A DECISION SUPPORT SYSTEM FOR INVENTORY MANAGEMENT

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ABSTRACT

Any manufacturing firm typically has thousands of parts that it deals with. Efficient production planning hinges on the right decisions being made at the right time. Each wrong decision costs the company very heavily in terms of money, labor, and other resources. One of the problems that production managers need to address frequently is the decision about which parts to manufacture in-house when the capacity is not enough to fulfill all the orders. The aim of this research was the development of an Integrated Inventory Ranking System for Inventory Management (IRSIM) that was based on an integrated inventory ranking procedure that takes into account both quantitative factors such as cost and demand, and qualitative factors such as importance, manufacturing expertise, causes for use and changing market conditions. The output reports that are generated by IRSIM aid the user in solving the problem of subcontracting vs. manufacturing in-house in manufacturing industries.

INTRODUCTION

Inventory management is important for the successful operation of most organizations due to the amount of money inventory represents. Inventories in a manufacturing plant are maintained either to support production or are the end result of production. No matter how well we predict the demand for various parts in a job-shop environment, in some instances, the production capacity may not permit the manufacturing of all the necessary parts within the specified time. In these circumstances, subcontracting becomes vital in order to avoid shortage costs and to maintain continuity in the manufacturing process.

Subcontracting is usually defined as "a situation where the firm offering the subcontract requests another independent enterprise to undertake the production or carry out the processing of a material, component, part or subassembly for it according to specifications or plans provided by the firm offering the subcontract" (Holmes, 1986). When the available capacity is not enough, a decision has to be made about what parts should be manufactured in-house and what parts should be subcontracted. The growing pressures of time-based global competition have led to the recognition of subcontracting as an important contributor to the competitive advantage of the firm (Stalk and Hout, 1990; Handfield, 1993; Das and Handfield, 1997).

Any manufacturing firm, regardless of size, has thousands of parts that it deals with. Efficient production planning hinges on the right decisions being made at the right time. Each wrong decision costs the company very heavily in terms of money, labor, and other resources. Extensive research has been done on the selection of suppliers or subcontractors and buyer-supplier relationships. For example, see Choi and Hartley (1996); Krause et al. (1999); Carr and Pearson (1999); Tayamaz and Kilicaslan (2000). However, in depth research in identifying which parts to manufacture in-house or subcontract is not common.

The major source of all knowledge regarding the existing approaches that help decide which parts should be manufactured in-house is from production managers working in the field and making those actual decisions. The most common approach being followed is to manufacture the parts for which deadlines are due and subcontract the ones that would not be possible to manufacture within the time frame. The problem with this approach is that the productivity of the plant decreases, because different setups are used for different parts.

Another approach that is being followed is to manufacture the parts that have similar setups to the part that is currently being manufactured, and subcontract the rest. The problem with this approach is that even though it increases the productivity of the plant, the inventory levels increase, thus increasing the costs associated with the inventory (Atamtürk and Hochbaum, 2001).

The third approach is to prioritize the inventory by using general inventory classification techniques like ABC, FSN, and VED methods and manufacture the parts that have the highest priority. The ABC classification (Russell and Taylor 1995; Martininch 1997) is used to rank the parts based on their dollar usage value. FSN classification is used to distinguish the fast moving parts from the slow and non-moving parts (Larson, 1980; Mukhopadhyay, et. al., 2003). VED classification is used to rank the parts based on their criticality. Classify the parts as Vital, Essential, or Desirable based on the functionality aspect and efficiency aspect of each part (Mukhopadhyay, et. al., 2003). The problem with this approach is that general classification schemes, when used in isolation, may not take into account all factors that should be considered while making such an important decision. Sometimes certain factors like dollar usage value, demand, importance, etc., are neglected by any single classification scheme. For example, ABC classification does not take into account the subjective importance of the part (i.e., the importance of the part in the eyes of the customer and in the manufacturing process).

To overcome the disadvantages of the existing approaches, a new technique needs to be developed that can rank the inventory based on multiple criteria and that takes into account both quantitative and qualitative factors. Once this technique is developed, there is a need to automate its implementation by developing a Decision Support System (DSS). A DSS is defined as a class of information systems that support decision-making activities (Holsapple and Whinston, 1996). Various DSS's that have been developed for inventory management deals with problem areas such as procurement, purchasing, and stock levels. Sadrian and Yoon (1993) developed a Procurement Decision Support System (PDSS) that can be used to improving the procurement practices of a company. Ronen and Trietsch (1988) developed a DSS for purchasing components and materials for large projects taking into account lateness penalties. Mukhopadhyay et al. (2003) developed a DSS for helping managers in decision making regarding stock control and calculation of reorder levels. None of these DSS's addresses the problem of Subcontracting vs. manufacturing in-house.

