A Decision Support Module for ERP System under VMI Collaboration

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Abstract—This paper is inspired by a real case, which occurred in a fastener manufacturer that provides VMI (Vendor Managed Inventory) service to a client that produces IT products. Under the VMI collaboration model, the electronic purchase order (ePO) provided by the client are usually very diversification, and sometimes, a numbers of demand items will be cancelled and/or terminated forever suddenly. This situation will yield many inventory management problems. In this study, a decision support module for ERP system is designed. It is a module embedded with Data Mining (DM) technology. By analyzing ePOs given from the client, correlations among demand items of the client would be detected, and the demand structure of the client would be established. The discovered demand associations among items were further utilized to build a virtual demand BOM for supporting the sales to create marketing strategies, to reduce risk of uncertainty from rolling forecasts, and may get more niches in the supply chain system.

Keywords—Vender Managed Inventory; Enterprise Resource Planning; Data Mining, Rolling Forecasting

I. INTRODUCTION

A. The Background

In recent years, in order to reduce inventory cost and to integrate supply chain resources, a growing number of firms have started to take advantage of an approach called Vendor-managed inventory (VMI). VMI, also known as continuous replenishment or supplier-managed inventory, is one of the most widely discussed partnering initiatives for encouraging collaboration and information sharing among trading partners. Most VMI studies focus on how it is to be on buyer's side. Those studies emphasize the advantages of applying VMI into supply chain; reveal various theoretical analyses and research based on organization adjustment, workflow design, and information system design and performance indicators [1][2][3][4]. This study, however, sets the seller who implements VMI corporation model, as the study object. Through the observation of fastener industry in Southern Taiwan and of other customers of VMI corporation model, the study has identified with some issues derived from VMI corporation model. So as to confront such issues, a supply and demand decision support module for Enterprise Resource Planning is generated.

Take the fastener industry in Taiwan as an example, IT electronic manufacturer (i.e., the buyer) will require a fastener manufacturer (i.e., the supplier) to provide VMI corporation model. The fastener manufacturer (i.e., the supplier) needs to take the initiative to access to electronic purchasing orders (ePO) (as shown in Figure 1) to receive information given by the electronic manufacturer (i.e., the buyer). There are four types of rolling ePO information to the fastener manufacturer:

- 4-week firmed purchasing order (inventories should be delivered within 4 weeks, but most of the time delivery must be made within 2 weeks)
- 12-week forecasting purchasing order (supplier's preparation stocking based on demand forecasting)
- Emergency purchasing order (irregularly released and immediate delivery is required)
- Cancelled purchasing order (firmed purchasing orders in previous period but are cancelled in this period)

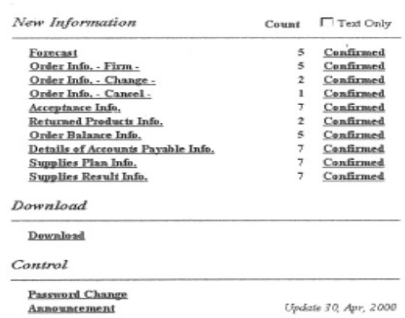

Fig. 1. Electronic Purchasing Orders under the VMI Model

B. The Problem

A 4-week firmed purchasing order, together with 12 weeks demand rolling forecasting, totally there are 4 months for an order to be completed, which is fairly long enough for the fastener manufacturer to make appropriate planning for production and supply. However, the estimation of every 2 weeks demand can fluctuate significantly from time to time and this problem might possibly be caused due to demand variability from IT electronic manufacturers (i.e., the buyers). The fluctuation of 2-week demand might also be caused by some randomly unpredictable factors from the IT electronic manufacturer (i.e., the buyer); even though in the same period, there will be a considerable degree of variation in orders' items and quantity that might effect on the fastener manufacturer (i.e., the supplier). As a consequence, at which reliability level of estimated demand can a supplier be relieved to produce stocks? Clearly, it is very challenging to give a certain answer to this question.

Comparing this kind of VMI based transaction model to the traditional non-VMI based transaction model where production only starts after orders are received, traditional transaction model seems to provide a relatively better safety level. However, when confronting buyers that ask for VMI services, the answers to how to deal with unstable demand and how to maintain a good business relationship with them are obviously very important.

