MATERIAL SUPPLY CHAIN MANAGEMENT SYSTEM FOR THE MANUFACTURED HOUSING INDUSTRY

Edgar M.Barriga[1], Jae G. Jeong[2], Makarand Hastak[3], and Matt Syal[4]

ABSTRACT

Advanced techniques for material management are scarcely used in the Manufactured Housing (MH) industry. The current material flow and management systems in use at different MH factories are independent demand systems that are based on personal experience of the material managers. Several years ago independent demand inventory control systems were widely used in many manufacturing industries, but this technique leads to a large amount of inventory at the factories and is slowly becoming obsolete. On the other hand, dependent demand systems reduce inventory levels at the factory using new techniques, such as, supply-chain management and just-in-time supply. They are being successfully applied in manufacturing industries and could also present substantial benefits for the MH industry. This paper applies lean inventory control and supply chain management techniques to the current material flow and management system, and proposes an effective and efficient material supply management system that can be applied at any MH factory.

Keywords: Manufactured Housing (MH) industry; material management; dependent demand system; supply chain management; inventory control; material requirement planning (MRP)

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INTRODUCTION

The Manufactured Housing (MH) industry scarcely uses available technologies and techniques for efficient material management. This industry stands to gain substantially by incorporating some of the more advanced and successful management techniques used by other industries for effective material management. Techniques such as lean production principles, supply chain management, and inventory control systems become essential in any efficient material management system.

Lean production techniques were developed to optimize a process by avoiding or reducing waste. Lean principles suggest that all processes can be divided into value adding and non-value adding activities. Waste is defined as an activity that does not add value to a product, and all such waste should be reduced or eliminated if possible. Some examples of waste in material management processes are: inventories, unnecessary processing, unnecessary transport of goods and material shortages (Ohno 1988). Well known terms in management, such as, just-in-time delivery (JIT), time based competition, concurrent engineering, total quality management (TQM), process redesign, employee involvement, are all partial approaches to lean production (Koskela 2000, Hastak, Vanegas, and Puyana-Camargo 1993). The application of these relatively new ideas results in a delivery system that could be applied to all types of processes related with production and/or material management (Howell 1999).

The Supply Chain Management is widely used for production and material management in other industries. It is defined as a system which encompasses all activities associated with the transportation and flow of information and goods from the raw material through to the end user as well as all information flows (Handfield and Nichols 1999). A well developed supply chain management system must involve all people related to the material delivery process, such as,

suppliers, manufacturers, distribution centers, retailers and customers (Vergara, Khouja, and Michalewicz 2002).

The basic idea of any supply chain system is that effectiveness and efficiency can be improved by sharing information and by joint planning (Bowersox and Closs 1996). The potential for the integration of the supply chain to improve profit and competitive position has been highlighted by past experiences and by experts (Wood 1997, Sohal, Power, and Terziovski 2002).

The common example of any manufacturing industry's supply chain system involves a minimum of five levels: Suppliers, Material Requirement Planning (MRP), Master Production Schedule (MPS), Distribution Resource Planning (DRP), and customers (Ptak 1997). Any successful supply chain system needs sub-systems that could generate quick information flow, quick material flow, as well as systems that can facilitate both quick information flow and material flow (Martin 1995).

Inventory control systems were developed to provide a buffer between variable and uncertain supply and demand. Its primary goal is to provide this buffer at a minimum stock level and for a minimum cost (Frenk and Kleijn 1997). The material flow and management system used by the MH industry can be considered as an independent demand system. Such a system considers that demand for an item is independent of the demand of any other item and uses mathematical and quantitative models to relate forecast demands, order sizes and cost. These systems work well in retail industries, but present several drawbacks when dealing with batch production (Waters 1992). Independent systems can use either fixed order quantities or periodic reviews to satisfy the demand. Fixed order quantity systems place an order of fixed size whenever a stock falls to a certain level. They are better suited for relatively expensive items

with low but irregular demand. Periodic review systems place order of different size at regular intervals to raise the stock level to a specified value, and they are better suited for low-value items with high but regular demand.