The objective of this research is to 1) develop an integrated inventory ranking procedure that takes into account both quantitative factors such as cost and demand, and qualitative factors such as importance, manufacturing expertise, causes for use and changing market conditions; and 2) develop a DSS called Integrated Inventory Ranking System for Inventory Management (IRSIM) that will implement the integrated inventory ranking procedure and thus help the production manager make the critical decision about what parts to make in-house and what parts to subcontract. The DSS can be used to generate various reports based on user-defined criteria that will help the production manager in selecting those parts for in-house manufacturing that best serve the company's interests.

INVENTORY CLASSIFICATION METHODS

The integrated inventory ranking procedure will make use of the ABC Classification, FSN Classification, and VED Classification. The other classification schemes are not needed as the combination of these three classifications takes into consideration both qualitative and quantitative factors. The ABC classification and FSN classification take into consideration the quantitative factors such as cost and demand; the VED classification takes into consideration the qualitative factors such as expertise, functionality, and efficiency. The following sections contain about the methodology followed for each of the classification techniques.

ABC Classification

The ABC classification ranks parts based on their dollar usage value. The general idea is that the high value parts are classified as A, the middle value parts are classified as B, and the lower value parts are classified as C. The procedure used to perform the classification entails the following steps:

1. Obtaining the quantity and the dollar usage of each item from the existing data.

   Dollar usage of each item = Quantity * Unit Cost
2. Arranging the data in descending order based upon the dollar usage values.
3. Calculating the % of dollar value for each item.

   % dollar value = (dollar usage value / total dollar usage value) * 100

4. Calculating the % quantity for each item.

   % quantity = (Quantity / Total quantity) * 100
5. Calculating the cumulative value of the percentages.
6. Classifying the top 20% of the parts as A, the next 30% of the parts as B and the remaining parts as C.

The cutoffs used in the procedure above are used as default the first time a set of parts are used. Managers may differ in the way they want to classify the inventory. So, the final decision about how the inventory should be classified as A, B, and C should be based on user input.

An example of ABC classification is shown in Table 1. The breakpoints are decided based on the %Cost, as the parts that have the high %Cost are classified as A, the parts having medium %Cost are classified as B and the parts having low %Cost are classified as C. The first 6.45% of the inventory is responsible for 71% of the cost and is classified as A. The next 58% of the inventory is responsible for 26.64% of the cost and is classified as B with the rest of the inventory classified as C.

Part number	Quantity	Unit cost	Total cost(Dollar usage value)	% Cost	Cumulative %cost	% Quantity	Cumulative %quantity	Class
1	10	200000	2000000	71.05%	71.05%	6.45%	6.45%	A
3	40	10000	400000	14.21%	85.26%	25.81%	32.26%	B
4	50	7000	350000	12.43%	97.69%	32.26%	64.52%	B
2	20	1500	30000	1.07%	98.76%	12.90%	77.42%	C
5	35	1000	35000	1.24%	100.00%	22.58%	100.00%	C
Total	155		2815000					

Table 1: An example of ABC classification

FSN Classification

FSN classification is used to distinguish the fast moving parts from the slow and non-moving parts. The general idea is that the parts having the highest demand are classified as fast moving and the parts having the least demand are classified as non-moving. The remaining parts are classified as slow moving. A similar idea based on the dynamics of the parts consumption is proposed by Kljajić et. al. (2004).

The FSN procedure used to perform the classification entails the following steps:

1. Obtaining the total demand for each part.
2. Arranging the data in ascending order based on the total demand.
3. Calculating the first and third quartiles (Q_1 and Q_3) as (n+1)/4 and 3(n+1)/4, where "n" is the number of parts, and interpolate as needed.
4. Classifying the parts using the following logic:

   If total demand > Q_3

   Classify as Fast Moving

   If total demand < Q_1

   Classify as Non-Moving

   Otherwise

   Classify as Slow Moving.

In this classification, Q_1 and Q_3 are used as default values for the cutoffs. The final decision about these classifications should be based on user input. For classifying the inventory as F, S, or N based on user input, the *Percentile* function of MS Excel can be used.

An example of a FSN classification is shown in Table 2. Here we see that the fast moving parts are those parts that have a total demand > 600, the slow moving parts are those parts having a total demand in between 400 and 600, and the non-moving parts are the ones with a total demand < 400.

