MATERIAL REQUIREMENT PLANNING SUPPORT SYSTEM FOR THE MANUFACTURED HOUSING INDUSTRY

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ABSTRACT

In order to design an efficient and effective material supply chain management system for the MH industry, it is necessary to accelerate the flow of information and products across the supply chain. To achieve this goal, the system needs three ingredients: generators of quick information flow, generators of quick material flow, and facilitators of both quick information flow and material flow. This paper proposes a material requirement planning (MRP) system that uses a database approach to manage the large amount of information involved in the material requirement estimation process. The Database has been created using information provided by a manufactured housing facility to demonstrate the benefits that the application of these systems can bring to the MH industry. The MRP database will be supported by a visual basic interface to demonstrate its functionality.

Keywords: Manufactured Housing (MH) industry; material flow; material management; material requirement estimation process; database; information management; material requirement planning (MRP)

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INTRODUCTION

The material requirement planning (MRP) system was designed as an inventory control system for manufacturing industries. Its principal goal is to reduce stock levels with consequent savings in capital, resources, and space (Frenk and Kleijn 1998). This improvement is reflected in the production process creating more reliable and faster delivery times, improving the use of facility space as materials are always available, and reducing the time to estimate and place material orders (Waters 1992).

The MRP systems determine all items that need to be purchased and completed to support the master production schedule. The most common MRP systems are designed to use backward scheduling as the primary tool. The master schedule date becomes the end point and then all elements are offset backward in time (Ptak 1997). Experience has shown that stocks are controlled by "pull" demand rather than "push" demand in manufacturing industries (Brigham and Ehrhardt 2002).

The result of the MRP application is a schedule of order strategies. It answers the question "when" the order needs to be placed and how much is needed. By using MRP, the companies can obtain dramatic decrease in inventory and improve profitability (Ptak 1997). Although MRP shows many advantages for manufacturing companies, it also presents some disadvantages. It is a very complex system that needs to manage great amounts of information; therefore this system requires the help of a computer software (Martin 1995).

This paper presents an MRP support system that uses computer database to manage the large amount of information involved in the material requirement estimation process. In order to fulfill this goal, this paper explains in detail the use and design of MRP databases for the Manufactured Housing (MH) industry, and it defines the different inputs that the user needs to

introduce into the system and outputs that can be expected from the MRP system. Finally, a MRP support system prototype was created to test the effectiveness of dependent demand systems. The database was created from real data provided by a manufactured housing facility and it is used as an example of how available tools can be utilized to get immediate benefits from MRP systems. This support system demonstrates how the MRP system for the MH industry can be used to develop better planning strategies and to respond quickly to the unexpected changes in demand.

MANUFACTURED HOUSING OVERVIEW

The term "manufactured home" appears for the first time in the early 80's and was adopted by the United States Congress to describe a house that is built in a factory complying with a building code developed by the Department of Housing and Urban Development (see Figure 1).

Manufactured housing is central to solving the housing affordability crisis. Manufactured homes are particularly important in promoting homeownership among the low-income households. The average price of a site-built home without land in 2001 was $164,217. The average home price without land for HUD-Code housing was $30,700 for a single section home, $55,100 for a multi-section home, and $48,800 for all Manufactured homes. On a per square foot basis, the average HUD-Code home cost 54% less than the average site-built home in 2001 (MHI 2003). When comparing identically sized units on similar foundations, the estimated price of a double-section HUD-Code home is 25% less than for a site-built home.

Over the last decade, the competitive advantages offered by the MH industry such as the aggregation of production, the availability of semi-skilled labor, bulk purchasing of materials,

and a single, uniform national building code, have strengthened the position of manufactured housing as the only viable option for providing modestly priced homes.

However, manufactured housing industry has gone through cyclical up and down in its history. In recent years, manufactured housing industry has experienced a sharp decline in sales since its most recent peak in 1998 as compared to the consistent condition of site-built housing industry. One of the reasons for the downstream trend of manufactured housing industry is that the overall economic recession has directly affected the manufactured housing industry. The other reason for the recent cycle is due to financing concerns. During the mid-to-late 1990s, a lot of lending firms approved many buyers with questionable credit to purchase manufactured homes. This was followed by loan defaults and home repossessions. Consequently, it has led to a complete restructuring of the financing side of the manufactured housing industry (MHRA 2003).

Today, the MH industry shares almost 25% of the total housing market, comprising the second biggest provider of housing units in the US. The MH Industry comprises of 130 companies with about 300 factories throughout the US. In the year 2002, the top 25 companies accounted for 90.9% of total industry shipments, while the top 10 accounted for 78.8% (MHI 2003).

DATABASE OVERVIEW

The word "database" refers to a broad range of data managing software systems. In general, a database is composed of one or more large structured sets of data, usually associated with software to update and query the data. A simple database might be a single file containing many records, each of which contains the same set of fields where each field is a certain fixed

width. The goal of these systems is to provide a structure for data that is organized, fast, efficient, easily accessible, and the ability to perform a variety of user-defined tasks. By using a database to manage and serve up the information, the “manual” method can be improved. Databases often map data using associative data structures.

