaluate the performance of the virtual warehouse system. The University provides the academic guidance and technical support for the TCA to undertake the project.

1.5 Research Scope

The scope of the project depends on the definition of inventory. The term, inventory, in this case is regarded as the major component among the parts in the bill of materials. The major components are selected in accordance with their criticalness to product assembly as well as regards the portion they take in the total inventory cost as compared with other components. The reasons for selecting them are because of their critical role in loosening production constraints as well as the large portion they take in the total inventory cost. Therefore, only components, which have not been undergone product differentiation, are studied in this research. Flexibility of inventory swapping before the assembly process takes place, is implied.

The virtual warehouse system (VWS) is a server based communication platform to enable geographically dispersed users to manage and to assimilate the knowledge of the product logistic activities. These include supply chain planning, inventory management, and the management of supply chain activities between internal and external suppliers.

1.6 Objectives

To enable the production logistic activities to meet the requirements from marketing affiliates, suppliers, and customers, a virtual warehouse system (VWS) is developed for manufacturing enterprises and it has been successfully trial implemented in the sponsoring company. The objectives of the project include:

- (i) To develop a virtual warehouse system (VWS) for manufacturing enterprises in order to support the production logistic activities between marketing affiliates, suppliers, production plants and customers.
- (ii) To trial implement the VWS at the sponsoring company.

The successful system should aid a manufacturing enterprise to be better equipped with the capabilities to cope with disruptive demands. The benefits include: faster response to the market changes, shorter lead-time of production, improved quality and speed of customer service, better ability to deliver the quality products to global customers, and improved communication and transportation systems.

1.7 Organization of Report

The report is composed of nine chapters. In chapter one, is a clear statement of the project background and the objectives of the research. In chapter two, a literature review is conducted to study previous work on various topics such as production logistics, inventory planning, information technology frameworks, artificial intelligence, etc. The concept of virtual warehousing is discussed in chapter three. In chapter four and five, the project methodology is discussed together with details of the system design. In chapter six, the capability of the system is demonstrated through a case study of a successful implementation in the sponsoring company. Chapter seven discusses project strength and weakness as well as business discussion. An overall conclusion and suggestions for further study are given in chapter eight and nine respectively.

Chapter 2 Literature Review

In this chapter, firstly, the definition of production logistics and its supporting information technology tools are introduced. They include the concept of virtual warehousing as well as planning support systems. These are very important definitions for the whole research because this is related to the system design and the outcomes of the project. Then a summary of literature review is presented in order to illustrate the limitations and opportunities in this industry.

2.1 Production Logistics

Production logistics accompanies the flow of purchase and job orders from primary requirements planning through to completion of the production order (Scheer, 1998). Due to its highly complex nature, the production logistics process is divided into several sub-processes. It refers to the manufacturer's transformation, movement, storage and control of goods from the acquisition of raw materials to the delivery of finished products to the customers (Curran, 2000). Production logistics particularly focuses on the transformation of products, and its effectiveness to satisfy customer requirements. The transformation is conducted during production, component assembly and product assembly. All parties throughout the supply chain that deliver physical products are the participants in production logistics (Hansmann, 1996). As production logistics concentrate on product processing and manufacturing under the restrictions of customization at maximum efficiency, it provides research opportunities in the process of production, installation, or in the design of product delivery models. The evaluation

of existing logistics information systems is an essential first step before we identify new approaches or features that were missing before. This is an opportunity to introduce a supplementary system integrated with the existing tools to improve the efficiency of production logistics.

As Crowston (1973) mentioned in his publication, production planning is one of the main streams in production logistics. It uses the statement of requirements obtained from demand management in conjunction with manufacturing resources and constraints to develop a workable manufacturing plan. The statement of requirements defines what items are needed and when they are needed (Ferdows, 1989). Production planning is long-medium range plan that is concerned with establishing the overall level of manufacturing output. The production plan is mostly stated broadly enough to show the needed finances, facilities, equipment, personnel, and materials. Forecasting is one of the important elements in production planning and inventory control. Although there has been a definite trend toward make-to-order (MTO) and assemble-to-order (ATO) manufacturing, such response-based practices are not always possible because of production capacity or resource constraints. The limitations occur in the form of facility, equipment, and labor availability.

2.1.1 Inventory Planning

Inventory planning (Kovacs and Paganelli, 2003) acts as a primary supply chain activity between forecasts and operations by means of requirement plans as well as through managing finished inventory from production to customer shipment. There are always

questions when replenishment orders are placed such as: how much stock is to be ordered? When should the inventory be moved through the supply chain? etc.

The first process of inventory planning is forecasting. The forecast predicts product requirements by customer and distribution centers to support enterprise planning. The forecasting activities require estimations of future demand in the forms of implicit or explicit forecasts (Viswanadham, 2001). Implicit forecasts, or named default forecasts, assume that next month's demand will be the same as last month's sales. Explicit forecasts are more scientific, using information about enterprise, customer, and competitor actions. The basic proposition is that more integrated forecast information facilitates inventory planning and results in lower inventory requirements.

The next process is inventory allocation that can be aided by decision supporting tools ranging from simple reactive models to complex planning. The inventory planners demand guidance and aids to decide when and how much to order. Reactive models respond to current demand and inventory situations using the parameters of reorder points and order quantity. The replenishment actions are reacted by current inventory levels (Magretta, 1998). Some planning tools can anticipate future requirements on the basis of forecasts and projections of cycle time. The planners are enabled to identify potential problems while they can be resolved using proactive management.

Primary drivers of inventory development and management are customer service objectives established by management (Kovacs and Paganelli, 2003). Service objectives are used to define target fill rates for customers and products. The combination of service objectives, demand characteristics, replenishment characteristics, and operating policies determines where, when, and how to plan for inventory. The level of inventory

assets required to meet specific service objectives can be significantly reduced by effective planning. The achievement of these objectives can be assessed with the measurement of inventory by monitoring stock level, turns, and productivity.

2.1.1.1 Vendor managed inventory (VMI)

Vendor managed inventory is a modification of quick response that eliminates the need for replenishment orders. The goal is to establish a supply chain arrangement so flexible and efficient that the retail inventory is continuously replenished (Taylor, 2004). The distinguishing factor between quick response and VMI is who takes responsibility for setting target inventory levels and making restocking decisions. The retailer makes the active decisions with a quick response. In VMI, the supplier assumes more responsibility and actually manages a category of inventory for the retailer. By receiving daily transmission of sales and shipments, the supplier assumes responsibility for replenishing retail inventory in the required quantities, colors, sizes, and styles (Waters, 2003). The supplier commits to keeping the retailer in stock and to maintaining inventory velocity.

The smooth running of VMI mainly depends on a comprehensive business systems network. It also requires effective teamwork between the retailer and the manufacturer. In order for both parties to gain full benefit from the system, appropriate performance measures need to be used. The most critical is the product availability at the retailer's end. It is in both parties' interests to maximize product availability, avoiding lost sales in the short term and building customer consuming habits in the long term. There are conflicting goals in VMI that the supplier's responsibility for maximizing product availability, but the aim of VMI is to achieve this with minimum inventories. It is

necessary to leverage the inventory availability and inventory carrying cost in this contradiction of inventory planning objectives.

2.1.1.2 Collaborative Planning, Forecasting, and Replenishment (CPFR)

Collaborative planning, forecasting, and replenishment is a process initiated by the consumer products industry to achieve coordination. It does not replace replenishment strategies but supplements them by a cooperative process (Taylor, 2004). In essence, CPFR coordinates the requirements planning process between supply chain partners for demand creation and demand fulfillment activities. The CPFR solution shares information that involves promotions, forecasts, item data, and orders, via either Electronic Data Interchange (EDI) or the internet. The collaboratively developed information is then used by joint and iterative planners to generate demand, determine replenishment requirements, and match production to demand.

The first step in the CPFR process is joint business planning, where a customer and supplier share, discuss, coordinate, and rationalize their own individual strategies to create a joint plan (Waters, 2003). The joint plan offers a common and consistent vision of what is expected to be sold, how it will be merchandized and promoted, in which marketplace, and during what time period. A joint calendar is created to share information determining product flow. A common sales forecast is created and shared between retailer and supplier based on shared knowledge of each trading partner's plan (Taylor, 2004). CPFR includes an iterative process in which the forecast and requirements plan is exchanged and refined between the partners until a consensus is achieved. Using this agreed forecast, the plans of production, replenishment, and

shipment are then developed mutually. Thus, the collaborative forecast ideally becomes a commitment between two parties.

2.1.1.3 Virtual Warehousing (VW)

Conventional logistics process seeks to identify optimal quantities of inventory and their spatial location. This business model requires complex formulae and algorithms to support the inventory plan. A virtual supply chain involves the use of information technology to share data between buyers and suppliers, it is information based rather than inventory based. Once the visibility of demand is achieved through shared information, the premise upon which complex formulae is based no longer holds good (Harrison et al., 1999). Information technologies have enabled parties in the supply chain to act upon the same data, rather than being dependent upon the distorted and noisy picture that emerges when orders are transmitted from one step to another in an extended chain.

Developing from the model of a virtual supply chain, the virtual warehousing (VW) approach is a business model targeting reduced cost, optimized production, and a high customer service level guaranteed to the customers. The basic concept of VW has appeared in a number of past research studies since 1995. Most of them focus on a single-location consolidated stock rather than on the multi-locations distributed stock of the virtual inventory approach (Ballou and Burnetas, 2003). The past studies clearly defined that,

“Virtual warehouse relies on information technologies and real-time decision algorithms to provide operating efficiencies and global inventory visibility comparable to that achieved in a single-location world-class warehouse”. (Stuart et al., 1995, Walker et al. 1996, Landers et al. 2000)

The VW (Landers et al., 2000) is a state of real-time global visibility for logistics assets such as inventory and vehicles. Landers pointed out that both efficiency of operation and inventory visibility accompanying the tools of information technologies and decision support system are the key approaches needed in order to achieve VW. This provides substantial gains in accuracy and throughput, on-line material visibility for customer service, precise control of transportation, and the higher capabilities of data analysis for any users who are capable of accessing the databases (Hoek, 1998). However, they only directed a generic approach to VW without concrete details on practical applications in supply chains. Most of them are proof of concepts, neither successful implementation nor case references are found to properly support the conventional VW.

Cost saving can be achieved in the single location in the previous definition of VW by coordinating inventory management across the supply pipeline. This allows duplication to be eliminated and safety stocks to be minimized, thereby lowering logistics costs and overall distribution cycle times (Hoek et al., 2002). Centralizing inventory can contribute to lowering overall speculative inventories. It also creates the ability to balance peaks in demand across regional markets from one central inventory.

It is well known that inventory can be leveraged to facilitate the functional performance of sales and marketing. The traditional usage is to maintain sufficient inventory to

protect against demand (Curran 2000). However, there is no mention about the leverage of semi-finished inventory in the existing conceptions of VW. Stockpiling both semi-finished and finished inventory leverages maximum manufacturing economy of scale. The economy of scale can result in low per unit cost of manufacturing. Forward commitment of inventory to local affiliates can leverage sales that are opportunities to enrich the VW approach. The benefit brought to enterprise is achieved by cost allotment. The challenge to supply chain planning is to achieve a balance between the cost of leveraging and the risks of obsolescence associated with the inventory.

2.1.1.4 Summary of Inventory Management Approaches: Demand for Enhancement of Virtual Warehousing in Inventory Management

In the previous two approaches, inventory stocking by different parties across the supply chain implies a significant financial investment to the enterprises, and it loses its value over time in risk of obsolescence, damage as well as shrinkage. Stocks are built up because of dynamic changes in the market and because of the continual increase in competition. Anyway, inventory stocking is a necessary logistics activity in the operation of enterprises, no matter which approach is taken. It serves as the buffer between demand and supply capability. The primary reason for holding inventory is to meet unforeseen and actual customer orders. Gattorna and Walters (1996) suggested that inventory requires sophisticated methods of planning and control.

Supply chain planning involved the foreseeing of a future environment in which an enterprise has to function with an overall regard to the constraints of supply capacity against the estimation of demand levels (Institute of Logistics and Transport, 2004).

Owing to delivery lead-time and rapid change in the market, the customers are unable to predict future demand on an aggregated level. Donk and Vaart (2004) even pointed out some customers are not willing to commit to their own demand forecast even though they can predict some part of future orders. In this situation, the manufacturers often find it difficult to plan inventory for disruptive demands (Fung et al., 2004), particularly if the production capacity is limited, or if the stock volume of the raw material and work-in-process (WIP) are limited. Thus, opportunities of virtual warehousing are identified to fill the gap and resolve the difficulties.

2.1.2 Production Strategies

The production strategic range is constrained by both marketing and technological forces. Prevailing marketing practices serve to ground production strategy in terms of customer acceptability (Dellaert and Jeunet, 2004). Technology drives strategy to a production model that is competitive. For a manufacturing firm to effectively compete, it must be able to integrate manufacturing capability into a meaningful marketing value proposition. The most common production strategies are make-to-stock, make-to-order, and assemble-to-order.

2.1.2.1 Make-to-stock (MTS)

MTS strategies are characteristic of industries exploiting economy of scale gained from long production runs. Significant finished goods inventory is typically manufactured in anticipation of future customer requirements. The logical requirement to support MTS is

warehousing capacity to store finished products and to facilitate product sorting to meet specific customer requirements. When flexible manufacturing is introduced to speed up switchover, the inventory lots produced are typically smaller in quantity. However, warehouses are still required for temporary storage and to facilitate product assortment.

2.1.2.2 Make-to-order (MTO)

MTO manufacturing strategies seek to manufacture products to customer specifications. While MTO may not be as limited as the traditional job shop, exact quantities and configurations are produced in relatively small quantities. Logistical capacity may be required for temporary storage and to achieve outbound transportation consolidation, but most products produced in an MTO environment are shipped direct to customers.

2.1.2.3 Assemble-to-order (ATO)

In ATO strategies, base products and components are manufactured in anticipation of future customer orders. However, the products are not fully assembled or customized until a customer's order is received. The need for logistical capacity is critical in ATO operations (Waters, 2003). An increasing amount of ATO product finalization is being performed in most supply chain models. The attractiveness of an ATO manufacturing strategy is that it has the potential to combine some facets of economy of scale from MTS and a degree of flexible characteristic from MTO. Full implementation of an ATO strategy requires that warehouse operations be integrated in the value creation process (Waters, 2003) to perform product customizing and assembly operations.

2.1.2.4 *Just-in-time (JIT)*

The efficient and effective coordination of manufacturing strategy with the procurement of material and components ultimately depends on logistics. Resources must be procured and positioned as needed to support manufacturing operations. No matter the manufacturing strategy is MTO, ATO, or MTP, logistics links suppliers and customers with manufacturing processes. Just-in-time is the favoured approach for achieving this coordination with them.

The goal of JIT is to time-phase activities so that purchased materials and components arrive at the manufacturing or assembly point just at the time they are required (Ballou and Burnetas, 2003). Raw material and work-in-process inventories are minimized as a result of reducing or eliminating reserve stocks. The key to JIT operations is that the demand for components and materials depends on the finalized production schedule. Requirements can be determined by focusing on the finished product being manufactured. Once the production schedule is established, JIT arrival of materials and components can be planned to coincide with those requirements, resulting in reduced handling and minimal inventories.

To make JIT works, absolutely reliable logistical performance is required which eliminates the need for buffer stocks of materials. It is necessary to deal with suppliers who have high and consistent levels of quality, since their materials will go directly into the production (Collins, 2001). JIT generally requires more frequent deliveries of smaller quantities of purchased inputs. Thus, close cooperation and communication is a must between a manufacturer' purchasing division and suppliers.

2.1.2.5 Summary of Production Strategies: Demand for a Production Constraint Loosening Tool in Order Fulfillment

The supply chain events that happen in between planning intervals has the most critical impact on the production logistics. Stadtler (2004) explained that those events might be a new demand order, a supply delay, a transportation or marketing issue. They mostly result in changing demand at short notice that often occurs in industry. The supply chain is appointed to handle these unexpected events quickly. Production planning and detailed scheduling have to be adapted to the specific needs and the change of conditions.

Erroneous inventory planning and an inflexible response may have the result that customer orders are not served in time (Stadtler, 2004). The production constraints are the major challenge to counter the abrupt demand changes. Dellaert and Jeunet (2004) demonstrate how stock-out situations may arise in a deterministic, multi-level, rolling schedule environment. Conventionally, the planners have to assess the orders by a rough-cut process on each production parameter. Planning experience and full vision of inventory status are required to judge the acceptance of an abrupt order. In some cases of serious resource shortage, an alternative solution is needed to ease up on the situation rather than simply to refuse orders.

The current software such as SAP, Baan, only implements simple rules on shortage planning (Fischer, 2001, Kilger and Schneeweiss, 2002). Current models of detailed production plans are absent from the rescheduling mechanism targeted on production resources (Kolisch, 2001, Stadtler, 2002). The need for decision support as well as

systematic classification of production types has already been brought out by Drexl et al. (1994).

2.2 Information Technology Supporting Production Logistics

The rapid advance in information technology means that IT is now deployed not only to improve the current operational effectiveness of a manufacturing enterprise, but also to build new capability to meet the existing business environment and complexity. Among various desirable capabilities, the ability to learn and adapt to change is important (Harrison and Storey, 2000). The core activity of manufacturing is no longer confined to making things but lies in the systematic processing of knowledge to create value for business.

The traditional operation of production logistics is being transformed radically by the rapid advancement in communications technology. A set of suitable tools can restructure an enterprise to face new and challenging demands from the market. Both communication technologies such as internet, wireless, and information technologies such as XML, Java, WAP, made the ubiquitous flow of information seamless (Harrison and Storey, 2000). The digital marketplaces emerge as key information and transaction nodes in the supply chain. The organizations can benefit from this development, because the processes are aligned to support the market growing with the aid of technologies (Donald, 2003). Thus, the application of technological tools is one of the ways to identify new business, reduce operation costs, and improve efficiency.

2.2.1 Information Technology Frameworks

Enterprise information systems initiate activities and track information regarding processes, facilitate information sharing both within the firm and between supply chain partners, and assist in management decision making. The following subsections describe the multiple roles that information systems play in enterprise management. These major components of systems include planning, coordination, operations, and inventory deployment. All information systems are aimed at integration by providing comprehensive functionality for the support of production logistics.

2.2.1.1 Material Requirements Planning (MRP)

Material Requirements Planning (MRP) is an important tool as a manufacturing planning and control system. It provides instant insight into the capacity required to manufacture products. Both high accuracy of the stock records and integrity of the bill of material (BOM) are requirements to implement MRP successfully (Donald, 2003). MRP uses the master schedule, along with other relevant information, to plan the supply of materials. MRP employs a lot of information about schedules, products and materials. They include the master schedule, BOM and inventory records.

2.2.1.2 Manufacturing Resource Planning (MRPII)

Manufacturing Resources Planning (MRPII) is a derivative of MRP. MRPII gives an integrated system for the synchronization of all functions within an enterprise. It connects schedules for all functions and resources back to the master schedule (Donald,

2003). Initially, MRP gives schedules for components production. Moreover, MRPII explodes the master schedule to give internal timetables for all the jobs, equipment, operators, machines, and facilities needed to achieve it. The master schedule is the basis for planning all the resources, such as associated finance, marketing, and human resources, in an enterprise. A point to note is that different names are often employed for incompletely implemented MRPII such as distribution resource planning, logistics resource planning.

2.2.1.3 Enterprise Resource Planning (ERP)

MRPII generates plans for all inbound activities and material movements within a manufacturer's environment. Following the trend of supply chain integration, Enterprise Resource Planning (ERP) follows similar logic but extends it to other organizational operations. In principle, the free flow of information required by ERP is organized with electronic data exchange (EDI), internet, and other tools of e-business. Those tools link the MRP system to both customers' and suppliers' sides. All parties know in advance when they need to deliver material.

Existing ERP systems only give support to the administration of conventional customer and supplier relationships with basic services such as ordering and invoicing. These systems are clearly insufficient to cope with modern manufacturing (Kovacs and Paganelli, 2003). ERP is employed mostly as the production operation and management solution such as SAP, Baan; and supply chain planning systems such as i2, Manugistics contribute to the production planning. Despite rich technological content, current supply

chain planning systems are still bounded by modern ERP software with limitations such as high implementation costs and centralized planning.

To overcome these limitations, major ERP producers are developing supply chain management add-ons on top of their production management solutions. This is often achieved through the partnerships with supply chain planning producers. Kovacs and Paganelli (2003) expected great diffusion could be foreseen in the future, as verified by the launch of supply chain planning projects in leading industries worldwide.

2.2.1.4 Advanced Planning and Scheduling (APS)

ERP systems in general do not evaluate alternative strategies or assist with decision making. Supply chain planning systems, commonly named Advanced Planning and Scheduling (APS) systems, are designed to assist the evaluation of supply chain alternatives and advise in supply chain decision making. Sophisticated APS systems are available those permit evaluation of complex alternatives under tight constraints of decision time (Taylor, 2004). Typical APS applications include production scheduling, inventory resource planning, and transportation planning. Using historical and current data, APS software systematically identifies and evaluates alternative courses of action within the constraints imposed (Fischer, 2001). Typical constraints involve production, facility, transportation, inventory, or raw material limitations.

Planning systems can generally be grouped into two categories, strategic and tactical. Strategic planning systems are designed to assist in analysis that involves a large number of alternatives, and the data is outside the range of current history. Tactical planning (Stadtler, 2004) focuses on operational matters as constrained by short-term resource

constraints such as production, facility, or transports capacity. The information support for tactical planning is typically available from an internal data warehouse in a corporation. Tactical planning processes evaluate customer requirements and identify an operational combination of production, inventory, facilities, and equipment that can be utilized within capacity constraints.

To correspond with the planning and execution of effective logistics and supply chain strategies, APS systems incorporate both spatial and temporal considerations. The spatial considerations include movement between raw material providers, manufacturing plants, warehouses, distributors, retailers, and the customers. The temporal considerations include the timing and scheduling of the movements.

2.2.1.5 Distribution Requirements Planning (DRP)

Distribution requirements planning (DRP) is an inventory management and process control tool (Taylor, 2004) that follows the logic of MRP. DRP converts a forecast of shipment demands to a gross requirement, subtracts on-hand and on-order balances, and then places replenishment orders on a time-phased basis. Further requirements (Gattorna, 1998) are based on forecasts, customer orders, and promotions. Forecasts are based on sales and marketing input in conjunction with historical activity levels. Customer orders include current orders, future committed orders, and contracts. And promotional activities imply a large percentage of variation in volume as well as a large impact on capacity. Unlike MRP, DRP only combines demands from different retailers, wholesalers and warehouses. It deals with end items only and excludes the exploding of BOM.

2.2.1.6 Summary of Information Technology Frameworks: Demand for Simulation Model in APS and ERP

Various software packages are available in the market for particular applications such as various Enterprise Resource Planning (ERP) systems, Advanced Planning and Scheduling (APS) systems. However, they are subject to some restrictions and are expensive to implement.

Kovacs and Paganelli (2003) described that ERP systems mainly give help on supporting administration and the operation of conventional customer, supplier relationships as well as supply chain management with core services such as ordering and invoicing. These systems are clearly insufficient to cope with the modern manufacturing which involves advanced planning. Stadtler (2004) also pointed out that the strength of transactional ERP systems is not in the area of planning. APS has been developed to fill up this gap for decision support within other processes, but is not an isolated process of supply chain management (SCM). APS systems offer complicated planning and scheduling capabilities, but the operational modules are not provided to translate plans into action. As shown in Figure 2.1, the industry combines the two applications to fit its business needs. In the field of production logistics, a single APS system is used to plan the movement of inventory across production facilities; each of the facilities is managed by a local ERP system.

Taylor (2004) identified that the APS models are still conditional on some limitations because of the use of linear programming and related mathematical techniques. They make some strict and simplified assumptions about the real world system. One

assumption is that all relations are well behaved, in linear form. It expels the true dilemma in the statistical data. Many of the mathematical models originate from purifying complex relationship down into relatively simple mathematical forms. However, the real cases that occur in supply chain do not conform to simple equations of the relations among components.

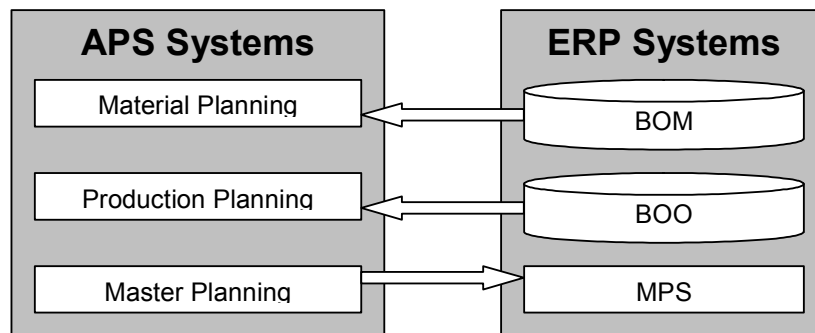


Figure 2.1 Existing systems network for production logistics (Taylor, 2004).

2.2.2 Planning Support System (PSS)

A planning support system (PSS) (Greertman & Stillwell, 2004) is a generic technology that can be applied in various industries. PSSs are used to support the planning process by communicating information as well as by generating solutions. These systems include instruments supporting different aspects of the planning process which includes problem diagnosis, data collection, mining and extraction, data modeling, visualization and display, plan formulation, evaluation, reporting and collaborative decision-making.

Greertman and Stillwell (2004) identified the existence and the use of PSS in the field of geo-information instruments. They developed a computer-based geo-information instrument with the use of PSS. It supports specific forms of planning in strategic planning, land-use and infrastructure planning and environmental planning. Greertman

and Stillwell (2004) also pointed out “there remains a general lack of knowledge and insight into the development, adoption and implementation of PPS in different planning contexts”. They identified a development opportunity for using PPS in other industries apart from geo-information technology. It was a good attempt to develop a tool for production logistics including production planning with the use of PPS.

2.2.2.1 Artificial Neural Networks (ANNs)

An artificial neural network emulates a biological neural network in that it consists of several interconnected layers of non-linear processing units. An input layer accepts scaled input values and passes these values along to a series of hidden layers and finally to an output layer (Haykin, 1999). An important function of the ANNs is the evaluation of its inputs and the production of an output response.

ANNs have been applied successfully in various fields. The pattern processors of ANNs can identify trends as well as important features even in relatively complex information. It also works with uncompleted information, such as blurry or static-filled pictures, that has been an insurmountable difficulty to other PSSs. Its ability to discern patterns allows ANNs to read handwriting, detect potential sites for new mining and oil extraction, and predicts the stock market. However, ANNs has enormous difficulty with problems like processing a visual scene, dealing with noisy or imperfect data, and adapting to change (Haykin, 1999). Its strength lies in the complex, fault-tolerant, parallel processing, however, its technical weaknesses are in formal reasoning and rule-following.

2.2.2.2 *Expert Systems*

Expert systems perform reasoning using pre-established rules for well-defined and narrow domains (Herrmann, 1995). Basically, an expert system contains a knowledge base and an inference engine. The knowledge base contains facts and heuristics about the domain, while the inference engine is a control mechanism that organizes the heuristic activation.

Expert systems have been used to solve a wide range of problems in the fields of medicine, engineering, and computer science. They are used to solve problems of different types involving diagnoses like disease or student errors; designs like computer systems or problems in architecture; and interpretation such as of geological data. The appropriate problem solving technique tends to depend more on the problem type than on the domain (Herrmann, 1995). However, it is also found that expert systems generally have difficulty in expressing exactly what knowledge and rules are employed to solve a problem (Kolodner, 1991). Much of it is almost subconscious, so expert systems are mostly needed to iteratively refine the outputs, based on feedback both from the expert and from potential users of the expert system.

2.2.2.3 *Knowledge-based Decision Supporting Systems*

Managerial decision makers are primarily knowledge workers. A knowledge-based decision supporting system enhances the capabilities of decision making by advisory tools and various computerized knowledge-based systems (Turban, 2001). Knowledge-based systems (KBS) offer expertise in data management and modeling.

Case-based reasoning (CBR) is a kind of a knowledge-based systems. It is a problem solving approach which relies on history and similar cases to search for solutions. CBR is a rich and knowledge intensive method to modify and evaluate the existing solutions (Kolodner, 1991). Experience capturing enables the CBR system to demonstrate decision-making as if a user solves an outstanding problem manually. Advice is given to the users while making decisions on new cases according to the stored historical cases in the system library. Each case comes with additional information attached to it, such as remarks made by the user.