Part Number	Total Demand	Category
1	50	N
2	400	S
3	500	S
4	600	S
5	1700	F

Table 2: An example of FSN classification

VED Classification

VED classification classifies parts as Vital, Essential, or Desirable based on the functionality aspect and efficiency aspect of each part. VED classification can also be used for other aspects of decision making such as taking into consideration the due dates and manufacturing setups if desired. This is a subjective decision made by the user and varies from part to part. An item is classified as Vital in any of the following circumstances:

- If the non-availability of the item shuts down the process completely and there is no standby unit as a spare.
- If the non-availability of the item completely reduces the efficiency of the manufacturing process.
- If the item is unique and/or the company involved is a world-class manufacturer of the item.

An item is classified as Essential in any of the following circumstances:

- If the non-availability of the item shuts down the process but a standby unit exists.
- If the non-availability of the item reduces the efficiency of the process.

An item is classified as Desirable in any of the following circumstances:

- If non-availability of the item does not affect the functioning of the manufacturing process
- If non-availability of the item does not significantly affect the efficiency of the process.

Once the three classifications are performed independently, a method for combining them needs to be developed. The different methods of combining the classifications along with their analyses are discussed in the next section.

INTEGRATED INVENTORY RANKING PROCEDURE

Every manager thinks differently and would want to combine the three classification techniques by giving priorities to each of the factors according to what he/she feels is appropriate. For instance, if a manager thinks that customer service is the factor of prime importance, then the classification that would be given the highest priority would be VED classification. In the same manner, if dollar values were considered as the most important factor, then the highest priority would be given to ABC Classification and if demand is considered to be the most important factor then the highest priority would be given to FSN Classification.

The notation that would be followed to indicate the priority levels for ABC, FSN, and VED classifications respectively is [ABC, FSN, VED]. If we consider three priority levels for the purpose of integration, then a total of 27 different combinations (3^3) are possible which can be generalized into 3 categories. They are:

1. Distinct priority levels for all classifications (e.g., [1,2,3])
2. Identical priority levels for all classifications (e.g., [1,1,1])
3. Mixed priority levels for all classifications (e.g., [1,1,2])

Further analysis is done on each of the above-mentioned categories so as to give a better insight into the kind of factors that need to be taken into account before deciding the priority levels.

Distinct Priority Levels

For the sake of analysis, consider the classification having the highest priority level as having the weights (300, 200, 100), the classification having the second highest priority level have the weights (30, 20, 10), and the classification that has the least priority level have the weights (3, 2, 1). In this example, VED classification is given the highest priority level and therefore the weight assignment is as follows:

V → 300, E → 200, D→100

ABC classification is given the second highest priority level and therefore the weight assignment is as follows:

A → 30, B → 20, C → 10

FSN classification is given the third priority level and therefore the weight assignment is as follows:

F → 3, S → 2, N → 1

The priority values that would be assigned to each of the different combinations of the three classifications for this category are shown in Table 3. The ranked list generated by this integration mechanism will have 27 different priority values for the 27 combinations.

Identical Priority Levels

The priority levels assigned to each of the classifications are identical. For the sake of analysis, the three classifications are assigned the third priority level i.e., the weights assigned to each of the classifications is (3, 2, 1). The priority values that would be assigned to each of the different combinations of the three classifications for the first category are shown in Table 4.

As is evident from the table shown above, the 27 different combinations of the classifications are given 7 different priority values. If this mechanism is used to generate a ranked list, then many parts will have similar priority values thus resulting in a lot of ties. The manager needs to break the ties in order to use the ranked list for making decisions.

PRIORITY	CLASSIFICATION	PRIORITY	CLASSIFICATION	PRIORITY	CLASSIFICATION
333	(A, F, V)	233	(A, F, E)	133	(A, F, D)
332	(A, S, V)	232	(A, S, E)	132	(A, S, D)
331	(A, N, V)	231	(A, N, E)	131	(A, N, D)
323	(B, F, V)	223	(B, F, E)	123	(B, F, D)
322	(B, S, V)	222	(B, S, E)	122	(B, S, D)
321	(B, N, V)	221	(B, N, E)	121	(B, N, D)
313	(C, F, V)	213	(C, F, E)	113	(C, F, D)
312	(C, S, V)	212	(C, S, E)	112	(C, S, D)
311	(C, N, V)	211	(C, N, E)	111	(C, N, D)