Currently, independent demand systems are being replaced by dependent demand inventory systems. These systems are used when the demand for materials is directly linked to the production plan. They use production and operation schedules to calculate stock requirements. Due to these specific characteristics, dependent demand systems are more suitable for the manufacturing industries (Waters 1992). Stocks are controlled by "pull" demand rather than "push" demand (Brigham and Ehrhardt 2002). Two approaches for dependent inventory systems include: Material Requirement Planning (MRP) and Just-in-Time (JIT). The JIT system was developed to minimize the stock of material by having them arrive just as they are needed. JIT was invented in Japan where it is widely used in assembly industries. This type of system needs intensive planning and communication between people involved in the process.

This paper uses the techniques described above and adapts them to the specific needs of the MH Industry. The current material management system used by the industry has been improved and activities and resources previously unconsidered have been added to the current system in order to complete the entire material supply chain. Finally, it proposes an efficient material supply chain management system based on dependent demand systems as an alternative to the current material management system based on independent demand systems. Such a system can be effectively utilized at any MH factory.

MANUFACTURED HOUSING INDUSTRY OVERVIEW

The residential building industry is one of the largest and most important sectors of the U.S. economy. After years of rapidly rising home rents and home prices, housing affordability has become a great concern. However, manufactured housing only cost approximately 60% to 70% of the cost of a similar site-built house. Therefore, manufactured homes offer an affordable alternative for the housing demand in the U.S. with the potential to meet the expectation for cost effective and better quality homes.

A manufactured home is a unit almost completed in a controlled factory setting. Since 1976, manufactured homes have been regulated by a national pre-emptive code enforced by the U.S. Department of Housing and Urban Development [HUD]. This code regulates the design, construction, strength, durability, fire resistance, energy efficiency, and performance of heating, plumbing, air conditioning and electrical systems. Consequently, manufactured homes are also known as "HUD-Code" homes.

A factory's production is measured in terms of housing floors whether it is a single wide (single chassis) or a double wide (two chassis) housing unit. The production line of a manufactured housing factory consists of several stations organized in a logical way considering the different products they produce. The number of stations varies from factory to factory, but the generic assembly line is composed of four main operations: (1) Floors, (2) Walls, (3) Roof, and (4) Finishing, appliances and testing (see Figure 1). Each of these operations can be broken down into one or more stations, feeder stations and sub-stations. Each manufactured housing factory creates its own scenario to transform the generic operations into an efficient production line (AbuHammad 2001, Senghore 2001). The section(s) is (are) then transported to the site, installed, and connected to the required utilities.

Today, 130 companies constitute the MH Industry with about 300 factories throughout the U.S. The top 25 companies accounted for 90.9% of total industry shipments, while the top 10 companies accounted for 78.8% in year 2002 (MHI 2003). The MH industry shares approximately 25% of the total housing market, becoming the second biggest provider of housing units in the U.S. This industry's principal customers include starter families, elderly and retired people, and low-income households.

However, the current economic depression and market trends have made it important for the industry to consider innovation as well as improvement in the production process and the material management system. There are two key areas in the manufactured housing industry that could benefit from research: (1) the production process and (2) the material flow and management system (AbuHammad et al 2002, Mehrotra et al 2003). These two areas are dependent on each other.

Uncertainties in the Material Management System

While the material delivery and control system used in this industry is functional, it presents many deficiencies that can be improved. There is no standard material flow and management system, which makes the purchasing manager indispensable. As a result of which, each factory has its own system based on the purchasing manager's experience instead of using a standard inventory control system. Furthermore, the lack of knowledge about management techniques and available tools make the current process slow and inefficient, leading to higher amount of inventory and large storage areas at the facilities (Barriga 2003).

From the previous research efforts, a generic material flow and management system has been developed through questionnaires, personal interviews, and site visits. The key parties of

the generic material flow and management system includes the material handlers, material supervisor and the purchasing manager. The material handlers move and store the material, whereas, the material supervisor checks quantities and quality of the material upon delivery and decides if the material is needed at the production station. The purchasing manager is responsible for the cycle counts, the tracking of inventory levels and records, and the quantity estimation and order of different materials (Barriga 2003).