The key to enhancing decision-making quality in SCM is to utilize the advantages of powerful computer-related concepts and techniques. There is a need to develop a computer-aided decision support system for managing inventories to reduce dependence on personal experience, to improve decision quality and shorten response time.

2.2.2.4 Summary of Planning Support Systems: Demand for a Knowledge-based System in Inventory Decision Support

For most worldwide manufacturers, profitability greatly depends on healthy inventory holding in which inventory decisions rely on the know-how, experience, and quality of the planning colleagues (Fung et al., 2004). This knowledge is intangible, so difficult to share and master. Staff training is both time consuming and costly under a high staff turnover rate in an enterprise. A solely human subjective judgment made on inventory decisions may induce a costly mistake if the decision is incorrect (Cheung et al., 2004). Automatic retention of the knowledge in effective inventory planning is identified as a need in an enterprise. The activities of knowledge acquisition, sharing, and diffusion in

an enterprise are much more appropriately undertaken by means of a knowledge-based system focusing on inventory control in the entire supply chain (Preece et al., 2001).

The complexity of logistics decision making is increased by factors such as market globalisation, decentralized manufacturing facilities, extended range of suppliers, high emphasis on total quality issues and customer satisfaction (Kovacs and Paganelli, 2003).

The key to enhance the quality of decision making in supply chain is to utilize the advantage of the computer-related concepts and techniques. There is a need to develop a computer-aided decision support system for managing inventories to reduce dependence on personal experience, improve decision quality and shorten response time.

Most of the available commercial software packages are data and information driven rather than knowledge driven. They are mostly used for data storage, database management and deriving information from the database for decision making. They are not capable of creating new knowledge or suggesting the best practice for improving various business processes, based on the data and information acquired during the daily operation of the enterprise (Cheung et al., 2004). Opportunities are thus identified to develop a support system to cooperate with the ERP systems as well as APS systems, that provide a broader sense of supply chain planning knowledge, but not to be a substitute for them.

Chapter 3 Virtual Warehousing

3.1 Theoretical Background of VW

To further discuss the conventional distribution in the industrial background in chapter one, the distributors individually take care of their own stock. They build up high inventory due to the bullwhip effect and the abrupt order, as shown in Figure 3.1. The customized products from each downstream distribution center can be consolidated into a large global facility. As no value is added to the finished products at the merge point, products are reserved at work-in-process (WIP) status and are earmarked in a supply chain planning system based on the allocation of production resources to fulfill the customer orders (Fung et al., 2004). The idea of postponement (Pagh et al., 1998) is introduced at this point to realign the manufacturing and distribution activities in a supply chain. Time postponement is about deferring the timing of the essential process in which the WIP items are converted to specific functionalities, features, identities, or into finished products (Bucklin, 1965, Fung et al., 2004).

The customization processes take place after some key demander information about specific needs or requirements is revealed. Just-in-time (JIT) delivery results from this practice to postpone assembly activities. It reduces the risk and cost associated with inventory of finished products, and enables products to be differentiated at the last moment upon customer orders. WIP inventory on the final customer order is thus assembled for product customization at the global upstream facility and shuttled promptly to downstream distribution centers.

Conventional Approach

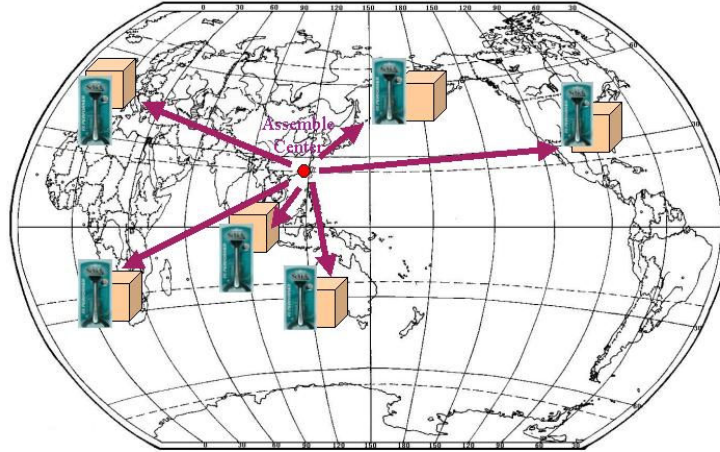


Figure 3.1 Inventory decentralization and overstock in the conventional approach.

3.1.1 Connotation of Virtual in the Proposed Concept

From a distributors' point of view, they are sheltered from market change if they have a centralized safety stock of finished products at the merged point. In fact, the merged point is at the manufacturer's end, and, is further pushed backward to the upstream suppliers in the supply chain. Also, the consolidated inventory is in the status of WIP instead of finished products (Fung et al., 2004). As shown in Figure 3.2, warehousing at the distribution center is indeed "virtual" in the eyes of distributors. The distributors are not informed of the fact that most of the inventory along the supply chain is centralized in the upstream suppliers, but they still regard that inventory as being stocked in the distribution center to protect their sales to retailers as well as dispatches to local distributors. Only in this way, the distributors be willing to release their exceedingly high stock for single location inventory, and be confident to minimize their local

inventory level for financially acceptable product availability in the supply chain downstream.

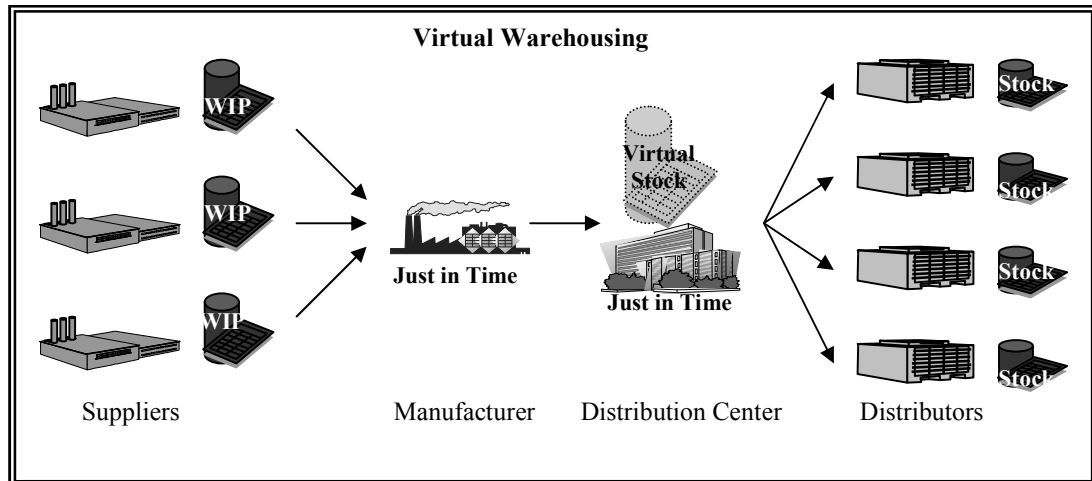


Figure 3.2 The allocation of inventory is merged under virtual warehousing upstream in the supply chain, where inventory is stocked in the status of WIP.

3.2 Elements of Virtual Warehousing

Four additional elements, as listed in the lower part of Figure 3.3, are proposed in this research, to enhance the ability of the conventional concept of VW to cope with disruptive orders. They are: postponement, make for assembly, inventory swapping, and overcome the supply gap. Under postponement, deferred production schedules can release time and increase the flexibility to swap planned inventory of components into the production belts in case of urgent orders. When the supply is insufficient to meet the demand in a critical market situation, the limited inventory is reallocated to fulfill the shipment orders according to the customers' behaviour and past experience. These four elements integrated with the basic VW concept can overcome the difficulties in planning inventory for disruptive demand as well as loosening production constraints while the supply chain events are occurring.

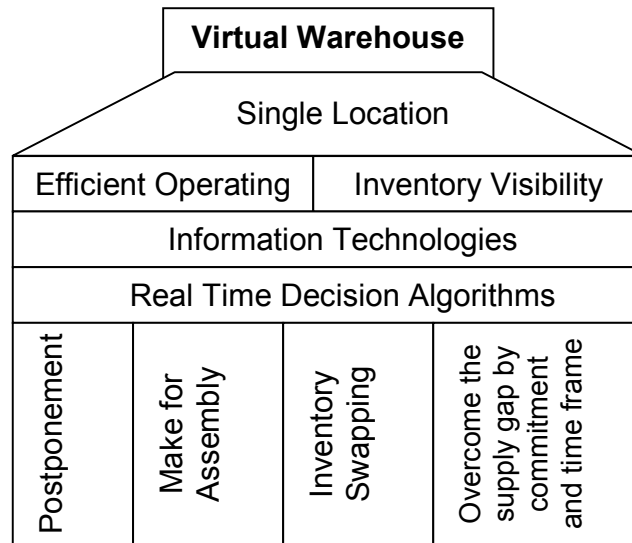


Figure 3.3 Virtual warehousing concept chart. This trapezoid chart shows information technologies and real time decisions are the main elements to achieve efficient operation and inventory visibility, in the traditional perception of virtual warehousing. It is proposed that four additional basic elements be added to the ground of this concept for coping with disruptive orders.

3.3 Illustration of Virtual Warehousing

3.3.1 Postponement

Collins et al. (2001) explained the principle of postponement (Bucklin, 1965) that the efficiencies can be achieved by delaying the point of spatial differentiation, as illustrated in Figure 3.4. Stockholding is consolidated into a single entity for a period as long as possible. The single entity can be a solitary common unit provided that the process of product differentiation has not yet taken place. The adoption of this principle reduces the stock at the distributors as well as at retail outlets (Collins et al., 2001). Meanwhile, the manufacturer combines the use of increased buffer stock at the upstream end of the supply chain. A smoothly operating and integrated chain is important to avoid the risk of stock out at the retailers' end.

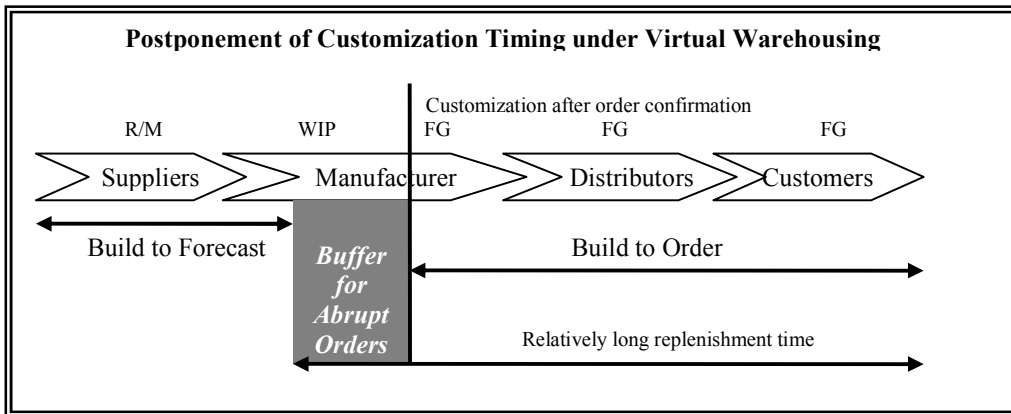


Figure 3.4 The customization processes of raw material (R/M) and WIP are only done at the last moment of the shipment due date after receipt of the customer's order.

3.3.2 Make for Assembly

Most companies operate on a model somewhat in between build-to-stock and build-to-order. Manufacturers simply build-to-stock and complete production prior to the placement of customers' orders. The production plan is totally based on forecasts that induce redundant inventory. The purely build-to-order model suffers from excessive waiting time by the customer for the product (Kolisch, 2001).

Virtual Warehouse Approach

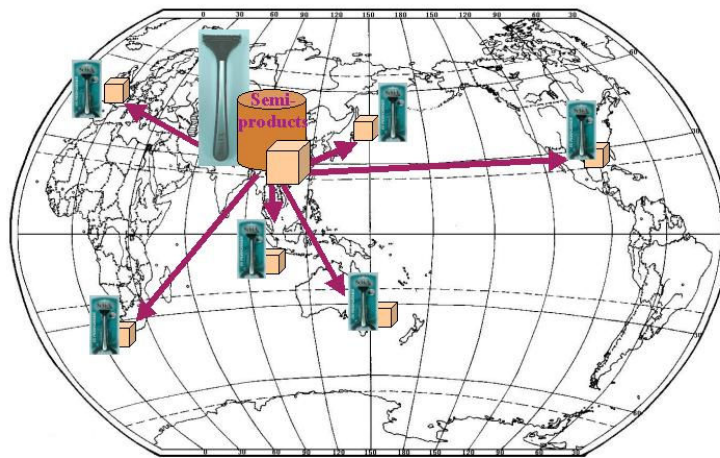


Figure 3.5 Inventory centralization and postponement of differentiation in the Virtual Warehousing approach.

In virtual warehousing, the early processes in the supply chain are operated as per forecast and the WIP items are stocked as seen Figure 3.5, the remaining customization processes are only done at the last moment of the shipment due date, after receipt of the customer's order (Lee and Billington, 1994, Fung et al., 2004). Further postponement after receipt of the order can be compensated for by the release of buffer stock to absorb new abrupt order thus maintaining a higher customer service level as illustrated in Figure 3.4.

3.3.3 Inventory Allocation

The concept of allocation under insufficient inventory was inspired from idea similar to that of limited capacity, which is discussed by Donk and Vaart (2004). They pointed out the case of a supplier using a limited capacity that is named as “shared resources” to deliver goods to a number of different buyers who are part of different supply chains (Donk and Vaart, 2004). However, there is relatively little attention paid to what level of integration is achievable in this case. In the virtual warehouse approach, the allocation is conducted on inventory that has not been undergone product differentiation as shown in Figure 3.6. This is the most flexible and beneficial to the supply chain planning, as compared with the similar activity being adopted downstream in the supply chain.

After a cycle of production planning, the planned schedules of production belts are aligned in a parallel and series matrix. Most of the schedules are planned with diverse opening and closing times, as well as some of unique duration. The time frame in between schedules is a marginal gap that can be used to insert schedules to cope with

urgent unexpected orders. The commitment to the customers' demands can be made outside of physical available WIP inventory, but bounded below the upper constraint, depending on the volume of on-hand inventory and on the duration of the time gap. The physical WIP are stocked at the manufacturer's end, and majority at its supplier's end. The allocation plan of this insufficient inventory is not visible to external customers. The over-committed demands are finally solved in accordance with to their degree of urgency by the means of reallocating inventory, schedule swapping, production belt outsourcing and delivery of partial shipments.

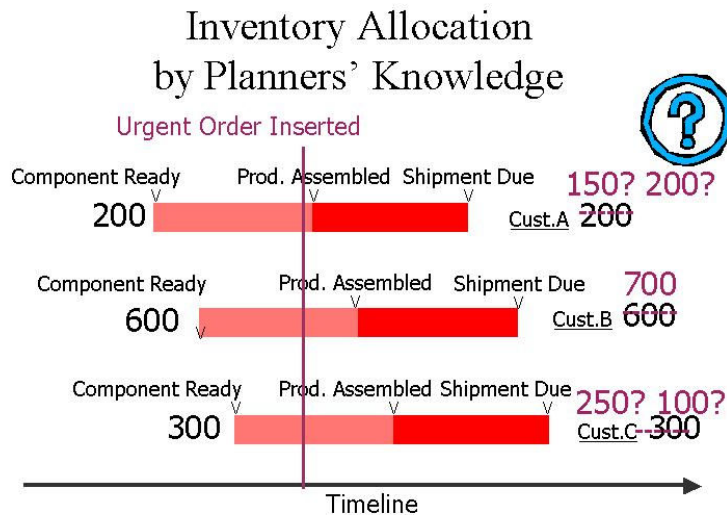


Figure 3.6 A timeline illustrated the decisions of inventory swapping.

3.4 Characteristics of VW for adoption to efficient SCM

Companies owning worldwide known brand name products, in the case of a large portion of their distribution volume, can decrease the costs of handling, labor and inventory levels by using virtual warehousing. Efficiencies are gained at the centralized facility for the customization of the WIP inventory because of direct controlling stock by

consolidation. The benefits of virtual warehousing include reduced impact on production stability due to the uncertainty of demand orders.

Chapter 4 Design of VWS

Virtual Warehousing is merely a conceptual initiative for managing inventory targeted for production logistics. It needs an approach to put this concept into a real practice so as to demonstrate its applicability. Various methods could be used such as, the paper record of the distribution of stock, figuring out the inventory status, or matrix worksheets for managing components. To build up a logistics information system is certainly the best way to prove the usefulness of Virtual Warehousing in term of efficiency as well as effectiveness. In this research the system is named the Virtual Warehouse System and includes the following objectives:

- (i) To demonstrate the applicability of Virtual Warehousing and proof of its concept.
- (ii) To design a list of system elements and requirements to facilitate the use of Virtual Warehousing in production logistics.
- (iii) To develop a set of software components as a platform of tools to manage inventory in support of Virtual Warehousing.

4.1 Design Requirements

This research study of existing logistics information systems is an essential step in the cycle of improvement. The modification of current systems and the development of an alternative material flow, as well as the development of new operation concepts, can help manufacturers to improve the efficiency of their production logistics.

4.1.1 Enhancement in Supply Chain Planning

The medium-short term functions of inventory planning and allocation are key tasks in the matrix of supply chain planning. These are shown in Figure 4.1. VWS adopts a virtual warehouse approach as well as applying information technology, to integrate with Enterprise Resource Planning (ERP) and Advanced Planning and Scheduling (APS) systems, in order to support the decisions of supply chain planning.

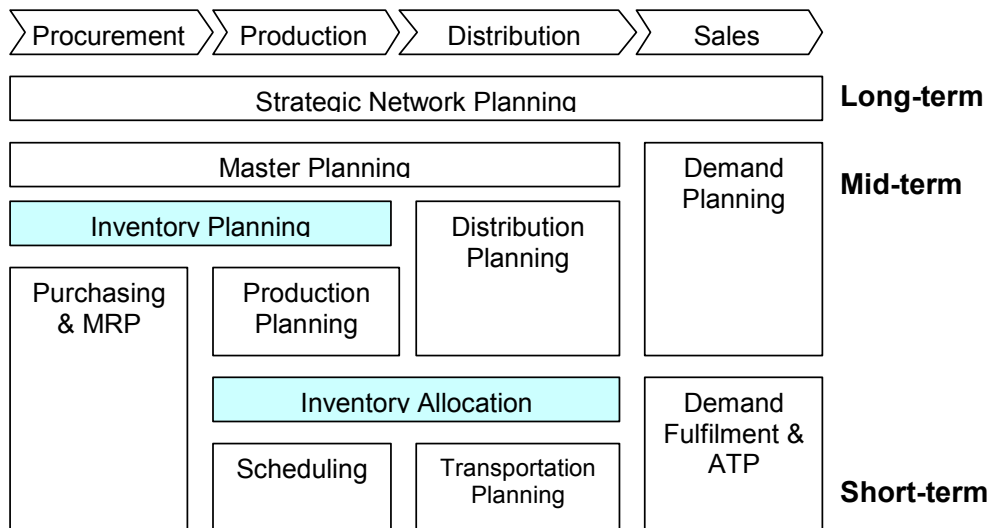


Figure 4.1 Function modules covering the supply chain planning matrix (Meyr et al., 2002).

Master planning is the most efficient way to fulfill demand forecasts over a medium-term planning interval that often covers a full seasonal cycle (Stadtler, 2004). Master components planning can balance demand forecasting with available components, materials, capacities, and leverage demands to production belts by intervals, in order to avoid production bottlenecks. It is associated with production planning and decides stock levels along the full cycle. The stock plan in master components planning is

coordinated with activities and processes along the supply chain and collaborates with supply chain decisions. This plan can be fine tuned to re-optimize itself for the consideration of seasonal stock buffers at different periods.

The required stock levels are directly related to the variance of the forecast errors observed (Silver et al., 1998). Frequent adjustments of demand forecasts also lead to dramatic changes in the master plan (Stadtler, 2004). This plan cannot quickly react to supply chain events happening in between master components planning intervals. The next module is thus proposed to fill this gap to act as event-based planning with the application of CBR.

Components allocation planning enables manufacturers to react to unplanned events with the support of advisor. These events might be a new demand order, a supply delay, a transportation or marketing issue. The plan can handle these short-term events with the available allocation of components, capacity utilization, and production outsourcing. The component inventory is marked with the name of its final receiver, i.e. names of different customers, at the backend of the information system before the inventory goes through the production belts for product differentiation. This activity is called allocation and is similar to physical stock distribution downstream in the supply chain, but it is conducted by means of inventory information instead of physical stock movement.

Before supply chain events occur, the production planning is carefully completed. This involves matching components, supplying and fulfilling production belt demands as well as considering the level of safety stock. Frequent changes of customer orders, owing to supply chain events, induce two main situations to the manufacturer. Firstly, available inventory at the source may exceed the demand from the end destinations. The VWS

regards this situation as surplus inventory. Secondly, which is the most common case, the manufacturer encounters the situation where the inventory at the source is less than the demand from the customers. This is regarded as insufficient inventory. In this case, it is suggested that inventory is reallocated to either solve or trim down the problem. With the application of CBR, a reasoning engine retrieves the stored past cases in which this problem has been solved. These are used for the purpose of giving advice in the present case. The recommended allocation solutions make the best use of available inventory based on the knowledge and the strategies obtained from the retrieved cases.

4.1.2 Enhancement in APS and ERP

Simulation models are introduced to overcome this problem, as shown in Figure 4.2. The inventory plan generated from the APS system is then fine tuned to handle the effect of variability, and other abrupt factors in the VWS. The APS models are entirely free from mathematical restrictions. A simulator can represent the most complex, nonlinear relations, and it accommodates any degree or type of variability in parameter values (Taylor, 2004).

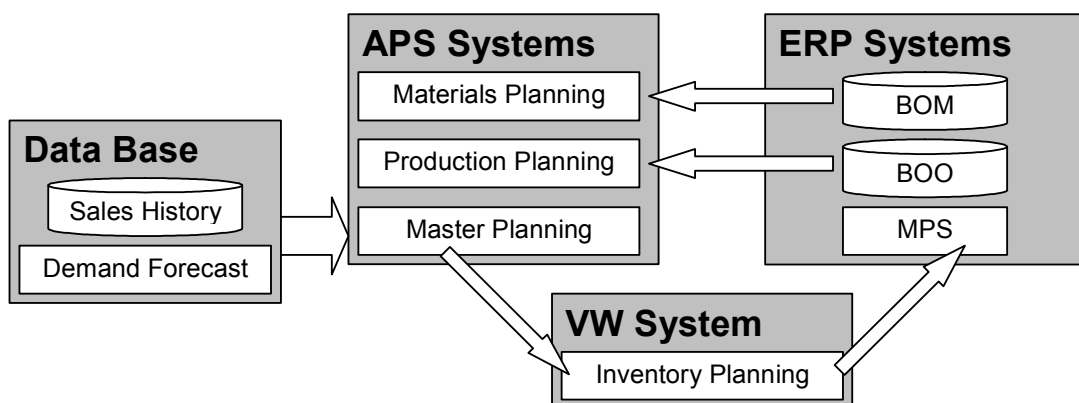


Figure 4.2 VW system integrated with logistics information systems.

A simulator is also able to experiment with possible scenarios. It is easy to evaluate several “what if” cases to find a good, or the best plan. To facilitate selection of the best from different solutions of inventory movement generated by APS systems, a deep analysis and appropriate simulation give strong assistance to production logistics (Kovacs and Paganelli, 2003).

4.1.3 Enhancement in Order Fulfillment

The literature review in chapter two brought out the need for systematic classification of production types as well as decision support to loosen resource constraints.

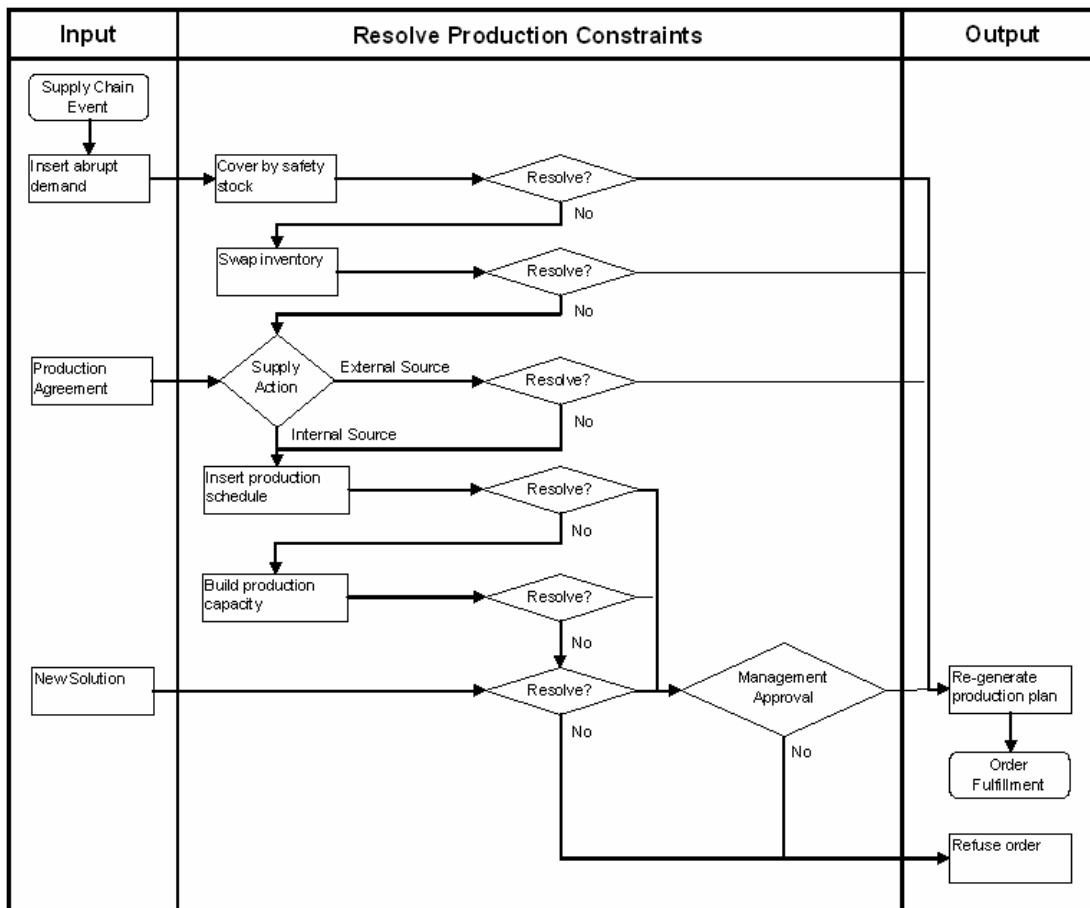


Figure 4.3 Mechanism to loosen production constraints adopted in VWS.

The existing software only implements simple rules on shortage planning. Based on the experience and records of past fulfilled orders, a mechanism is developed to untie production constraints as shown in Figure 4.3. This is one of the elements included in the VWS to streamline production logistics activities, especially when supply chain events occur.

4.1.4 Enhancement in Inventory Decision Support

A support system of problem solving is embedded into VWS to teach the knowledge of supply chain planning. Figure 4.4 illustrates a knowledge-based system to help decision makers get knowledge from past events. Experience capturing facilitates VWS to demonstrate decision-making in the same way as a user solves an outstanding problem manually.

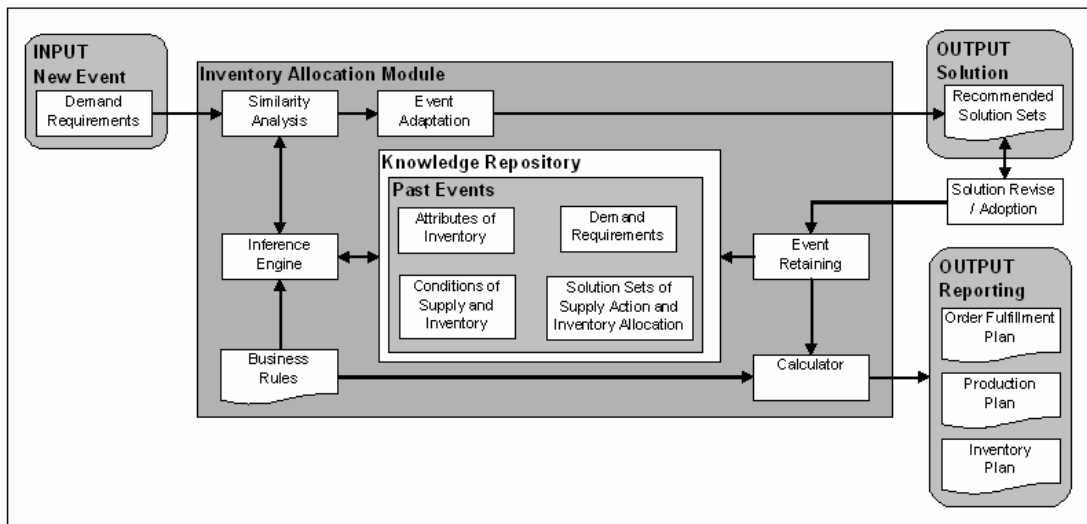


Figure 4.4 A schematic diagram of knowledge-based system applied in VWS.

