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ARTICLE

Development of an expert system for demand management process

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ABSTRACT

In a competitive environment, companies need to respond to customers faster. Knowing what customers exactly want may enable firms to plan more accurately. Hence, synchronising demand and supply is important for order processing to achieve responsiveness. This study focuses on demand integration practices and is carried out at the office furniture factory. Considering the integration of customer and supply chain strategy, a web-based expert system (ES) is developed in this study. Moreover, database of enterprise resource planning (ERP) of factory is integrated to the web-based ES in order to take account of availability of materials and capacities. The developed ES captures the customers' requirements in a consistent manner and compares them against the specifications of product inventory on hand. If there is a need, it evaluates factory capabilities in order to decide to manufacture or not according to the requested due date and then, it can generate new alternative due date when there is no feasible schedule for the requested due date. Moreover, the proposed web-based ES can order new product on ERP of factory at the distant retailer to fulfil the customer's needs comparing production planning schedules. As a result, improved order fulfilment is expected in terms of quantity, speed, lower inventory levels and increased flexibility.

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1. Introduction

Knowing what customers exactly want may enable firms to plan more accurately. By providing a close relation with customers for demand management, companies could ensure the efficiency of flows throughout the entire supply chain. Lee, Kut, and Tang (2000) emphasise that the characteristics of the demand process and the lead time have a significant impact on obtaining reductions of inventory and cost.

Synchronisation between demand and production facilitates the planning of manufacturing. Jüttner, Christopher, and Baker (2007) proposed three integrative themes: managing the integration between demand and supply processes; managing the structure between the integrated processes and customer segments; and managing the working relationships between marketing and supply chain management. Coordinating all potential demands on manufacturing capacity through demand management conducts daily interactions between customers and company (Vollmann, Berry, and Whybark 1992). Demand management can be interpreted as a firm's capability to understand the customers' demand and requirements and balance them. An important component of demand management is finding ways to reduce demand variability and improve operational flexibility. Reducing demand variability aids in consistent planning and reduces costs (Croxton et al. 2002). Also, Ryu, Tsukishima, and Onari (2009) indicate that higher demand variability decreases the value of information sharing. Hence, demand information sharing plays a critical role to integrate customer demand into manufacturing.

In order to provide real-time demand information and inventory visibility, a smooth two-way flow of information from the customer interaction into manufacturer is necessary by utilising web-based integration. Note that the web makes easy to attain a vast amount of data widely available. While assisting the customer with a solution, it needs to fully understand both customers' need and company's capabilities. Therefore, appropriate questions should be asked to acquire the customer's requirements by sales person at the retailer in order to provide an exact match between demand and supply. However, sales person may not have the experience for the purpose and the customer may be kept waiting while the solution is being researched. Kadiri et al. (2016) indicate that the lack of qualified personnel and the lack of information on technology as being the major factors hampering innovation. Additionally, if there is the static inventory of finish products leading to increased carrying costs due to cancelled orders, efforts should also be made to dissolve them. Besides, manufacturer should obtain information from the retailer about the customer demand to help reduce uncertainties coming from demand process while planning and to generate feasible production schedules. At the point of integrating demand and supply, it is necessary to know the manufacturing capability to react to the customer needs. To satisfy all of the needs, in this study, a web-based expert system (ES) is developed as a prototype for demand management proses. Also, the database of enterprise resource planning (ERP) in the factory is integrated to the web-based ES in order to evaluate the static inventory, material and capacity for a solution. Moreover, the case study is carried out at the office furniture company in this study. The proposed ES captures the customers' requirements in a consistent manner and compare them with the specifications of product inventory on hand and investigates its manufacturability according to the desired due date of new

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demand information to satisfy the customer's needs. In this respect, the success of the manufacturing system, such as that improved order fulfilment in terms of quantity, speed, lower inventory levels and increased flexibility, is expected. It is obvious that synchronising demand enables automated system for evaluating real-time information and hence provides mechanism for better production plans and successful manufacturing system.

The paper continues with literature review. Following that, ESs and the developed process for the integrated demand management will be presented. In the next section, an application of synchronising between demand and supply is proposed and carried out at the office furniture factory. Finally, a conclusion is discussed in the last section.