C. *The Motivation*

Can we resolve the two problems through an ERP (Enterprise Resource Planning) system? The purpose of this study is to design a supply and demand decision support module, embedded into an ERP system (as shown in Figure 2). It is a module for analyzing supplier's rolling forecasting demand and the core concept for this module is listed as below:

- What are the associations among the ordering items and with their potential final products?
- What are the product structures of the ordering items?

Once the associations and structures of the ordering items are analyzed, the supplier can establish a virtual demand bill of materials (virtual D-BOM). The virtual D-BOM is considered as core decision support data based on which the fastener supplier can keep up with the buyer's constantly unstable demand. This makes it possible for the fastener supplier to identify in advance some problems caused by abnormal material demand. For example:

- One item belonging to a specific virtual D-BOM in previous period, but abruptly disappears from the virtual D-BOM in this period.
- Requested rates for a specific virtual D-BOM vary.
- A specific virtual D-BOM just disappears.

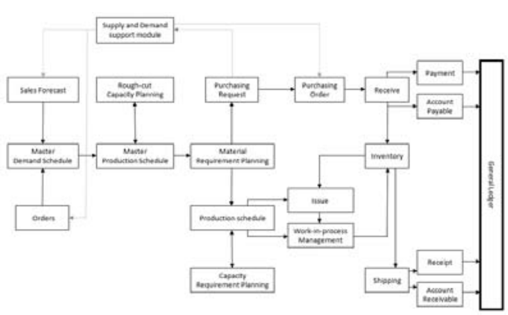

Fig. 2. Business resource planning module and supply-demand decision support module

The supply and demand decision support module described in this study can help suppliers observe the changes in customer demand mentioned previously. It also presents suppliers with helpful strategies referring production planning and customer behavior. Additionally supplier can tighten trading relationship and build loyalty with its customers by showing deep understanding into customer's item associations through virtual D-BOM. On the other hand, before creating shop flow production planning, suppliers can foresee the possibility of customer switching suppliers. As a result, the possibility of producing dead stock can be reduced; overinvestment and overproduction can both be avoided. Better sales forecast through virtual D-BOM can also help suppliers reduce transportation cost resulting from emergency orders.

II. The Virtual D-BOM Mining Mechanism inside the Decision Support Module

We designed a decision support module, called supply and demand support module. It is a tactic embedded ERP module developed for the following phenomenon. The phenomenon in fastener industry is that a customer usually orders different types of fasteners from a fastener manufacturer. Those fasteners usually utilized in several products. In other words, one customer product might require several types of fasteners. This implies associations among those fasteners. With rolling forecasting data, if we could identify those associations and build customer virtual D-BOMs, then better demand accuracy can be improved and dead stocks can be avoided. This is because that purchasing requests (PR) of the fastener manufacturer did not only be generated from MRP calculation but also referred the virtual D-BOM based supply and demand support reports. The detail design of the virtual D-BOM mining mechanism and virtual D-BOM based supply and demand support module is described in Figured 3.

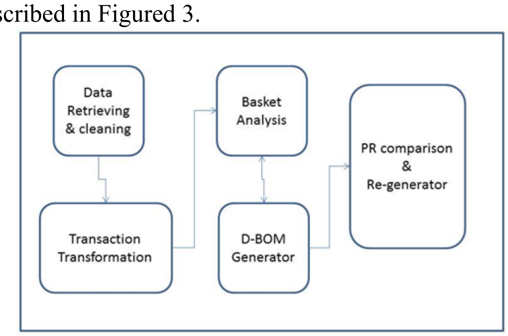

Fig. 3. Virtual D-BOM based Supply and Demand Support Module

There are five elements in the virtual D-BOM based supply and demand support module.

A. *Data Retrieving and Cleaning*

This element is in charge of retrieving sales forecasting data categorized by customers (buyers) and also cleaning inconsistency forecasting data (for example, product description, format of date, etc.) compared with the company's current ERP system. In a VMI based supply chain network, a company has to access each customer's ePO system periodically. Usually a customer would release a revised rolling forecasting ePO data every week. A rolling forecasting ePO normally includes release date, item number, delivery date, and delivery quantity. Table I. is a sample of customer rolling forecasting ePO. For analyzing purpose, all rolling forecasting data need to be distinguished by buyers. Therefore a buyer-embedded item number will be added to the rolling forecasting ePO.