Table 3: Distinct priority levels for all three classifications

PRIORITY	CLASSIFICATIONS
9	(A, F, V)
8	(A, F, E); (B, F, V); (A, S, E); (A, S, V)
7	(A, F, D); (C, F, V); (A, N, V); (B, S, V); (A, S, E); (B, F, E)
6	(A, N, E); (A, S, D); (B, S, E); (B, F, D); (B, N, V); (C, F, E); (C, S, V)
5	(A, N, D); (B, S, D); (C, N, V); (B, N, E); (C, S, E)
4	(C, N, E); (B, N, D); (C, S, D)
3	(C, N, D)

Table 4: Identical priority levels for all three classifications

Mixed Priority Levels

In this case, two of the classifications have the same priority level, with the third classification either having higher or lower priority. For the sake of illustration, the two classifications ABC and FSN are considered as having the same priority levels and are assigned the weights (3, 2, 1). VED classification is assigned a higher priority level with weights of (30, 20, 10). This integration mechanism will result in a ranked list that has a lesser number of ties when compared to the identical priority levels case. Nonetheless, the manager has to break the ties before using this mechanism to integrate the three classifications.

DECISION SUPPORT SYSTEM

A DSS called Integrated Inventory Ranking System for Inventory Management (IRSIM) is developed in MS Access (Jennings, 1999) to implement the integrated inventory ranking procedure. IRSIM had three major modules that needed to be developed and designed. They are: the database module, the model management module, and the user interface module. The database module and the model management module made up the internal design of IRSIM. The internal structure of IRSIM is designed in a manner that makes it easy to follow and changes can be implemented as desired. The model management module comprises of the code that was written to perform the classification techniques automatically and also to integrate them based on user input.

The design of the user interface makes up the external design of IRSIM. The user interface was designed in a fashion that made it as interactive and user friendly as possible. The input that the system would normally require to perform the classifications and integrate them was kept as simple as possible since this system was developed primarily for those who are not completely computer-savvy. Options have been provided in IRSIM to generate various other reports other than the reorder lists, so that the user can choose the kind of information he/she would like to use for making a decision.

The user of IRSIM can choose to perform any of the classifications in any order. The ABC and FSN classifications are performed based on the cutoffs that are entered by the user while the VED classification is a subjective input of the user. Once the classifications are performed, the priority levels and weights are assigned to each of the classifications. This can be done in at least 27! ways for the 27 different combinations of the classifications that a part can belong to and is worthy of careful consideration as each choice can significantly affect the ranked list. In case the user does not want any classification to affect the decision-making procedure, he/she can assign the weights for that classification as (0, 0, 0). The parts are sorted in the descending order of their priority values once they are calculated. In case ties occur when priority values are assigned, the ABC classification is given the highest priority followed by FSN and VED classifications to sort the parts in descending order.

One thing that is common in the approach being followed in all three inventory classification techniques, and in their integration mechanisms, is that all of them should be based on the ideas of the manager such that it best serves his/ her purpose. It is not feasible for a person following this approach to go over the entire procedure of performing the calculations each time a subcontracting vs. manufacturing in-house decision needs to be made.

CONCLUSIONS

The research is conducted to develop an integrated inventory ranking procedure to help the production manager in taking decisions regarding what parts to subcontract, and what parts to manufacture in-house. A DSS called IRSIM is created to implement the procedure using MS

Access database software. Three different inventory classification techniques including ABC classification, FSN classification, and VED classification are integrated into IRSIM to combine both quantitative factors and qualitative factors for decision-making.

The validity of IRSIM is tested and verified by utilizing real world data. The real world data is converted to a format that IRSIM requires by making some preliminary adjustments like importing the file and getting it into the correct table format. The output of the integrated inventory ranking procedure allows the user to take into consideration various factors as compared to any of the classifications used in isolation. The output reports generated from IRSIM confirm the benefits of our proposed procedure in providing information to solve the problem of subcontracting vs. manufacturing in-house thus fulfilling our research objectives.

Future enhancements to this research can be done in two areas. The model that IRSIM is based on takes into account only the quantitative and qualitative factors associated with each part. Future research endeavors could consider other factors such as due dates and similar setups that this research has not taken into consideration. The integration mechanism can be enhanced to allow additional weights to be given based on due dates and parts that need similar setups to manufacture.

The IRSIM developed in this thesis concentrates on helping the production manager make the subcontracting vs. manufacturing in-house decisions. The scope of IRSIM can be further extended to deal with other inventory management problem areas such as reorder strategies. Different reorder strategies can be developed for parts belonging to specific categories that are delineated once the various classifications have been performed.

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