As a result, many drawbacks associated with the generic material flow and management system have been identified (see Table 1). For example, there is no standard material management system. The purchasing managers have poor knowledge about inventory control systems so that most of material processes are done manually. Such a process consumes unnecessary time and resources as well as redundancy of information. In addition, multiple suppliers and production of various types of houses at a MH factory makes it difficult to control constant inventory level and lead-time. The current system can be qualified as an independent demand system. It estimates the material requirement based on historical data instead of estimating directly from the actual demand. Sometimes the materials are also moved many times within the factory before they are actually used. All these cause irregular lead-time and high inventory level that result in unfavorable use of space and resources. Consequently, an advanced material flow and management system is needed that would incorporate the state of the art practices in material management.

NEW MATERIAL SUPPLY CHAIN MANAGEMENT FOR MH INDUSTRY

The system proposed in this paper is based on dependent demand systems. These systems were developed to replace independent demand systems in manufacturing industries. The

demand for material at manufacturing facilities is directly linked to the production plan. These systems use supply chain management concepts to estimate the material requirement directly from the different products manufactured at the facility and also backward scheduling to determine when the material needs to be ordered. This characteristic leads to a significant reduction in material stock.

Supply chain management is a concept poorly known in the MH industry environment, but it can be used to solve some of the biggest drawbacks detected within the current material flow and management system. An effective and efficient supply chain management system for the MH industry must consider 6 essential parties (see Figure 2): Customers, Dealers, Distribution Resource Planning (DRP), Master Production Schedule (MPS), Material Requirement Planning (MRP), and Suppliers.

These key players are available at any MH facility, but are not efficiently utilized. MRP responsibilities can be fulfilled by the Purchasing Department, while MPS and DRP responsibilities can be satisfied by the Production Department and Sales Department respectively. Currently, these parties are considered as independent departments, but it is necessary to integrate them in order to design an efficient and effective supply chain management system. This integration will optimize and accelerate the flow of information and products across the supply chain (see Figure 3).

Figure 3 shows the information flow used in the current system and compares it with the proposed system. The new system proposes the use of the same parties that exist in the MH facility by adding responsibilities to each of them and optimizing the information flow. The proposed system is a leaner process avoiding unnecessary duplication and processing of information.

Parties within the System

It is important to define the role of each of the six parties within the system and how they support each process and add value to the entire material supply chain management system. These parties need to work together and share information to lead to an optimum system.

Customers

The customers are the beginning and the end of the material process flow. They must be considered as part of the supply chain because they select the products that are going to enter the assembly line. The MH industry allows product customization; therefore they have the option to do small changes to the original product. These changes are only permitted for finishing because the layout and structure is standard.

Dealers

The dealers are the intermediates between the MH factory and the customers. The MH industry does not work directly with customers. All products that enter the production line are already sold, therefore the dealers are the ones who work with customers to define the specific characteristics of the house and then transmit this information to the MH factory.

Distribution Resource Planning (DRP) Department

The requirements of this department can be fulfilled by the sales department and is responsible for the logistic part of the process. They select the different dealers with whom the factory is willing to work. The information flow between these two parties must be efficient and a constant relationship between them needs to be created. The DRP department shares information on the range of housing products offered by the factory with the dealer so the latter can show them to the customers. The DRP receives the housing requirements from the dealers and transmits them to the production department in order to accomplish these demands.

Master Production Schedule (MPS) Department

This function can be fulfilled by the production department which is responsible for developing the master production schedule. MPS department must consider the housing requirement defined by the DRP department during the schedule development and then define when the house is going to be ready. The master plan schedule is shared with the MRP department in order for them to estimate the material requirements to support the production demand.

Material Requirement Planning (MRP) Department

The responsibilities of this department can be fulfilled by the purchasing department. It is responsible for selecting the different suppliers with whom the factory is going to work, keep track of the goods inside the factory, and order the different materials to support the production schedule. It uses the master production schedule by transforming it into a material need schedule. Then this schedule and the inventory records are used to develop the material purchasing schedule. The purchasing schedule defines different material quantities and times when materials need to be ordered. Finally, the material orders are sent to the proper supplier. The MRP department is formed by material handlers, head receivers, and the purchasing manager.

