IMPLEMENTING DDMRP IN A LEBANESE MULTIPRODUCT INDUSTRIAL COMPANY

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ABSTRACT

This article describes the implementation of DDMRP in a multiproduct industrial company.

The term DDMRP, or Demand-driven MRP (Materials Requirements Planning) is a relatively new concept that is not well elaborated in the academic literature. The article reviews the academic literature, which, one has to note, is limited due to the young age of the concept. It will explore how the concept can be used as an inventory replenishment model by exploring its implementation at Liban Cables SAL - a Lebanese diversified multiproduct industrial company having to deal with different production cycles and processes.

INTRODUCTION

Industrial companies are in constant search for ways to optimize their business models, increase their profit, ensure customer satisfaction and increase market share. One of many paths to achieve those targets is the implementation of a right supply chain strategy. Implementing the supply chain strategy that best suits a company's business model could minimize the inventory levels and capital employed, and at the same time optimize customer satisfaction and enhance market share by making sure that the company does not reach a stock-out position on strategic items on demand.

Such challenges are amplified when operating in a country with high level of volatility in terms of political, military, social and security matters. In such conditions, customer demand would suddenly change during short term periods, both in quantities demanded, or in types of products requested. If not properly handled, this kind of volatility could push companies into sharp bullwhip effects, reducing the health or quality of their inventories by having both items of very high unsold inventory levels and items in shortage positions, reducing their customer satisfaction and increasing their operating working capital (OWC).

In this article, we will try to shed some light on the existing literature related to push production control strategies, mainly the MRP & MRP II, and the new concept of DDMRP (demand-driven MRP). In addition, we will try to study the implementation of DDMPR at a multi-product industrial company.

The case study will be done at Liban Cables SAL, which is a leader of electrical cables production in the Lebanese market. Liban Cables produces thousands of cables, for various applications, which come in different colors, lengths and packing types. The company carries out a rather complex operation because its several hundred of cable types are produced using just few dozens of raw materials, while having to respond to the diversified needs of numerous local and international market segments.

Push Management Strategy

The terms Push and Pull refer to the means for releasing jobs into the production facility. In a push system, a job is started on a start date that is computed by subtracting an established lead time from the date the material is required, either for shipping or for assembly. A pull system is characterized by the practice of downstream work centers pulling stock from previous operations, as needed. All operations then perform work only to replenish outgoing stock. Work is coordinated by using some sort of signal (or Kanban) represented by a card of a sign (Spearman and Zazanis, 1992).

Push management strategy refers usually to traditional western approaches to multistage production scheduling, mainly characterized by the determination of a production schedule for each stage. The most prevailing approaches to calculate component and raw material requirements, and to schedule each work center, is the manufacturing resource planning (MRP-II) which was an extension of the material requirements planning (MRP), (Deleersnyder et al., 1992).

The main advantages of this approach are:

- All relevant information (including material requirements, work in process levels, machine status, and inventory levels) is stored in a central computer, implying a centralized control and coordination among the work centers.
- Implementation has stimulated the development and use of well-organized information systems.

According to the authors, under the MRP type systems, work is pushed through the system, and such push approach has all the characteristics of a Just-in-time (JIT) system, mainly knowing when the end assembly should occur, the preceding operations could be scheduled just in time by accounting for the lead times, however it also has clear disadvantages, mainly:

- The inability to maintain data information at a level of high reliability
- A lack of inherent improvement mechanism
- A lack of real-time coordination among the consecutive stages means that frequent rescheduling is necessary to keep the total system under control
- Approximations in the approach can cause excess safety stocks.

Hopp and Spearman (2004) explained that, prior to the dominance of the computer in manufacturing, inventory was controlled using reorder-point/reorder-quantity (ROP/ROQ) type methods. During the 1960s, Joseph Orlicky, Oliver Wight, and George Plossl along with others developed a new system, which they termed Material Requirements Planning (MRP). Orlicky obviously believed that they were on to something big as suggested by the subheading of his book : The New Way of Life in Production and Inventory Management (1975). After a slow start, MRP began to gather steam during the 1970s fueled by the "MRP Crusade" of the American Production and Inventory Control Society (APICS). Orlicky (1975) reported 150 implementations in 1971. By 1981, the number had grown to around 8,000. As it grew in popularity, MRP also grew in scope, and evolved in the 1980s into Manufacturing Resources Planning (MRP II), which combined MRP with Master Scheduling, Rough-Cut Capacity Planning, Capacity Requirements Planning, Input/output Control, and other modules. In 1984 alone, 16 companies sold $400 million in MRP II software. By 1989, over $1.2 billion worth of MRP II software was sold to American industry, constituting just under one-third of the entire software industry.