Databases can be classified as: “flat” or “relational”. The main difference between them is the way the information is stored. While the first one keeps the information in only one record, the latter uses several interrelated tables to manage the information in a more efficient way.

Flat Database

A "flat" database means all of the information about a record is kept in a single database. A flat database is very easy to manage, because it has its information stored in one source. The limitation of a flat database is usually not in the number of records you can put on, but in how much information you can track per record. Limits of a flat database are usually realized by the information you need to track about each record, rather than by adding records to the database.

Relational Database

“Relational” databases organize the information in separate tables that are linked to one another by a common field. Users do not see the separate records by looking at the view file; instead, they see different pieces of information stored in different tables about an item. Upgrading from a flat database to a relational database allows for a great deal of growth for information-tracking. When databases are relational, adding a new record to the main database will add the same record to all of the joined databases.

To join a database, there must be a field that has something unique about each and every record in a database. It is best to create a field specifically for the joining process; this field should hold a unique identification number. When a new record is added, it should automatically assign a unique number in the main database; this number is then copied automatically to every other joined database.

MRP SYSTEM

The proposed MRP system uses the information available at any factory and recommends the use of a computer database as a tool to optimize their utilization. It uses the information provided by the Master Production Schedule (MPS) department and the information compiled in the inventory records system to answer the MRP planning questions shown in Table 1.

The proposed MRP support system is designed to use backward scheduling as the primary tool, where the master schedule date becomes the end point and then all elements are offset backward in time. MRP completes the material supply chain developed for the MH industry, and it uses the resources and information provided by the other parties to optimize the material order and the production process (see Figure 2).

MRP SYSTEM FRAMEWORK

The process flow described before became the basis for the development of the MRP support system (see Figure 3), and helped to create the framework that the system will use to provide the necessary material management reports used by the purchasing manager to support the demand set by the production department. Due to the large amount of information involved in this process, the use of a relational database is necessary.

MRP SUPPORT SYSTEM

The MRP support system must be designed and developed from two different points of view: the administrators and the users. The administrator is the person in charge of updating the system, and the latter is the one who determines the material requirements to support the demand set by the production and the sales department.

Level 1: Administrator Mode

The MRP support system must be designed to facilitate the work for the database administrator. This database is the basis of the system and hence the most important part of the support system. The MRP support system must be easy to edit, update, and modify the different tables and fields inside the database.

MRP Database Design

The first step in developing the MRP support system is to develop the computer database that is going to be used by the system to determine the material requirements at the MH factory. The database was developed in Microsoft Access by using real data provided by one of the factories visited during this research. This database contains the required information about: materials, suppliers, and house types, and it organizes and manages the information to obtain the material reports needed to support the production process. The database was designed to be a relational database where different tables of data are related to each other by a common field.

Material Records

The Material records table contains all the material used by the MH facility and important data related to them (see Figure 4). This table was divided into seven fields described below:

- Material ID: Each material must be identified by a unique material identification number. The bill of materials provided for this database did not have any ID numbers; as a result one was assigned to each material. This field was selected as the primary key of the table due to its characteristics.
- Material Description: Each material ID number must be linked to a description of its characteristics, such as, color, type, dimensions, etc.
- Supplier Name: This field relates each material ID and description with the supplier that is going to provide that specific material.
- Purchasing Unit of Measurement: It is the unit utilized by the suppliers; therefore it is the measurement unit that needs to be used for purchasing orders.
- Lead time: It is the time between the order and delivery of the material. It is important to include the required time for inspection in the total lead time to avoid shortage of materials.

Suppliers Records

The Suppliers Records contain all the suppliers used by the MH facility and their contact information (see Figure 4). This table was divided into three fields including the supplier name, phone, and fax number. The field "supplier name" was selected as the primary key for this table. The fields included in this table are the ones currently used by the industry. Additional fields, such as, online supplier stores and web sites can be added once the purchasing system is modified and when the internet online orders are available.

House Records

The MH facilities provide a range of products to customers; therefore house records need to be created for each house type. For this research, only two house records were created, because only two types of houses were provided by the selected MH facility. These records were used to test the MRP system. These tables were divided into two fields described below (see Figure 4):

- Material ID: The unique identification code assigned to each material. This field was selected as the primary key of this table due to its characteristics.
- Purchasing Quantity: The quantity of material that goes to each house in purchasing units.

Each of these tables becomes an individual database by themselves that needs to be linked in order to share the information stored in each of them. The primary keys selected for each table were used to achieve this goal. The links between the different records can be seen in Figure 5.