Suppliers

The suppliers are the ones who produce or supply the different materials used by the MH factories, and send them to the facility. The relationship between suppliers and the MRP department must be strong in order to develop an efficient material delivery and control system. Suppliers must be involved in the inventory control system, and share the responsibility for keeping track of the material levels at the factories.

Proposed Activities of the System

The activities of the new system have being developed from a material point of view; therefore some activities are explained considering only their influence in the material flow and management system. The material supply chain management system is broken down into two main activities: the material flow and the information flow system. Each of these activities is divided into different processes that define the complete material cycle for any MH factory (see Figure 4).

This paper focuses on the information flow system. The material flow inside the factory will be explained briefly while the information flow will be explained in detail, since the MRP activity is the most important activity of the system. The other activities feed the MRP department with the required information to estimate the material requirements at the factory.

Material Flow System

The material flow system considers all physical material movement. This system compiles not only the movement of material inside the manufacturing facility, but also the movement outside from suppliers to the factory. This system is divided into three sub-activities: material delivery, material inspection and storage, and material utilization. The people involved in these processes include suppliers, head receivers, and material handlers.

Material Delivery

This activity was not considered as part of the system by the MH industry, but it is part of the proposed system. Suppliers are responsible for this activity. It begins when suppliers receive the purchasing order from the MRP department. They process the order and produce or obtain

the different items. The required material is transported to the manufacturing facility, where it awaits inspection (see Figure 5).

Material Inspection and Storage

The proposed system joins together the material inspection and material storage used in the current system and gives more responsibility to the head receiver who is in charge of the activity. The material inspection must be done by the head receiver and the suppliers. Inspection affect both, therefore it is in the supplier's benefit to help with this process. The material must be inspected considering three criteria: material type, quantity and quality. This process consumes time that must be considered inside the lead time, but it is essential to verify these criteria and compare them with the original order.

Once the material is accepted, the head receiver has to evaluate if the material is needed at the station or if it is going to be stocked. The material is normally moved to the main storage where the material is held until it is needed at the different stations. Finally, the head receiver updates the stock card and provides this information to the purchasing manager (see Figure 5).

Material handlers use forklifts to supply material to different stations located in the assembly line. The material is supplied to each station when it is needed. The different materials are placed as near as possible to the working station in order to minimize the number of times the material is moved and also avoid wasting time required by the labor to look for the material.

Material Utilization

Once the material is placed at the proper station, it enters the manufacturing process. The material is used by the labor and it passes through all production steps in the assembly line. This process usually takes 2 days. Finally, the house is finished and it is transported to the dealer.

Information Flow System

The information flow system includes all material related activities without the physical movement. These activities must be integrated in order to have an efficient information flow system. The information shared by each part of the system is compiled by the MRP system which uses it to estimate the material required at the factory to support the production process.

Inventory Records

Inventory Records are used to keep track of the goods inside the MH facility. Every material that is stocked at the factory must be identified and have an inventory record available for use during the material estimation process. Inventory records for each material must include: ID code, on hand, on order, lead times, and planning data (see Table 2).

Purchasing managers and head receivers are responsible for this activity. The head receivers update the stock cards upon delivery while purchasing managers update the inventory records and store them in a database for future use during the material estimation process.

Distribution Resource Planning (DRP)

The DRP process handles the logistics at any manufacturing facility, developing strategies to plan and set goals. An efficient DRP system in the MH industry must be able to answer three logistic questions that become the basis of any planning strategy that it needs to take. These questions are shown in Table 3.

From the material point of view, the DRP process becomes the first information chain inside an MH facility. The DRP receives the house order from dealers and the information of any specific item the customer wants. Then, the DRP processes the order and sends it to the MPS, giving the required information to do the master production schedule. It can be concluded that the DRP is the customer of manufacturing (see Figure 5).

Master Production Scheduling (MPS)

The job of the master production scheduling system is to plan the production so that the demand set by logistic can be satisfied. The MPS process is divided into two steps: the development of the master plan schedule and the estimation of the production rates required to satisfy the manufacturing demand. MPS department uses the information provided by the DRP department with respect to the two related questions shown in Table 3.