2. Literature review

By integrating the demand and supply activities, companies can create competitive advantage. Therefore, most of the researchers investigated the web-based supply with demand integration and its influence on supply chain performance. For example, Frohlich and Westbrook (2002) collected random sample from UK manufacturers and services, and there was strong evidence that demand chain management led to the highest performance in manufacturing. Welker, Vaart, and Pieter (2008) examined the effect of business conditions on internal and external information sharing using a multi-case study among SMEs (Small Medium Enterprise). Their study showed that the role of information and communication technology is also limited in supply links in moderately complex business situations: catalogues are not available on the Internet, and timing issues are still largely discussed by phone.

Indicating business benefits, Zhou et al. (2014) examined two supply chain practices of sourcing and delivery as well as information quality and developed scales measuring them. This study showed that firms need to align supply chain practice with the level of their information quality in order to achieve good overall business performance. Additionally, Chong and Zhou (2014) expressed that web-based demand management implementation has also a significant impact on service innovation performance in organisations. Moreover, Gonzálvez-Gallego et al. (2015) studied to test the direct effects and the relationships of information technologies, employing the hierarchical multiple regression analysis with proposed research hypotheses. They used questionnaires for data collection and their results show that external and internal information and communication technology capabilities and integrated information systems are important drivers of firm performance.

Furthermore, Pillai and Min (2010) proposed a conceptual model for a firm's capability to calibrate supply chain knowledge. Although this study emphasises determinations on the necessity to calibrate information, how to calibrate the knowledge of customer demand is not shown. For facilitating the detection of market opportunities, Fidel, Schlesinger, and Cervera (2015) regarded customer knowledge management as a strategic resource. They emphasised collaborating with customers within the innovation process according to the obtained results. But, their research model is established hypotheses; meanwhile, there is no web-based application on customer knowledge. Similarly, Khodakarami and Chan (2014) explored how customer relationship management systems support the internalisation process by providing learning opportunities. They used case study approach and interviews as the main technique for data collection. Their results reveal that organisations often do not make good use of their customer relationship management systems' capabilities to obtain knowledge from their customers. In addition to these studies, Cheng et al. (2016) proposed architecture for supply–demand matching based on complex networks. However, their study merely consists of road map. Although they present suggestions on how demand management might be such as task analysis, digital description, database, artificial intelligence and reasoning, there is no any application on web-based integration in their study.

Most of the studies in literature as mentioned earlier focus on signification of information sharing for synchronisation supply and demand and effects on business performance. However, the realisation of this integration with web-based applications still need more attention and research. Although the web-based applications have their own advantages, the literature review shows that there are still few studies on this subject. Some research along this line is already being carried out as summarised below.

Chengalur-Smith, Duchessi, and Gil-Garcia (2012) examined information sharing via the web-based supply chain application known GEOPS (GE Operations), developing questionnaire. It stores data about supply chain participants and their activities in a centralised database and makes it readily available to participants through a web browser. But, this application does not consists of individual customers. Moreover, although GEOPS is capable of connecting companies in any arrangement, most companies prefer to implement just a dyadic connection, limiting visibility to just their immediate suppliers/customers. Similarly, Thimm and Rasmussen (2013) presented a conceptual framework and a rule-based approach for business networks. They aim to automate information provisioning to the network participants. Information provisioning in their research means that when certain expected events occur, information is automatically provided to subscribers. Informed firms know about the resources and competences of other firms too, and may wish to engage them in co-production networks, through alliances and strategic partnerships. While this study focuses more on inter-firm collaboration, it misses individual customers.

Furthermore, Zhou et al. (2013) presented a method to analyse customer requirements from the perspective of information. In their proposed method, it benefits from the enterprise web page to offer customers product information. When customer finishes the selection, the enterprise will record their options in its database and send feedback to them. The online chat tool on enterprises' websites provides customers with a real-time communication channel. However, it mainly focuses on customer-facing functions and neglects manufacturer' capacity to fulfil customer demand.

Moreover, Saha et al. (2016) developed an ES for customer order management. This study identifies the attributes and their importance to prioritise orders, predict order completion time and quantify strategic and operational levels risk indices for a capacity-constrained supply chain stage. It provides a prioritised order list for an individual brand based on its own goal, order due dates, shipping destination, level of complexity and customer satisfaction criteria. However, their study does not consider inventory and resource constraints of the channels while prioritising orders.