Process Flow

The database design should be flexible for changes during the operation of the MH facility, for that reason it must be able to update the MRP Support System every time a change is introduced to the database. The administrator of the database will need to update the database every time a new product is offered by the MH facility or a product becomes obsolete. In the same way, the MH facility can change its vendors or the material type and quality; consequently the administrator will need to edit the different tables to satisfy the new necessities at the facility.

These database administrative actions have been considered in the proposed MRP support system as described below (see Figure 6):

Edit Tables

The MRP database administrator must be able to edit any of the tables created in the database; therefore the database needs to be designed to be flexible. An Editing Table Form for each table must be developed to facilitate this action. The administrator will be asked to select the table which he wants to modify, telling the database which Editing Table Form needs to be opened. Finally, all modifications are saved in the database and the MRP support system is updated.

Add New House

The MH industry changes with time and new products are offered; consequently the database also needs to be changed. When the "Add New House" or "Product" is selected, the MRP database will open the Create New Table Form. This Form will facilitate any changes in the product, asking all the necessary information to create this new table. Once the table is created, the MRP database updates itself, adding the new information into the MRP support system.

Remove House

The changes in the MH industry could make some products obsolete with time; consequently the database also needs to be changed. The "Remove House" or "Product" button in the MRP database facilitates this operation and automatically updates the database which in turn updates the MRP support system.

Level 2: User Mode

The MRP support system was designed to use the database as a feeder element to estimate the material requirements at the facility by using a visual basic interface to create a friendly environment. The database does not have all the required information for the process and additional information is needed from the user as follows:

Inputs

This support system was designed to ask the user for the data necessary for the material requirement estimation process (see Figure 7). The user will be required to provide the inputs described below:

- House Type: The house type that is entering the assembly line.
- Quantity: How many houses of each type are going to enter the assembly line?
- Production Date: When are the houses going to enter the assembly line?
- Material Holding Time: It is the time in working days that the purchasing department wants to keep the inventory in stock before use.

The House Type, Quantity, and Production Date data are provided by the Master Production Schedule (MPS). Any changes to the MPS will invalidate the outputs of the system, but this can be corrected by appropriately modifying the input and running the system again.

Process Flow

The MRP support system follows a step by step process to use the inputs provided by the user and send specific queries to the database. This query looks for the required information and gives them to the users in report format. This process is represented in Figure 8.

Step 1: Material Need Query

The system uses the information extracted from the master production schedule to call the material need query. This query takes the house types provided by the user to transform them into a list of materials. Then it looks into the material records table for the required information to create the material need report.

Finally, the query calculates the quantity of material needed to support the production demand introduced by the user. The query takes the quantity of each material and multiplies it by the quantity introduced by the user, then it does the same for each house, and finally it adds the quantities to obtain the total amount. The formula used by the query is shown below:

$$TotalQuantity = (Quantity_1 \times N_1) + (Quantity_2 \times N_2) + ... + (Quantity_i \times N_i)$$

Where, Quantity = Quantity of material per House.

N = Number of houses.

I = House Type.

The output of this process is a material list with the relevant information. This output becomes the Material Need Report described in the previous paragraphs.

Step 2: Purchasing Need Query

Once the material need query is finalized, the purchasing need query uses the information and the material inventory time provided by the user to determine the purchasing date by using backward scheduling as discussed earlier. The following formula is used in the process:

$$Purchasing\ Date = Production\ Date - Lead\ Time - Material\ Holding\ Time$$

Finally, this query looks for the supplier name in the material records table and creates the Purchasing Need Report.

Step 3: Purchasing Orders Query

The final step followed by the MRP support system is the Purchasing order development. This query is used to create the Purchasing Orders with respect to different suppliers.

Level 3: MRP Reports

The system includes the information provided by the users and identifies the relevant information about material requirement quantities, purchasing dates, purchasing orders, etc. This system provides three different types of reports described below:

Material Need Report

The material need report will answer "what" material is needed, "when" the material is needed and "how much" material is needed. The MRP support system will use the information provided by the house type, quantity and production date to send a query to the database transforming the list of houses into a bill of material. This report provides the material ID, material description, purchasing unit of measurement, purchasing quantity, and lead time for each material (see Figure 9).

Purchasing Need Report

The purchasing report will use backward scheduling as the primary tool. The master schedule date becomes the end point and then all elements are offset backward in time. The MRP system will use the holding time and lead time of each material to determine the "when" and

"where" to buy the different materials. The report provides the material ID, material description, purchasing unit of measurement, purchasing quantity, and the supplier name for each material. It also provides the date that the material is going to be purchased (see Figure 9).

Purchasing Order Report

The MRP system will use the information stored in the database to transform the purchasing need report into individual purchasing order. Each of these orders provides a list of material ID, description, purchasing unit of measurement and purchasing quantity. One purchasing order is developed for each supplier (see Figure 9).

CASE STUDY

A prototype of the MRP support system was developed to test the effectiveness of the user interface part of the MRP inventory control method and to evaluate the advantages that the application of these systems can bring to the Manufactured Housing Industry. This system was created in Microsoft Access and was used to estimate the material requirement for one factory.