The current inventory situation and recent planning activities are accessible by the users via the system. A knowledge-based system enables VWS to explain its reactions in the

context of past cases from which it was used to solve the previous problems. The useful information is given to the users to guide the assessment of the situation of new cases (Choy et al., 2002). It is a rich and knowledge intensive approach to modify and evaluate the existing solutions in production logistics (Kolodner, 1991).

4.1.5 Assumptions on VWS

The terminology of inventory in this project is identified as major common components across all kinds of inventory such as raw materials, semi-products, and finished products. The major components are selected in accordance with their criticalness to product assembly as well as the part they play in the total inventory cost compared with other components. Before assembly, the components do not undergo product differentiation. This implies flexibility in inventory swapping.

Focusing on component inventory, there are several product series, “lines of business”, (LOB) commonly, existing in each component levels. They may not totally benefit from the implementation of this system. Product series are assumed to have the following requirements:

- (i) The lines are consuming exactly the same major component. Some are even similar in part number, but they are apparently of dissimilar colour.
- (ii) The lines are preferred if they are fast moving in term of inventory turnover. Both marketing sales and shipment orders can show turnover rate fairly clearly.
- (iii) The lines contribute comparably high sales revenue and volume that contributes to a significant edge.

4.1.6 Data Requirements

As shown in Figure 4.5, the customer orders or forecast firstly submitted from affiliates are their preferred demand based on the market situation and on on-hand stock levels. All those demands are regarded as first requests. The production may not totally fulfill all the demand because of capacity constraints. The planners then rough cut the demand under the production capacity and revise the first requests to promised orders. The constrained orders after customers' agreement become the actual demand to production.

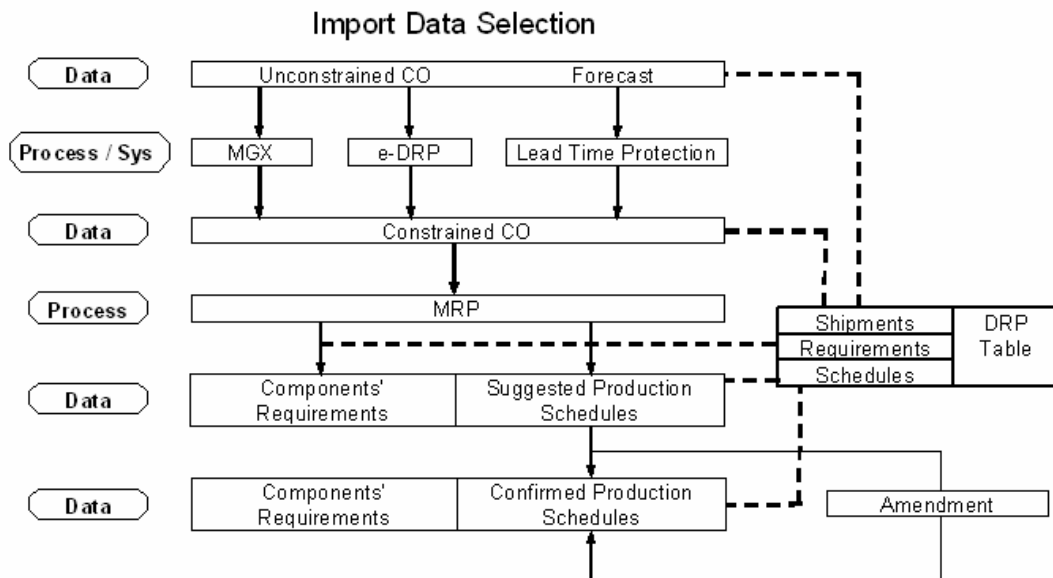


Figure 4.5 A schematic diagram of data flow.

After MRP cycle, the running result is generated which includes a set of existing inventory, the supply and demand data. It is fresh outcome suggested by the system without any amendment yet. The planners then confirm suggested production schedules. No matter before or after confirmation, the planners can amend production schedules according to the actual situation. The schedules can be newly inserted or changed in date

and quantity. The MRP results after amendment mean the actual scheduled supply to fulfill the customer orders.

4.2 Architecture of the VWS

The architecture of VWS consists of two core modules which are an inventory planning module and an inventory allocation module. The inventory planning module is designed to achieve three objectives, namely: inventory visibility, stock alarm, and the suggestion of supply volume. The inventory allocation module includes parts of available-to-promise as well as capable-to-promise that are accomplished with the use of a knowledge-based system.

4.2.1 Inventory Planning Module

The inventory planning module is a decision support tool for supply chain planning that collaborates with ERP and APS systems. The principal master plan is initially generated by the APS system. The WIP part of this plan is then extracted, to fine tune its inventory level associated with the production plan in the inventory planning module. It is able to handle the effects of variability, non-linear relations, and other factors beyond the scope of APS. Based on the virtual warehouse approach, the inventory is stocked at the status of WIP under postponement. The common WIP of finished products is the key to deciding the stock level along a complete cycle.

The inventory planning module acts as a simulator to fine-tune the inventory plan, which controls the inventory flow upstream in the supply chain. It can fulfill the foreseen demand with available WIP and materials. The demands are leveraged against capacity

such as production belt volume in order to avoid production bottlenecks. The feature of stock alarm is added to alert the user when over-stocking or under-stocking occurs. The sensitivity of the alarm depends on user's preferred months of stock coverage, on the moving average of the demand.

The inventory plan is coordinated with activities and processes across the supply chain. This module facilitates the re-optimisation of the plan with the consideration of seasonal stock buffers at different periods. In the re-optimisation, the supply volume is computed to suggest what can be achieved with production in order to maintain the tuned target stock level. The volume of the stock buffer depends on the variance of the forecast errors. Frequent adjustments of demand forecasts also lead to dramatic changes in the master plan. The tuned version of the master plan is then passed to the execution set of ERP system for detailed scheduling.

4.2.2 Inventory Allocation Module

After each planning cycle, the production plan is tuned so it achieves a good balance between WIP supply and demand from production belts; safety stock is also considered. Owing to supply chain events, frequent changes in customer orders induce two main situations to the manufacturer. Firstly, inventory available at the source exceeds the demand from the end destinations. The VWS regards this situation as surplus inventory. Secondly, and this is the most common case, the manufacturer encounters the situation where available inventory at the source is less than the demand from the customers. This is regarded as insufficient inventory in which case there is a need to reallocate the inventory to solve the problem. The inventory allocation module is able to respond

quickly. It can swap available resources in order to maintain the level of customer service guaranteed to the customers, at the minimum cost.

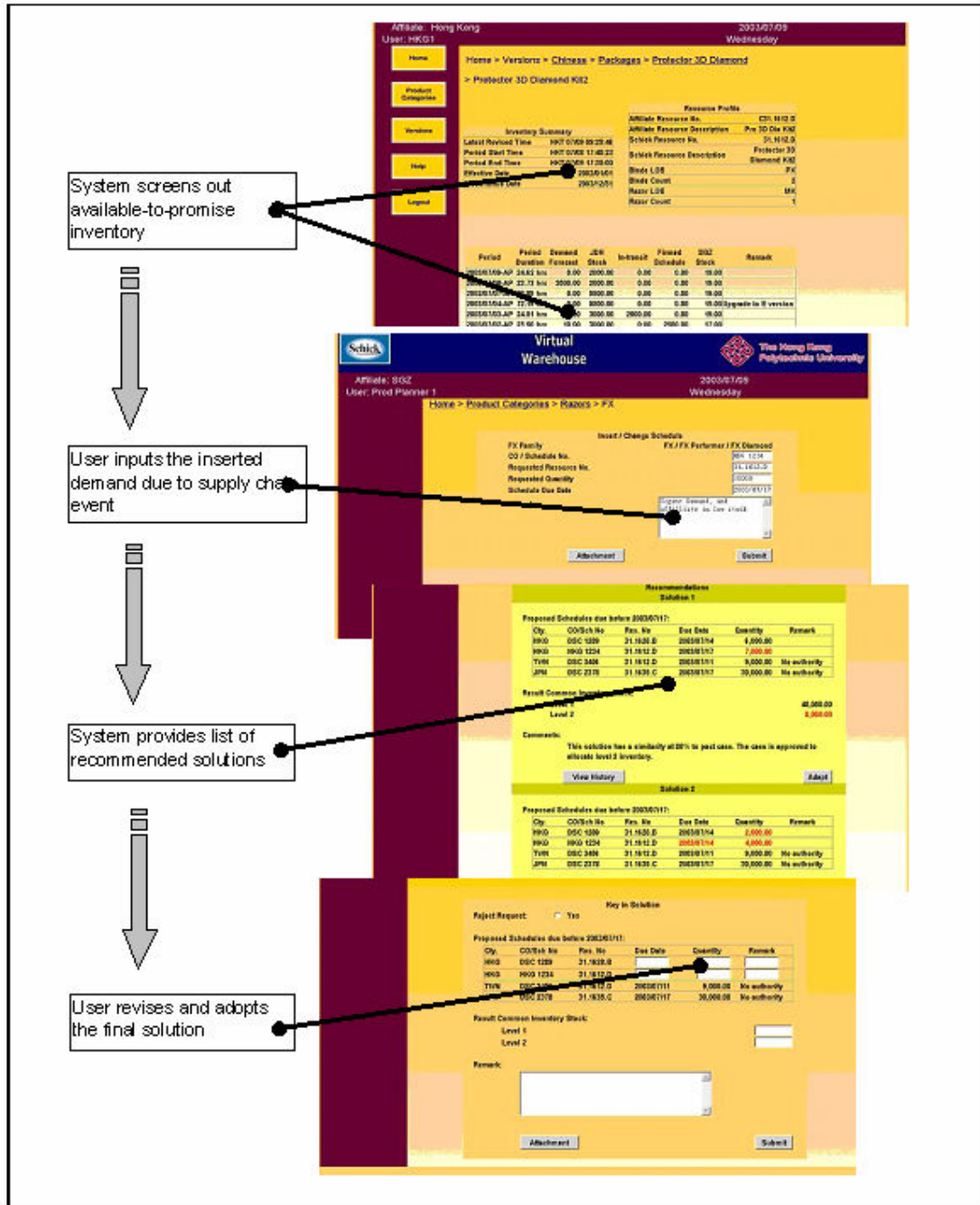


Figure 4.6 Mock-up interface to conceptually describe the workflow in the inventory allocation module.

As shown in Figure 4.6, the inventory allocation module enables manufacturers to respond to unplanned events with advisory support. Available-to-promise in this module allows users to check scheduled multilevel availability of supply and the inventory on the transporting way. It is the uncommitted inventory balance that can be consumed to make promises to the customers' requests based on the availability of inventory. The plan can handle short-term events with available WIP allocation, capacity utilization, and production outsourcing. The available WIP are kept earmarked for their receivers across the supply chain in production belts, warehouse and distribution centers in different locations. This inventory distribution is performed at the backend of the information system before the inventory goes through the production belts for product differentiation. This activity is called allocation which is similar to the distribution of physical stock downstream in supply chain, but it is conducted by means of inventory information instead of physical stock movement.

In this module, to accomplish allocation, an advisory tool is integrated with "capable-to-promise" in order to support decisions on inventory allocation. The advisory tool aims to convert customers' shipment expectations into realistic orders. Delivery date, quantity, and other logistics decisions are revised as a solution coping with demand change due to supply chain events. The solution is stored in the system library and may contribute to a new, similar event in the future. The module provides a self-adaptive capability for the acquisition, reuse, sharing, and diffusion of planning knowledge from the user. With the application of this knowledge-based system, a reasoning engine retrieves the stored past solutions of solved supply chain events for giving advice. The recommended solutions

of allocation make the best use of available inventory based on planning knowledge and business strategies.

Chapter 5 Development of VWS

In chapter four, system architecture was proposed in the design of the VWS. Based on this design, the development of the system is now described to explain how these approaches are attained in this project.

5.1 Systems Overview and Data Flow

The VWS (version one) was developed using Visual Basic (version 6.0), and its database constructed using the 2003 version of Microsoft Access. The technology of ODBC was employed as a programming connection to the database. And the development tool of VWS (version two) was Java (version 1.4.2), its source code is enclosed in the Appendix A. MySQL was employed to construct database in VWS version two, and J-connector was used to drive the database.

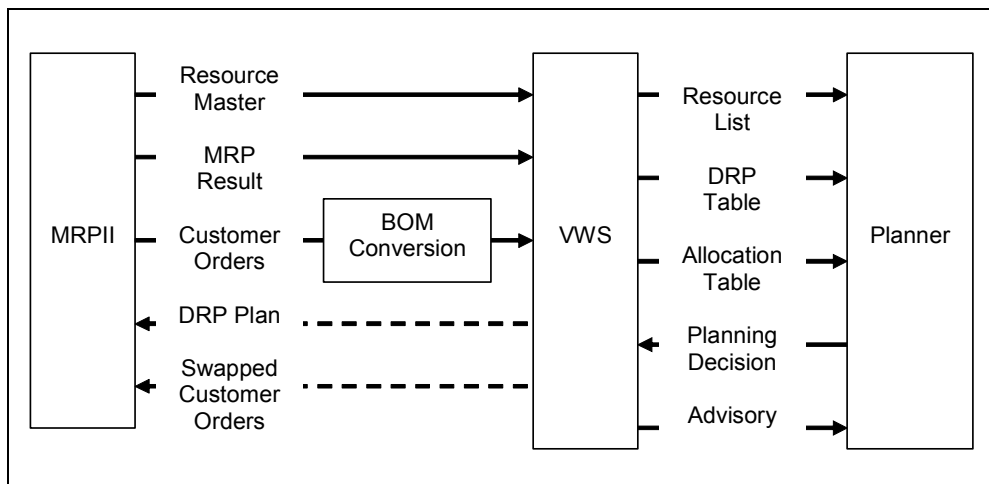


Figure 5.1 This diagram denotes the direction and type of information transmitted across three parties.

Before execution of the system shown in Figure 5.1, a resource master, a material requirements planning (MRP) result and customer orders are sourced from the MRPII

system so as to be able to draw up an inventory plan and allocation. They are extracted from MRPII queries as files format: comma separated variable file format, and uploaded to the system, illustrated in Figure 5.2. Generally, three files are required, namely the resource master, the MRP results, and the customer order.

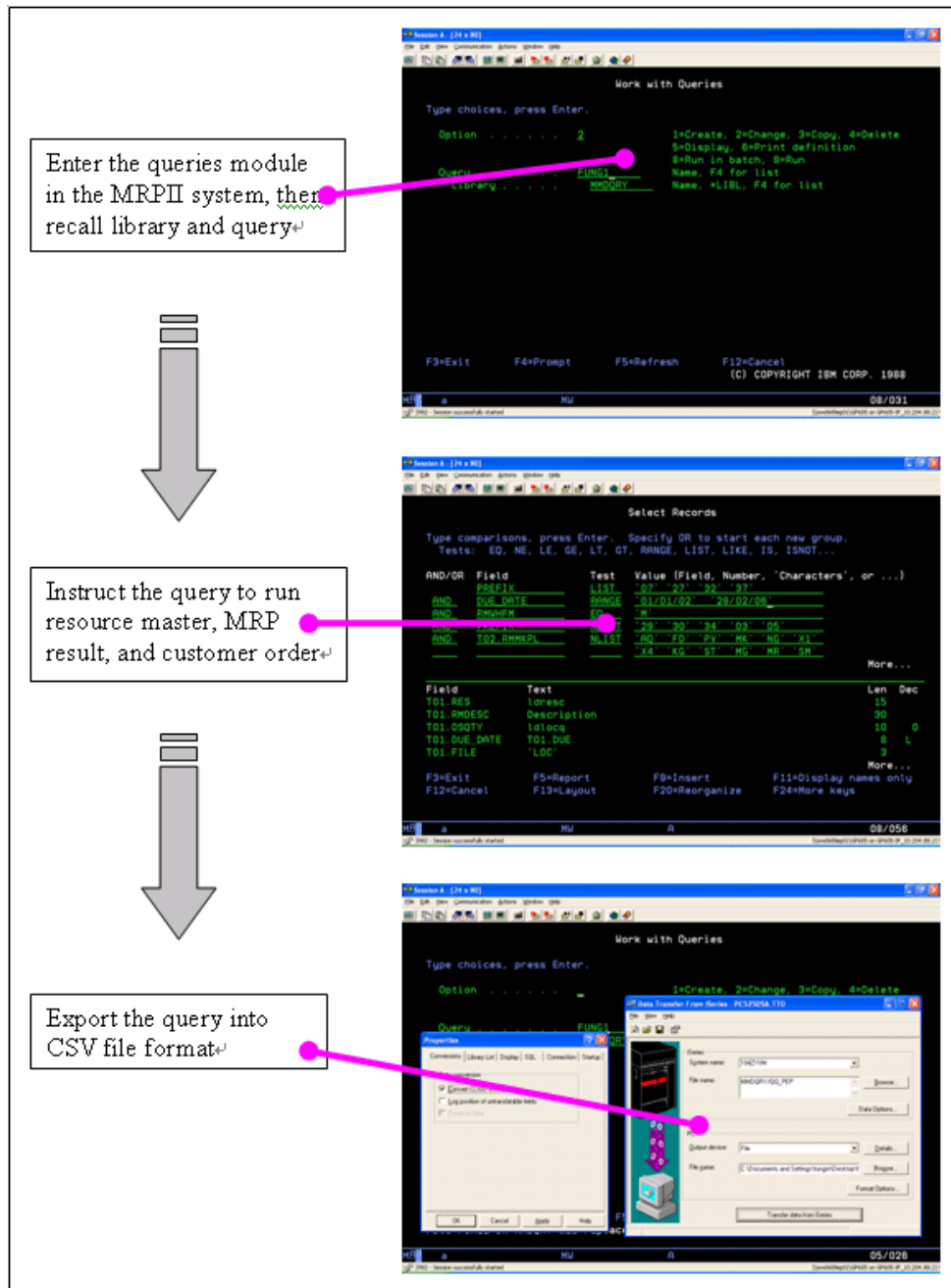


Figure 5.2 Conceptual interfaces to acquire data from MRPII system.

The resource master file shows which items are going to run the planning, the MRP result file provides data on the demand, supply and stock, while the customer orders file gives detailed supply data about the customer, the due date, and other related information. However, the customer orders are counted at the level of packaging. These orders need to be reversed into the level of component items counting after the customer order is entered, in order to correspond with the order required for bills of materials (BOM).

5.2 Simulation Module for the Determination of the Initial Inventory Parameters and Inventory Plan Setting

VWS is a supply chain planning decision support tool that collaborates with the ERP and APS systems. The principal master plan which is initially developed by the APS system extracts the components that are the most critical among all the production constraints. This module acts as a simulation model to fine-tune the plan, which controls the inventory flow across the supply chain. This model is enabled to handle the effect of variability, non-linear relations, and other factors beyond the scope of the APS. The tuned version of the master plan is then passed to the support set of the ERP system for detailed scheduling and operation.

5.2.1 The Function List of the Simulation Module

The exhaustive functions of the Simulation Module include the following capabilities:

- (i) Capture standard templates of source data
- (ii) List resource items for selection

- (iii) Assort each resource item and map a DRP table
- (iv) Calculate the inventory level index each month as the Month of Supply (MOS)
- (v) Warn about and manage any exceptions that occur if the system goes beyond its default range
- (vi) Provide boxes for index range amendment and preferred MOS input
- (vii) Extend DRP worksheet to suggest preferred inventory level and production volume
- (viii) Save each system ran result in a temporary database
- (ix) Provide an option to retrieve a result for reporting and data extraction

5.2.2 Formulation of the Distribution Resource Planning Table

Upon receiving files of source data, one needs to perform the following activities. For each resource item, its material requirements planning result is mapped with the standard template as shown in Table 5.1 to generate the Distribution Resource Planning (DRP) table ascending to time periods in columns.

Table 5.1 Standard Table of Distribution Resource Planning

Razor:	27.1234.A	Description:	FTT Razor w/o Button			Packing Size:	160
Commodity Code:	RA	Resource Class:	46	Existing Inventories:		600	
				Extraction Date: 02/05/2003			
	Source	5/03	6/03	7/03	8/03	9/03	10/03...
Shipments	Prism, Merged CO		500		1000	200	
Requirements	Prism, MRP Result		500		1000	200	
Schedules incl. PLS	Prism, MRP Result		450	300		500	
Ending Inventories	Instant Calculation	600	650	950	-50	360	
MOS	Instant Calculation	0.42	0.54	0.87	-0.13	0.46	
Amend MOS	Key in				0.15		
Amended Inventories	Driven by a.MOS				60		
Amended Schedules	Driven by a.Inv.				1060		
Upper Margin (MOS)	Default or Key in	0.7	0.7	0.9	0.7	0.7
Lower Margin (MOS)	Default or Key in	0.25	0.25	0.25	0.25	0.25
+/- Variance Alarm	Instant Calculation	-	-	■	■	-	-

Its basic resource information and existing inventory are also screened out in the heading. The date of the data extraction is required to be displayed for user reference.

- (i) Both *Shipments* and *Requirements* are the demand values for a specific item, but are extracted from different data sources. *Shipments* are the raw demand of final products that is extracted from the data of confirmed orders, and *Requirements* are the demand calculated to the item that sourced from MRP result.
- (ii) Production schedules plus the forecast orders (*Schedules incl. PLS*) form the supply value for a specific resource item that has been sourced from the MRP result. These planned production schedules are used to meet confirmed orders and to forecast future orders (*PLS*).
- (iii) *Ending Inventory* is the calculated on-hand stock of a specific item. The current month *Ending Inventory* is directly calculated from the *Existing Inventory* of the MRP result.

To calculate the *Ending Inventory* starting after each current month (E+1), we use:

$$\text{Ending Inventory}^{E+1} = \text{Schedules incl. PLS}^{E+1} - \text{Shipments}^{E+1} + \text{Last Month Ending Inventory}^E \quad (5.1)$$

To calculate the *Ending Inventory* for each current month (E+0), we use:

$$\text{Ending Inventory} = \text{Schedules incl. PLS} - \text{Shipments} + \text{Existing Inventory} \quad (5.2)$$

5.2.3 Inventory Indicator and Stock Level Alarm

An index, Month of Supply (MOS), is then calculated to indicate the inventory level for the coming periods. This index is bounded within a default range, and its upper and

lower boundaries are unfixed so that users can change them to acceptable levels for their particular cases. If the calculated index flows beyond the range, a signal will be given to the users who are warned to take appropriate action.

- (iv) *MOS* (Month of Supply on a moving average of 2 months) is a calculated index of stock level which indicates the number of months that the *Ending Inventory* could safely cover the upcoming monthly demands.

To calculate the *MOS* from the current month (E+0):

$$MOS^E = \text{Ending Inventory}^E / \text{Average Shipments of forthcoming 2 months}^{E+1,E+2} \quad (5.3)$$

- (v) The *DRP* table is then formulated from the current month (E+0) for a further 12 months (E+12).

Based on the common *DRP* functions, the latter activities are conducted to extend the *DRP* table. These tools could aid the user to formulate an inventory plan.

Activity A:

Each resource item is given an *MOS* tolerance that is a default margin to bound the stock level. The preliminary *upper* and *lower margins* of *MOS* are 0.7, and 0.25 respectively. The default margins are shown in each period and are amendable by the users.

Activity B:

The calculated *MOS* of each period in the *DRP* table is checked to make sure it falls in between the *upper* and *lower margins*. If *MOS* falls beyond its tolerance, an alarm signal will be activated to alert the users which *MOS* period(s) is outside the default margin.

Alarm if, $MOS \geq \text{Upper Margin}$ OR $MOS \leq \text{Lower Margin}$

Activity C:

Once the users revise the *upper* and/or *lower margins*, the activity B will be performed over again.

5.2.4 Multi-objective Optimization

In the extended DRP worksheets, the users may input a preferred MOS index into the specific periods. The preferred MOS reacts to business environment as well as corporate strategy. An inventory level target and supply volume are then calculated to suggest to the users which level to be kept. Involved production schedules may be amended at the end to achieve the preferred MOS. This function feature is similar to a reverse DRP process, but it does not change the original DRP data performed in table elements. Based on the extended DRP table, the users can key in preferred *MOS's* index for specific period(s). The logic of this function is outlined below:

- (i) After the user inputs his preferred MOS, the *Suggested Ending Inventory* target is then calculated to achieve the keyed-in value.

$$\text{Suggested Ending Inventory}^E = \text{Preferred MOS}^E \times \text{Average Shipments of forthcoming 2 months}^{E+1,E+2} \quad (5.4)$$

- (ii) Suggested production schedules plus forecast orders (*Suggested Schedules incl. PLS*) and targets are proposed to the users for their preferred MOS as per the equation 5.5. *Shipments* are a constant amount that cannot be changed in a version of MRP result.

$$\text{Suggested Schedules incl. PLS}^{E+1} = \text{Suggested Ending Inventory}^{E+1} + \text{Shipments}^{E+1} - \text{Last Month (Suggested) Ending Inventory}^E \quad (5.5)$$

The users are allowed to amend the preferred ending inventory for the current month (E+0), and the VWS is then able to instantly advise the suggested production schedules for the current month. However, even though this result from the VWS could be sent off to the MRP system immediately, the latter probably could not update its schedules in time to achieve the target production schedules. The calculation of the suggested schedules for the current month (E+0) is expressed as follows:

$$\text{Suggested Schedules incl. PLS} = \text{Suggested Ending Inventory} + \text{Shipments} - \text{Existing Inventory} \quad (5.6)$$

5.2.5 Searching for the Global Optimal Inventory Setting

Users can adopt a better resource plan for calculating demand by using an inventory level simulation whose usage could be extended by being applied to global production planning. Extension to the global plan is constructed upon the results of regional inventory plans. This model can provide ‘what-if’ analyses to simulate global business cases with the help of the MOS index on global inventory.

5.3 Advisory Module for the Determination of Production Schedules Control and Inventory Allocation

When the supply of components is not in line with demand owing to supply chain events or unexpected orders, the components allocation module is able to respond quickly. It can swap available resources in order to maintain customer service at the minimum cost. It also acts as an advisory tool for searching solutions from the planning knowledge as well as helping planners to compare various options.

Case-based reasoning (CBR) is used to give advice on inventory decisions in this module. Figure 5.3 shows the three major processes involved: a case similarity search, a case retrieval, and a case adaptation. The flow of these processes is listed, and its detailed development described in the following subsections.

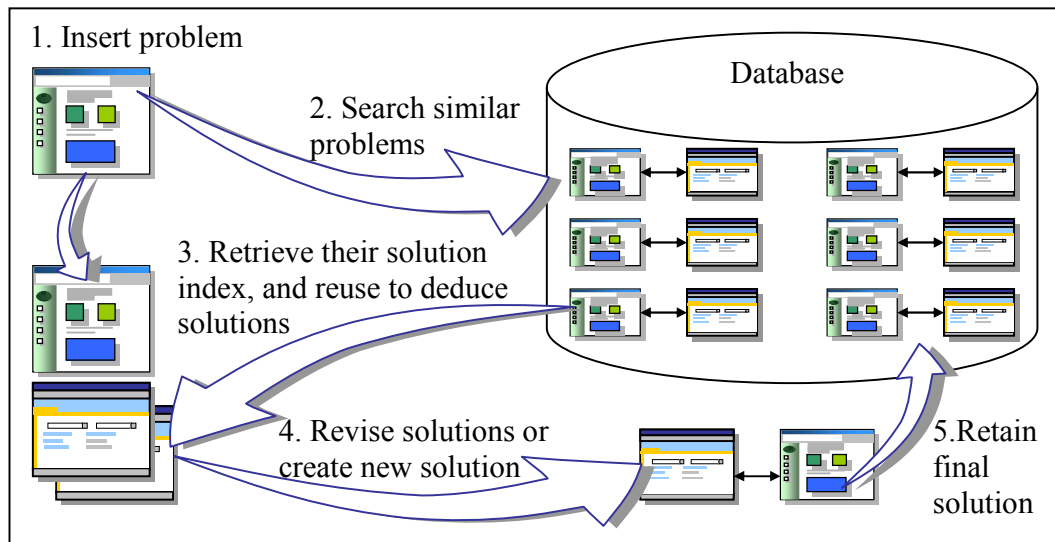


Figure 5.3 Process flow chart of advisory module.