It is seen that the previous studies reveal that companies often do not make good use of their systems' capabilities to obtain knowledge from their customers. Mostly, it is communicated by phone, faxing or direct contact between the two parties to discuss issues such as the technical production possibilities, the suitability of products and especially possible delivery times. A contribution of this study is to improve customer relationship processes enhancing collaboration with customers by interacting mechanism of ES. The answers by the customers to the questions are compared with the specifications of the products in the inventory for a possible match before ordering a new product from the factory. At the same time, with the developed ES, it is provided to capture the customer's requirements in a consistent manner without overlooking by a sales person. Note that the number of studies involving web-based applications in literature is scarce. The most important contribution of this paper is the link between the manufacturer and the customer with web-based integration. The customer can be guided by real-time information from factory. Also, real-time flow of demand information to company facilitates activities of manufacturing planning and proper use of resources. Better interaction with their customers enables to avoid both customer loss and adaptation to existing production plans. In this paper, customer at the retailer is integrated to the manufacturer with web-based ES. Unlike the previous studies, the capacity and material constraints are taken into account while accepting new orders in this paper. Although the aforementioned papers do not consider generating due date taking into account company capabilities, the developed ES suggests a new due date to the customer according to availability in the factory when there is no suitable the delivery time requested by customer.

Another contribution of this study is that the customer order is created automatically on the ERP database via web-based ES at the distant retailer when the customer accepted the suggested new due date by ES. Similarly, shipping order can be created automatically on ERP database at the distant retailer, when there is product inventory. In this manner, this study provides the valuable coordination mechanism to create a mutually beneficial supply chain system for both the company and the customer.

3. Expert systems

ESs or knowledge-based systems are programmes that emulate this decision-making process instead of a human expert. They are computer programs embodying knowledge about a narrow domain for solving problems related to that domain. Figure 1 illustrates the basic concept of a knowledge-based ES. Knowledge acquisition involves the acquisition of knowledge from human experts, books, documents, sensors or computer files (Turban, Aronson, and Liang 2005).

The knowledge base as seen Figure 1 is the part of an ES that contains domain knowledge which may be expressed as

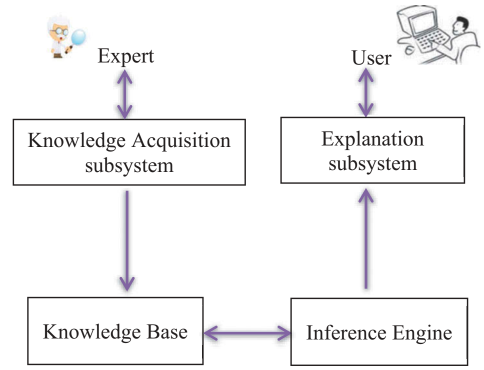

Figure 1. Basic structure of an expert system.

any combination of 'IF–THEN' rules, factual statements, frames, objects, procedures and cases. The inference mechanism manipulates the stored knowledge to produce solutions to problems (Pham and Pham 1999). The inference engine uses the rules to automatically determine what information is needed, the implications of various facts and arrives at a logically reasoned conclusion. It interprets knowledge in the knowledge base and makes reasoning among knowledge rules. Explanation is an attempt by an ES to clarify its reasoning, recommendations or other actions, e.g. asking a question.

An ES is built to perform at a human expert level in a narrow, specialised domain. Thus, the most important characteristic of an ES is its high-quality performance (Negnevitsky 2002). More, in certain cases, an ES attempts to integrate the opinions of several experts and hence may increase the quality of the advice. In addition to these advantages, the knowledge base of an ES (Turban 1995) is easy to maintain and it can be modified when something new is learned; therefore, the system is relatively inexpensive to maintain.

At the development stage of this study, the ES shell named Exsys Corvid was used as an ES development tool. Exsys Corvid is a very powerful environment for developing knowledge automation systems. It allows the logical rules and procedural steps used to make a decision to be converted to a 'rule' representation (Exsys, 2010). Moreover, this shell allows the web which has become the primary communication channel with customers in order to provide automated interactive systems. Hence, through Internet, updated information on database can be reached in order to make correct evaluations. In this study, the developed web-based ES using Exsys Corvid is integrated to the database of ERP of the case factory in order to evaluate actual company capabilities.