TABLE I. CUSTOMER PURCHASING ORDER

Serial number	
Production date	
Product name	
Item number	
Unit quantity	
Delivery date	
Delivery quantity	

B. *Transaction Matrix Transformation*

In order to discover associations among items from buyer rolling forecasting ePO data, we need to transfer the data into a delivery date based transaction matrix (as shown in Table Ⅱ.). Each row on the transaction matrix represents customer order items (SKUs) in a specific delivery date. The second process of this transformation element is to prune some noise data. The following are the cases where data pruning must be applied:

- Data obtained during the first working day of each month:

  During the month, there are items that are seldom requested and only appear in a monthly time window. Also, material requirement planning (MRP) is often made at the beginning of the month and safety stock is often at its peak during this time. These explain why data obtained during the first working day of each month is always excessive and data pruning is indeed much needed."

- On one specific date, only one item is requested:

  Data pruning must be applied when data shows that only one item is requested on a specific date.

- A specific item is requested only once:

  The requested rate of item, that is requested only once, is very low which seems strange compared to other items in the table.

In current design, the delivery quantities in first three date of each month are pruned. Because there are some monthly planning items released from buyers' ERP system in those three days. For example, C class items (from ABC analysis perspective) are normally excluded in a MRP calculation, and are always planned in a monthly time window. Re-order pointed based items are other monthly planned items. This causes difficulty to discover associations among items.

TABLE II. DELIVERY DATE BASED TRANSACTION MATRIX

Delivery date	YYYYMMDD	YYYYMMDD
SKU	Qty	Qty
SKU	Qty	
SKU		
SKU	Qty	Qty
SKU	Qty	
SKU	Qty	
SKU		
SKU	Qty	Qty
SKU	Qty	

C. *Frequency Matrix Generator*

This element is in charge of transferring a transaction matrix into a frequency matrix. The transfer logic behinds this element is basket analysis. There are three indexes utilized in the basket analysis to evaluate if there is an association among some items. One is minimal support, another is minimal confident, and the other is minimal improvement. The transaction occurring frequencies, which are over those three indexes, are filtered. Based on those filtered occurring frequencies, a frequency matrix (as shown in Table VI of case study) could be generated.

D. *Virtual D-BOM Generator*

This element is in charge of building demand bill of materials from frequency matrix. The procedures for building virtual D-BOM are:

Step 1: Identify the pairwise items that have the same occurring frequency.

Step 2: Group items with the same occurring frequency into a single level virtual bill of materials

Step 3: Identify the lower occurring frequency item in pairwise items that does not have the same occurring frequency.

Step 4: Generate other lowest level virtual D-BOM, and potential virtual D-BOM.

Step 5: Transfer frequency matrix into a lowest level virtual D-BOM frequency matrix.

Step 6: If still possible, go back to Step 1.

Using data mining technique makes it possible to drill out customer's rolling forecasting of associated items. Consequently, supplier can establish item association table inferring from the number of times items are simultaneously requested. Data from item association table can then be summed up into virtual D-BOM (as shown in Figure 8 of case study).

E. *PR Comparison and Re-Generator*

This element is in charge of adjusting the purchasing requests (PRs) generated from MRP calculation. Since MRP calculation considers dependent items directly from independent items, the correlations among independent items are neglected. This element would compare PRs with buyer virtual D-BOMs to generate a negative correlation report for decision-making of purchasing orders. A production planning and purchasing requests decision are cases usually made on a rolling horizon basis. That is, a production planning and purchasing requests are made for a fixed number of periods for which the demand is known. The first production and purchasing decisions are implemented and the horizon is rolled forward to the period where the next production and purchasing decision needs to be made. With rolling forecasts one keeps a finger on the pulse of changing conditions and can quickly refocus the business accordingly, for example, decisions on which projects to scrap and which to invest in can be made timeously.

III. CASE STUDY

The design of the proposed module has been validated by a real world case. It is a fastener manufacturer located in south Taiwan. The major products of the manufacturer are to computer, communication, and consumer electronics manufacturers. Multinational manufacturers such as Panasonic, SONY, Brother, RICOH, HP, Canon, ASUS, etc. are its direct or indirect customers. An illustration of sales channels is shown in Figure 4. As we can see, their products are distributed either through brokers to IT manufacturers or through direct sales to IT manufacturers.

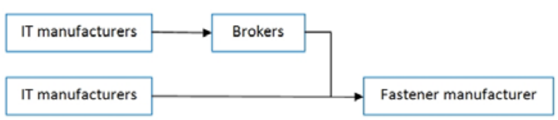

Fig. 4. Sales Channels

Those international wide customers integrate their supply chain network companies and cooperate with them via their ERP systems. Under the VMI based supply chain management agreement, the manufacturer or its brokers have to provide an online purchasing order system so that suppliers can access, retrieve, and reply their online purchasing order (PO) every two weeks.