As shown in Figure 5.3, the reasoning process starts with:

- (i) Conducting indexing on the “problem”, i.e. the user inputs an abrupt order.
- (ii) Calculating and contrasting the similarity of this particular “problem” with past “problems” which have been stored in the database.
- (iii) Extracting the ten most similar past problems, and retrieving their solution indices.
- (iv) Reusing these on the “problem” inputted in process (i), and deducing ten solutions in descending order of their similarity percentage.
- (v) Providing individual buttons on each solution to recall its past original problem and solution.

- (vi) Providing blocks to input the final solution (revising on deduced solutions) which will respond to the “problem”.
- (vii) Saving the final solution with the “problem” into the database.

5.3.1 A Function List for the Advisory Module

The exhaustive functions for the Advisory Module include the following capabilities:

- (i) Capture standard templates of source data
- (ii) Inscribe a component items code by mapping with its resource item; and deducting weeks on components due dates as per conversion file
- (iii) List out resource items for selection
- (iv) Assort each component item and formulate daily DRP table
- (v) Provide boxes to input demand volume as a new case, as if inserting demand to execute the Change of Delivery Notice (DNCN) process
- (vi) Search from database to list out numbers of most similar cases according to pre-set similarity rules. This is the case retrieve process of the CBR
- (vii) Provide information for decision-making: Deduce similar case solutions into the new demand request by indexing; Recall similar cases showing past demand request details and their action results. This is the case-reusing process of the CBR
- (viii) Provide boxes to amend the quantity and date of supply schedules as well as demand requests, but excludes MRP result. This is the case-revising process of the CBR
- (ix) Provide boxes to select action for case indexing of the CBR

- (x) Provide boxes to type advice for individual cases
- (xi) Save final inventory allocation decision as well as advice into temporary database. This is the case-retaining process of the CBR
- (xii) Provide the option of downloading system execution data

5.3.2 Formulation of a Daily Distribution Resource Planning Table

Upon receiving the files of source data, the Advisory Module lists the material requirements planning result in the form of a Distribution Resource Planning (DRP) table which ascends in time periods in rows, as shown in Figure 5.4. Seven major elements of the Daily DRP table are listed in Table 5.2.

Table 5.2 Daily DRP Table Elements

Front-end Block		Back-end Logic	Feature
<i>Extraction Date</i>	←	Date of system run	
<i>Balance (First Row)</i>	←	Same as first row quantity	
<i>Balance</i>	←	$Quantity_{\text{same row}} + Balance_{\text{last row}}$	Turn Red if <0
<i>Days to Due Date</i>	←	$Due\ date_{\text{first demand}} - Extraction\ Date$	
<i>Total Supply</i>	←	Sum of supply quantity	
<i>Total Demand</i>	←	Sum of demand quantity	
<i>Balance Rough Cut</i>	←	$Balance_{\text{last row}} + Quantity_{\text{insert order}}$	

The locations of these elements are highlighted on the Daily DRP table in Figure 5.4. The nature and the logic of these elements are similar to those elements in DRP table mentioned in subsection 5.2.2. The only difference is their presentation interface to the users, because short-term inventory planning is focused on a daily basis.

Indicating signal blocks are built into both the Available to Promise (ATP) part and the Capable to Promise (CTP) part. The calculated inventory indicators in the daily DRP table, as shown in Figure 5.4, are used to check the stage of inventory balance in the ATP part as well as an inventory balance rough cut in the CTP part.

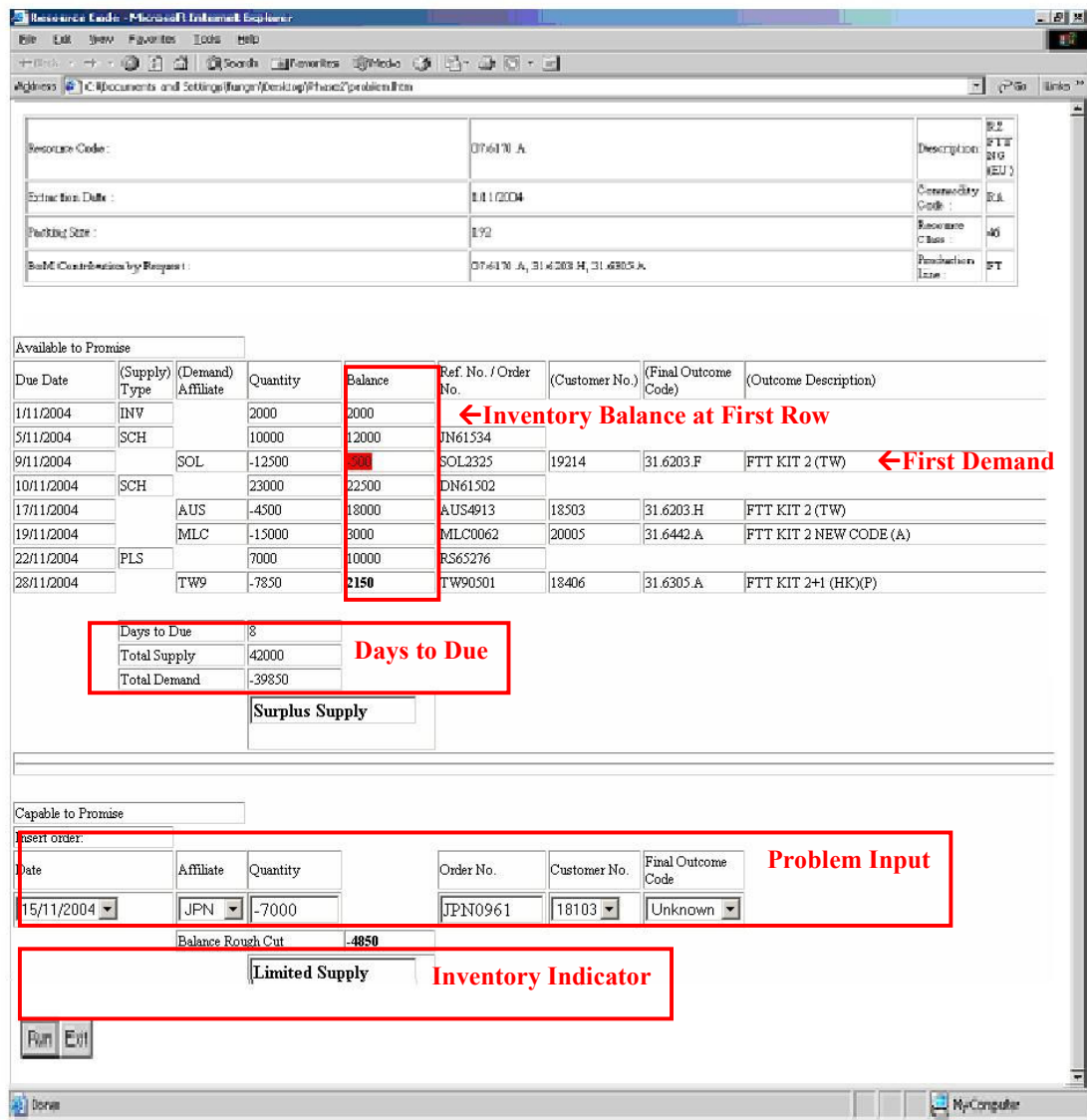


Figure 5.4 Daily Table of Distribution Resource Planning.

A signal would be issued to remind the users as the latter rules,

Shown “Surplus Supply” at ATP if $\text{Balance}_{\text{last row}} \geq 0$

Shown “Surplus Supply” at CTP if $\text{Balance Rough Cut} \geq 0$

Shown “Limited Supply” at ATP if $\text{Balance}_{\text{last row}} < 0$

Shown “Limited Supply” at CTP if $\text{Balance Rough Cut} < 0$

5.3.3 Input of Case

When the demand changes every moment, the users input the variation to initiate the processes. Each single change is a problem regarded as a new case, even if it is exactly the same as has happened before. Some conditions which would initiate a new case are given below:

- (i) “*Insert Order Date*” is limited to 30 days after Extraction Date.
- (ii) “*Insert Order Quantity*”, it is possible to enter “0”. This simply means that the inventory will be automatically reallocated without inserting a new order.
- (iii) “*Affiliate*”, “*Customer No.*”, “*Final Outcome Code*”. These provide 2 alternatives to the users: they are either free to input characters and numbers; or click out the selection bar.

5.3.4 Case Searching & Similarity Analysis

The most similar problem is determined by using the similarity analysis. The similarity of demand variation between a new case and the retained cases is analyzed. In the trial, 5 characteristics were considered in the analysis which included: production line, commodity code, balance rough cut, days to due and the parties involved respectively. The aggregated similarity index to problem can be calculated based on the following formula. The similarity of the problem is determined as:

$$Similarity = \frac{\sum_{j=1}^m w_j sim(v_j^o, v_j^r)}{\sum_{j=1}^m w_j} \quad (5.7)$$

where m is the number of inputs, w_j is the weighting of the j th input, v_j^o and v_j^r are values of the j th inputs and that for the retrieved problems.

As shown in Table 5.3, five features are preliminarily identified as being similar to the inserted order. Their initial weight settings were done in consultation with experienced planners in the logistics industry. They generally imply the view of decision makers' initial overall consideration. The initial relative weights can be revised if the setting does not comply with the business model or the changes of business model.

Table 5.3 Five features of a problem with their corresponding weights

Initial	Input	Input type	Weight	Remark
l	Production Line	NAME	10	Determined in Table 5.4
c	Commodity Code	NAME	5	Analyze its product series
b	Balance Rough Cut	NUMBER	35	
d	Days to Due	NUMBER	35	
p	Parties Involved	NAME	15	Analyze its demander ranking

Thus, the similarity(s) in the trial is given in the Equation (5.8):

$$S = \frac{10sim(v_1^o, v_1^r) + 5sim(v_c^o, v_c^r) + 35sim(v_b^o, v_b^r) + 35sim(v_d^o, v_d^r) + 15sim(v_p^o, v_p^r)}{100} \quad (5.8)$$

For NUMBER type of inputs, the similarity is determined by:

$sim(v_j^o, v_j^r)$ is the similarity function for the j th inputs in the aggregated equation.

$$sim(v_j^o, v_j^r) = 1 - \frac{|v_j^o - v_j^r|}{|v_j^o| + |v_j^r|} \quad (5.9)$$

where j are b and d .

For NAME type of inputs, the similarity is determined in Table 5.4:

Table 5.4 Similarity table of initial I, p

Sim	AQ	EP	FD	FT	H3	KG	MG	MK	MR	NG	PV	SM	SP	XI	(other)
AQ	1.0	0.5	0.5	0.5	0.5	0.6	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.4
EP	0.5	1.0	0.6	0.6	0.6	0.5	0.7	0.6	0.7	0.6	0.6	0.9	0.9	0.6	0.4
FD	0.5	0.6	1.0	0.6	0.6	0.5	0.6	0.6	0.6	0.6	0.7	0.6	0.6	0.7	0.4
FT	0.5	0.6	0.6	1.0	0.7	0.5	0.6	0.7	0.6	0.7	0.6	0.6	0.6	0.6	0.4
H3	0.5	0.6	0.6	0.7	1.0	0.5	0.6	0.7	0.6	0.7	0.6	0.6	0.6	0.6	0.4
KG	0.6	0.5	0.5	0.5	0.5	1.0	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.4
MG	0.5	0.7	0.6	0.6	0.6	0.5	1.0	0.6	0.9	0.6	0.6	0.7	0.7	0.6	0.4
MK	0.5	0.6	0.6	0.7	0.7	0.5	0.6	1.0	0.6	0.8	0.6	0.6	0.6	0.6	0.4
MR	0.5	0.7	0.6	0.6	0.6	0.5	0.9	0.6	1.0	0.6	0.6	0.7	0.7	0.6	0.4
NG	0.5	0.6	0.6	0.7	0.7	0.5	0.6	0.8	0.6	1.0	0.6	0.6	0.6	0.6	0.4
PV	0.5	0.6	0.7	0.6	0.6	0.5	0.6	0.6	0.6	0.6	1.0	0.6	0.6	0.8	0.4
SM	0.5	0.9	0.6	0.6	0.6	0.5	0.7	0.6	0.7	0.6	0.6	1.0	0.9	0.6	0.4
SP	0.5	0.9	0.6	0.6	0.6	0.5	0.7	0.6	0.7	0.6	0.6	0.9	1.0	0.6	0.4
XI	0.5	0.6	0.7	0.6	0.6	0.5	0.6	0.6	0.6	0.6	0.8	0.6	0.6	1.0	0.4
(other)	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4

5.3.5 Case Retrieval

There are two outcomes from the retrieval of similar cases. Each similar case has its percentage of similarity to the existing problem indicated. The past case also has its extraction date attached so that users can tell when this problem happened. The first outcome is the original sets of past problem and solution. Its window is always at the bottom. Next, in the second outcome, which is more useful to users, new solutions based on retrieved case indices are deduced to advise inventory decisions. The detail is described in the following section.

5.3.6 Case Indexing and Solution Reasoning

Case indexing is a process that looks for measurable parameters of actions carried out in similar cases, and then deduces them into the new case. It could be either as simple as

substituting one action in a solution, or as complex as modifying the degree of action in a solution. In general, there are two kinds of indexing: transformation, and substitution.

5.3.6.1 Action Transformation in Solution Reasoning

Transformation employs rules and structured indexing models for changing a retrieved solution into a new solution. Some models were developed with mathematic proportion for the determination of numbers. Some rules were also developed for the selection of date. The following is a list of adapted transformations. Two keywords are noted in the transformation: *Old* refer to the past case retrieved from the database, and *New* means the new case.

(i) Action Date Index:

$$Suggested\ Date_{new} = Days\ to\ Due_{new} \times \frac{Suggested\ Date_{old}}{Days\ to\ Due_{old}} \quad (5.10)$$

It subjects to the latter condition,

$$Days\ to\ Due_{new} \geq Suggested\ Date_{new} \quad (5.11)$$

Figure 5.5 illustrates the timeline of action date. From left to right is the timeline movement. The current day (E+0) always stays after or on the data extraction date (extraction date). It is reasonable that the suggested action date (Suggested Date_{new}) must not be allocated after the production due date (Days to Due_{new}), otherwise buffer of the production lead time would be damaged. The two labeled periods on the right hand side of the timeline are the normal duration of production and delivery respectively.

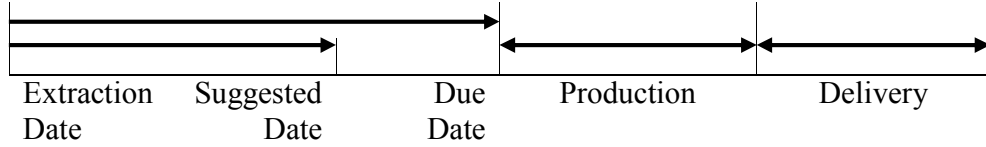


Figure 5.5 Action date timeline in the transformation of solution reasoning

(ii) Action Quantity Index:

$$Supply\ Quantity_{new} = Balance\ Rough\ Cut_{new / problem} \times \frac{Supply\ Quantity_{old}}{Balance\ Rough\ Cut_{old / problem}} \quad (5.12)$$

Taking a suggested solution as an example of the Action Quantity Index:

And assuming that: Supply Quantity_{old} = 4639, Balance Rough Cut_{old/problem} = -5000

$$Supply\ Quantity_{new} = (-4850) \times \frac{4639_{old}}{(-5000)_{old / problem}}$$

So, = 4500

(iii) Allocated Quantity Index

Assume that various demanders (*AFF*) are named from *a* to *z*,

And note that, for a single demander, there may be two or more individual orders being allocated.

In the past case retrieved from the database, it can be derived as follows:

$$Outstanding\ Supply + \sum_{AFF=a}^z Sum\ of\ Allocated\ Quantity_{AFF} = Total\ Supply$$

$$\frac{Supply_{Out} + Allocated\ Quantity_a + Allocated\ Quantity_b + Allocated\ Quantity_c + \dots}{Total\ Supply} = 1$$

Then, the Allocated Quantity Index (AQ Index) is defined as follows:

$$AQIndex_a = \frac{Allocated\ Quantity_a}{Total\ Supply} = A\%(Demander\ a)$$

$$AQIndex_b = \frac{Allocated\ Quantity_b}{Total\ Supply} = B\%(Demander\ b)$$

$$AQIndex_{AFF} = \frac{Allocated\ Quantity_{AFF}}{Total\ Supply} = X\%(Demander\ AFF) \quad (5.13)$$

In the new problem, not all of the total supply has been allocated to the demand orders at the beginning. The “Demand Quantity” is applied with its affiliate’ AQ Index, and allocated its “Suggested Allocation” according to row sequence. If the AQ Index of the corresponding demander is not found, 100% of the allocation is then given. The allocation is ended once there is no “Outstanding Supply”.

$$Suggested\ Allocation = Demand\ Quantity \times AQ\ Index_{AFF} \quad (5.14)$$

$$\text{Allocation stops when } \begin{cases} 1. Supply_{Out} = 0 \\ 2. \text{ All orders allocated, then } Supply_{Out} \geq 0 \end{cases}$$

Taking another suggested solution as an example of *Suggested Allocation*:

Let’s assume that: AQ Index_{SOL} = 100%; AQ Index_{AUS} = 95%; AQ Index_{MLC} = not found; AQ Index_{TW9} = 90%; AQ Index_{JPN} = 100%, then:

$$\begin{aligned} Suggested\ Allocation_{SOL} &= 12500 \times 100\% \\ &= 12500 \end{aligned}$$

$$\begin{aligned} Suggested\ Allocation_{AUS} &= 4500 \times 95\% \\ &= 4275 \end{aligned}$$

$$\begin{aligned} Suggested\ Allocation_{MLC} &= 15000 \times 100\%, & \text{no AQ Index}_{MLC} \text{ found} \\ &= 15000 \end{aligned}$$

$$\begin{aligned} \text{Suggested Allocation}_{\text{TW9}} &= 7850 \times 90\% \\ &= 7065 \end{aligned}$$

$$\begin{aligned} \text{Suggested Allocation}_{\text{JPN}} &= 7000 \times 100\% \\ &= 7000 \end{aligned}$$

5.3.6.2 Action Substitution in Solution Reasoning

Substitution relies on the direct substitution of numbers or action relevant to the new case. The action types in solutions of the similar cases are given directly to the corresponding solution of the new problem. Direct substitution is applied to determine the action because the final actions in solutions are normally standardized to particular types.

(iv) Action Index:

$$\text{Suggested Action Type}_{\text{new}} = \text{Suggested Action Type}_{\text{old}} \quad (5.15)$$

Options of action type: Dummy; Insert Schedule; Outsource; Commitment; Withdraw Schedule; Write Off; Other; N/A.

(v) Comment:

The whole text of the past problem is directly retrieved and transferred to the new deduced solution.

$$\text{Comment}_{\text{new}} = \text{Comment}_{\text{old}} \quad (5.16)$$

5.3.7 Case Adaptation

Case adaptation is a process that accepts the solution suggested by the advisory module. It also provides an opportunity to revise the prominent differences between the new case

and the retrieved similar cases. Those differences can be amended by the users to fit their real situation, though similarity analysis has already taken into account and made adjustments correspondingly. Undoubtedly, this approach encourages human collaboration and support in the decision-making process. The users have to fine-tune the suggested solution, or reconfirm the solution even though they totally agree with the suggested solution. However, the performance of the adaptation pretty well relies on the final decision of the users. Their experience is thus valuable to the learning of this module.

Although the users are free to revise or accept the suggested solution, they are bound in their final decision by the following conditions:

- (i) “*Action Date*” is limited to 30 days after Extraction Date.
- (ii) “*Action*” includes list of options for users which are: Dummy; Insert Schedule; Outsource; Commitment; Withdraw Schedule; Write Off; Other; N/A.
- (iii) “*Action Quantity*” is ranged with digits of –ve, +ve and 0.
- (iv) “*Allocated Quantity*” of each demand order is defaulted as 0 at the beginning, and it is subjected to the following rules:
“*Demand Quantity*” \geq “*Allocated Quantity*” and,
“*Total Supply*” \geq Sum of allocated quantity
- (v) “*Comment*” is the explanation of the captioned final solution recorded by the users.

Another daily DRP table always displays a similar format to Figure 5.4. The final decision of inventory allocation with material requirements planning result is also listed in ascending time periods in rows. Once the users confirm the final solution, it will be

retained with the problem as another case in the database for possible future retrieval. Table 5.5 contains the five major elements in the daily DRP table. The logics considered are the same as the previous daily DRP elements in Table 5.2, but the calculated result is supposed to be different unless no result of quantity is changed.

Table 5.5 Daily DRP Table Elements (II)

Front-end Block		Back-end Logic	Note
<i>Total Supply</i>	←	Sum of supply quantity + <i>Action Quantity</i>	
<i>Total Demand</i>	←	Sum of demand quantity	Remarkd
<i>Outstanding Supply</i>	←	<i>Total Supply</i> – Sum of <i>Allocated Quantity</i>	
Balance Rough Cut	←	<i>Total Supply</i> – <i>Total Demand</i>	
<i>Days to Due</i>	←	<i>Due date</i> _{first demand} – <i>Extraction Date</i>	Remarkd

5.4 Data Reporting

The decisions by these modules retained in the database can be exported via queries in the data server. It is open in common format for data extraction. The recalled data can be used for training or reporting or uploading to the MRP system for execution. After such an execution, the next period MRP results would become yet another set of data to help verify previous decisions made by the system.

Chapter 6 Case Study

To prove the concept, a prototype of the VWS was trial-implemented in the sponsoring company. The realistic logistical functions in an international company are a well-trying site for the implementation of virtual warehousing for production logistics.

6.1 Company Background

Schick Asia Limited is a worldwide manufacturing company that has its operations in geographically different locations. Its headquarters are in the United States, it has a regional office in Hong Kong, a manufacturing plant in China, and suppliers in other regions of China as well as customers and marketing affiliates around the world.

The company is continually improving its logistics operations for systematic storage, access and dissemination of inter-departmental and inter-enterprise data across various units and business partners along the supply chain. The emphasis on the use of enterprise information technology tools by the company has shifted from office automation within an enterprise to inter-enterprise applications (Fung et al., 2004).

6.1.1 Company Products

Schick is a worldwide prestigious manufacturer of shaving products, and their products are mostly assembled as per bill of components. Figure 6.1 shows the major components of the shaving product which is basically composed of a razor, blade and package. The various parts are assembled using a staking or a snap-fit technique. The finished product from the assembly line is then moved to the packaging operation.

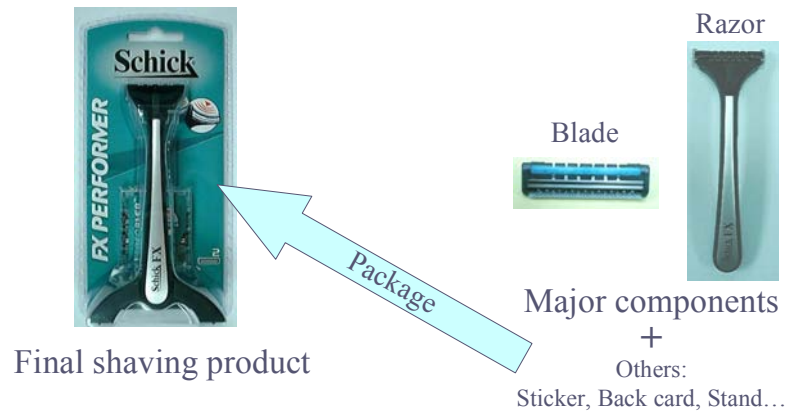


Figure 6.1 Components of a shaving product.

The assembly of these components is a critical step on the way to the marketplace from the view of supply chain planning. The major components such as razor and blade take a certain portion of cost as well as space in overall product unit cost. The inventory implied cash is held behind, and induces an inventory carrying cost. Particular quality control processes take place after assembly in order to ensure a functional and safe shaving product. Machine operators routinely monitor the quality of the work in process, and every cartridge is automatically inspected to ensure that all parts are present and in the correct position.

6.1.2 Master Scheduling

Master scheduling in Schick composes of two levels of consideration. As shown in Table 6.1, the upper one is the scheduling of product packaging. The packaging components are produced and be then assembled into the end product. The scheduling of this level of production does not process DRP. The manufacturing plant would not keep any finished products stock. The packaging is made to order and its scheduling is planned for order as well.

Table 6.1 Scheduling Levels

Level 1	Packaging	Plan for Order	Make to Order
Level 2	Razor	Plan for Stock	Make to Assembly
	Cartridge		

The lower level of consideration involves the scheduling of major components. Razors and cartridges are the highest cost-dedicated among all the components. These semi-products are critical production constraints in the upper level scheduling. The plant thus produces these components to build inventory biweekly. The scheduling of this level is mainly but not wholly related to stock.

For the upper level, the scheduling of packaging deducts the components from this level to facilitate the production of finished goods. It takes about 40% of the components stock. Another 60% of the stock is characterized to be the common components fitting to various finished product requirements. The rest of the stock is shared with other manufacturing plants in different regions world wide, namely Milford, Solingen and Caracas, with the transportation being in bulk shipments. The outcome of this level of production will probably be assembled somewhere in the world.

6.1.3 Distribution Channels

The kits of shaving products mostly consist of razor, blade, refill pack and packaging. The packages are grouped into four languages, Chinese, English, Korean and Japanese. As shown in Figure 6.2, the manufacturing plant in Guangzhou is the main assembly center, and the external suppliers are located nearby. The internal supplies are regularly shipped from overseas manufacturing plants.

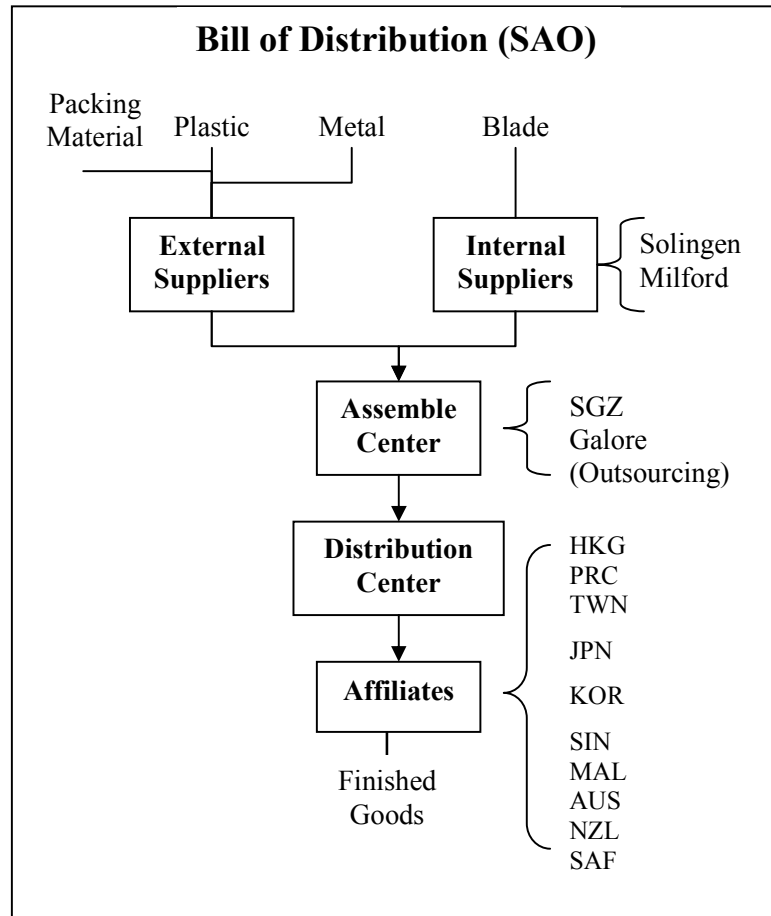


Figure 6.2 Bill of distribution.