The complete list of material currently used by one MH Facility, along with the required information of two types of houses was provided. This data was used to develop the MRP Database for this specific factory (see Table 2).

The material ID was not provided by the factory and therefore an ID was assigned for each material, and this was used in the different tables of the MRP database. In a similar fashion, the lead times of the different material were not provided, as a result a lead time of 5 working days was assigned to each material.

Results

The MRP prototype support system was successfully used to determine the material requirements at this particular MH facility. Different MRP reports were generated based on the input provided by the user (Figure 8).

The material requirements of an entire MH facility were calculated in a manner of minutes, resulting in a radical reduction of the material estimation time. The MRP support system minimized the probability of errors by doing all calculation with a computer application. The values obtained by the system are more accurate because all estimations are obtained directly from the different MH products. Table 3 shows a comparison between the conventional method and the proposed system.

CONCLUSIONS

The proposed MRP system was successfully tested to estimate the material requirement for the MH facility. This system answered all questions described in the previous paragraphs, demonstrating that MRP systems are more efficient planning tools that can be used to propose back-up strategies when demand changes appear. Any changes to the master schedule can be plugged into the support system automatically updating the outputs of the MRP system.

The main advantage of a MRP system is its ability to relate demand for material directly to the master production schedule. This process provides better planning reducing the amount of items in stock thus reducing holding cost and increasing the inventory turnover of the facilities. Reduced stock levels improve the utilization of facilities as materials are always available when needed.

This system has demonstrated the importance of having an efficient information flow. The system utilizes the information available in the database and that provided by the user to determine the material needs. Additionally, MH factories can also utilize local networks and internet capabilities to further increase the speed of information flow between the parties.

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REFERENCES

AbuHammad, A. (2001). "Simulation Modeling for Manufactured Housing processes". *Master Thesis,* University of Cincinnati. Cincinnati, OH.

AbuHammad, A., Senghore, O., Hastak, M., Syal, M. (2002). "Simulation Model for Manufactured Housing Processes." *In: refereed proceedings of the Joint Workshop – ASCE & EG-ICE*, November 2-3, 2002, Washington, D.C.

AbuHammad, A., Hastak, M., Syal, M. (2002). "Manufactured Housing Production Process". *Proceedings of the 10th International Symposium Construction Innovation and Global Competitiveness Joint Symposium of CIB Working Commission.* Cincinnati, Ohio.

Allen, G. F. (1999). "Upscale Manufactured Home Communities". *Journal of Property Management*, pp. 46-48. Institute of Real Estate Management, Chicago, IL.

Barriga, Edgar M. (2003). "Manufactured Housing Industry: Material Flow and Management". *Master Thesis Report, Purdue University*. West Lafayette, IN.

Brigham, E.F. and Ehrhardt, M.C. (2002). "Financial Management: Theory and Practice". 10th Edition, *Harcourt Inc*. Orlando, FL.

Frenk, J.B.G. and Kleijn, M.J. (1998). "On regenerative processes and inventory control". *Pure Math. Appl.*, 9(1-2):61-94 (1998).

Harriger, A., Lisack, S., Gotwals, J. and Lutes K. (1999). *Introduction to computer programming using Visual Basic 6.0*. Needham Heights, MA: Macmillan Publishing.

Rutherford, R.C., Thomson, T.A. (1999). "What affects Mobile Home Sales Price?" *The Real State Appraiser and Analyst Journal*, 67(3), pp. 233-237.

Martin, A.J. (1995). *Distribution Resource Planning: The Gateway to True Quick Response and Continual Replenishment*. *John Wiley & Sons, Inc.* Hoboken, NJ.

Mehrotra, N., Syal, M., Hastak, M. (2003) "Manufactured Housing Production Process and Factory Layout". *In: refereed proceedings of the Construction Research Congress 2003*, March 19-22, 2003, Honolulu, Hawaii.

Manufactured Housing Institute. (2003). *Quick Fact*, < www.manufacturedhousing.org > (May 4, 2003)

Manufactured Housing Research Alliance (MHRA). (2003). "Technology Road mapping for Manufactured Housing." MHRA, New York, NY.

Microsoft. (1997). *Microsoft Access 97*: *Step by Step*. *Microsoft Press*. Redmond, Washington.

Ptak, C.A. (1997). "MRP and Beyond: A Toolbox for Integrating People and Systems". *The Educational Society for Resource Management*. APICS, Chelmsford, MA

Senghore, O. (2001). "The production and Material Flow Process Model for Manufactured Housing." *Master Thesis,* Michigan State University.

Shilling, A.G. (1996). "Home sweet Factory-built Home". *Forbes*, 157(3), pp. 181-182.

Waters, C.D.J. (1992). *Inventory Control and Management.* John Wiley & Sons, Inc. Hoboken, NJ.

Willenbrock, J. (1998). *Residential Design and Construction*. Prentice Hall, New Jersey.