In this case, a two-weekly ePO normally has several hundred demand rolling forecasting transactions starting from the very first data source of the transactions, which include around 10 to 100 different purchasing items, and around 40 to 50 different delivery dates. Each customer's demand rolling forecasting fields have different formats; however their key fields are similar (see Table III):

TABLE III. DEMAND ROLLING FORECASTING TRANSACTION SAMPLE

Serial number	Production date	Product name	Item number	Unit quantity	Delivery date	Delivery quantity
16734	20110427	TAPTITE,CUP S M4X14	T002	1000	20110610	2000
16735	20110427	TAPTITE,CUP S M4X14	T002	1000	20110627	3000
16736	20110427	TAPTITE,CUP S M4X14	T002	1000	20110706	2000
16737	20110427	TAPTITE,CUP S M4X14	T002	1000	20110801	5000
16650	20110427	SCREW	T003	1000	20110606	1000
16651	20110427	SCREW	T003	1000	20110701	1000
16652	20110427	SCREW	T003	1000	20110801	2000
16311	20110427	TAPTITE,BIND S M3X10	T004	2500	20110628	2500
16312	20110427	TAPTITE,BIND S M3X10	T004	2500	20110719	2500
16333	20110427	SCREW4X26	T005	500	20110712	1000
16738	20110427	BOLT,(S/P WASHER) M5X12	T006	500	20110609	3000

A. *Data Retrieving, Cleaning and Transaction Matrix Transformation*

In order to gather all items that have the same delivery date so that support and confidence calculation of items can be obtained, data must be processed through the first step where delivery date is set as a key dimension for ePO to transform into a transaction matrix.

Each buyer provides a demand forecasting date every 31 to 120 days, mainly after they start to establish MRP. In this supply study case, there are around 527 set of data in a single cycle, distributed in 43 request date, including 95 item types. In order to do basket analysis, data must be also transformed to a binary transaction matrix. After that, use "0" and "1" to represent if an item is not requested or requested respectively, as shown in Table IV.

TABLE IV. BINARY FORMAT TRANSACTION MATRIX

request date	T002	T003	T004	T005	T006	T007	T008	T009	T012	T013	T015	T016	T017	T026	T027	T028	T029	T030	T033	T035	T036	T037	T038	T039	T044
20110530										1								1							
20110601						1			1		1			1		1			1			1	1		1
20110602										1		1						1	1						
20110603									1					1	1									1	
20110606		1																							
20110607											1											1	1		
20110608																									
20110609					1	1			1	1				1		1		1				1		1	
20110610	1																		1						
20110613											1										1				
20110615															1										
20110616						1			1	1	1			1				1	1				1	1	1
20110617																				1					
20110620							1	1								1						1			

The previous transformation into a transaction matrix includes 95 item types distributed on 43 request dates. After all data are processed through three data pruning conditions, the remaining data include 364 requests, 77 item types on 34 request dates. If these above cases still happen after the first data pruning, then data must be again processed from the first step to the third step. Such pruning data action is very burdensome and actually it can be complete by computer programming.

B. *Frequency Matrix Generator*

After all data has gone through data pruning process, basket analysis will be executed to drill out the correlation between items. 77 cases met all constraints, as shown in details in Table V.

TABLE V. RULES DRILLED BY BASKET ANALYSIS

Rule #	If...	... then	Support,(%)	Confidence	Improvement
1	"T026"	"T012"	20.59	1	4.86
2	"T012"	"T026"	20.59	1	4.86
3	"T030"	"T013"	23.53	1	4.25
4	"T013"	"T030"	23.53	1	4.25
5	"T053"	"T012"	11.76	1	4.86
6	"T053"	"T013"	11.76	1	4.25
7	"T053"	"T026"	11.76	1	4.86
…	…	…	…	…	…
…	…	…	…	…	…
73	"T012"	"T125"	20.59	1	4.86
74	"T125"	"T026"	20.59	1	4.86
75	"T026"	"T125"	20.59	1	4.86
76	"T053"	"T125"	11.76	1	4.86
77	"T090"	"T125"	11.76	1	4.86

As seen from Table V, there are pairwise items that meet all constraints and have the same occurring frequency (confidence ratio between the two items reach 100%). For example in Rule 1 and Rule 2: confidence ratio between T026 and T012 is 100%. On the other hand, case 77 has P (T090|T125) = 100%, however there is no rule in the table that shows P (T125|T090) = 100%. The reason is that in buyer's product structures, when T090 appears in order, it must be accompanied with T125; however, T125 can be accompanied with another item type which may not be T090.