A master plan schedule is a statement of what can and will be created by the MH facility. It becomes a realistic consensus between production and sales. This schedule indicates the date that different house models are entering the assembly line. Once the master plan schedule is updated, it is sent to the MRP department to be utilized for the material requirement estimation (see Figure 5).

Material Requirement Planning (MRP)

The MRP process plans all items that need to be purchased and completed to support the master production schedule. In this manner, the replenishments can be planned and managed. Its principal goal is to reduce stock levels with consequent saving in capital, resources, and space.

This MRP system uses the information available at any factory and proposes the use of a computer database as a tool to optimize their utilization. It uses the information provided by the MPS department and the information compiled in the inventory records system to answer the five related questions shown in Table 3.

The proposed MRP system is 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. MRP completes the supply chain and uses the resources and information provided by the

other parties to optimize the material order, delivery and therefore the production process. This process has been divided into three different steps described below:

- Step 1: Material Need schedule.

This step uses the master plan schedule to develop a material need schedule for the MH facility. The bill of materials and quantities that are used in each house is known, therefore the information needed to develop the material need schedule is available. This information is used to transform the master production schedule into the material need schedule. The schedule will help the MRP department to answer questions 1, 2 and 3 described in the previous paragraphs (see Figure 6).

- Step 2: Purchasing Schedule.

The second step in the MRP process is to use the lead time for each material to determine the material purchasing schedule. The lead time must consider also a material inventory holding time that needs to be defined by each factory. This additional time becomes a safety factor for the purchasing manager and it is used to assure that the material will be available for use when it is needed. The purchasing schedule will help the MRP department determine when the material needs to be ordered (see Figure 6).

- Step 3: Purchasing Orders.

Finally, this purchasing schedule is converted into different purchasing orders with respect to the suppliers. These purchasing orders are completed with the supplier's contact information. Once these orders are ready, they are sent to the different suppliers. This step uses the existing database to relate the different materials with the different suppliers. The purchasing orders will answer the question where it is going to be bought (see Figure 6).

All the questions described in previous paragraphs have been answered using these different steps. MRP is a more efficient planning tool that can be used to propose back-up strategies when demand changes appear. Any changes to the master schedule automatically update the outputs of the system.

Material Process Flow

The entire material supply management system process is summarized in Figure 5. All activities are linked to each other forming the entire material cycle at any Manufactured Housing Facility. Each individual step inside the process must be done efficiently to support the success of the entire supply chain. The process flow indicates the customers as the starting point and ending point of the material cycle.

COMPARISON BETWEEN CURRENT AND PROPOSED SYSTEM

The proposed system has been compared with the standard system used in the MH factories (see Table 4). The proposed system presents many advantages over current practices used by the MH industry. Some of them are described below:

- The new system can be qualified as a pull system that uses backward scheduling as the primary tool by relating material requirement to the master production schedule.
- This system eliminates the need of historical data for material requirement estimation. Instead the material requirement is estimated directly from the products that the facility is producing. This system provides more accurate values and therefore it reduces wastage of material.

- It replaces a weekly order process with a daily ordering process, leading to lower levels of inventory at the facility, therefore improving the use of space at the MH factory.
- It eliminates unnecessary processes and redundant information making the system leaner.
- It introduces inventory control and supply chain management concepts to the MH industry opening a new frontier for further application.
- This new system solves the drawbacks detected in current practices by optimizing the use of information and available resources, and by radically reducing the process time of material requirement estimation.

CONCLUSIONS

A material supply management system has been developed from the standard material flow and management system currently used by the MH industry. This new system is based on dependent demand systems, and it integrates the different parties related with material management and proposes the use of modern practices for material quantities estimation.

In order to have an efficient material supply chain management system, the system must be supported by facilitators of quick information and material flow. Today, there are technologies available that can be used to accomplish this task. Internet, local networks and electronic data interchange (EDI) are being successfully used by other manufacturing industries, and they show potential benefits for the MH industry.

The proposed system presents potential benefits to the MH industry by solving the problems detected in the current system. Experience shows that application of this type of system has brought several benefits in other manufacturing industries. The main advantage of the proposed new MRP system is its ability to relate demand for material directly to the master

production schedule. This process reduces the amount of items on stock thus reducing holding cost and provides better planning.