4. The developing process to integrate demand with manufacturing system

Effective demand integration provides efficient flow throughout the supply chain. For companies, it is important to sustain master production schedule with minimum deformation and obtain more customers without affecting capacity and utilisation negatively. Figure 2 shows the relationship between the receipt of the accurate demand knowledge and the manufacturing system's success. If consistent customer demand information does not flow, the company will not be able to

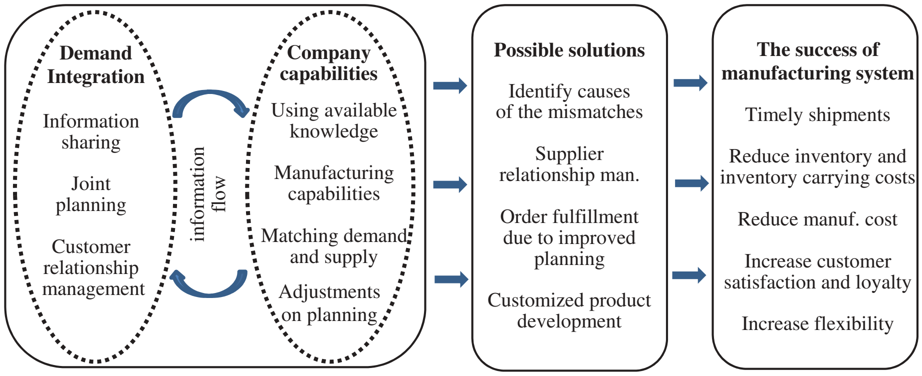

Figure 2. The impact of demand integration on the manufacturing system's success.

respond to differentiated needs. When demand exceeds supply, it can be either encouraged supply or discouraged demand. It requires understanding the level of demand and matching with manufacturing speed.

Manufacturing and sourcing plan is developed, identifying causes of the mismatches and providing better supplier relationship as possible solutions (see Figure 2). Because determining the requirements back through the supply chain enables to realise manufacturing operations in the right place at the right time. Corrupted information about demand visibility and factory capabilities can lead to misguided capacity plans, missed production schedules, redundant inventory investment and loss of customers. Therefore, firms should be more responsive to their customers providing balance between demand and supply. Demand integration aids to enable consistent planning and fewer inventories, and hence reduces time and costs, increase customer satisfaction and loyalty as well as flexibility.

Due to the reasons explained earlier, companies need to synchronise dynamically customer demand and manufacturing capabilities building the right customer relationships. Also, considering successful demand integration is related to information technologies, ES technology is used in this study taking into account most manufacturing decisions require expert knowledge on how to understand and use the data to make decisions. Figure 3 demonstrates the proposed structure. The developed ES evaluates dynamic data which changes according to customer request using sales and manufacturing data. The domain knowledge is represented in a collection of production rules in 'IF–THEN' form, and the data about the current situation are represented by a set of facts. The inference engine is responsible for comparing each rule in the knowledge base with the fact in the database. Note that enterprise resource planning called ERP system is information system in the manner of enterprise wide which contains all data for software modules, such as manufacturing, distribution, purchasing, warehouse management and finance. This study presents web-based interaction with ERP database in the manufacturing company in order to evaluate material and capacity constraints to satisfy the demand. This is so significant for indicating the ability of the company to generate feasible production schedules. Another important aspect of the proposed structure is customer satisfaction. In this way, firms can be responsive to fast-changing customer preferences. Also, by using developed ES, even sales people with less technical training can field a customer inquiry using the questions built into the system.

Taking into account answers of customers according to defined rules within the knowledge base in ES as well as database of ERP, it helps users to supply product with the desired attributes. These attributes are listed in options and will act as the guidance for the user. When the selection process is completed, it is investigated from static product inventory in its database and sends response to the users. If there is a need, the manufacturing decision is evaluated for related product. Also, according to the condition of factory

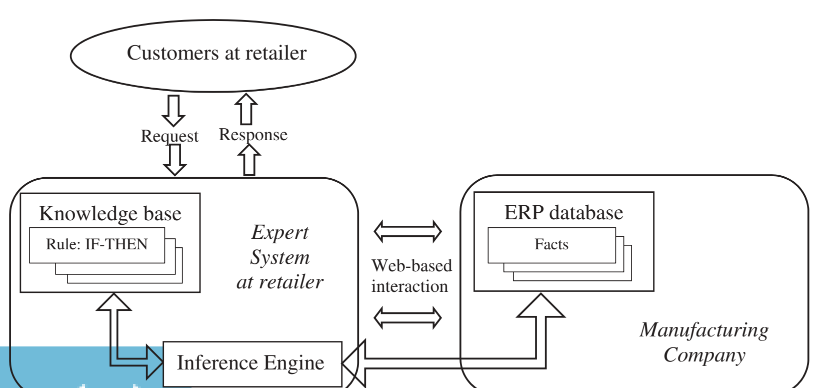

Figure 3. The proposed structure to integrate demand with manufacturing system.