C. Generate Virtual Demand Bill of Material

In Table VI., the items' occurring frequency matrix represents the number of same occurring frequencies of two matched items.

TABLE VI. ITEMS' OCCURRING FREQUENCY MATRIX

		T002	T004	T007	T008	T009	T012	T013	T015	T016	T017	T026	T027	T028	T030	T033	T035	T036	T037	T038	T039	T044	T048	T049	T052	T053
		3	2	5	4	4	7	8	8	3	2	7	2	6	8	7	2	3	6	5	7	4	3	2	2	4
T002	3	3														1				1			1			
T004	2		2		1	1			1		1								1		1	1				
T007	5			5			4	3	2			4		2	3	2			2	2	2	2				3
T008	4		1		4	2			2				1	1			1	1	1		1		1	1		
T009	4		1		2	4			1		1			1					1		1	1				
T012	7			4			7	5	2			7	1	3	5	4			3	2	4	2			1	4
T013	8			3			5	8	1	1		5		2	8	6			3	2	4	2			1	4
T015	8		1	2	2	1	2	1	8			2	1	2	1	1		1	1	3	2	1	2	2		1
T016	3							1		3					1	1		1								
T017	2		1			1					2								1			1				
T026	7			4			7	5	2			7	1	3	5	4			3	2	4	2			1	4
T027	2				1		1		1			1	2								1		1	1		
T028	6			2	1	1	3	2	2			3		6	2	1			2	1	2				1	2
T030	8			3			5	8	1	1		5		2	8	6			3	2	4	2			1	4
T033	7	1		2			4	6	1	1		4		1	6	7			2	2	3	2	1		1	3
T035	2				1												2	1								

Highlighted pink numbers represent the number of same occurring frequencies of items with another items. For example, Item T026 on the horizontal bar and Item T012 on the vertical bar each occurs 7 times, the number of same occurring frequencies between them is also 7 times, which means that the confidence ratio among two items is 100%: P (T026|T012) = P (T012|T026) = 100%

Non-highlighted blue numbers represent the number of occurring frequencies of items whose support ratio is 100%. For example, Item T053 on the horizontal bar occurs 4 times; as it occurs, Item T012, T013, T026, T030 also follow to occur. It means that when T053 is requested, T012, T013, T026, T030 are also requested; so that P (T012|T053) = P (T013|T053) = P (T026|T053) = P (T030|T053) = 100%. However, when Item T012, T013, T026, T030 are requested, it does not necessarily mean that T053 is also requested.

Based on analysis results, data that does not meet constraints (support ratio less than 8% and confidence ratio less than 99%) must be eliminated, so as to generate into frequency matrix. From the frequency matrix, we can see clearly the association relationship among items.

Generate the single level virtual D-BOM:

From Table VI, we can categorize 5 groups of items whose confidence ratio is 100%. Items that belong to the same group are requested on the same requested date (as shown in Figure 5).

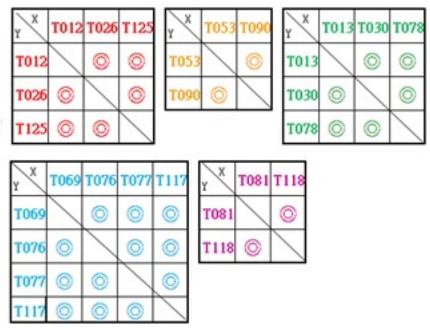

Fig. 5. Completely Correlated Items

Based on categorized result as shown above, we can configure the following 5 possible single level virtual D-BOM wherein items are completely correlated, as shown in Figure 6.