ACKNOWLEDGEMENT

This study is supported by the National Science Foundation (NSF) and the Partnership for Advancing Technologies for Housing (PATH). The opinions and findings expressed here, however, are those of the authors alone and not necessarily the views or positions of NSF and PATH.

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LIST OF TABLES

LIST OF FIGURES

Table 1. Problems of the Generic Material Flow and Management System

Problem Description
1. No standard material management system exists
2. Redundancy of information.
3. Poor use of advanced technology.
4. High inventory levels resulting in waste of space, money and resources.
5. Difficulty to estimate amount of material needed due to various types of house.
6. Irregular lead times due to dealing with great number of suppliers
7. Dependence on historical data in estimating the material requirement
8. Employee's poor knowledge about inventory control

Table 2. Inventory Records

	Description
ID code	An identification code.
On Hand	How many items are currently in stock available for using?
On Order	How many items have been already ordered from the suppliers and when they are due to arrive.
Lead Time	Time that takes between the order and delivery. A common error is not to include the time that takes the supplier to process the order and the time that takes the inspection upon delivery.
Planning Data	List of Houses. List of Materials. List of Suppliers. Material Quantities per House. List of Materials per supplier.

Table 3. DRP Logistical, MPS, MRP Questions

Questions	Answers
DRP Questions	
What am I going to sell?	Different house models.
Where will I sell it?	Interrelationship with the dealers.
What do I have to get?	House Type and specific items to built.
MPS Questions	
What do I need to build?	Different house models.
When do I need to build it?	Date that the house is going to enter the assembly line.
MRP Questions	
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 4. Comparison between Current and Proposed System

Characteristics	**Standard Material Flow & Management System**	**Proposed Material Supply Management System**
Inventory Control System	Independent Demand System Push system	Dependent Demand System Pull system
Ordering System	Periodic Ordering System Weekly	Perpetual Ordering System Daily
People involved in the Process	Material Handlers Head Receivers Purchasing Manger	Customers Dealers DRP Department MPS Department MRP Department: Material Handlers Head Receivers Purchasing Manager Suppliers
Activities	Material Flow: Material Inspection Material Storage Inventory Control System: Inventory Records Material Requirement Est.	Material Flow: Material Delivery Material Inspection & Storage Material Utilization Information Flow: Inventory Records DRP MPS MRP
Inventory Records	On Hand On Order Historical Data Lead Times	On Hand On Order Lead Time Planning Data
Material requirement estimation	Historical Data	Directly from the products
Stock	Higher Inventory Level	Lower Inventory Level
Technology used in the System	None	Computer Database Computer Software

FIG. 1. Manufactured Housing Construction Overview

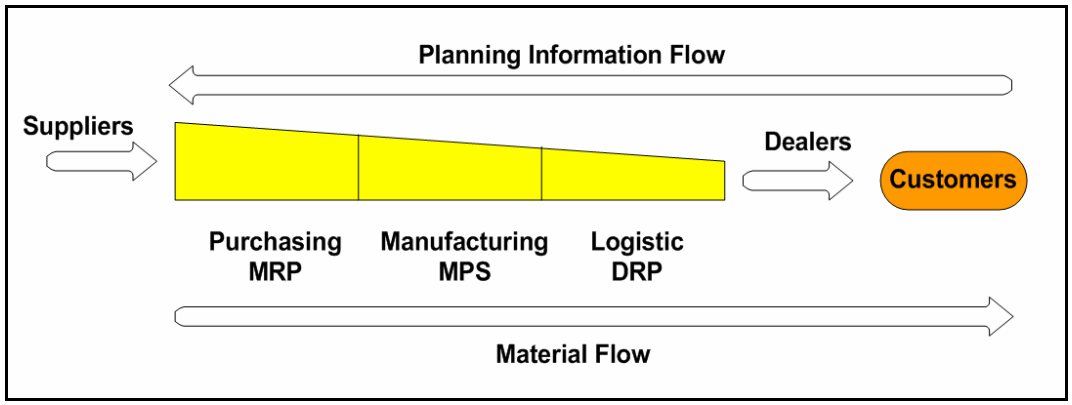

FIG. 2. Supply Chain Management System for Manufacturing Housing Industry (Barriga 2003)