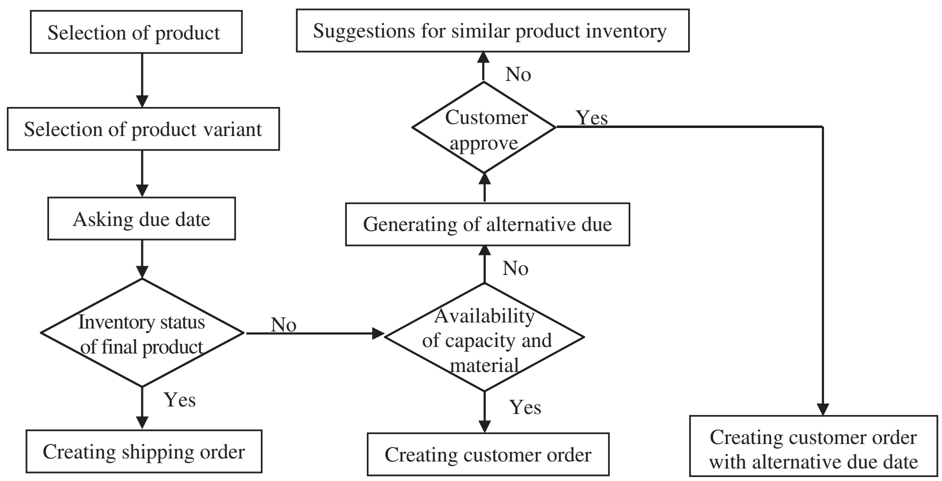

Figure 4. The flow diagram for integrating demand to manufacturing on web-based ES.

capacity, alternative due date to be presented to the customer can be generated. Figure 4 illustrates the flow of this for demand management integrated manufacturing.

The decision process of web-based ES is listed as follows:

- The chosen product, features for related product and requested due date are asked to the customer, and a new session is started for the customer.
- If there is any inventory of that product, the product would be sold to the customer creating shipping order automatically via web-based ES at the distant retailer.
- If there is no inventory of product, appropriateness of the requested due date of order is analysed. In that sense, firstly, it should be investigated whether having sufficient capacity and material to satisfy the requested customer requirement such as due date and quantity. This is necessary for the rough cut capacity planning in the master production scheduling. The condition for checking capacity feasibility is as follows:

$$\sum_{1 \in I_t} xs_i \leq C_t, \qquad \text{for every } t$$

Let $I_t = \{i|li = t\}$, which contains all the orders with due dates in week t. Each order consumes the capacity in the last period that could be used to produce. Let x_i be the demand quantity of order i and s_i the standard time required by a single unit item of order i. The available capacity limits the expected output capability of a work centre or calculated capacity, that is, the demand quantity of order multiplied by the corresponding standard times per unit. If the required capacity is greater than the available capacity, this leads to a bottleneck, that's for; constraints can take the form of limited capacity.

- In subsequent flow, the statement is evaluated which is too much demand relative to capacity at a given time. If factory capabilities are not balanced with demand, alternative due date is generated assigning the expected demand to the coming planning period and then asked to the customer for approval.
- If the given convenient date as alternative due date is accepted by the customer, the customer order is created automatically on the ERP database via web-based ES at the distant retailer.
- If the customer does not approve alternative due date, similar products in inventory according to customer requirements are suggested to the customer.
- If customer does not approve these suggestions, appropriate orders and related customers of them are determined for the same product requested by customer in order to investigate alterability of due date.

This developed expert system also provides to increase the utility and benefit gained from ERP. In addition to that, running different algorithms on database and integration results of algorithms with ES expands the consideration perspective in the proposed system.