Evolution of Manufacturing Planning

Under the title "Evolution of manufacturing planning and control systems: from reorder point to enterprise resource planning", Rondeau and Litteral (2001) explained the evolution of manufacturing planning and control systems (MPC), which had existed since the earliest days of industrial evolution, by studying the five major stages of evolution: (1) reorder point (ROP) systems, (2) material requirement planning (MRP) systems, (3) manufacturing resource planning (MRP-II) systems, (4) MRP-II with manufacturing execution systems (MES), and (5) enterprise resource planning systems (ERP) with MES. Each stage was considered to be the following logical stage over the previous stage in term of manufacturing philosophy and technological innovation. Furthermore, information technology was considered to have the most impact among the other factors in changing the foundation of production economics through the process of automation of many administrative tasks and significantly improving manufacturing accuracy, reliability, and predictability.

Brief history of MPC system evolution

MPC started to take shape at first when, in a manufacturing facility, group of plant foremen where assigned the task of scheduling production and ordering raw materials and coordinating shipments for products involved in their areas of responsibilities, all in a most simple manner which allows the poorly trained foreman to operate them successfully. Later, these kinds of industrial practices evolved to pave the way for highly specialized reorder point systems of production and inventory control which naturally substituted the simple plant foreman system, Skinner W. (1985).

Orliky (Material requirements planning – 1975) explained the reorder point systems "*as being positional in nature, by using a historical approach to forecasting future inventory demand, which assumes that past data are representative of future demand. Whenever an item's inventory level falls below some predetermined level, either additional inventory is ordered or new production orders are released in fixed order quantities*". The ROP were implemented manually at their early sates, but were quickly automated after the introduction of the commercial mainframe computers the 1950s and 1960s.

In the 1960s, the ROP system was gradually replaced by computerized materials requirements planning systems, with much more added value by proposing forward-looking and demand-based view for planning and inventory management. The method allowed to soften the high volatility of inventory level generated by the peaks and valleys under the ROP approach, and managed it more effectively and precisely under MRP's lot-for-lot order-generation capabilities.

Building on the demand-based material management capabilities of MRP systems, manufacturing resource planning was introduced in the mid-1970s, creating an integrated or closed-loop MPC by adding capacity requirements planning (CRP) capabilities. This addition allowed the integration of both raw materials and production capacity needs and limitations in the overall calculation of production capabilities. When adding the shop floor control (SFC) reporting capabilities to the MRP-II, it allowed companies to become more efficient in scheduling and monitoring the execution of production plans.

Rondeau and Litteral (2001) continued explaining that the information technology which branded the 1960s, 1970s, and 1980s' manufacturing environment was mainly focusing on the automation capabilities of the technology which could lead to much more efficient manufacturing operations in large industrial companies. To the authors, "*The ROP, MRP, and MRPII systems that eventually evolved were characterized by large mainframe computers, hierarchical databases, and complex transactions processing systems geared primarily toward managing a production environment of few products, produced in high volumes, under conditions of constant demand. Although highly efficient, these systems were often inflexible when it came to producing variable quantities of more custom products on short order*".

Manufacturing Execution systems

Rondeau and Litteral continued by explaining how rapid advances in information technology rendered the old rules of competition and long-standing understandings of customer-supplier relationships obsolete, and how this new reality translated into the need for a dynamic production environment in which products and processes may change weekly and production schedules may change on a daily or hourly basis, through a more advance MPC system, capable of real-time manufacturing planning and execution control.

The solution came through the emergency of manufacturing execution systems (MES) in the 1990s, which represented the development of a critical interface between a firm's MRP-II systems and its shop floor and device control systems, providing flexible, real-time execution, feedback and control of a wide range of manufacturing related processes to better meet future market requirements. The implementation of MES, with its capabilities to support greater vertical and horizontal integration within the manufacturing function, transformed the MRP-II from a closed loop MPC system on its own, to a continuous loop MPC system when combined with MES.