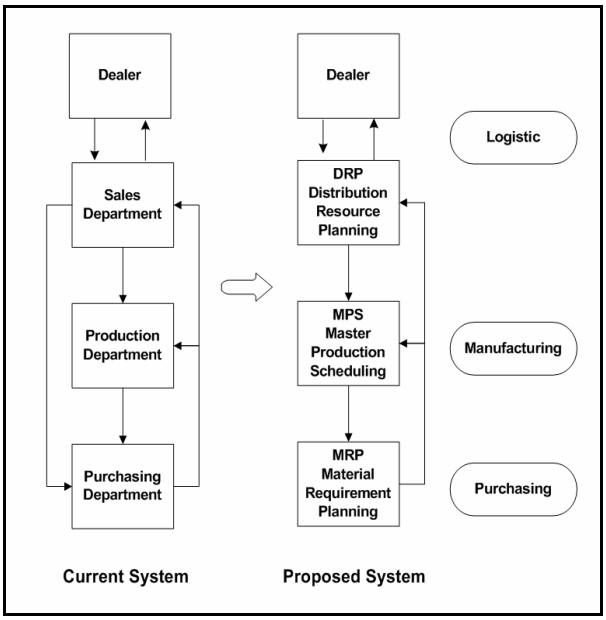

FIG. 3. Integrated Supply Chain Management System for Manufacturing Housing Industry