5. An application of ES for integrating demand and supply

This study is carried out at the office furniture factory. The enterprise has two main product groups. One of the groups is standard products whose specifications are defined by designers in factory, and the other group is customised products whose specifications are defined by customer. Of 1400 standard products, 328 have inconstant attributes like colour, width and length. So these products have 6276 variants that can be sold. Variants of these products have 51,227 different specifications in ERP database. Customised products are defined when a customer wants a new product and customising products causes increment of variants and product specifications in ERP database. Therefore, there is a need for mechanisms in order to support decision balancing between supply chain and sales operations in dynamic environment by integrating ES into the database. The proposed mechanism provides to

- place shipping order automatically from the factory on ERP through web-based ES when it is needed
- analyse requested due date of the new demand information for feasibility when there is no requested product in inventory
- generate new alternative due date, if the requested due date is not feasible
- place a new order automatically from the factory on ERP through web-based ES when it is needed
- present similar products in inventory for the same due date requested by customer
- determine appropriate orders and related customers who can be accepted alteration for related order.

This paper enables that customer demand is integrated to the production planning processes in the factory using Exsys Corvid which is ES shell. Customer orders are evaluated depending on the schedule of factory by sales staff at the retailer using web-based ES. That's for, ES asks to the user some questions such as product type, variant, due date. For example, firstly, it is expected to choose a product as shown in Figure 5.

After asking due date, a session is created for customer and then logic block for static inventory control is fired. Note that the knowledge base of the ES is created by using the logic blocks of the Exsys Corvid. If there is any inventory of product which customer wants, ES also can notify to user the earlier due date as an alternative. Then, after the approval of customer, a shipping order is created automatically for sales of product. If there is a new customer, it is necessary to add customer information into the ERP database before choosing the customer in ES. Hence, the knowledge of customer is chosen at the last step in ES.

If there is no inventory of product, ES considers production phase and runs production logic block. Production block looks for the following items:

- Is there enough materials?
- Is lead time for manufacturing feasible for due date?
- Is there enough capacity?
- If there are not enough materials to produce the product, is lead time feasible for procurement and manufacturing of related materials to begin manufacturing in time?

Figure 6 shows the logic block indicates the production knowledge base of ES. The numbers in Figure 6 such as 1 and 0 represent results of database query; 1 and 0 mean yes and no, respectively. If the necessary items such as capacity, material and lead time are enough, manufacturing of the product is feasible and approval block for sales is fired. After the approval of the customer, the customer order is created automatically on ERP database by ES at the distant retailer.

If lead time for supply and manufacturing is not feasible when there is no material of the requested product, alternative due date is generated and asked to the customer for approval. After the user answers, the results block is fired and order status is seen in the screen. Following this, order approval block is run. Then, customer accepts or rejects the order. If order is accepted by the user, the customer order is created automatically on ERP database by ES. On the contrary, if the customer does not approve alternative due date, ES is looked for similar products in inventory in order to present to the customer. If the customer chooses one of the similar products, the results and approval blocks for sales are fired.

When there is no similar product or the customer does not approve suggestions of similar products in inventory, it is investigated whether there is a customer who may be appropriate to change for the requested due date of customer orders. When appropriate customers are found, ES suggests the orders of customers which can be swapped for same products as a list in order to assist sales staff. Because, in that sense, it also can become important to prioritise among customer orders in order to satisfy the most important customers and to maximise profits. For this, the sales personnel would like to negotiate with the related customer about postpone of order having same product for a time period together with marketing activities such as a discount or free gift.

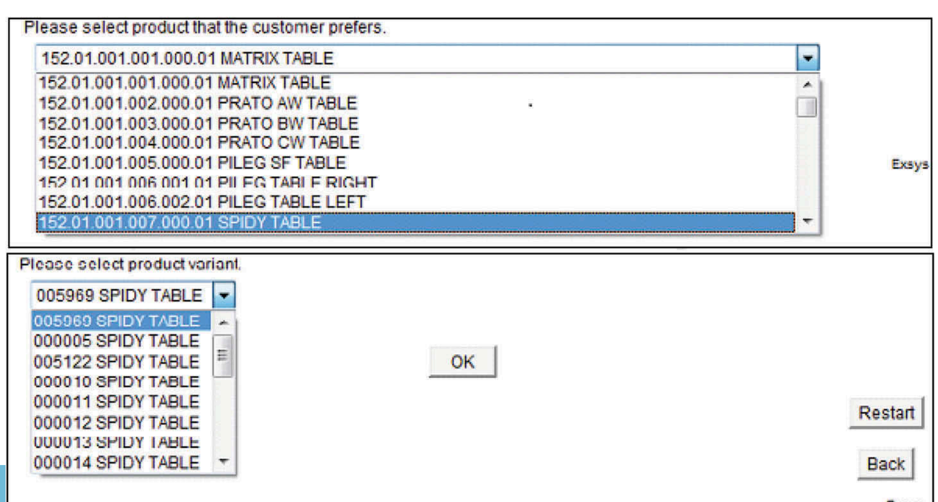

Figure 5. Customer query images on ES.