All product demands are requested with purchasing orders by a number of affiliates. Schick Asia Limited covers three main regions and deals with other affiliates in the Asia Pacific. The SAANZ region includes the affiliates of South Africa, Australia and New Zealand. The Asia region includes affiliates from Hong Kong, the PRC, Singapore, Malaysia, Taiwan and Korea. Japanese affiliates are treated as a separate region.

6.1.4 Production Lead Time

The entire production involves different parties along the supply chain. As shown in Figure 6.3, it is a timeline which illustrates the lead time spending on the production of a

finished product. The left hand side is the weeks spent for packaging production which is a comparatively simple and labor-intensive process. The other side is the months spent for components production which is more complicated and parties involved processes.

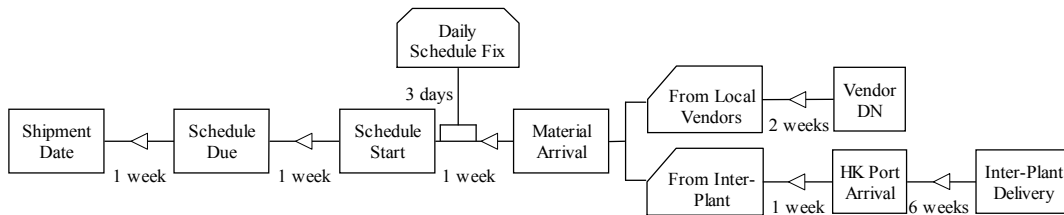


Figure 6.3 Lead Time.

The overall lead time takes about three months. This means that the customers have to place an order three months in advance. This is one of the reasons which cause inaccuracy in ordering due to the need for long term forecasting. The three months sale forecast eventually induces final order amendments to the manufactures at the end.

6.2 Business Analysis and Problem Identification

Schick is often requested by the affiliates to add or amend shipment orders owing to fluctuating market competition. The changes in production schedules are induced by these requests, but are constrained by production capacities and limited major WIP stock. Schick may be put in a weakened market position due to a lack of stock or shipping orders which go missing unexpectedly.

6.2.1 Suffering in Business Model

The common root cause of this problem, which was investigated by the Institute of Logistics and Transport (2004), was the large scale error in demand forecasts which may

result in late changes to production schedules causing increased costs incurred in production changeover and overtime payments. The distributors and customers may misestimate market demand forecasts. Additionally, production schedules adjusted at short notice to meet one customer's orders could then lead to the disappointment of another customer.

Companies who are the market leaders continually focus on increasing their market share or at least maintaining the existing segment by eliminating newcomers while increasing worldwide competition. The reality is that the end customers are becoming increasingly demanding and are not prepared to wait for the next stock replenishment when an item is sold out at the retailing point (Blackwell, 2001). They want products ready for immediate sale otherwise the competitors' products would be chosen as a substitute. This may deadly damage the market share of the company that owns her brand name in a highly competitive global market (Zikmund, 2003). This approach then causes further suffering to the supply chain.

6.2.2 Suffering in the Supply Chain Model

The variety of localized versions of shaving products, coupled with increasing pressure for stock availability, has resulted in millions of dollars of finished products accumulating in the distribution centers. As the finished product is already customized to local packaging, it is cost inefficient to repack the product swapping it to conform to those regions in need. Reworking of the components is also not practical. Expensive write-offs often happen agonizingly at the end of a product life cycle. Shipping by air

freight can shorten the lead time from manufacturer to customers. However, the transportation cost is then significantly increased affecting the profits of Schick.

The inventory management in Schick has conventionally relied on a manual planning process. Under management instruction, the planners are allowed to adjust the inventory level and allocate inventory to the production belts according to their professional judgment. Such a conventional approach to inventory management is based on the information shown in the manufacturing resource planning tool and distribution resource planning worksheets (Fung et al., 2004).

6.2.3 Suffering in the Manufacturing Model

Such problems do not only apply to Schick. Most manufacturers experience this situation. Whenever the sum of the final orders is greater than the demand forecasts that were underestimated way beforehand, then the production capacity and raw materials may not have been planned on a large enough scale to cover all the orders. Unless standard electronic chips are available, then the manufacturers may damage their customer service performance due to missed orders.

In a further situation, that orders are cancelled at short notice, the planned production capacity and the pre-built WIP inventory may become partially redundant. If the inventory is uniquely saleable to one specific customer, then manufacturers may suffer from this slow moving inventory until the next demand, or even have to write off the stock. Both of these scenarios have a financial impact on the business because of the inventory holding cost. Healthy inventory levels which contribute to the profitability of the manufacturers (Krautter, 1999) greatly depend on the kind of tacit knowledge of the

planners. They rely on sensitivity to management instructions, a familiarity with business behaviour, and experience of conducting inventory planning (Fung et al., 2004). Such planning knowledge and its tools are thus significantly important to the logistics of production.

6.3 Virtual Warehousing in Case Company

To provide a solution to the case company's problems, Virtual Warehousing proposed to overcome the difficulties in the resource planning. The following are key suggestions proposed to strengthen the production logistics function in Schick Asia Limited.

- (i) Adjustment of business model as per the concept of Virtual Warehousing
- (ii) Building up a tool to facilitate Virtual warehousing

6.3.1 Business Adjustments to the Virtual Warehousing Approach

To enhance the customer service level for shaving product consumers, Schick is required to provide accurate order fulfillment quicker than its competitors. The postponement of product customization was firstly introduced into its supply chain model as a primary stride of virtual warehousing. Postponement releases time to carry out bundle product flexibly responding to the competitors' action in the market. The inventory is consolidated at the WIP stage of the manufacturer. Safety stock in the WIP inventory is reduced due to risk pooling. The razor module of the shaver at the WIP stage can be bulk -shipped at a much lower weight and smaller size. More items can thus be loaded onto each carton and pallet. This reduces the carrying and transportation costs.

6.3.2 System Development for Virtual Warehousing Approach

Systems are always the important key to improving processes, and such a system, VWS, supports Virtual Warehousing in improving the production logistics process. Three objectives are targeted by using VWS.

- (i) Show distributors the inventory allocation so as to build up their confidence in a huge stock backup in the distribution center.
- (ii) Enable the supply source to be controlled thereby reducing total inventory.
- (iii) Enable the flexible reallocation of semi-products.

All these require the system to earmark the semi-products most commonly sought by their customers. The VWS in Schick can only operate with regard to regional supply chains as it has no international distributing functions. The effective utilization of VWS enables the efficient management of the flow of inventory with the aid of control and allocation of WIP. This system development is based on virtual warehousing which helps to strengthen commerce communication links and can enhance decision making capabilities for the company operation in relation to the supply chain.

To facilitate the customization of the postponement, the state of available inventory is made clear and the VWS is able to capture all the required data and is capable of managing the knowledge of inventory planning. The template of required data is enclosed in Appendix B. Provided that it is used effectively, it contributes significantly to supporting supply chain decision making and optimizing supply chain performance. VWS dynamically allocates WIP earmarked for customer orders at the point of the upstream facility before product customization.

6.4 Implementation of VWS

A prototype of VWS is built based on the industrial needs and current approaches found in the literature. VWS for production logistics has been trial implemented incrementally which mainly consists of a simulation module and an advisory module. Their application in case company is shown as a reference to illustrate the capacities and operations of VWS in the determination of inventory parameters, inventory plan setting, production constraint resolving, and inventory allocation.

6.4.1 Process Overview

Schick aims to meet the highest level of demand accuracy and order fulfillment satisfaction. Its supply chain network is committed to fully support orders, products, execution tracking, and logistics operations. The planning capabilities in Schick are thus the key to maximizing the return on assets and ensuring a profitable match of supply and demand. The supply chain information systems are linked to VWS with updated information, enabling the dynamic synchronization of demand driven planning, logistics, and supply chain network.

Figure 6.4 shows the overview of data flow in the supply chain operations. Schick is typical of the enterprises operating this kind of infrastructure model. Demand planning and forecasting are prior activities from supply chain planning. The forecasting algorithms are used to anticipate the demand for products or product characteristics. Marketing personnel also adjust the model as well as the plan to do new product

introductions, trade promotions, or causal events. Those significantly impact on demand.

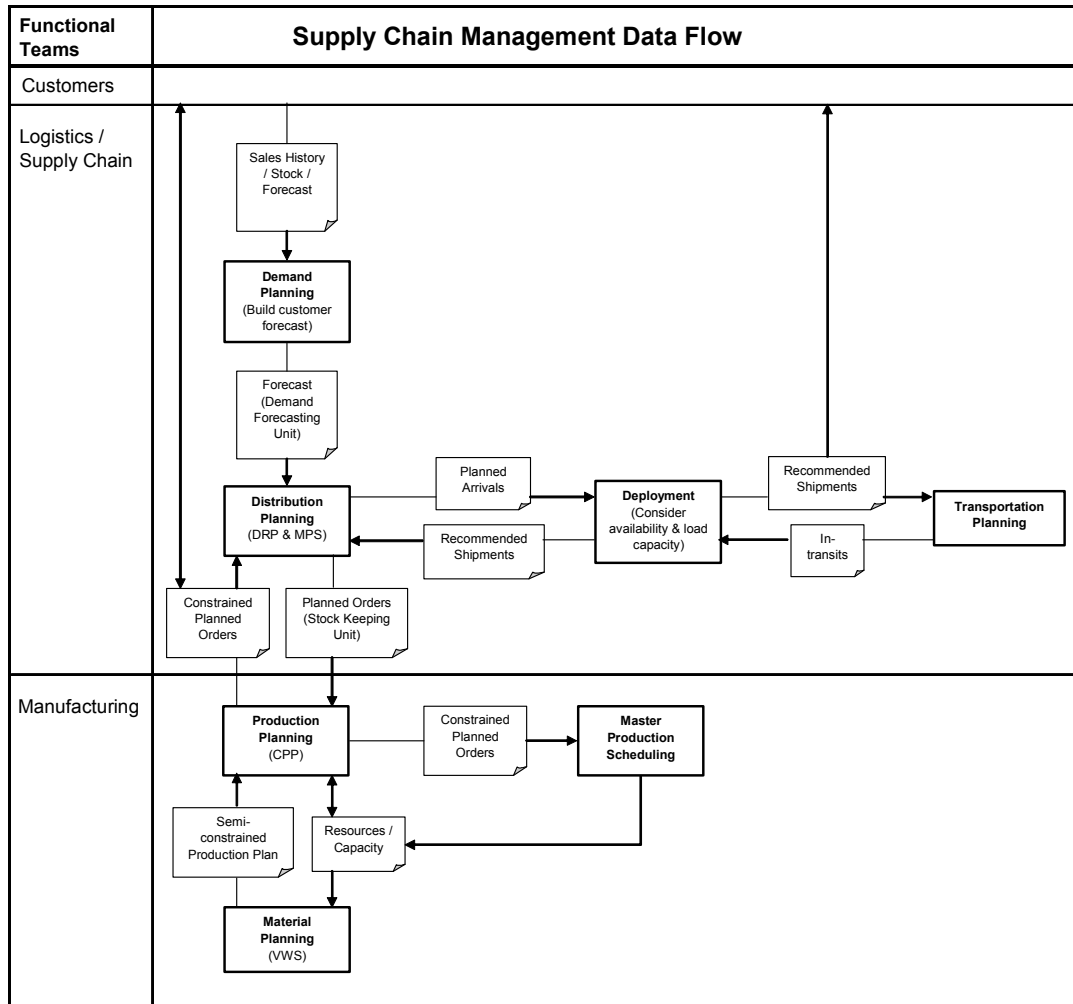


Figure 6.4 The typical processes and key operations in supply chain planning in Schick.

The next process is distribution planning that converts the unconstrained demand forecast into realistic and committable planned arrivals. This planning mainly allocates the available supply to meet forthcoming demands. It determines the locations of the stock replenishment to match the demands by foreseeing supply elements.

To collaborate with the distribution plan, production planning takes a role in the discipline of manufacturing. It monitors the operation of the output rate, the workforce

size, and capacity utilization as well as WIP and material consumption. As the manufacturing operations need to be smoothly aligned with the supply of materials and WIP, material planning supports the production plan by facilitating its detailed production schedules. VWS is assigned at this point to optimize the inventory plan on materials including raw components, i.e. WIP and finished goods. To sustain the inventory movement from production to distribution, the achievements on optimal planning and stable supply imply that it is meeting target customer service levels at the same time.

6.4.2 System Overview

The comprehensive information systems are the foundation to facilitating the logistics and supply chain operations. The ERP system used in Schick is named 'Prism'. Figure 6.5 illustrates the information flow and the processes between the different information systems in Schick. Looking at Figure 6.5, the block named e-DRP is an electronic distribution requirements planning tool which is driven by affiliates' demands. While the MRP usually coordinates the scheduling and integration of materials into finished goods, e-DRP coordinates the allocation of finished goods from the manufacturing plants to the distribution warehouses and finally to the customers.

The building block of the ERP system is called Prism which is the backbone of the information systems in Schick. It is designed as transaction modules integrated operations and reporting to initiate, monitor, and track critical activities. Prism facilitates supply chain transactions including order entry, inventory assignment, and shipping. It also includes finance, accounting, and human resource capabilities.

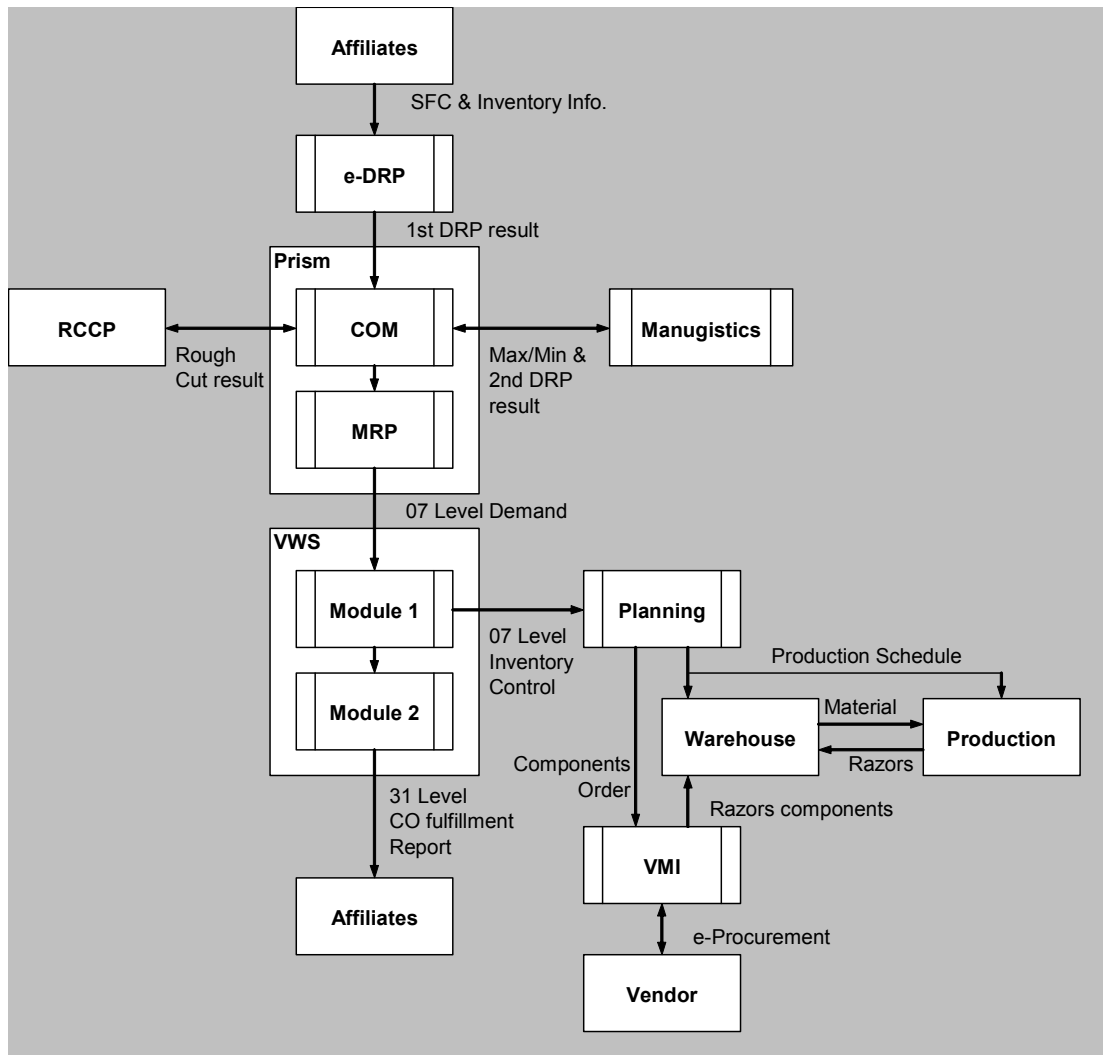


Figure 6.5 The information flow and processes between information systems in Schick

The block next to Prism is an Advanced Planning and Scheduling (APS) system named Manugistics. It is designed to assist in evaluating supply chain plans and alternatives. Its applications include production scheduling, inventory resource planning, and transportation planning.

And the bottom block of VMI is a miniature tool to execute a vendor-managed inventory model. The qualified major suppliers utilize this tool to manage the selected categories of components. By receiving the forthcoming components consumption in Schick'

production, the suppliers take responsibility for the replenishment of the demanded quantities.

The middle block is VWS which contains two modules, i.e. a simulation one and an advisory one. It closely cooperates with Prism and Manugistics, but they cannot be substituted for each other due to their independent roles in the supply chain information systems. The applications of VWS include the formulation of an inventory plan and simulation, and an inventory allocation. It provides support in decision making with regard to supply chain planning such as solution recommendations within the imposed constraints.

6.4.3 Data Flow

VWS is closely co-coordinated with the existing supply chain information systems. Data absorption from co-systems enables the complete synchronization of distribution, production and supply chain planning. The following six types of information are the minimum requirement for the operation of the VWS.

Information requirements to run VWS include:

- (i) Constrained confirmed order (CO): This pack of information includes the confirmed order with the demand quantity, the estimated date of delivery, the product code and related information. Those are the results after the execution of the e-DRP replenishing inventory.
- (ii) Bill of material (BOM): All updated BOMs of selected razor lines are critical to find out which products are consuming which razor. BOM can be extracted from the product manual (PM) in the resource master in MRPII tool, i.e. Prism.

- (iii) Transit time: This is the duration of the process from the assembly center via the distribution center to the affiliates, in which two transit periods are considered. One is production lead-time which refers to the duration of time taken from assembly to razor and final packing. The other transit period is the shipment lead-time which covers the duration of time taken for the product to be delivered from the distribution center to the affiliate.
- (iv) Shipment frequency and shipping mode: These are factors to be considered while the inventory is allocated.
- (v) Sales history: It could be presented as a demand trend for each product line throughout the various marketing seasons. Planners may refer back to past sales trends to estimate probable inventory levels.
- (vi) Machine and material constraints: Both machines and materials are major restrictions to razor production, assembly and packaging. The restriction may affect the inventory allocation plan no matter whether it happens in-house or on the vendors' side.

Figure 6.6 shows the flow of data acquisition from other information systems, its procedure is enclosed in Appendix C. The block named 'proposed interface program' in the diagram refers to VWS. Another block labeled 'data warehouse' illustrates that it is data processed on the information of constrained CO and BOM. They are processed data transformation from incoming data of Prism before the manipulation in the temporary database of VWS. The data warehouse is the relational information repository for the supply chain information systems in Schick. Its corporate-wide database links to the

information regarding operational entities that directly facilitates supply chain operations.

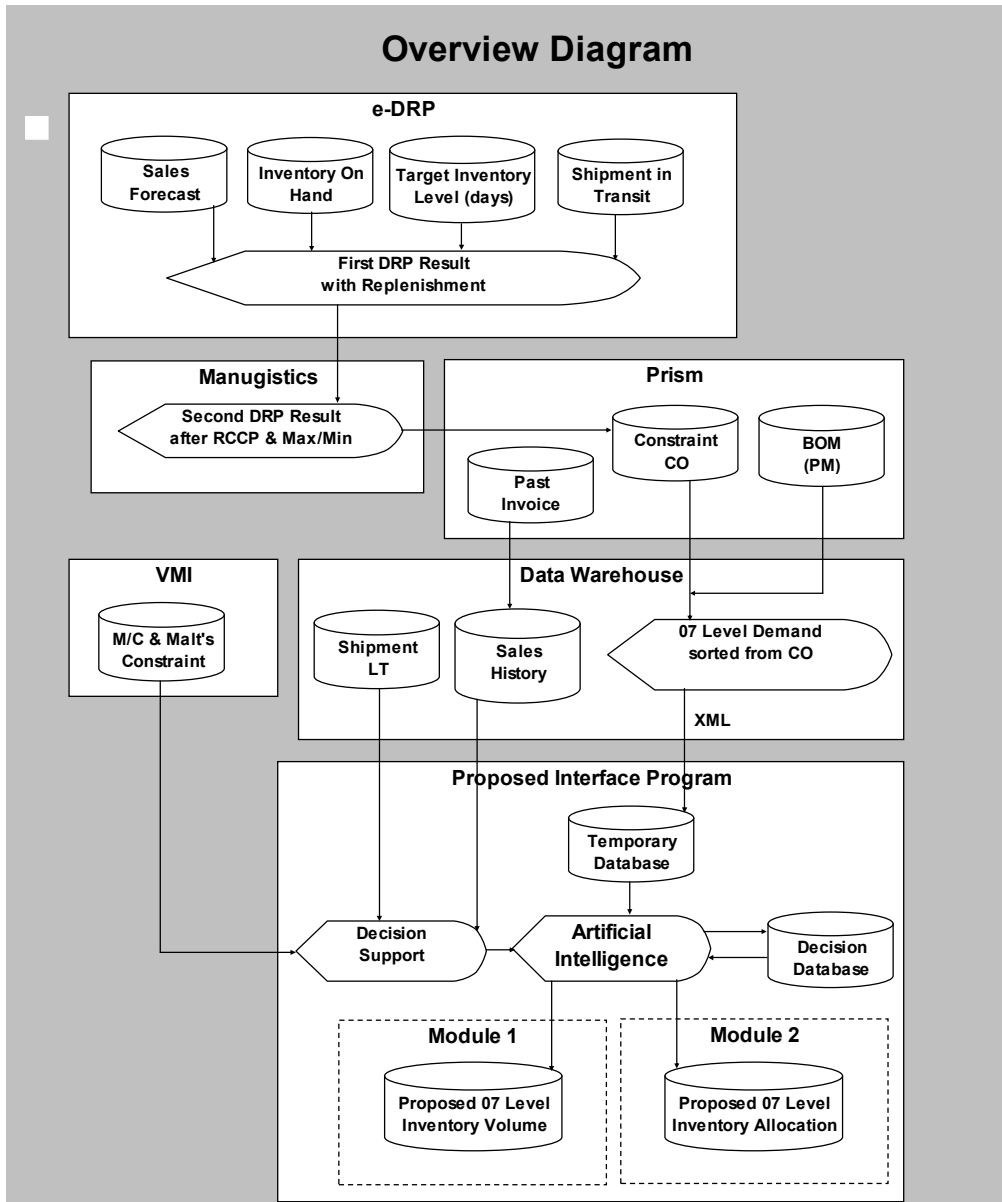


Figure 6.6 Overview of related data in the information systems co-coordinated with VWS.

The details of the data transformation flows are shown in Figure 6.7. The ‘mapper’ functionality of the data warehouse is used to transform confirmed orders into a query of demands based on the array of BOM’s for each product.

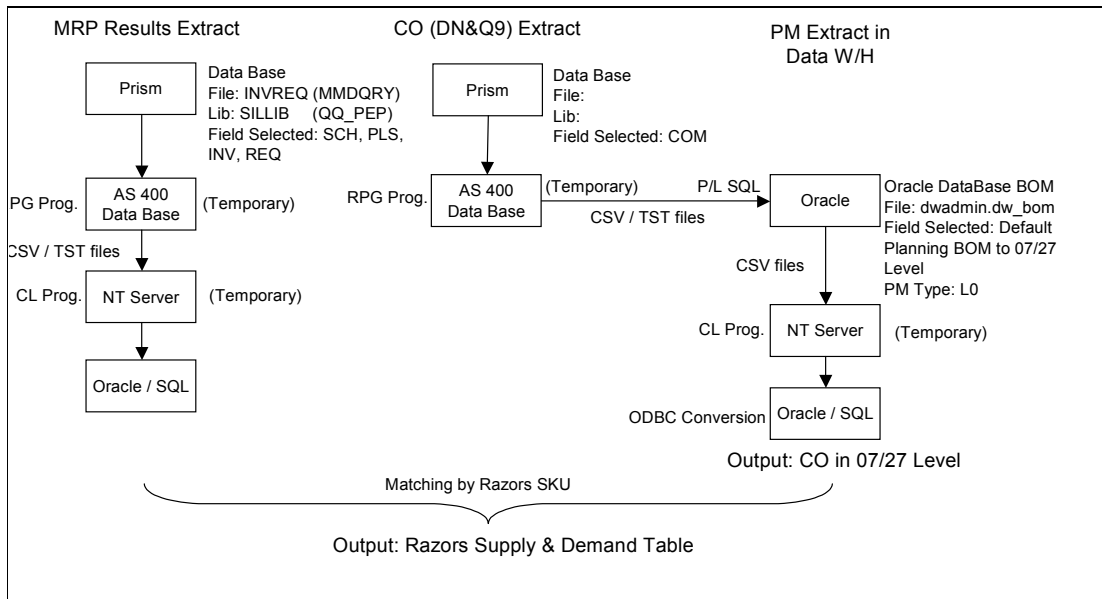


Figure 6.7 Flow chart of data transformation in the data warehouse for VWS.

6.5 Illustration of the Operations of VWS

6.5.1 Initiation into the System

After the VWS is installed according to the enclosed user manual in Appendix D, the users can initiate the system. Figure 6.8 shows the system log-in interface with the input of user log-in and password. The authorized users list is updated from the human resource management module of the ERP system in Schick. All planners can input their corporate intranet log-in name and password to enter VWS.

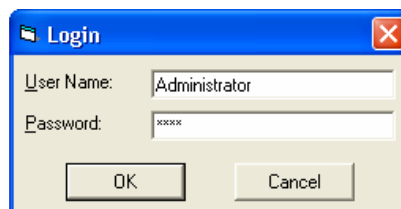


Figure 6.8 Users log-in interface of VWS.

Based on the virtual warehousing approach, the control point of inventory is its status at WIP under postponement. The common WIP of finished products is the key to deciding stock levels along the supply chain. Figure 6.9 shows the interface of a list of resource items for user selection. This is also an index page to initiate the simulation module as well as the advisory module on the selected WIP items.

Production Line	Commodity Code	Resource Class	Resource Number	Description	Packing Size	Detail/Problem
FT	RA	46	27.6132.A	RZ FTT W/RED NAMEPLATE	192	D P
FT	RA	46	27.6140.A	RZ FTT W/O BLADE (BLUE PIVOT)	192	D P
FT	RA	46	27.6141.A	RZ FTT W/O BLADE (EURO)	192	D P
FT	RA	46	27.6150.A	RZ FTT W/O BLADE (RED HDL)	192	D P
FT	RA	46	27.6161.A	RZ FTT W/NY LOGO ON NAMEPLATE	192	D P
FT	RA	46	27.6170.A	RZ FTT NG W/O BLADE (EU)	192	D P
FT	RA	46	27.6171.A	RZ FTT NG W/O BLADE (US)	256	D P
FT	RA	46	27.6183.A	RZ FTT NG W/O BLADE (J)	192	D P
H3	RA	36	07.6800.A	RZ H3 W/NAMEPLATE	192	D P
H3	RA	36	07.6800.B	RZ H3 W/NAMEPLATE	252	D P

Figure 6.9 The list of WIP being the inventory planning key.

6.5.2 Determination of Initial Inventory Parameters and Inventory Plan Settings for Production Logistics in the Simulation Module

The simulation module is a supply chain planning decision support tool that collaborates with both the ERP and APS systems. As shown in Figure 6.10, the principal master plan is initially developed by the APS system, Manugistics. This plan then extracts the main components data that are the most critical core among all production constraints.