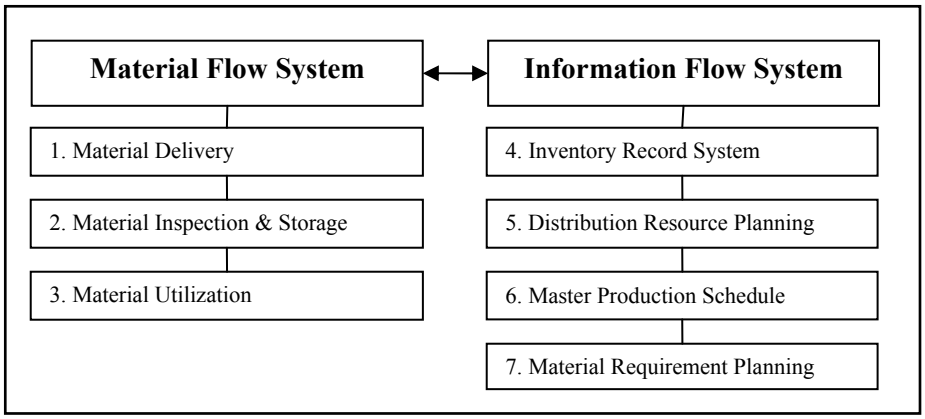

FIG. 4. Proposed New Material Supply Management System

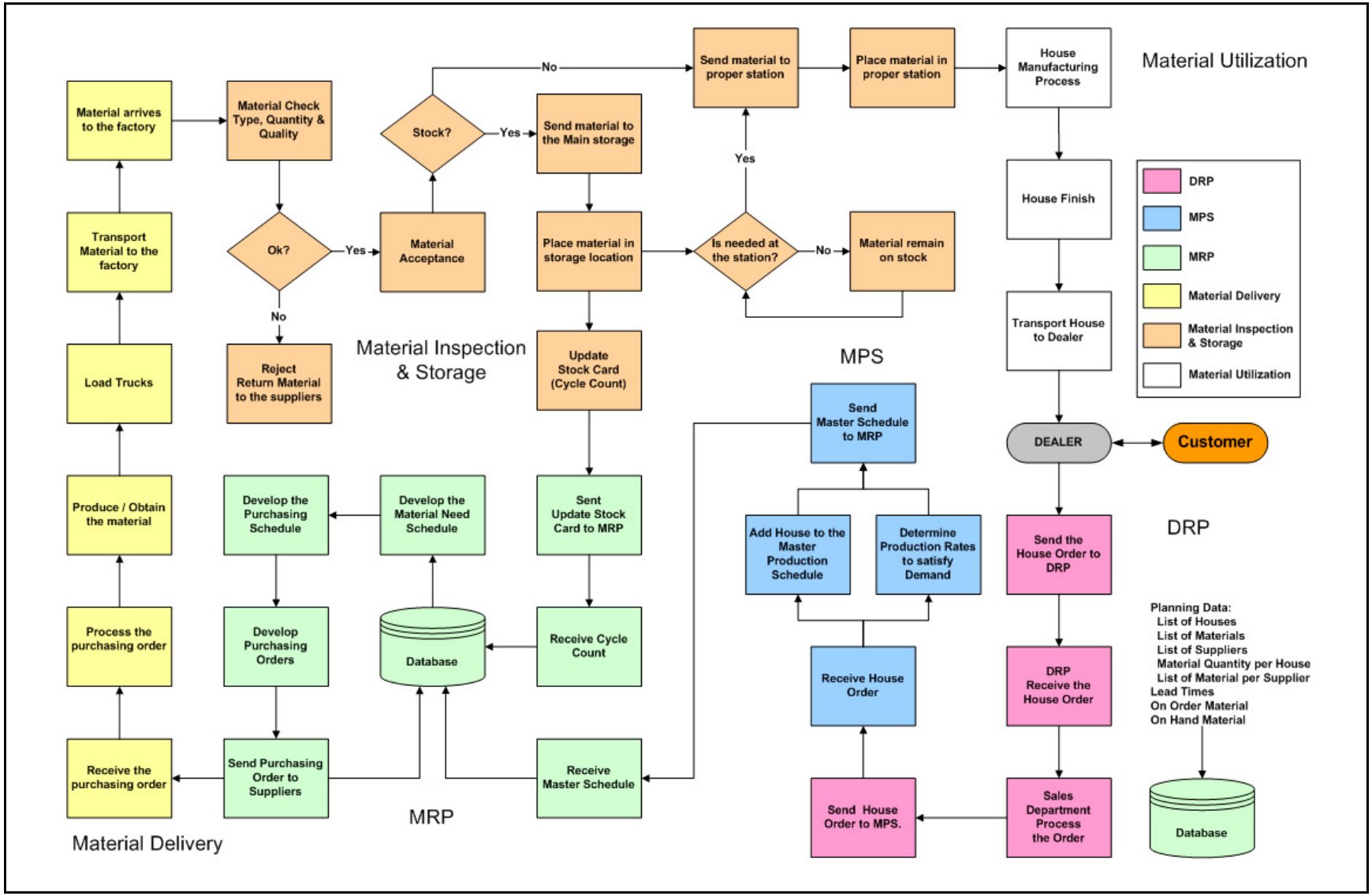

FIG. 5. Material Cycle in the Proposed New Material Supply Management System

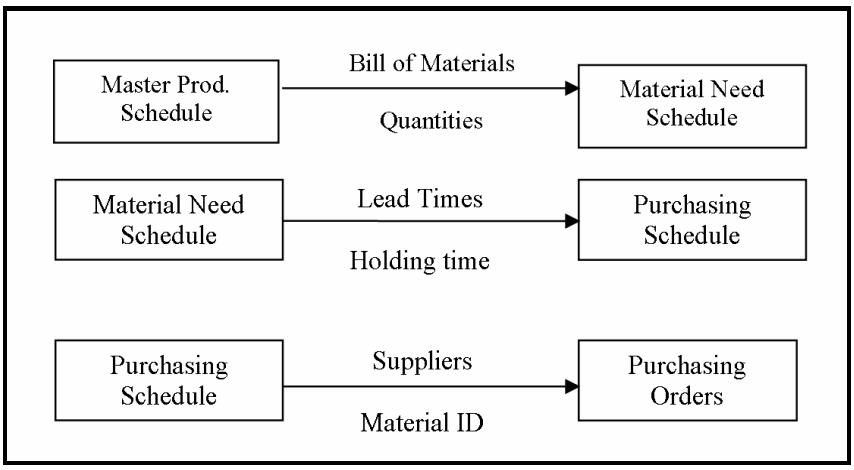

FIG. 6. First Three Steps in the MRP Systems