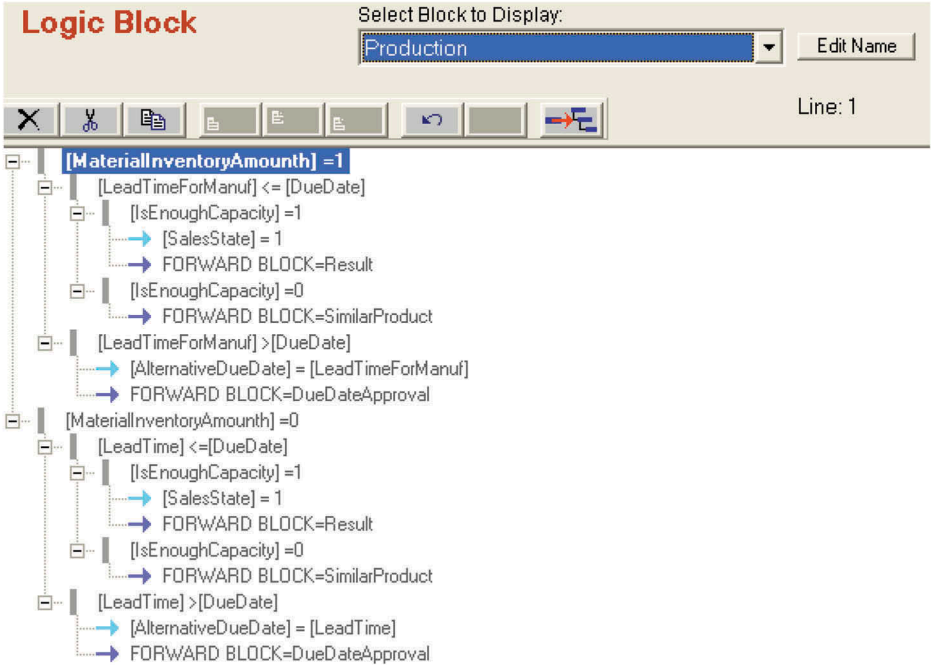

Figure 6. An example of the logic block.

In this study, eight logic blocks are created in Exsys Corvid to develop ES. Note that the knowledge base of the Exsys Corvid is created by using the logical blocks. Every logic block has its own ‘if–then’ rules and logic blocks are called from another logic blocks related to case. Generating combinatorial ‘if–then’ blocks provides more condition for consideration with less definition.

6. Conclusions

This paper includes the development of a web-based ES as a prototype integrating ERP database for demand integration. A smooth two-way flow of information from the customer interaction back into manufacturer is necessary in order to provide demand information and visibility of manufacturing requirements such as on-hand inventory, present and future material to meet the related demand. This study focuses on demand management practices and is carried out at office furniture factory. The proposed ES provides to

- capture the customers’ requirements in a consistent manner,
- compare them against the specifications of product static inventory,
- creating shipping order on ERP from the factory automatically at the distant retailer to fulfil the customer’s needs,
- evaluate for deciding to manufacture or not comparing factory capabilities,
- determine new alternative due date when it is needed,
- creating customer order for new product on ERP of the factory automatically at the distant retailer to fulfil the customer’s needs and
- suggest some possible customers that can be appropriate for postponing of their order when it is needed.

In other words, customer orders are evaluated depending on the schedule of factory by sales staff at the retailer using web-based ES. Companies can effectively produce product based on customer’s need with better demand visibility. Namely, they can handle their manufacturing operations to achieve economies of scale, and coordinate inventory replenishment to be sustainable. Providing proper use of the resources, the significant benefits from the system, such as improved order fulfilment in terms of quantity, speed, lower inventory levels, and increased flexibility and growing revenue, are expected.

This research can be extended in several directions. Firstly, this paper limits supply chain as a manufacturer and retailer taking into individual customers; hence, it can be expanded to include inter-firm integration involving suppliers. Secondly, this study can be extended by adding prioritisation of customer orders into the proposed ES. Finally, future research was able to develop new innovative products with better understanding of customer’s current and future needs and expectations enabling customer insight.

Disclosure statement

No potential conflict of interest was reported by the author.

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