LIST OF TABLES

LIST OF FIGURES

Table 1. MRP Planning Questions

MRP Questions	Answers
What do I need to purchase?	Different material to support the production process.
When do I need the material?	A material need schedule at the facility.
How much do I need to buy?	Material quantities needed to support the manufacturing process.
When do I need to buy them?	A purchasing schedule to support the demand.
Where will I buy them?	Different suppliers

Table 2. Case Study MRP Database

Material Records	Material ID (Not Provided, an ID was assigned to each material) Material Description Lead Time (Not provided , a lead time of 5 days was assigned) Unit of Material (U/M) Supplier Name
Supplier Records	Supplier Name Phone Number (Not provided, a random number was assigned) Fax Number (Not provided, a random number was assigned)
House Type 28A	Material ID Material Quantity
House Type 28B	Material ID Material Quantity

Table 3. Comparison between Conventional and Proposed Material Estimation Process

	Conventional Material Estimation Process	Proposed MRP Support System
Inventory Control System	Independent Demand System Push system	Dependent Demand System Pull system
Inventory Records	On Hand On Order Lead Times Historical Data	On Hand On Order Lead Time Planning Data
Estimation Tool	Mathematical Formulas	Backward Scheduling
Based on	Historical Data (Forecast the demand)	MH products (Demand obtained from MPS)
Processing Time	1 Week	1 Day
Stock	Higher Inventory Level (Weekly ordering)	Lower Inventory Level (Daily ordering)
Technology used in the System	None	Computer Database Computer Software