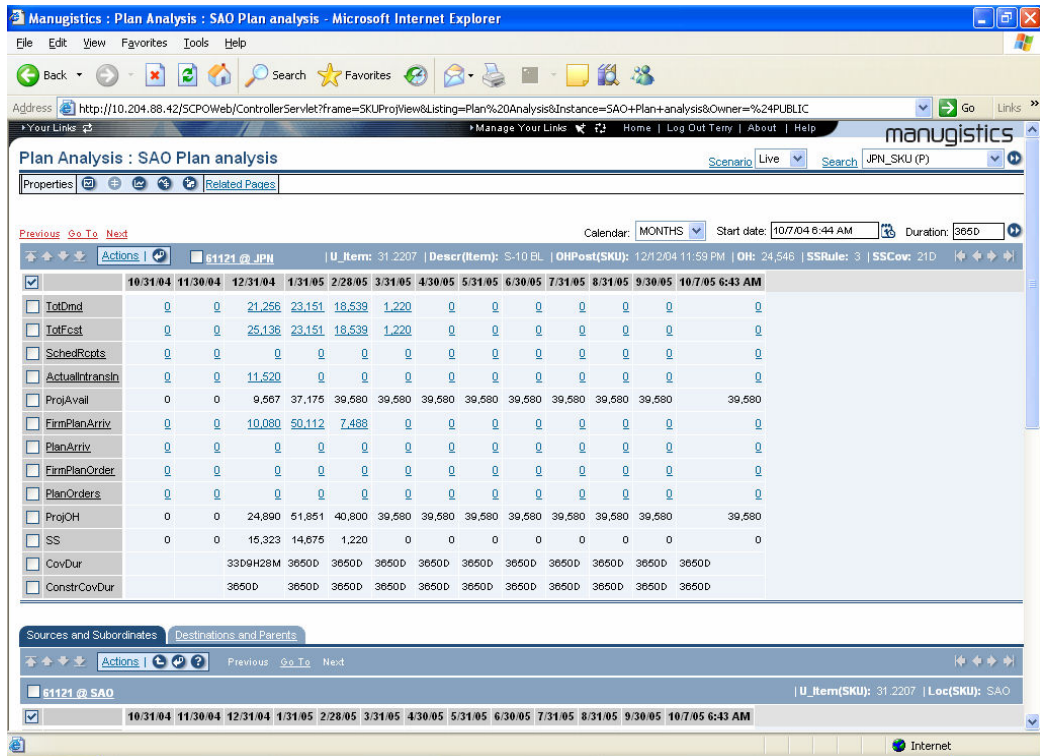


Figure 6.10 The master supply chain plan generated by the APS system.

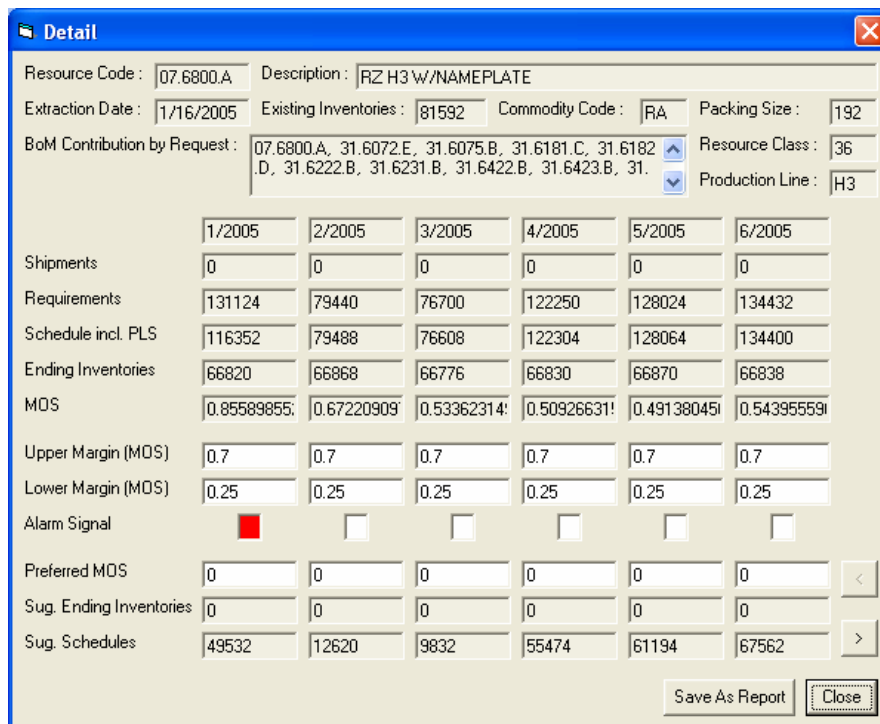


Figure 6.11 A snapshot of the inventory plan on a common component in the simulation module.

As shown in Figures 6.11 and 6.12, the simulation module acts as a simulation model to fine-tune the plan, which masters the inventory flow throughout the supply chain. As the effects of variability, non-linear relations, and other factors cannot be handled by APS, this module provides a platform for identifying the best alternatives until a near-optimal inventory plan is achieved. ‘What-if’ analyses can be conducted to determine the impact of sales orders from the affiliates.

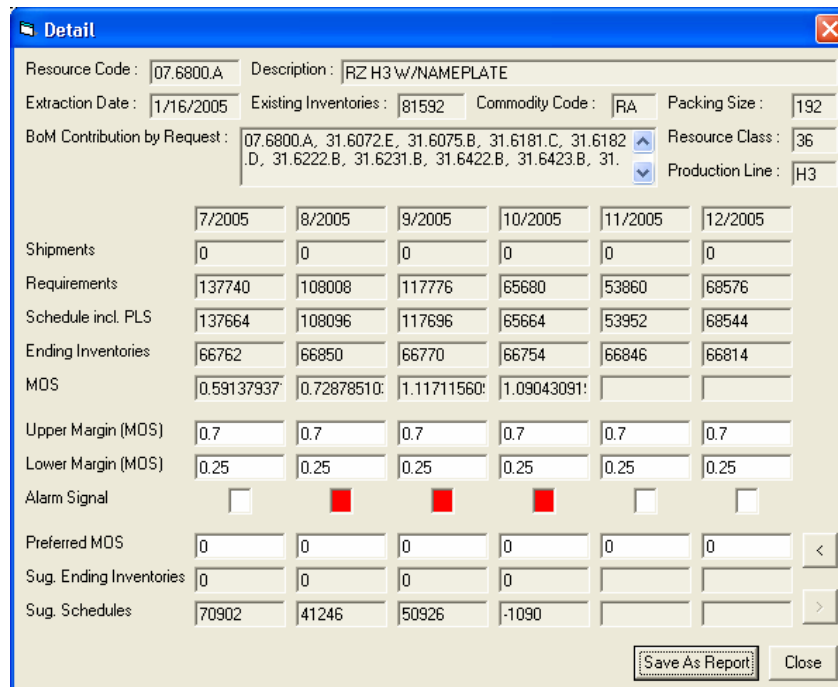


Figure 6.12 A snapshot of the inventory plan for the next 6 months in simulation module.

Values for the inventory index for each month are targeted by the forthcoming demands on WIP components. The relations between the variable inventory parameters and the production requirement of WIP components can be linked up by using this 12-months platform. The result is then converted to formulate a component production plan as well

as an inventory plan. Finally, the tuned version of the master plan is passed to the supporting set of the ERP system for detailed scheduling and operations.

6.5.3 Determination of Production Constraint Resolving and Inventory Allocation for Production Logistics in Advisory Module

Figure 6.13 shows the interface of the advisory module with the input of the supply chain event and the information about order promising that includes basic common component information, affiliates' requirements, supply information concerning production, and inventory information. Its level of detail is drilled down to involve production scheduling. Once the parameters of an unexpected order are inputted, this module can give advice with regard to decision making along the rest of the supply chain.

Problem

Resource Code : 07.6800.A Description : RZ H3 W/NAMEPLATE

Extraction Date : 1/16/2005 Existing Inventories : 81592 Commodity Code : RA Packing Size : 192

BoM Contribution by Request : 07.6800.A, 31.6072.E, 31.6075.B, 31.6181.C, 31.6182.D, 31.6222.B, 31.6231.B, 31.6422.B, 31.6423.B, 31.

Resource Class : 36
Production Line : H3

Order Promising
Available to Promise

Due Date	Supply Type	Demand Affiliate	Quantity	Balance	Ref. No. / Order No.	Customer Number	Outcome Code	Outcome Description
11/29/2004	INV		81592	81592				
12/10/2004		NZL	-2880	78712	NZL4189	18502	31.6422.B	H3 KIT 2 (A)
12/10/2004		MEA	-3000	75712	MEA4011	18805	31.6422.B	H3 KIT 2 (A)
12/31/2004		SAF	-15000	60712	SAF2248	18901	31.6422.B	H3 KIT 2 (A)
12/31/2004		SAF	-10020	50692	SAF2246	18901	31.6422.B	H3 KIT 2 (A)
1/6/2005	SCH		14976	65668	JNC1401			
1/14/2005		AUS	-1920	63748	AUS4968	18503	31.6422.B	H3 KIT 2 (A)
1/20/2005	SCH		101376	165124	JNB2528			
1/21/2005		SPE	-3000	162124	SPE4159	18410	31.6422.B	H3 KIT 2 (A)
1/21/2005		SAF	-10020	152104	SAF2247	18901	31.6422.B	H3 KIT 2 (A)

Days to Due : -37

Capable to Promise: Total Supply : 209848 Total Demand : -47760 Surplus Supply

Date: 1/20/2005 Affiliate: KOR Quantity: -1600 Order No.: KOR1234 Customer No.: 18604 Outcome Code: Unknown

Balance Rough Cut : 160488 Surplus Supply

Page 1 of 2

Test Run Exit

Figure 6.13 Inventory allocation with problem input in advisory module.

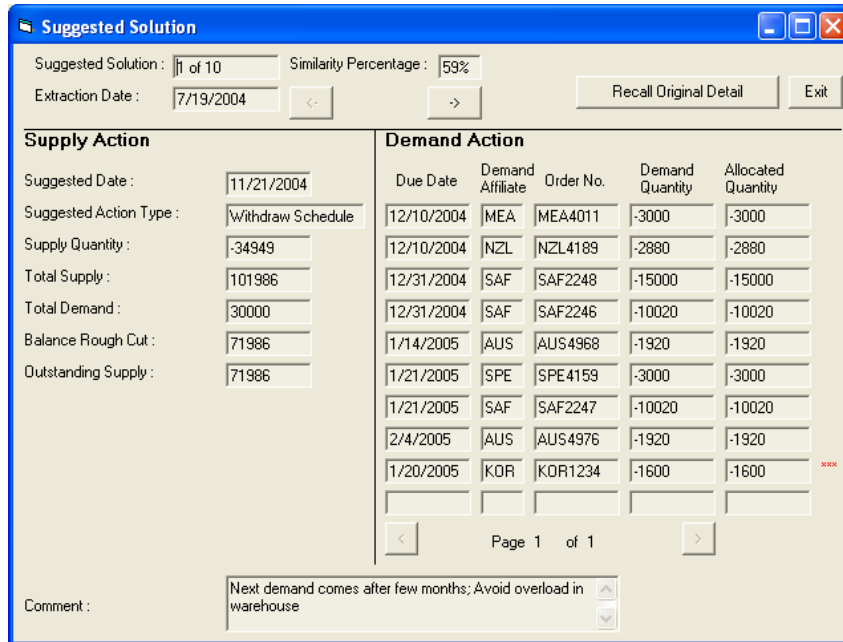


Figure 6.14 A snapshot of the most suggested solutions to reallocating resources.

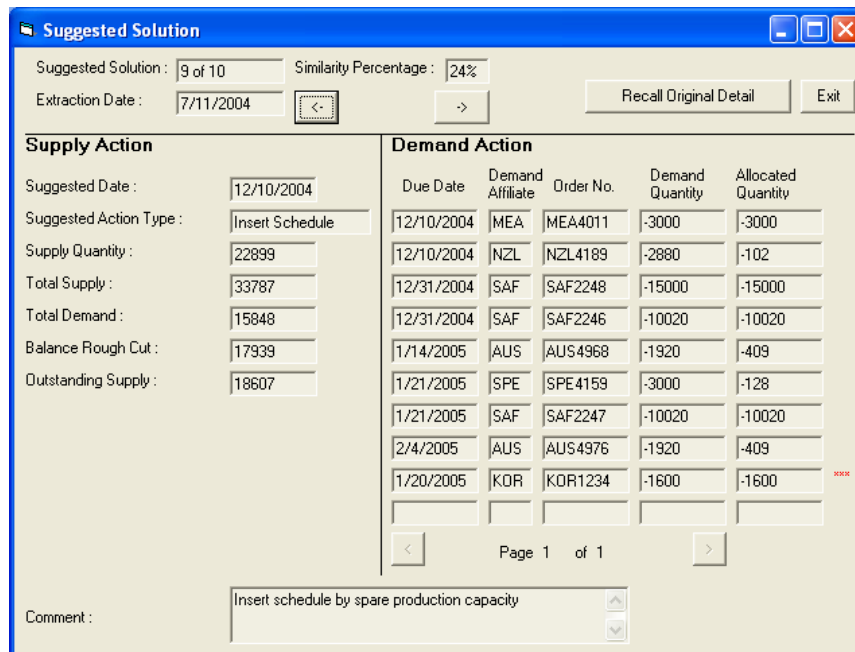


Figure 6.15 One of the less- suggested solutions for dealing with a supply chain event.

With the use of the historical and current supply chain events, the advisory module systematically identifies and evaluates alternative means of action and recommends a list

production season one is in. As shown in Figure 6.17, the planners have to reconfirm their final decision on dealing with the impact of supply chain events brought to the inventory plan. Lastly, the final solution is transmitted to the MRPII system and is executed by production operations.

Solution Input

Resource Code : 07.6800.A Extraction Date : 11/16/2005

Final Solution

Due Date	Supply Type	Ref. No.	Supply Quantity	Due Date	Demand Affiliate	Order No.	Demand Quantity	Allocated Quantity
11/29/2004	INV		81592	12/10/2004	MEA	MEA4011	-3000	0
1/6/2005	SCH	JNC1401	14976	12/10/2004	NZL	NZL4189	-2880	0
1/20/2005	SCH	JNB2528	101376	12/31/2004	SAF	SAF2248	-15000	0
2/3/2005	SCH	JNC1403	1920	12/31/2004	SAF	SAF2246	-10020	0
2/10/2005	SCH	JNC1406	9984	1/14/2005	AUS	AUS4968	-1920	0
				1/21/2005	SPE	SPE4159	-3000	0
				1/21/2005	SAF	SAF2247	-10020	0
				2/4/2005	AUS	AUS4976	-1920	0
				1/20/2005	KOR	KOR1234	-1600	0

Page 1 of 1 Page 1 of 1

Total Supply : 209848 Total Demand : -47760

Outstanding Supply : 209848 Balance Rough Cut : 257608

Days to Due : -37

Comment :

Download Reset Confirm Exit

Figure 6.17 Snapshot to input final decision reacting on supply chain event.

Chapter 7 Results and Discussion

Applying a supply chain perspective to current distribution operations reveals that the conventional material flow is obsolete when called upon to satisfy a worldwide brand name product series. Customers prefer improved levels of service especially instant product availability at the retailing points. Companies try to fine-tune their internal flow of products and information thereby aiming to provide a competitive customer service level. The VWS is an indispensable tool for improving the supply chain operations.

7.1 Order Promising in Virtual Warehouse System

Achieving both plan- and order-driven supply chain activities is the current trend in enterprise development. The VM approach synchronizes the collaborative planning activities both internally and externally. VWS helps the supply chain operates with greater flexibility and to quickly respond to any market changes. In this system, the ability to see demand, inventory and capacity information can be an aid to optimize the production plan and the operational schedules thereby meeting business objectives. All planning activities are performed with the ultimate purpose of order promising.

Available to Promise (ATP) enables the users to check scheduled multilevel availability of supply and transporting resources. ATP quantity is the uncommitted inventory balance, so that all available material and components are kept track of in the production plants, warehouse and distribution center locations. The planners can make promises to customers' about their requests based on the availability. They then perform resource substitution after demand promised.

The requirements and confirmed production schedules of MRP result are actual information to contrast demand and supply in ATP. The DRP table in VWS aims to check the availability to commit promises, with the absence of decision supporting system. To move step from a single production plant to global planning, it helps to implement true global ATP and provide the availability of the accurate material availability and substitution possibilities.

7.2 Determination of the Initial Inventory Parameters and the Inventory Plan Setting for the Production Logistics in the Simulation Module

The simulation module in the VWS acts as a 'Capable to Promise' (CTP) tool for demand planning. The ATP is simply concerned with foreseen occurrences and assumes that all planned production schedules and shipments are correct at the end while the CTP in this module aims to convert customers' shipment expectations into realistic orders. As such it may need to make delivery date and quantity decisions because of capacity constraints.

The CTP thus has the role of overcoming the gap between unconstrained fresh orders and current planned production schedules. Apart from materials availability, other capacity constraints have also to be taken into consideration. In the resource planning table, only the production schedules are adjustable to react to changes in demand. To achieve CTP, the VWS needs to be further developed to allow it to adjust to changes in demand. Fresh orders can then be flexibly fulfilled by amending quantities and due dates

in cases of production capacity. Furthermore planners can match supply and demand in CTP.

7.3 Determination of Production Constraint Resolving and Inventory Allocation for Production Logistics in the Advisory Module

Unlike the ATP, 'Capable to Accomplishing' (CTA) initially assumes that the aim is to totally fulfill all first requests. These requests are simply treated as pre-actual demand in the CTA that simulates a contrast with material capability while the advisory module in the VWS uses this CTA tool for supply planning purposes.

The level of logistics service can be raised by using CTA, because it primarily commits fresh requests by adjusting other constraints. It responds promptly to fulfill demand not only as promised, but also any further requests. In fact, production capacity is not unlimited to expand meeting first requests. If a particular component is unavailable for any reason, it is a function of CTA that it can alert the planner and suggest a production schedule which would still allow the request to be fulfilled subject to the planner's decision.

To achieve CTA in the VWS, un-compromised fresh requests are contrasted with actual MRP results. This contrast then highlights the gap between customers' preferred demand and production planned supply.

7.4 Real Life Examples of the Best Use of the Simulation Module

7.4.1 Scenario 1 – Oil Crisis

The price of fuel oil often fluctuates due to any number of regional issues, such as official policy on oil production, war, oil refining capacity, global climate change, and so on. At times of an oil crisis, the price of petrol rises following the increase in demand for crude oil. The oil price escalation not only threatens a worldwide recession, it also impacts closely on domestic living costs related to the production. This high price of fuel oil results in a short to medium term increase in manufacturing costs. This is particularly true for those industries which are oil dependent. Manufacturing plants consume not just fuel oil to maintain production and operation, but some of its raw materials are by-products of oil refining. For example, plastics, moulding lubrication oil, artificial fiber cables, and coloring paint are all refined from crude oil. Their price and stability of supply are highly reliant on the crude oil market.

In this case, as a global supply chain planner, the user of the simulation module of VWS ought to build up a WIP inventory, because it is reasonable to anticipate the price of plastics and all other oil related materials will rise following the increasing price of fuel oil. As this industrial raw material is the by-product of crude oil and involves refinement lead time, its market price lags time wise behind the rise in oil price. As a result, pumping the inventory up in the simulation module indirectly pushes the production plans of WIP forward to utilize current material cost as well as low manufacturing cost.

The VWS feeds the simulation process with the required market level of intelligence to deal with global issues such as an oil crisis. The simulation module provides

functionalities to help users to decide by how much inventory should be built up, and how it should be distributed in the near months before the wave of price rises is reflected in the oil related materials market.

7.4.2 Scenario 2 – New Product Phase-in

A wide range of considerations need to be taken into account when successfully launching of a new product. Capturing a larger market share is certainly one of the main objectives in new product development, but it is not the only one. The success of a new product launch also embraces a long term sales goal, a wide range of product series vending and, more importantly, the collaborative back-up from other corporate functions such as production, supply chain, purchasing, etc. Business competitive intelligence needs to be used to maintain a stable supply of products including the new product line, alongside keeping the inventory of the overall product series at a financially healthy level.

From a marketing point of view, when a new product is launched into the market, it is likely to just pump up stock levels of the new product to fulfill customers' trendy interest while at the same time the older product series suffer low stock turnover, and even worse, accumulate inventory along the supply chain. This phenomenon is more obvious in those mature markets such as commodity products, as their market sizes are more or less constant. It can be reasonably anticipated that the growth sales on a new product will not only drain the sales of competitors' products, but also deplete other own product series. In this case, the simulation module of VWS can act as a crucial tool to

enable a company to formulate a strategic product launch program from a macro-view and test it in a risk-free environment.

The process of product launching involves a complex set of activities that involve most business functions. In terms of supply chain planning, further collaborative action ought to be taken so as to reduce the stock level of other product series, while a new product is being introduced. Without the aid of the simulation tool highlighted in this present study, supply chain planners may decide to adjust the inventory plans of each production line. However, it is difficult to evaluate the seriousness of the impact of a new product launch on ones own product series. It is confusing to try and estimate the duration of the slow moving stock, when will be the lowest dip-point in turnover rate, individual impact on each product' supply chain. The simulation module, however, enables the planners to view the indicators, propose product phase-in, view competitor actions and reactions, and then make supply decisions as they would do in real life. It assists the users in the determination of the dynamics of their competitive landscape by allowing them to experiment the product phase-in within a safe environment. The users can try many different strategies and view many different outcomes without any dangers of risk. It helps to ensure that the supply chain planning process yields realistic and achievable trial results as well as collaboratively sustaining the strategic sales and marketing plan of a new product launch.

7.5 Selection of the Development Method

The development method of the client server application is relatively cost effective, flexible and usable as compared with other techniques such as web- based applications.

VWS involves many calculations based on business logic and operational rules, whereas web-based applications have fewer functions available for fulfilling a users requirements of VWS. In the design of VWS, there are several or more data assessors communicating to the data base, while client server application has no constraint on the device application to obtain data from the server. This development method is able to input, process, store, as well as access data anytime and anywhere from the node. Popularizing its adoption by users can be rapidly achieved among departments in the organization.

Client server application development has been working efficiently and reliably for more than ten years. It has proven ability to commit mission critical requirements. Any platforms can simply use it for the development that eases the system design as well as shorten the entire system development lifecycle. Client server application uses structured methodologies to develop highly efficient and usable interfaces for the users. It is a comparatively mature tool due to the reduced development complexity and risk making, which indirectly run the system faster. The client server application can be launched from a start menu, and a server application runs on the server.

7.6 Validation of VWS

After implementing VWS to the selected WIP components in Schick, the performance result is compared with the conventional approach without virtual warehousing approach. The selected performance criteria are the indicators of schedule instability, customer service level and inventory level. As shown in Table 7.1, results indicate that the adoption of VWS has a significant contribution to Schick, which is shown by the

increase in overall customer service level in term of shipment punctuality, although there is a significant increase in production schedule instability. This can be shown more actions of inventory swapping with VWS resulting in better customer service as well as more change in production schedule. It also shows the significant decrease of inventory level for key components. It is likely to note that there are improvements for performance indicators before and after implementation of the VWS. This indicates that the VWS can help the manufacturing enterprises to better manage its inventory and customer service.

Table 7.1 Results of the performance evaluation of the VWS.

Performance Indicators	The month before implementation					The month after implementation					% of Improvement
	Wk 18	Wk 19	Wk 20	Wk 21	Average	Wk 26	Wk 27	Wk 28	Wk 29	Average	
Schedule Instability	0%	5%	1%	7%	3.25%	1%	15%	1%	0%	4.25%	30.77%
Measurement:	% of production schedule changed										
Data Source:	Production										
Customer Service Level (CSL) -- Overall	99%	100%	96%	98%	98.25%	100%	100%	100%	100%	100.00%	1.78%
Customer Service Level (CSL) -- Japan	100%	100%	100%	100%	100.00%	100%	100%	100%	100%	100.00%	0.00%
Measurement:	Shipment Punctuality; (Punctual Shipment / Orders)%										
Data Source:	Logistics										
Inventory Level (MOS) for key components											
Consolidated MOS - Bulks (On hand)	0.89	0.73	0.73	0.87	0.81	0.68	0.75	0.89	0.62	0.74	-8.70%
Consolidated MOS - Bulks (In-transist)	0.79	0.54	0.54	0.45	0.58	0.49	0.37	0.40	0.39	0.41	-28.88%
Data Source:	Logistics										

7.7 Benefits and Significance

Some benefits are gained by Schick from the use of VWS. The planners are enabled to conduct mid to short-term inventory planning, do ‘what-if’ analyses with different configurations, and discover the effect of business policies governing fulfillment,

replenishment, and other operations. At the preliminary stage of implementation, a list of the advantages to manufacturers over the conventional process would be as follows:

- (i) Reduction of inventory – A manufacturer can better predict demand through improved planning. It reduces the need to hold excess inventory, and schedules production and logistics activities more effectively.
- (ii) Optimal utilization of resources – Best manufacturing practice dictates that the resource spent on capacity and inventory is measurable to monitor the plant efficiency. It is achieved by improved planning with better demand anticipation to stabilize production.
- (iii) Increased order fulfillment – As the overall inventory is diminished, manufacturers face a higher risk of delivery delay or loss of business when they are unable to fulfill orders. However, inventory planning can better prepare for demand peaks. Its optimal inventory plan increases the flexibility of production and inventory to meet short-term demand, and raise order fulfillment rates.
- (iv) Clearer vision on inventory – Better insight into the all-in-one inventory plan, including its constituent parts, offers a clear understandable screen through which to identify the opportunities for improvement. It enables a manufacturer and its partners to monitor their inventory and improve their strengths.
- (v) Retention of knowledge – The absorption of staff knowledge and invaluable experience enriches business intelligence that is retrievable and so can be used to minimize the risk of wrong decision making.

All these benefits, brought about by the use of VWS, offer the possibility of cost reductions across the supply chain. Another significance of this system is the

assimilation of accumulated tacit knowledge and experience from the planners. The artificial intelligence computational tool of the reasoning engine embedded inside VWS is a new invention since there is no similar system using the knowledge-based technique to master WIP inventory in production logistics.

The allocation feature of VWS enhances ability and flexibility to counteract unexpected events such as urgent orders. This kind of supply chain event management tool introduced to Schick can quickly respond to the unplanned event, and adjust plans accordingly. The partnership between distributors and customers is then strengthened due to a higher customer service level. Confidence building among the parties along the supply chain allows the demanders to reduce their buffer stock subsequently.

Chapter 8 Conclusion

Owing to the delivery lead-time and rapid fluctuations in the market, customers are unable to predict future demand on an aggregated level. Some customers are even not willing to commit to their demand forecast though they can predict some part of future orders. In this market of dynamic change in orders, a proper inventory level for abrupt demand is unlikely to be managed by a manufacturer. Nevertheless, the profitability of an enterprise depends a great deal on healthy inventory holdings in which inventory decisions rely on the know-how, experience, and quality of the planners. In this situation, manufacturers often find difficulties in managing inventory which is subject to such fluctuating demands, specifically if the production capacity is scarce, or if the stock volume of the raw material and work-in-process (WIP) are limited. The highly complex nature of production logistics involves the manufacturers in the transformation, movement, storage and control of inventory, so some kind of multi-faceted system is needed to co-ordinate all these activities.

This project, initiated under the Teaching Company Scheme, has collaborated with an industrial organization to make full use of the latest knowledge and research skills to solve a real-life problem. To ensure the above-mentioned production logistic activities meet the requirements of the marketing affiliates, the suppliers, and the customers, a virtual warehousing approach is proposed to manufacturing enterprises. The customization processes are implemented after some key demander information about specific needs or requirements have been ascertained from the manufacturers. Just-in-time delivery can be assured by implementing this practice. It also reduces the risks and costs associated with the inventory of the finished products, and enables customer to

configure new products at the last moment. A WIP inventory on the final customer order is then assembled for product customization at the global upstream facility and shuttled promptly to downstream distribution centers. The WIP inventory can be built for different customers as per forecast demands. The stock will be stirred as buffer to fulfill the unexpected demand changes. The distribution activities conducted at the upstream of the supply chain before product differentiation is one of the significant characteristics of the virtual warehousing approach.