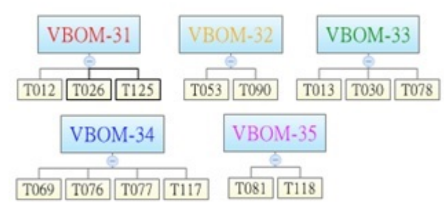

Fig. 6. Single Level Vitural D-BOM

Again from Table VI, we can categorize groups of items whose support ratio is 100% to generate the lowest level of D-BOM-36. Item T094 can become one of D-BOM-36 components to make another level virtual D-BOM, as shown in Figure 7:

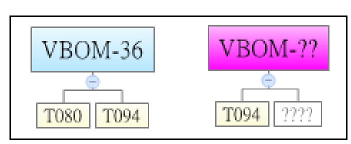

Fig. 7. Another Level Virtual D-BOM

Generate another level of virtual D-BOM:

Data obtained from the lowest level virtual bill of materials that include 5 groups of completely correlated items (confidence ratio = 100%) together with other D-BOM data can be generated as a group. As a result, we can refer to another frequency matrix to obtain a new pattern of frequency matrix, since data of the 5 groups of completely correlated items has been taken away. For example: D-BOM-34 occurs totally 7 times, which also include D-BOM-33's occurrence; therefore it can be assumed that D-BOM-34 and D-BOM-33 are likely to have mutual components. However, D-BOM-33 totally occurs 8 times, which means D-BOM-33 is likely to have mutual component with another D-BOM. Repeat the 6 virtual d-BOM generating steps, the final virtual D-BOM, as illustrated in Figure 8, can be generated.

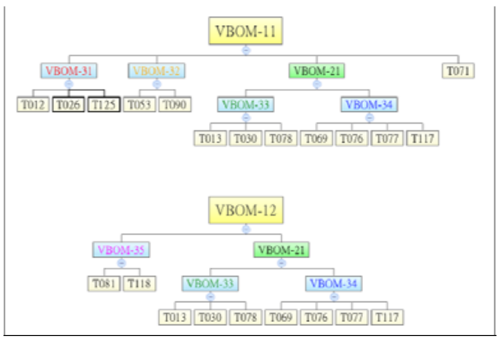

Fig. 8. Virtual D-BOM of the Case Study

The Decision Support Module:

Finally, a prototype of the VMI decision support module was designed as Figure 9. There are two sub-functions inside this module. One is D-BOM generator, and the other is purchase order checking. Given a time window of a specified VMI client (as shown in Figure 10), the D-BOM of that VMI client will be generated. Next time, when new purchase orders are going to be released, the fastener manufacturer can check if purchase order changes are required based on the comparison results of the D-BOM.

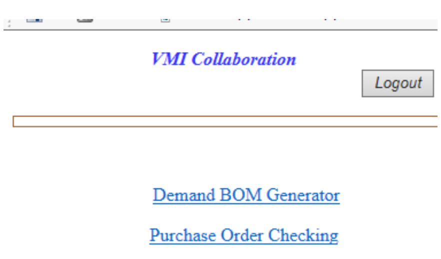

Fig. 9. VMI Decision Support Module

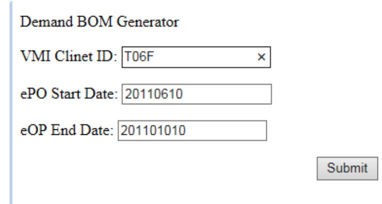

Fig. 10. Demand BOM Generator

IV. Conclusion

Some firms have successfully improved their supply chain performance by implementing an approach known as Vendor Managed Inventory (VMI). With VMI, the vendor specifies delivery quantities sent to customers through the distribution channel using data supported by information technologies, for example EDI. Vendor Managed Inventory, Just in Time (JIT) Distribution, and Efficient Consumer Response (ECR) all refer to similar concepts, but applied to different industries. For example, the grocery and apparel industries tend to use ECR, whereas the automobile industry tends to use VMI and JIT distribution.

VMI reduces stock-outs and reduces inventory in the supply chain. It can be made to work, but the problem is not just one of logistics. VMI often encounters resistance from the sales force and distributors. Its issues can be roles and skills, trust, and power shifts. For a VMI system to work, the concerns of distributors and sales force must be addressed. This study addressed a case study about how to transform the sales role into one of marketing.

In this study, the VMI approaches, for instance, rolling forecasting, of a fastener manufacturer are described. A data mining approach for analyzing demand associations from customer rolling forecasting based orders is proposed. The discovered demand associations among items were further utilized to build a virtual D-BOM for supporting the sales to create marketing strategies, to reduce risk of uncertainty from rolling forecasts, and may get more niches in the supply chain system.

Acknowledgment

This work is supported in part by the Ministry of Science and Technology of Republic of China under the grant MOST 103-2221-E-327-038.

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BIOGRAPHY

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