FIG. 1. Manufactured Housing Construction Overview

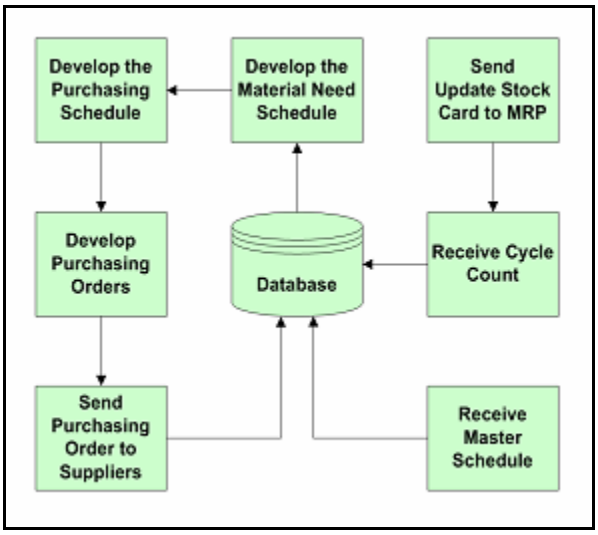


FIG.2. Proposed MRP system for the MH Industry

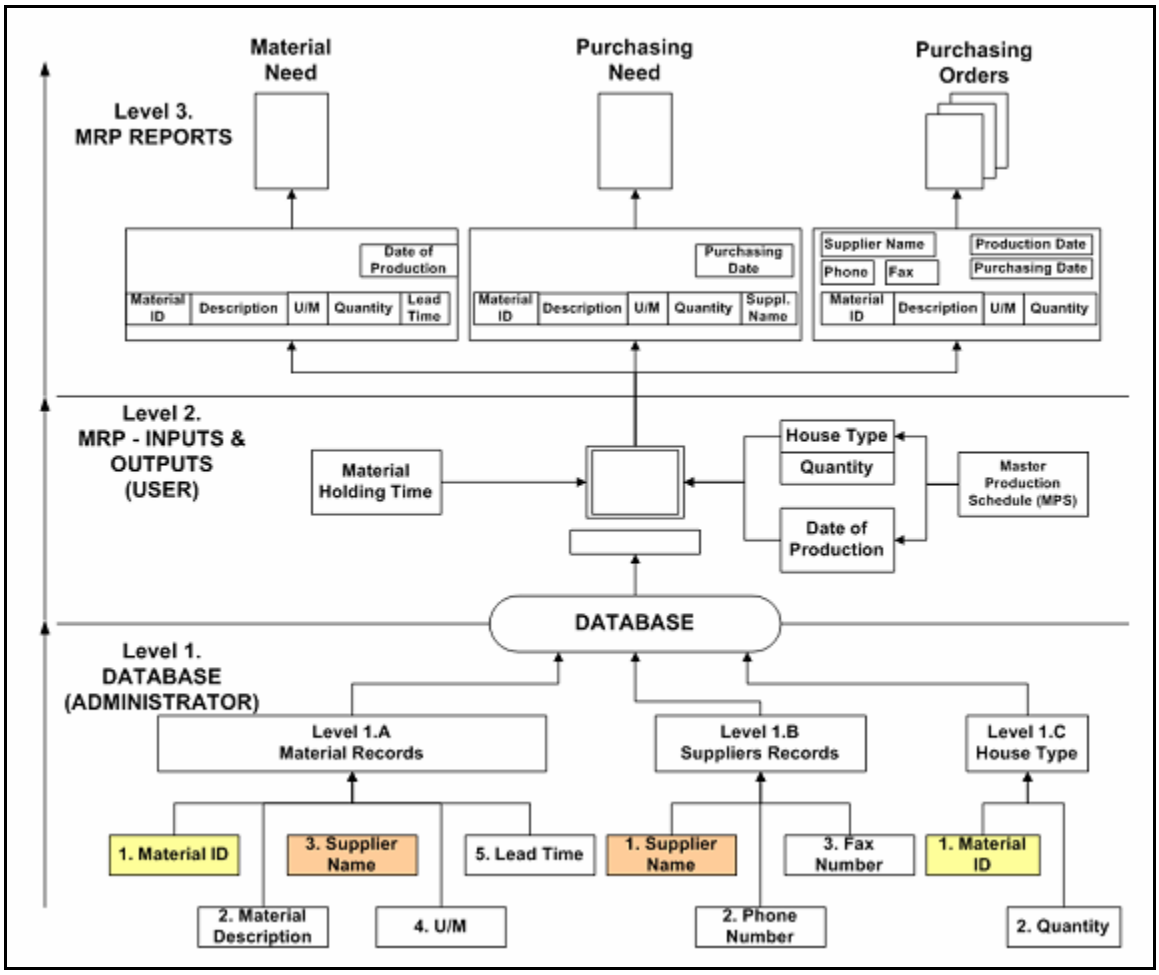


FIG.3. MRP Framework

Material ID	Material Description	Supplier Name	U/M	Lead Time
001	Frame 40x28 (36' Box)	Lippert	EA	5
002	Frame 44x28 (40' Box)	Lippert	EA	5
003	Frame 48x28 (44' Box)	Lippert	EA	5

Supplier Name	Phone	Fax
Adorn	555-0001	555-0060
Adv Aff	555-0002	555-0061
Amerimax	555-0003	555-0062