To facilitate this approach, Virtual Warehouse System (VWS) has been developed with the application of information technology to plan, control, and allocate work-in-process for production logistics. The major contributions of this project are listed as the following:

- (i) The evaluation of existing logistics information systems is a new approach or feature that was missing from previous systems. This gap has been filled by introducing a supplementary system integrated with the existing tools to improve the efficiency of production logistics.
- (ii) The VWS proposed in this project allows the assimilation of knowledge from the experienced planners. The key to enhancing the quality of decisions necessary in supply chain planning is to utilize the advantage of powerful computer-aided concepts and techniques. There is a need to develop a knowledge-based decision support tool for inventory management. It reduces the dependence on personal experience, improves decision quality and shortens response time.
- (iii) With the simulation module in the VWS, the inventory plan is fine tuned to handle the effects of variability, non-linear relations, and other abrupt factors.

Rapid changes in demand orders impact on the tuned master plan and the stability of production.

- (iv) When a supply chain event occurs and results in a shortage in WIP, then VWS can also act as an advisory tool for use in the decision making to WIP inventory allocation. As human decisions on inventory swapping to production belts are different case by case, this system has been built with various information technologies such as knowledge-based system to allow it to solve such problems.

A prototype of the VWS has been built, and trial implemented in Schick Asia Limited. This is a worldwide manufacturing company that has its operations in geographically different locations. With the aid of VWS, the most appropriate solutions are generated to advise the allocation of WIP inventory of Schick's shaving products. The inventory allocation is conducted by means of an inventory information system. It earmarks products with the names of the final receivers who are different customers, before product differentiation takes place. It is the planning practice in the virtual warehousing approach in Schick' distribution system, performed downstream in the supply chain, to swap WIP inventory instead of moving actual physical stock. VWS should not be treated as a stand-alone solution with discrete functions in the same way as viewing ERP, or APS. It ought to be regarded as an enabling tool that requires integration with other enterprise systems across a network, as well as the collection of operational data from week to week.

The inventory visibility offered in the VWS facilitates the monitoring of the supply chain, and allows the device to fine tune the supply plan. It directly contributes to the stabilization of the production plan. Whenever unexpected events occur, VWS supports

the planners in taking curative action with the assistance of decision analytics and functionality. VWS aids a manufacturing enterprise like Schick to be better equipped with the capabilities to cope with disruptive demands. These capabilities include faster response to the market changes, a shorter lead-time of production, improved customer service quality and speed, a better ability to deliver quality products to global customers, and improved communication and transportation systems.

Chapter 9 Suggestions for Further Work

Retail customers are demanding more and more improved levels of service especially with regard to the instant availability of products. Companies struggle to fine-tune their internal flow of products and information in an attempt to offer a more competitive improved customer service level. Intra-logistics are targeted to strengthen the networks integrated with the supply chain for cost reduction. Decentralizing the supply chain intelligence enables individual components to be more easily integrated into the process synchronization. It facilitates the commercial development of vertical integration in each chain, such as the distribution process. Horizontal integration could be achieved in terms of the logistics information transformation process.

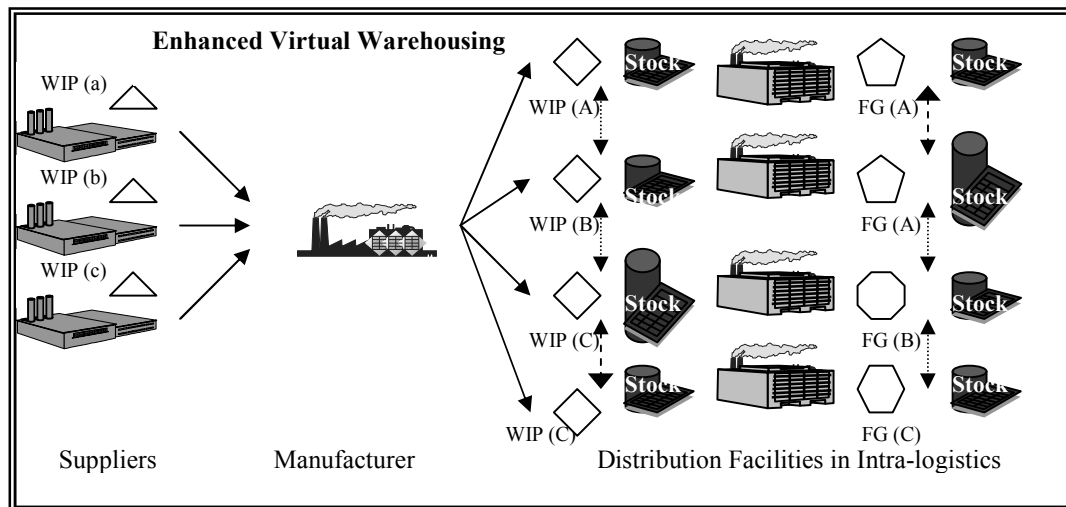


Figure 9.1 The retailers' in-stock duration is improved, as enhanced virtual warehousing drives the replenishment on a shorter lead time and cross docking among distribution facilities.

Enhanced virtual warehousing is introduced on the condition that distribution facilities are operated under intra-logistics. The product differentiation is performed at supply chain downstream closer to the customer after the order is revealed, as shown in Figure

9.1. The process of product customization is postponed geographically and will be conducted in the distribution facility, along with time postponement in the concept of virtual warehousing. The retailers' in-stock duration is improved as enhanced virtual warehousing drives the replenishment on a frequent basis, instead of projecting orders with longer lead times mainly based on forecasting. The postponement of customization can be regarded as a logistics information strategy of enhancing virtual warehousing. The flow of inventory and demand data is increasingly needed to be synchronized with the aid of information technology. System development here is a must to act as a tool being in place to capture customer orders and transform them to the supply chain plan as well as to facilitate executive instructions to carry out the fulfillment process. Flow through enhanced virtual warehousing, the distribution and continuous replenishment techniques are used to reduce the product value-adding costs and the inventory levels, and hence the distribution expenses are lowered. A better understanding of logistics processes in other industries, combined with the particular requirements of the product and its customer, is probable to develop optimal enhanced virtual warehousing practice for other companies as well.

This model is a further step in enhancing previous virtual warehousing, in terms of improving customer service levels. It specifically benefits the worldwide consumer products manufacturer who is aiming at raising or maintaining its share of the highly competitive global market. Under enhanced virtual warehousing, the overall customer service level is improved with the replenishment activity being closer to the point of consumption. Not only is the time of product customization postponed in the virtual

warehousing, but the customization process is also geographically postponed in the supply chain in the enhanced model.

Publication Arising from the Thesis

S.H. Fung, C.F. Cheung, W.B. Lee, S.K. Kwok, Catherine Wong. "A Knowledge-based Virtual Inventory System for Inventory Management in Production Planning", Proceedings of Second International Workshop on Supply Chain Management and Information Systems, Hong Kong, China, pp. 511-518.

S.H. Fung, C.F. Cheung, W.B. Lee, S.K. Kwok. "A Virtual Warehouse System for Production Logistics", International Journal of Production Planning and Control, Vol.16, No.6, pp. 597-607.

S.H. Fung, C.F. Cheung, W.B. Lee, S.K. Kwok. "Enhanced Virtual Warehousing for Distribution Process in Intra-logistics", Conference Proceedings of International Trade and Logistics, Corporate Strategies and the Global Economy, Le Havre, France, pp. 227-234.

S.H. Fung, C.F. Cheung, W.B. Lee, S.K. Kwok. "A Planning Decision Support System for Virtual Warehousing: A Case Study of a Manufacturing Enterprise", Annual Journal of IIE(HK), Vol.26, 2005-2006, pp. 80-90.

S.H. Fung, C.F. Cheung, W.B. Lee, S.K. Kwok. "Enhanced Virtual Warehousing for Distribution Process in Intra-logistics", In C.H. Fredouet and P.J. Rimmer eds. International Transport and Logistics: East Asian and European Experiences, Routledge, in print (2007).

References

- Ballou, R.H. and Burnetas A. Planning multiple location inventories. *Journal of Business Logistics*, 2003, 24(2), 65-89.
- Bucklin, L.T. Postponement, speculation and the structure of distribution channels. *Journal of Marketing Research*, 1965, 12(5), 26-31.
- Cheung, C.F. et al. An agent-oriented and knowledge-based system for strategic e-procurement. *Expert Systems*, 2004, 21(1), 11-21.
- Choy, K.L. et al. Development of a case based intelligent customer-supplier relationship management system. *Expert Systems with Applications*, 2002, 23(2), 76-89.
- Christopher, M. *Logistics and Supply Chain Management: Strategies for reducing cost and improving service*, 2nd Edn. London: Financial Times Prentice Hall, 1998.
- Collin, S. et al. Logistics customer service: performance of Irish food exporters. *International Journal of Retail & Distribution Management*, 1998, 29(1), 6-15.
- Crowston, W.B. Economic lot size determination in multi-stage-assembly systems. *Management Science*, 1973, 19, 517-29.
- Curran, T. et al. *SAP R/3 Business Blueprint: Understanding the Business Process Reference Model*. Prentice Hall, 1998.
- Curran, T. *SAP R/3 Business Blueprint: Understanding Enterprise Supply Chain Management*. Prentice Hall, 2000.
- Dellaert, N. and Jeunet, J. An alternative to safety stock policies for multi-level rolling schedule MRP problems. *European Journal of Operational Research*, 2004, 10.1016/S0377-2217, (04), 41-4.

- Donk, D.P. and Varrt, T. A case of shared resources, uncertainty and supply chain integration in the process industry. *International Journal of Production Economics*, 2004, 10(7), 67-74
- Drexl, A. et al. Konzeptionelle Grundlagen Kapazitaetsorientierter PPS-Systeme. *Zeitschrift fuer betriebswirtschaftliche Forschung*, 1994, 46, 1022-1045.
- Ferdows, K. Mapping international factory networks. In Ferdows, K. eds. *Managing International Manufacturing*. Elsevier Science, pp.3-22, 1989.
- Fischer, M. *Available-to-promise: Aufgaben und Verfahren im Rahmen des Supply Chain Management*. Regensburg, 2001.
- Fung, S.H. et al. A knowledge-based virtual inventory system for inventory management in production planning. In *Proceedings of the 2nd SCMIS Workshop*. 187-203, 2004.
- Gattorna, J.L. and Walters, D.W. *Managing the Supply Chain*. Macmillan Press, 1996.
- Haykin, S. *Neural Network, A Comprehensive Foundation*. Prentice Hall, 1999.
- Hansmann, K. *Industrielles Management*. Muenchen-Wien, 1996.
- Harrison, A. et al. *Creating the agile supply chain*. Institute of Transport and Logistics, 1999.
- Herrmann, C. A hybrid fuzzy-neural expert system for diagnosis. In *Proceedings of International Joint Conference on Artificial Intelligence*. 494-500, 1995.
- Hoek, R. Reconfiguring the supply chain to implement postponed manufacturing. *International Journal of Logistics Management*, 1998, 9(1), 95-110.
- Hoek, R. et al. Managers in supply chain management: the critical dimension. *Supply Chain Management: An International Journal*, 2002, 7(3)&(4), 119-125.

- Harrison, A. and Storey, J. Coping with world class manufacturing. *New technology, Work and Employment*, 2000, 13(13), 643-664.
- Institute of Logistics and Transport, *A Survey of Trends and IT Solutions in the Supply Chain*. DCE Consultants, 2004.
- Kilger, C. and Schneeweiss, L. Demand fulfillment and ATP. In Stadtler, H. and Kilger, C. eds. *Supply Chain Management and Advanced Planning – Concepts, Models, Software and Case Studies*. Berlin, 161-175, 2002.
- Krautter, J. Inventory theory: New perspectives for corporate management, *International Journal of Production Economics*, 1999, 59, 129-134.
- Kolisch, R. *Make-to-order Assembly Management*. Berlin, 2001.
- Kolodner, J.L. Improving human decision making through case-based decision aiding. *AI Magazine*, 1991, 12(2), 52-68.
- Kovacs, G.L. and Paganelli, P. A planning and management infrastructure for large, complex, distributed projects – beyond ERP and SCM. *Computers in Industry*, 2003, 51, 165-183.
- Landers, T.L. et al. The virtual warehousing concept. *Transportation Research*, 2000, Part E (36), 115-125.
- Magretta, J. Fast global and entrepreneurial: supply chain management Hong Kong style. *Harvard Business Review*, 1998, Sep/Oct, 102-114.
- Meyr, H. et al. Structure of advanced planning systems. In Stadtler, H. and Kilger, C. eds. *Supply Chain Management and Advanced Planning – Concepts, Models, Software and Case Studies*. Berlin, 99-104, 2002.

- Oliver, R.K. and Webber, M.D. Supply chain management: Logistics catches up with strategy. *Outlook*, 1982, 6, 42-7.
- Preece, A. et al. Better knowledge management through knowledge engineering. *IEEE Intelligent Systems*, 2001, Jan/Feb, 36-43.
- Scheer, A. *Business Process Engineering: Reference Models for Industrial Enterprises*. Springer, 1998.
- Stadtler, H. Multi-level capacitated lot-sizing and resource constrained project scheduling: An integrating perspective. In Stadtler, H. eds. *Working Paper*. Darmstadt University of Technology, 1/2002.
- Stadtler, H. Supply chain management and advanced planning - basics, overview and challenges. *European Journal of Operational Research*, 2004, 10(4), 57-68.
- Stuart, D.E. et al. Establishing the virtual warehouse. *Manufacturing Science and Engineering*, 1995, 2(2), 54-62.
- Taylor, D. *Supply Chains: A Manager's Guide*. Addison-Wesley, 2004.
- Walker, B.H. et al. Information technology and the virtual warehouse. *The Mechanical Engineer*, 1996, 8(4), 38-55.
- Walker, B.H. et al. Communications technology requirements for virtual warehousing. *Manufacturing Science and Engineering*, 1996, 3(2).
- Waters, D. *Inventory planning and control*. John Wiley, 2003.

Appendix A Program Source Code of System Algorithm

```
-----Logic and DB-----
/*
 * cmdDisplay.java
 *
 * Created on 16-1-2006, 5:03pm
 *
 * To change this template, choose Tools | Options and locate the template under
 * the Source Creation and Management node. Right-click the template and choose
 * Open. You can then make changes to the template in the Source Editor.
 */

//package vws;
import java.sql.*;
import java.text.DecimalFormat;
import java.util.*;
import java.text.SimpleDateFormat;

/**
 *
 * @author Administrator
 */
public class cmdDisplay {
    //ResultSet rs;

    /** Creates a new instance of cmdDisplay */
    /* public cmdDisplay() {

    }
    */
    static int existingInv = 0;
    // static int MONTH_PERIOD =0;

    static String PL[];
    static String CC[];
    static int RC[];
    static String RN[];
    static String Desc[];
    c int PS[];

    static int RC1=0,PS1=0,EI1=0;
    static String PL1,CC1,RN1,Desc1,ED1;
    static String BoM[];

    static String dateList[];
    static int ship[];
    static int req[];
    static int sch_incl_PLS[];
    static int ending_inv[];
    static double MOS[];
    static String _MOS[];
    static String upperMOS[];
    static String lowerMOS[];
    static String alarmSign[];
    static String pref_MOS[];
    static double sug_ending_inv[];
    static double sug_schedule[];
    static int _sug_ending_inv[];
    static int _sug_schedule[];

    static int AVG_MONTH_PERIOD =0;
    static String UPPER_MARGIN = "",LOWER_MARGIN= "",PREFERRED_MOS="";
```

```

        static DecimalFormat f;
//List of all recourse
public static int getList(String start , String range){

    try{
        DB db = new DB();
        String str=null;
        ResultSet rs = db.executeQuery("select count(*) from rlist");
        rs.next();
        int count = rs.getInt(1);
        System.out.println(count);
        PL = new String[count];
        CC = new String[count];
        RC= new int[count];
        RN = new String[count];
        Desc = new String[count];
        PS = new int[count];

        str+="ProductLine\tCommodityCode\tResourceClass\tResorceNumber\tDescription\tPackingSize\n";

        ResultSet rs1 = db.executeQuery("select * from rlist limit "+start+", "+range+"");
        int count_s=0;
        while(rs1.next()){
            PL[count_s] = rs1.getString("RMMKPL");
            CC[count_s] = rs1.getString("RMCOMM");
            RC[count_s] = rs1.getInt("RMRSC");
            RN[count_s] = rs1.getString("PRRESC");
            Desc[count_s] = rs1.getString("RMDESC");
            PS[count_s] = rs1.getInt("PTSIZE");
            str+=PL[count_s]+"t"+CC[count_s]+"t"+ RC[count_s]+"t"+RN[count_s]+"t"+Desc[count_s]+"t"+ PS[count_s]+"n";
            count_s++;
        }
        rs.close();
        rs1.close();
        db.close();
        System.out.println(str);
        return count;
        //return str;

    }catch(Exception e){
        e.printStackTrace();
    }
    return -1;
}

//top half path of details table
public static String getRecord(String ResNo){

    try{
        System.out.println("ResNo="+ResNo);
        DB db = new DB();

        String str=null;

        ResultSet rs = db.executeQuery("select * from rlist " +
            "where PRRESC = '"+ResNo+"' limit 0,1");

        rs.next();
        PL1 = rs.getString("RMMKPL");
        CC1 = rs.getString("RMCOMM");
        RC1 = rs.getInt("RMRSC");
        RN1 = rs.getString("PRRESC");
        Desc1 = rs.getString("RMDESC");
        PS1 = rs.getInt("PTSIZE");

        ResultSet rs1 = db.executeQuery("select * from impinfo limit 0,1");
        rs1.next();
        ED1 = rs1.getString("IMPDATE");

        try{
            ResultSet rs2 = db.executeQuery( "select * from mrp " +

```

```

        "where RES = '"+ResNo+"' " +
        "and File = 'INV' limit 0,1");
        rs2.next();
        E11 = rs2.getInt("OSQTY");
        rs2.close();
    }catch(Exception f){
        //        f.printStackTrace();
    }
    //past to global variable
    existingInv = E11;

    str= "ResourceCode:\t "+ RN1+"\n"+
        "Description:\t "+ Desc1+"\n"+
        "ExtractionDay:\t "+ ED1+"\n"+
        "ExistingInventories:\t "+ E11+"\n"+
        "CommodityCode:\t "+ CC1+"\n"+
        "PackingSize:\t "+ PS1+"\n"+
        "RescorceClass:\t "+ RC1+"\n"+
        "ProductionLine:\t "+ PL1+"\n"+
        "BoM Contribution by Request: \n";

        try{
            ResultSet rs3 = db.executeQuery("select distinct PMNAME from mrp where RES =
            '"+ResNo+"' order by PMNAME");

            int count_b=0;
            while(rs3.next()){
                count_b++;
            }
            BoM = new String[count_b];
            rs3.first();
            int count_c=0;
            while(rs3.next()){
                BoM[count_c]=rs3.getString("PMNAME");
                str+=BoM[count_c]+" ";
                //System.out.println(BoM[count_c]);
                count_c++;
            }
            rs3.close();
        }catch(Exception f){
            //        f.printStackTrace();
        }

        rs.close();
        rs1.close();

        db.close();

        System.out.println(str);

        return null;
    }catch(Exception e){
        e.printStackTrace();
    }
    }
    return null;
}

//below half path of details table
public static String getMonthlyRecord(String ResNo,String show_month_period, String avg_month_period, int action){
    //System.out.println("cmd="+ResNo+" "+ show_month_period +" "+ avg_month_period);
    try{
        DB db = new DB();
        String str=null;
        ResultSet rs = db.executeQuery("select IMPDATE from impinfo");
        rs.next();
        String ext_date = rs.getString("IMPDATE");

        int MONTH_PERIOD = Integer.parseInt(show_month_period);
        AVG_MONTH_PERIOD = Integer.parseInt(avg_month_period);
        //AVG_MONTH=0;
    }
}

```

A Virtual Warehouse System for Production Logistics

```

//UPPER_MARGIN =0,LOWER_MARGIN= 0,PREFERRED_MOS=0;

dateList = new String[MONTH_PERIOD];
ship      = new int[MONTH_PERIOD];
req       = new int[MONTH_PERIOD];
sch_incl_PLS = new int[MONTH_PERIOD];
ending_inv = new int[MONTH_PERIOD];
MOS       = new double[MONTH_PERIOD];
        _MOS       = new String[MONTH_PERIOD];
//    upperMOS = new double[MONTH_PERIOD];
//    lowerMOS = new double[MONTH_PERIOD];
alarmSign = new String[MONTH_PERIOD];
//    pref_MOS = new double[MONTH_PERIOD];
sug_ending_inv= new double[MONTH_PERIOD];
sug_schedule = new double[MONTH_PERIOD];
        _sug_ending_inv= new int[MONTH_PERIOD];
        _sug_schedule = new int[MONTH_PERIOD];

int ext_year   = Integer.parseInt(ext_date.substring(0,4));
String ext_month = ext_date.substring(5,7);

//    System.out.println("AVG_MONTH="+AVG_MONTH+" PREFERRED_MOS="+PREFERRED_MOS+
//        " UPPER_MARGIN="+UPPER_MARGIN+" LOWER_MARGIN="+LOWER_MARGIN);

// get dateList , Shipment and requirement
ResultSet rs1 = db.executeQuery( "SELECT substring(due_date,1,7) as mm,abs(sum(OSQTY)) as qty FROM mrp " +
    "where RES="+ResNo+" "+
    "and file = 'REQ' "+
    "group by mm "+
    "having mm>= substring("+ext_date+",1,7)"+
    "and mm<=substring(DATE_ADD("+ext_date+", INTERVAL "+(MONTH_PERIOD-1)+
MONTH),1,7)");
int count_s=0;
while(rs1.next()){
    dateList[count_s]=rs1.getString("mm");
    ship[count_s]=0;
    req[count_s]=rs1.getInt("qty");
    // System.out.println(dateList[count_s]+"t"+ship[count_s]+"t"+req[count_s]);
    count_s++;
}

//get schedule incl. PLS and Ending Inventories
ResultSet rs2 = db.executeQuery( "SELECT substring(due_date,1,7) as mm,abs(sum(OSQTY)) as qty FROM mrp " +
    "where RES="+ResNo+" "+
    "and file in('SCH','PLS') "+
    "group by mm "+
    "having mm>= substring("+ext_date+",1,7)"+
    "and mm<=substring(DATE_ADD("+ext_date+", INTERVAL "+(MONTH_PERIOD-1)+
MONTH),1,7)");
count_s=0;
while(rs2.next()){
    sch_incl_PLS[count_s]=rs2.getInt("qty");
    if (count_s==0){
        ending_inv[count_s]=sch_incl_PLS[count_s]-req[count_s]+existingInv;
    }else {
        ending_inv[count_s]=sch_incl_PLS[count_s]-req[count_s]+ending_inv[count_s-1];
    }
    count_s++;
}

//get MOS,Preferred MOS and Sug. Ending Inventories
int totalReq=0;
for(int i =0; i<MONTH_PERIOD; i++){
    if( i < ( MONTH_PERIOD - AVG_MONTH_PERIOD )){
        for(int j =i; j<(i+AVG_MONTH_PERIOD); j++){
            // System.out.println("j="+j+" j+1_req="+req[j+1]);
            totalReq+=req[j+1];
        }
        //System.out.println("MOS"+i+"="+(double)ending_inv[i]/(totalReq/AVG_MONTH_PERIOD));
    }
}

```

A Virtual Warehouse System for Production Logistics

```

                                MOS[i]
=(double)ending_inv[i]/(totalReq/AVG_MONTH_PERIOD);

    if(action ==0){
                                pref_MOS[i]=MOS[i]+"";
    }

    //pref_MOS[i] =PREFERRED_MOS;
    //System.out.println("pref_MOS["+i+"]="+pref_MOS[i]+" AVG_MONTH_PERIOD="+AVG_MONTH_PERIOD);
    sug_ending_inv[i] =(Double.parseDouble(pref_MOS[i])*(totalReq/AVG_MONTH_PERIOD));
    totalReq=0;
} else {
    MOS[i]=0;
    sug_ending_inv[i]=0;
}
}

//get Sug. schedules
for(int i =0;i<MONTH_PERIOD; i++){
    if( i < ( MONTH_PERIOD - AVG_MONTH_PERIOD )){
        if (i==0){
            sug_schedule[i]=sug_ending_inv[i]+req[i]-existingInv;
        } else {
            sug_schedule[i]=sug_ending_inv[i]+req[i]-ending_inv[i-1];
        }
    } else {
        sug_schedule[i]=0;
    }
}

//set the number format

double temp = 0.0;
String str_temp="";
for(int i =0;i<MONTH_PERIOD; i++){
    f = new DecimalFormat("0.00000");
    str_temp = MOS[i]+"";
    if(Double.compare(Double.NaN, MOS[i])==0){
        _MOS[i] = "Err";
        pref_MOS[i] = "0";
    } else {
        temp = MOS[i];
        _MOS[i] = f.format(temp)+"";
        if(action ==0){
            pref_MOS[i] = f.format(temp)+"";
        }
    }
    temp = sug_ending_inv[i];
    _sug_ending_inv[i] = (int)Math.round(temp);
    temp = sug_schedule[i];
    _sug_schedule[i] = (int)Math.round(temp);
}

//set default value for upperMargin(MOS), lowerMargin(MOS) and get Alarm Signal
double pre_mos,up,low;
for(int i =0;i<12; i++){
    pre_mos = Double.parseDouble(pref_MOS[i]);
    up = Double.parseDouble(upperMOS[i]);
    low = Double.parseDouble(lowerMOS[i]);
    //System.out.println("Alarm="+up+"-"+pre_mos+"-"+low);
    if(pre_mos > up || pre_mos < low ){
        alarmSign[i] = "X";
    } else {
        alarmSign[i] = "OK";
    }
}

//updateSetting(ResNo);

//Display on cmd only
```

```

String dateList_str="",
    ship_str="",
    req_str="",
    sch_incl_PLS_str="",
    ending_inv_str="",
    MOS_str="",
    upperMOS_str="",
    lowerMOS_str="",
    alarmSign_str="",
    pref_MOS_str="",
    sug_ending_inv_str="",
    sug_schedule_str="";

String tmp_str="000000";
for(int i =0; i<MONTH_PERIOD;i++){
    dateList_str += dateList[i] +"\t";
    ship_str+=   ship[i] +"\t";
    req_str+=    req[i] +"\t";
    sch_incl_PLS_str+=sch_incl_PLS[i] +"\t";
    ending_inv_str+= ending_inv[i]+"\t";
    tmp_str="00000000";
    tmp_str = _MOS[i] + tmp_str;
    MOS_str+=   tmp_str.substring(0, 7)+"\t";
    //MOS_str+=   MOS[i]+"\t";
    upperMOS_str+= upperMOS[i]+"\t";
    lowerMOS_str+= lowerMOS[i]+"\t";
    alarmSign_str+= alarmSign[i]+"\t";
    //pref_MOS_str += pref_MOS[i]+"\t";
    pref_MOS_str += tmp_str.substring(0, 7)+"\t";

    tmp_str="000000";
    tmp_str = _sug_ending_inv[i] + tmp_str;
    sug_ending_inv_str+= tmp_str.substring(0, 7)+"\t";
    tmp_str="000000";
    tmp_str = _sug_schedule[i] + tmp_str;
    sug_schedule_str+= tmp_str.substring(0, 7)+"\t";
}

str = "\nMonthly: \t"+   dateList_str +
    "\nShipment: \t"+   ship_str+
    "\nSchedule PLS: \t"+ req_str+
    "\nSch incl.PLS: \t"+ sch_incl_PLS_str+
    "\nEnding Inv. : \t"+ ending_inv_str+
    "\nMOS      : \t"+ MOS_str +
    "\nUpper MOS: \t"+ upperMOS_str +
    "\nLower MOS: \t"+ lowerMOS_str +
    "\nAlarm Sign: \t"+ alarmSign_str +
    "\nPref MOS:  \t"+ pref_MOS_str+
    "\nSug.Ending Inv:\t"+ sug_ending_inv_str+
    "\nSug.Schedule: \t"+ sug_schedule_str;

rs.close();
rs1.close();
rs2.close();
db.close();

                System.out.println(str);

return null;

} catch(Exception e){
    e.printStackTrace();
}
return null;
}

public static String[][] getSetting(){
    String [][] value;
    String sql;
    try{

                DB db = new DB();