Material ID	Quantity
001	1.00
002	1.00
003	3.00

FIG. 4. Example of Material, Supplier, House Records Table

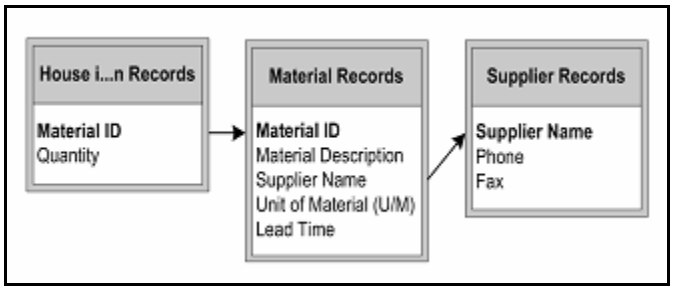


FIG. 5. Links between MRP Records

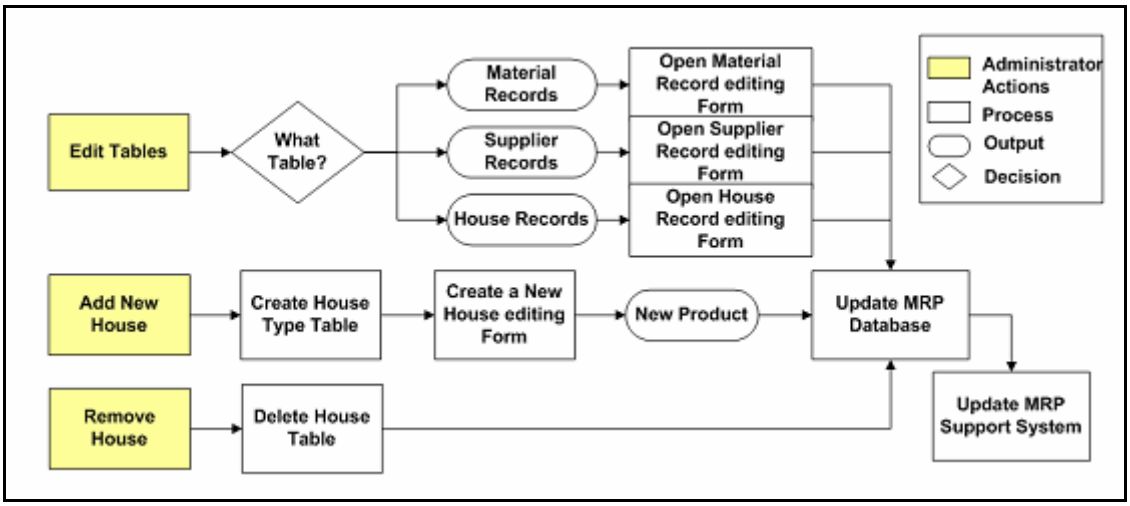


FIG. 6. MRP Administrator Mode

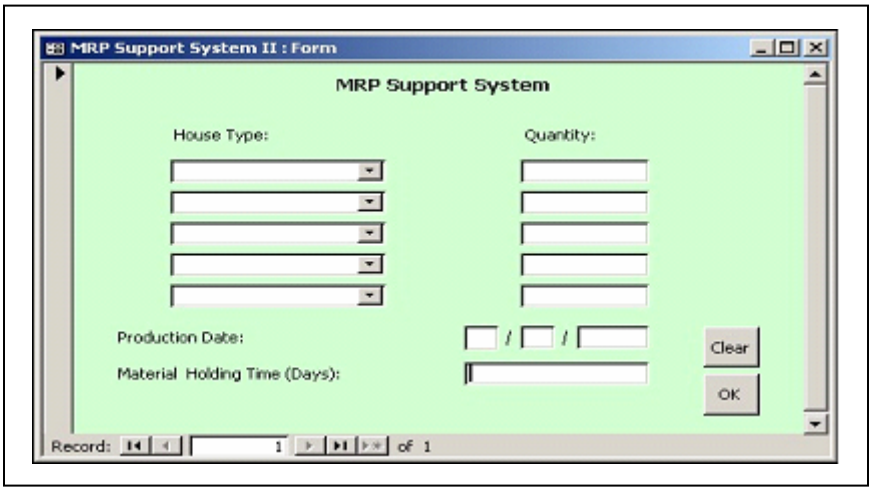


FIG. 7. Visual basic interface of Input Data

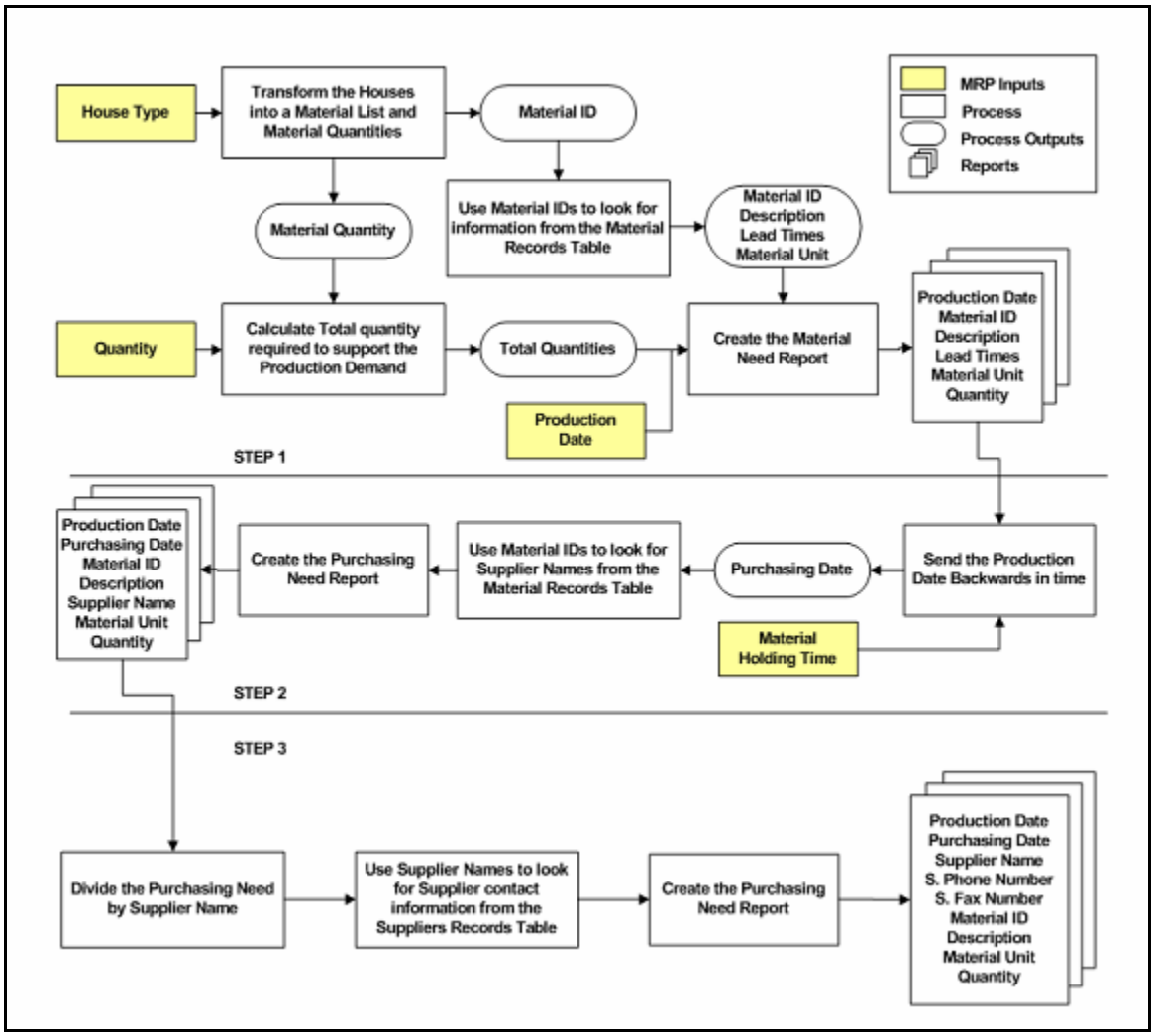
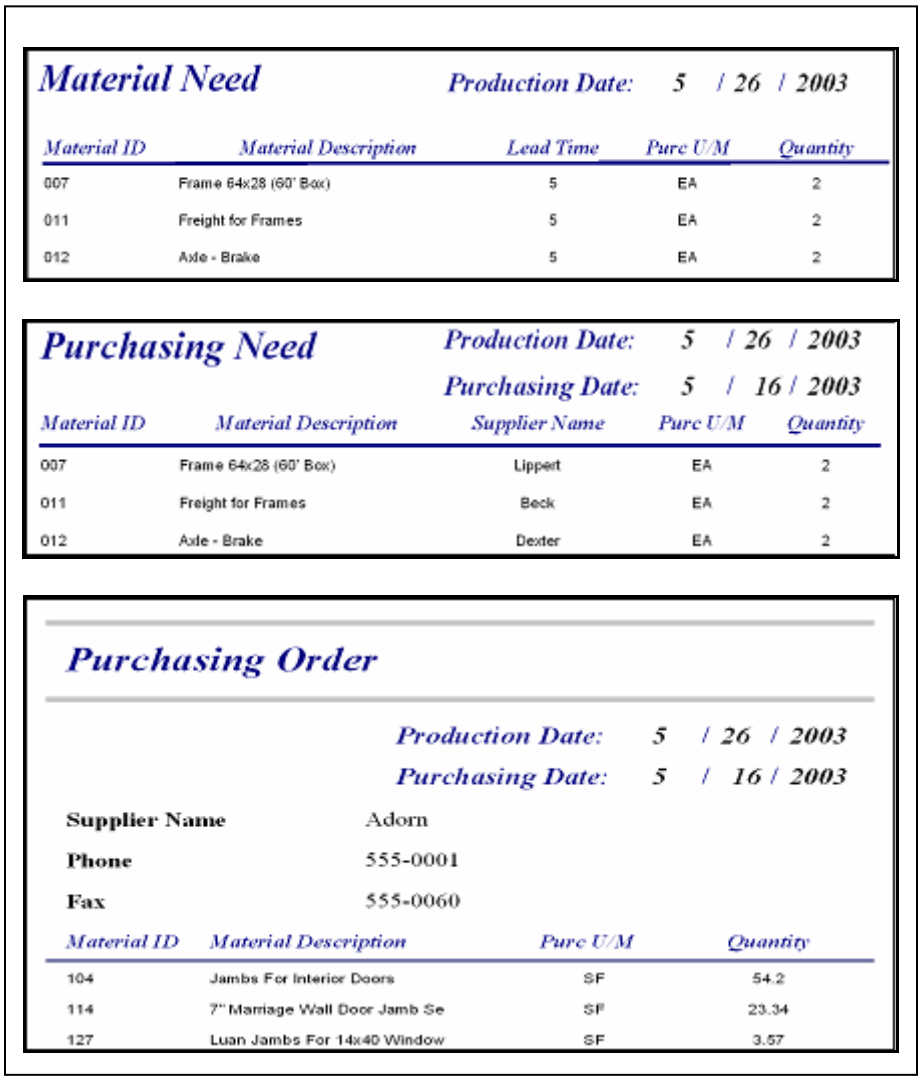


FIG. 8. MRP Step by Step User Mode Process



Material Need

Production Date: 5 / 26 / 2003

Material ID	Material Description	Lead Time	Purc U/M	Quantity
007	Frame 64x28 (60' Box)	5	EA	2
011	Freight for Frames	5	EA	2
012	Axle - Brake	5	EA	2

Purchasing Need

Production Date: 5 / 26 / 2003

Purchasing Date: 5 / 16 / 2003

Material ID	Material Description	Supplier Name	Purc U/M	Quantity
007	Frame 64x28 (60' Box)	Lippert	EA	2
011	Freight for Frames	Beck	EA	2
012	Axle - Brake	Dexter	EA	2

Purchasing Order

Production Date: 5 / 26 / 2003

Purchasing Date: 5 / 16 / 2003

Supplier Name Adorn

Phone 555-0001

Fax 555-0060

Material ID	Material Description	Purc U/M	Quantity
104	Jambs For Interior Doors	SF	54.2
114	7" Marriage Wall Door Jamb Se	SF	23.34
127	Luan Jambs For 14x40 Window	SF	3.57

FIG. 9. Example of a Material Need, Purchasing Need, Purchasing Order Report