```

A Virtual Warehouse System for Production Logistics

```
ResultSet rs4 = db.executeQuery("select count(*) from setting");
rs4.next();
rs4.getInt(1);
value = new String[rs4.getInt(1)][2];
//get default setting set default value
ResultSet rs3 = db.executeQuery("select * from setting");
String temp_name="",temp_value="";
int j=0;
while(rs3.next()){
    temp_name=rs3.getString("name");
    temp_value=rs3.getString("value");
    if (temp_name.equals("AVGMonth")){
        AVG_MONTH_PERIOD = Integer.parseInt(temp_value);
    }else if (temp_name.equals("PreferredMOS")){
        PREFERRED_MOS = temp_value;
    }else if (temp_name.equals("upperMargin")){
        UPPER_MARGIN = temp_value;
    }else if (temp_name.equals("lowerMargin")){
        LOWER_MARGIN = temp_value;
    }
    //System.out.println(j+","+temp_name+","+temp_value);
    value[j][0]=temp_name;
    value[j][1]=temp_value;
    j++;
}

//set default setting to blank field
upperMOS = new String[12];
lowerMOS = new String[12];
pref_MOS = new String[12];
for(int i=0;i<12;i++){
    upperMOS[i] = UPPER_MARGIN;
    lowerMOS[i] = LOWER_MARGIN;
    pref_MOS[i] = PREFERRED_MOS;
}
// System.out.println("pref_MOS="+pref_MOS[i]);
}

rs3.close();
rs4.close();
return value;

} catch(Exception e){
    e.printStackTrace();

    return null;
    //return false;
}

}

public static boolean updateSetting(String ResNo){
    try{

        DB db = new DB();

        //ResultSet rs4;
        String sql;

        ResultSet rs = db.executeQuery("select IMPDATE from impinfo");
        rs.next();
        String ext_date = rs.getString("IMPDATE");

        sql = "SELECT substring(due_date,1,7) as mm FROM mrp " +
            "group by mm "+
            "having mm>= substring("+ext_date+",1,7)+"
            "and mm<=substring(DATE_ADD("+ext_date+", INTERVAL "+(12-1)+"
MONTH),1,7)";

        rs = db.executeQuery(sql);
        int count_s=0;
        dateList = new String[12];
        while(rs.next()){
            dateList[count_s] =rs.getString("mm");
```


A Virtual Warehouse System for Production Logistics

```
        count_s++;
    }
    if(!ResNo.equals("0")){
        ResultSet rs5 = db.executeQuery("select * from pref_mos_record where ResNo =
"+ResNo+"");
        if(rs5.next()){
            rs5 = db.executeQuery("select max(no) from pref_mos_record where ResNo
="+ResNo+"");
            rs5.next();
            //upperMOS = new String[12];
            //lowerMOS = new String[12];
            //pref_MOS = new String[12];
            int i=0;
            sql = "select * from pref_mos_record where ResNo = "+ResNo+" and no =
"+rs5.getInt(1)+"";
            System.out.println(sql);
            ResultSet rs4 = db.executeQuery(sql);
            while(rs4.next()){
                //System.out.println("dateList["+i+"]="+dateList[i]+"
rs4.getString(Date)+"rs4.getString("Date"));
                if(dateList[i].equals(rs4.getString("Date"))){
                    upperMOS[i] = rs4.getString("Upper");
                    lowerMOS[i] = rs4.getString("Lower");
                    pref_MOS[i] = rs4.getString("Pref_MOS");
                }
                //System.out.println("pref_MOS="+pref_MOS[i]);
                i++;
            }
            return true;
        }
        return false;
    }
    //rs4.close();
    return false;
} catch(Exception e){
    e.printStackTrace();
    return false;
}
}

public static boolean setSetting(String [] name_str,String [] value_str){
    try{
        DB db = new DB();
        boolean check=true;

        //get default setting set default value
        for(int i=0; i < name_str.length; i++){
            //System.out.println(name_str[i]);
            //System.out.println(value_str[i]);
            if(!db.executeUpdate("update setting set value="+value_str[i]+" "+
" where name="+name_str[i]+"")){
                return false;
            }
            //System.out.println("OK");
        }
        return true;
    } catch(Exception e){
        e.printStackTrace();
        return false;
    }
}

public boolean save(){
    try{
        DB db = new DB();
```

A Virtual Warehouse System for Production Logistics

```
boolean check=true;

String sql="";
int temp=0;

sql="select max(no) from pref_mos_record where ResNo = '"+RN1+"'";
ResultSet rs4 = db.executeQuery(sql);
if(rs4.next()){//insert the value for same date
    temp = rs4.getInt(1);
    //System.out.println("0");
    for(int i=0;i<12;i++){
        sql = "insert into pref_mos_record values ( '"+RN1+"'," +
            """+dateList[i]+"""," +
            """+(temp+1)+"""," +
            """+upperMOS[i]+"""," +
            """+lowerMOS[i]+"""," +
            """+pref_MOS[i]+""");";
        System.out.println(sql);
        if(!db.executeUpdate(sql)){
            return false;
        }
    }
}
}else{//insert the value
    //System.out.println("1");
    for(int i=0;i<12;i++){
        //sql="select count(*) from pref_mos_record where ResNo like '"+RN1+"'";
        sql = "insert into pref_mos_record values ( '"+RN1+"'," +
            """+dateList[i]+"""," +
            """+0+"""," +
            """+upperMOS[i]+"""," +
            """+lowerMOS[i]+"""," +
            """+pref_MOS[i]+""");";
        System.out.println(sql);
        if(!db.executeUpdate(sql)){
            return false;
        }
    }
}
return true;
}catch(Exception e){
    e.printStackTrace();
    return false;
}
}

public String getDateTIme(){
    try{
        DB db = new DB();
        String sql="";
        int temp=0;

        sql="select * from pref_mos_info where ResNo = '"+RN1+"' order by no desc";
        ResultSet rs4 = db.executeQuery(sql);
        if(rs4.next()){//insert the value for same date
            return rs4.getString("Date");
        }
        }else{//insert the value
            sql="select * from impinfo";
            ResultSet rs5 = db.executeQuery(sql);
```

A Virtual Warehouse System for Production Logistics

```
        rs5.next();
        return rs5.getString("IMPDATE") + " 00:00:00";
    }
    //return null;
} catch(Exception e) {
    e.printStackTrace();
    return null;
}
}

public String setDateTime(){
    GregorianCalendar gc = new GregorianCalendar();
    gc.setTime(new java.util.Date());
    SimpleDateFormat sdf = new SimpleDateFormat("yyyy-MM-dd HH:mm:ss");
    String datetime = sdf.format(gc.getTime());
    System.out.println(datetime);
    String sql;
    DB db = new DB();

    try {
        sql="select * from pref_mos_record where ResNo = '"+RN1+"' order by no desc";
        ResultSet rs4 = db.executeQuery(sql);
        if(rs4.next()){
            sql="insert into pref_mos_info values
("+RN1+"','"+rs4.getInt("No")+"'','"+datetime+"'";
            db.executeUpdate(sql);
        }else {
            sql="insert into pref_mos_info values ('"+RN1+"','0','"+datetime+"'";
            db.executeUpdate(sql);
        }
        return datetime;
    } catch(Exception e) {
        e.printStackTrace();
        return null;
    }
}

//return null;
}

public static void getMOS(){
    //set default value for upperMargin(MOS), lowerMargin(MOS) and get Alarm Signal
    double pre_mos,up,low;
    for(int i =0;i<12; i++){
        pre_mos = Double.parseDouble(pref_MOS[i]);
        up = Double.parseDouble(upperMOS[i]);
        low = Double.parseDouble(lowerMOS[i]);
        //System.out.println("Alarm="+up+"."+pre_mos+"."+low);
        if(pre_mos > up || pre_mos < low ){
            alarmSign[i] = "X";
        }else{
            alarmSign[i] = "OK";
        }
    }
}

public static void show(){

}

public static void main (String args[]){
    //System.out.println(args[0]);
    //System.out.println(args[1]);
    //System.out.println(args[2]);
    try{
        if(args[0].equals("-l")){
            System.out.println("F0");
            System.out.println(getList(args[1],args[2]));
        }else if(args[0].equals("-r")){
```

A Virtual Warehouse System for Production Logistics

```
        System.out.println("F1");
        System.out.println(getRecord(args[1]));
    } else if (args[0].equals("-m")) {
        System.out.println("F2");
        System.out.println(getRecord(args[1]));
        getSetting();
        System.out.println(getMonthlyRecord(args[1], args[2], args[3], 0));
    } else {
        System.out.println("FX");
        System.out.println("USAGE: java cmdDisplay [-l/-r/-m] [ResourceCode] [ShowPeriod] [AVGPeriod]\n"+
            "-l \t\t-> Will show the list of Resource\n"+
            "-r ResourceCode\t\t-> Will show the Details for entered ResourceCode\n"+
            "-m ResourceCode\t\t-> Will show the furture Monthly Record");
    }
} catch (Exception e) {
    //e.printStackTrace();
    System.out.println("FX");
    System.out.println("USAGE: java cmdDisplay [-l/-r/-m] [ResourceCode/StartRecord] [ShowPeriod/RecordRange] [AVGPeriod]\n"+
        "-l \t\t-> Will show the list of Resource\n"+
        "-r ResourceCode\t\t-> Will show the Details for entered ResourceCode\n"+
        "-m ResourceCode ShowPeriod AVGPeriod\t\t-> Will show the furture Monthly Record");
}
}
}
```

Appendix B Templates of Upload Data Files

1 File Name: F1_razorlist / *resmstraz*
 Description: Razor List
 Source File: MMDQRY / *RESMST*
 Source Library: FUNG1 / *P4FILES*

No	Field Name	Field Type	Description
1	RMMKPL	CHAR	Production Line
2	RMCOMM	CHAR	Commodity Code (RA = Razor)
3	RMRSCCL	NUM	Resource Class
4	PRRESC	CHAR	Resource No
5	RMDESC	CHAR	Description
6	PTSIZE	NUM	Packing Size
7	RMRSSC	NUM	Resource Subclass

2 File Name: pep
 Description: MRP Result
 Source File: MMDQRY
 Source Library: QQ PEP

No	Field Name	Field Type	Description
1	RES	CHAR	Resource No
3	OSQTY	NUM	Result Quantity
4	DUE_DATE	DATE	Result Due Date
5	FILE	CHAR	MRP Result Type (INV = Existing Inventory; SCH = Production Schedules; REQ = Requirements; PLS = Forecast Schedules)
7	REF	CHAR	Result Reference No
8	PMTYPE	CHAR	BoM Type
9	PMNAME	CHAR	BoM Contribution by Request
10	CUSORD	CHAR	Customer Order No (Partial)

3 File Name: allco / *all*
 Description: CO Info Dilled down to Resource Level / *Manual Drilled DN*
 List in Resource Level
 Source File: MMDQRY
 Source Library: FCST FUNG / *FUNG3*

No	Field Name	Field Type	Description
1	ODRESR	CHAR	Item Code (Demanding Package No)
2	ODITDS	CHAR	Item Description (Demanding Package No)
3h	res	CHAR	Resource No Calling
4	AFF	CHAR	Affiliate
5	OMCUSN	NUM	Customer No
6	OMORDN	CHAR	Order No (our order no)
7	OMMODE	CHAR	Shipment Mode
8	BAL	NUM	Invoice Balance

A Virtual Warehouse System for Production Logistics

9	PROM_DATE	DATE	Order Detail Promised Date
10	OMRQDT	NUM	Order Detail Requested Date
11h	resprdt	DATE	Promised Resource Ready Date
12h	resrqrt	DATE	Requested Resource Ready Date

4 File Name: tempBOM
 Description: Temporary BoM for Ordered Items Downgrading to Resource
 Level

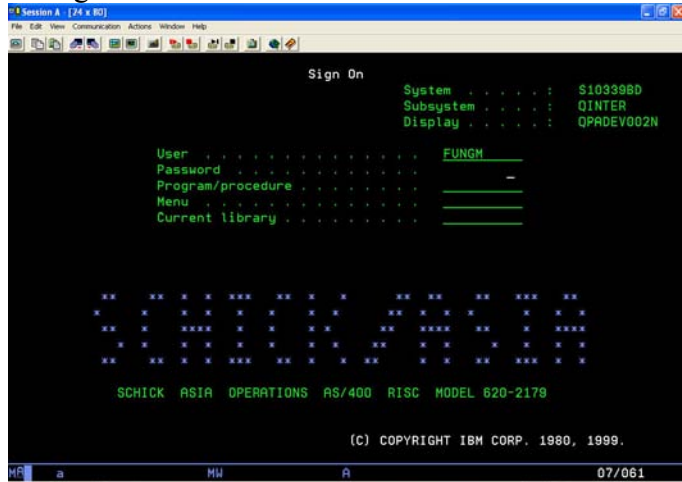
 Source File: MMDQRY
 Source Library: QQ_PEP

No	Field Name	Field Type	Description
9	PMNAME	CHAR	Item Code (Demanding Package No.) cut last digital
1	RES	CHAR	Resource No Calling
2	RMDESC	CHAR	Resource Description
5	FILE	CHAR	MRP Result Type (SCH = Production Schedules; REQ = Requirements; PLS = Forecast Orders)
7	REF	NUM	Result Reference No (1 = Self Calling; 2 = Resource Calling)
8	PMTYPE	CHAR	BoM Type (G0 = Local Supply; L0 = Export Supply; A0; I0; K0; Z3)

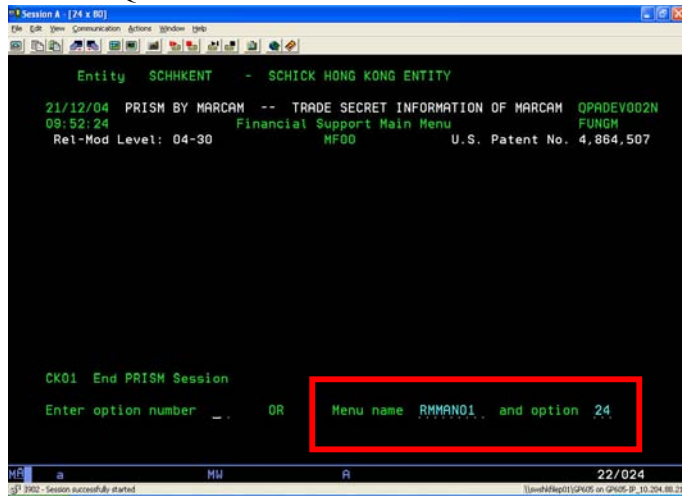
Appendix C Procedures of Source Data Download

F1_razor File Download Procedures

1 Log in Prism

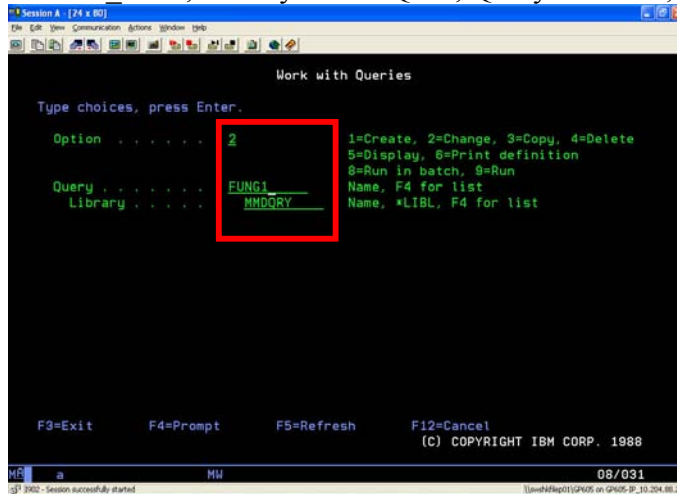


2 Enter Queries Module

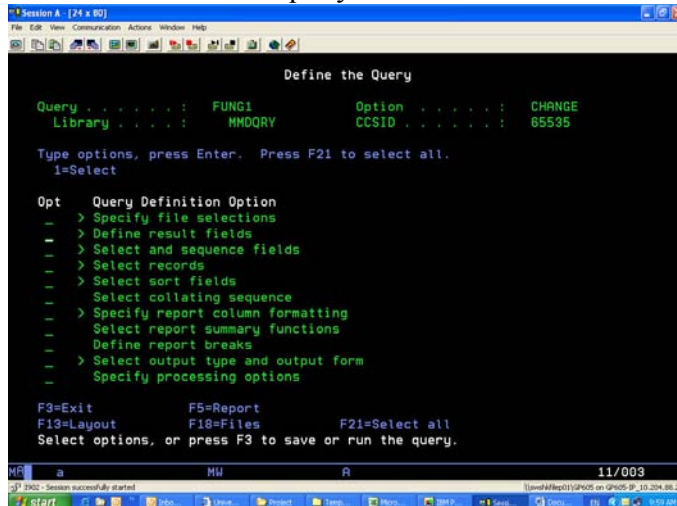


3 Recall library and its query:

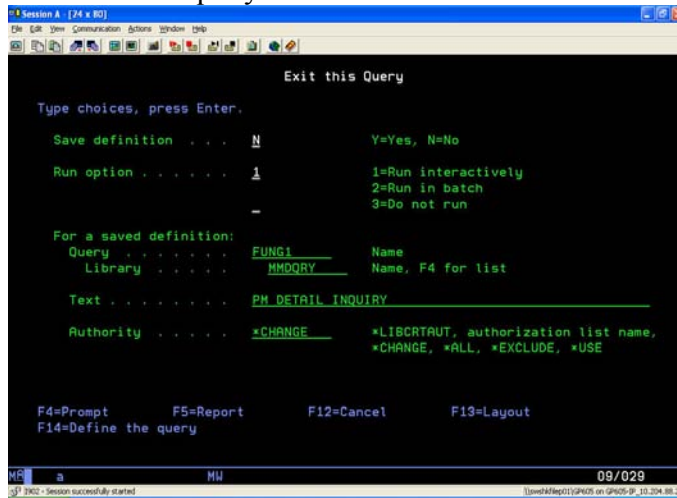
File: F1_razor, Library: MMDQRY, Query: FUNG1;



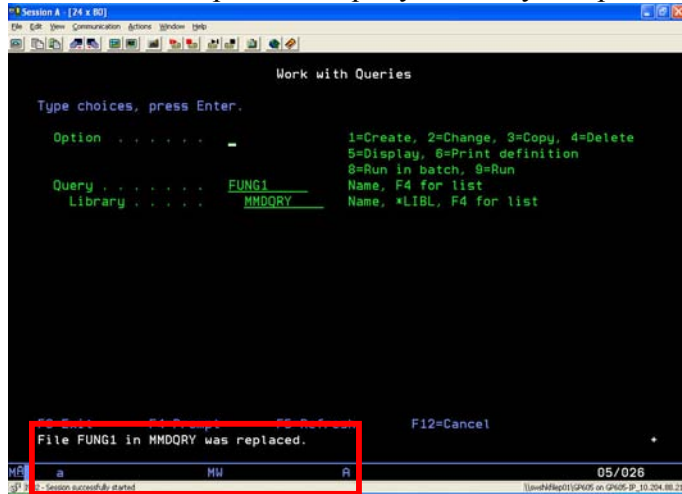
4 Press F3 to run the query



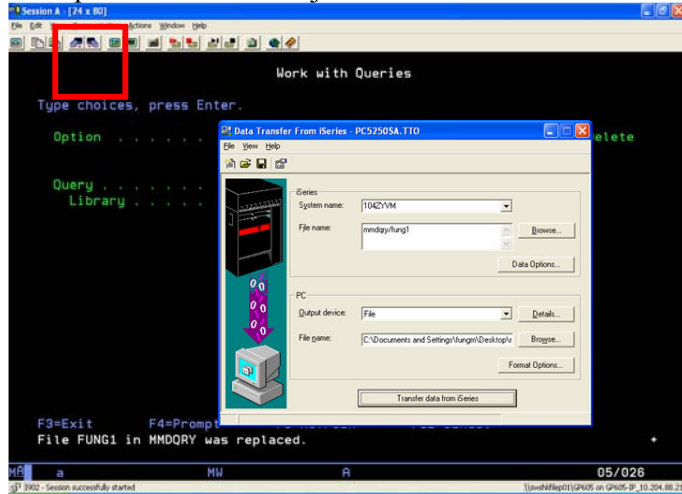
5 Instruct the query to run



6 Wait until output file of query in library is replaced



7 Export file to the 'Project' folder

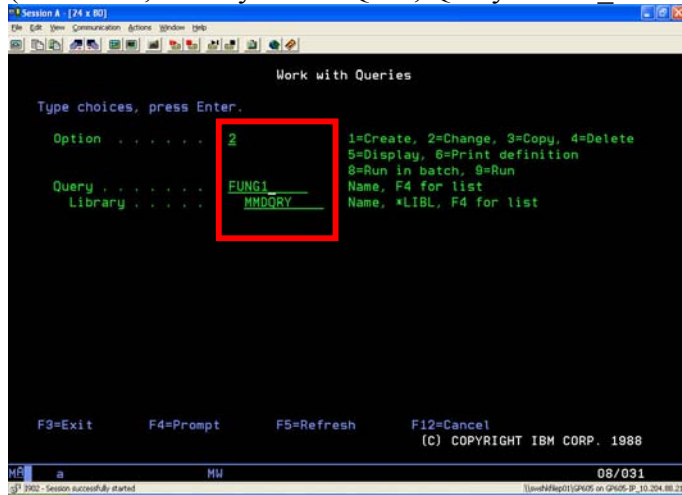


pep & allco File Download Procedures

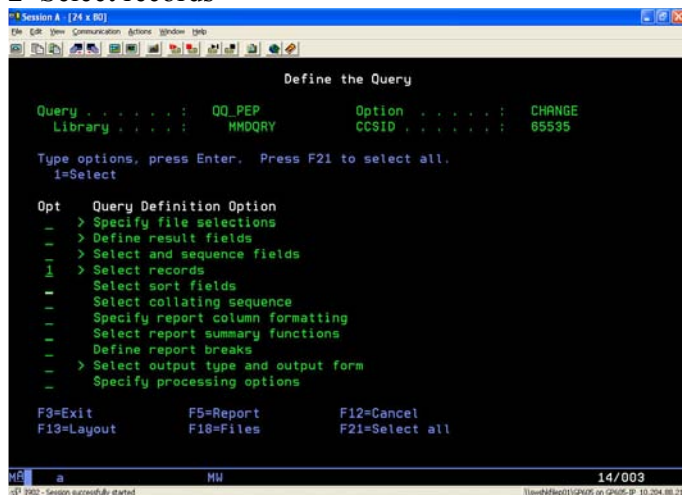
1 Recall library and its query:

File: pep, Library: MMDQRY, Query: QQ_PEP;

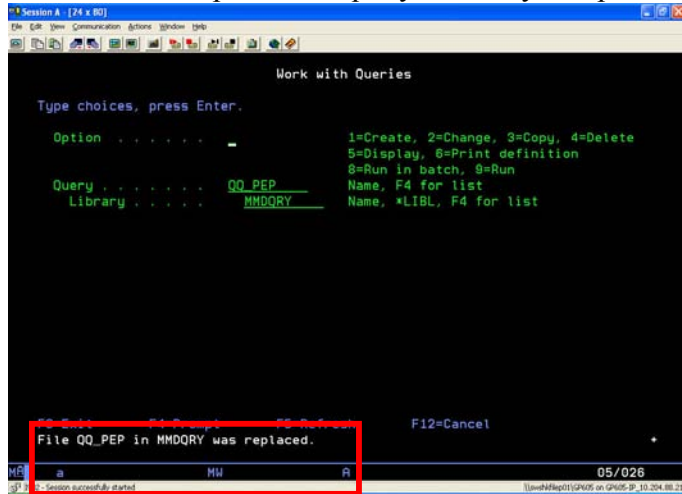
(File: allco, Library: MMDQRY, Query: FCST_FUNG);



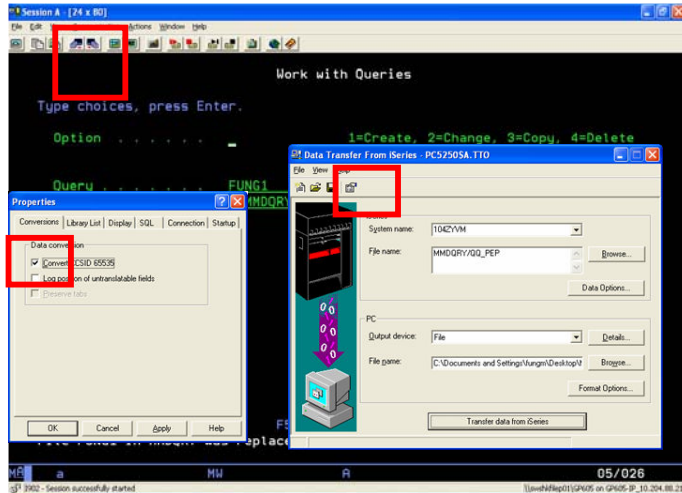
2 Select records



6 Wait until output file of query in library is replaced



7 Export file to the 'Project' folder
Select data conversion standard if non-encoded outcome is occurred



8 Repeat step 1 for alloc file download

Appendix D User Manual of System Installation

Installation

1. Copy a folder of six files to disk drive (csv X4, mdb X1, exe X1)
2. >Control Panel
 - >Administrative Tools
 - >Data Sources (ODBC)
 - Click “System DSN” sheet
 - a. Add “Microsoft Text Driver (*.txt; *.csv)”
 - Double click driver
 - >Data Source Name: IMPFILE
 - Unclick “Use Current Directory”
 - >Select Directory: disk drive location of pasted folder
 - >Option >Define Format
 - Select Tables: allco.csv
 - >Guess
 - Select Columns: F1
 - Change “Data Type” to “Char”
 - Change “Width” to “255”
 - >Modify

 - Select Tables: fl_razorlist.csv
 - >Guess
 - Select Columns: F6
 - Change “Data Type” to “Integer”
 - >Modify
 - Select Columns: F10
 - Change “Data Type” to “Integer”
 - >Modify
 - Select Columns: F11
 - Change “Data Type” to “Integer”
 - >Modify

 - Select Tables: pep.csv
 - >Guess
 - Select Columns: F4
 - Change “Data Type” to “Date”
 - >Modify

- Select Tables: tempbom.csv
- >Guess
- Select Columns: F2
- Change “Data Type” to “Char”
- Change “Width” to “255”
- >Modify
- >OK

- >OK
- b. Add “Driver do Microsoft Access (*.mdb)”
 - Double click driver
 - >Data Source Name: VWSDB
 - >Select Directory: disk drive location of Access file in pasted folder
 - >OK
- >OK
- 3. Double click “VWS.exe” in pasted folder

Upload Templates

The users have responsibility of maintenance of four source files for data absorption.

- 1 Run pre-set enquiries in ERP system
 - a. fl_razorlist.csv
Source file: MMDQRY, Source library: FUNG1
 - b. pep.csv
Source file: MMDQRY, Source library: QQ_PEP
 - c. allco.csv
Source file: MMDQRY, Source library: FCST_FUNG
- 2 Download enquiries as Excel comma separated variable (csv) files
- 3 Check the data content as the following:
 - a. fl_razorlist.csv
 - > Delete the duplicated record sets
 - > Align “Resource Class” records only being 36 or 46 Temporary solution: resource class is defaulted as character but not integer
 - b. allco.csv
 - > Delete the duplicated record sets (customer orders) Temporary solution: add more key of record in the database (“Balance”)
 - > Delete all “ ‘ ” in the record sets (description mainly) Temporary solution: >Edit, >Replace: Find what: (‘) Replace with: ()
- 4 Update tempBOM.csv file:
 - > Open pep.csv file
 - > Rearrange columns of records as the following order
9th column “PMNAME”, 1st column “RES”, 2nd column “RMDESC”, 5th column “FILE”, 7th column “REF”, 8th column “PMTYPE”
 - > Delete other excluded columns of records
 - > Delete the duplicated record sets of “PMNAME”
 - > Save as tempBOM.csv

(see procedure.doc)

Users Input

1 Log In Interface

Password: Key in password (N/A)

2 Selection Interface

Convert: Convert fresh Excel files into system, * files must be pasted in the folder
Display: Display the latest converted files in the system
Select D: Select one or more resource to display DRP table
</>: Page up / page down for further resource selection

3 Detail Interface

Margin: Key in upper / lower margin of MOS for tolerance change
Preferred MOS: Key in preferred MOS index for suggestion
Exit: Close DRP table without save