Developing automatic identification and data-collection systems were part of the information technology drivers that helped the wide adoption and acceptance of MRP-II/MES. Greatly improved technologies such as Vision systems, radio frequency transponders, touch systems and device control systems were all tools of the improved technologies that progressively replaced people or reduced the potential of mistakes in manufacturing data collection.

Enterprise resource planning

With the customer-centered supply chain becoming the standard mode of operation for most global competitors by late 1990s, firms were compelled to adopt a cross-functional customer-driven MPC systems designed to improve organizational speed and flexibility, unleashing the informing power of the technology systems and enabling workers to act with co-workers to process information, make decision, and solve problems.

In comparison with the MES, the Enterprise resource planning (ERP) brought higher level of horizontal integration, providing firms with important turning point in developing MPC systems, allowing companies to reach desired strategies of supply chain continuous improvement by using flexible and customer-driven information management.

Olinger, C (1998) found that *"relevant Business Systems defines a fully functioned ERP system as performing eight major types of business functions: (1) engineering part and bill of material control, (2) engineering change and documentation control, (3) purchasing, (4) materials management, (5) manufacturing planning and control, (6) cost management and control, (7) finance (accounting), and (8) marketing and sales systems".*

Rondeau and Litteral expressed that ERP systems at their best performance levels should identify and handle the impact of the internet and various advanced technologies on modifying a company's customer base, these advancements could contain data mining software, statistical analysis software, and other systems that help in decision making.

The authors made the below summary table of the evolution of the MPC systems:

Table: Manufacturing Planning and Control System Stage Characteristics

MPC Stages →	ROP	MRP	MRP-II	MRP-II / MES	ERP / MES
MPC characteristics: 1. Overall production planning orientation	Positional (based on historical demand)	Predictive (based on future demand)			
2. Material planning	Min/max reorder point logic	Lot-for-lot & min/max reorder point logic			
3. Capacity planning	Manual capacity planning		Capacity requirements planning (CRP)		
4. Manufacturing execution & control	Manual production execution & control		Shop floor control (SFC)	Real-time machine feedback & control	
5. Master planning	Manual master scheduling		Limited decision support (DSS) features		Full DSS features
6. Cross-functional data linkages	Degree of cross-functional information access and sharing varies by firm				Real-time information access and sharing
IT characteristics: 1. Information technology focus	***Automating*** power of technology (i.e., IT enables manufacturing firms to realize greater cost efficiencies.)			***Informating*** power of technology (i.e., IT enables more effective decision making.)	
2. Computer hardware environment	Mainframe Systems →	Mini-Computer Systems →		Client-server systems →	Web server systems →
3. Information processing	Batch-processing	Online transaction processing		Real-time transaction processing	
4. User interface	Command-based		Menu-based	Graphical user interface (GUI)	
5. Database technology	Sequential files	Hierarchical database →		Relational database →	Object-oriented Database →
6. External MPC interfaces to customers and suppliers	Manual forms & correspondence →	Magnetic tape →	Electronic data interchange (EDI) →		Internet & Extranets →

(Source: Rondeau, Patrick and Litteral, L. A. (2001), "The evolution of manufacturing planning and control systems: From reorder point to enterprise resource planning.")

While MRP was steadily dominating the American production control scene, history was taking a different course in Japan. There, perhaps because it lacked a strong indigenous computer industry, the computer was far less pervasive in production and inventory control. Instead, several Japanese companies, most notably Toyota, developed the older ROP/ROQ methods to a high level (Hopp and Spearman, 2004).

Demand-Driven MRP (DDMRP)

The Demand-Driven MRP (DDMRP) is a method for managing flows in manufacturing and distribution flows that is supposed to manage uncertainties better than traditional Manufacturing Resources Planning (MRP) using some of the principles of pull approaches.

Description of DDMRP

Ihme & Stratton (2014) explained the various characteristics of DDMRP by listing the main problems of MRP and explaining the implementation process of DDMRP. According to the authors, traditional MRP had several problems, so they summarized the work of various authors on MRP-related problems in the below table:

Table: Common MRP-related problems

Problem area	Characteristics
Forecast and MPS	All forecasts and sales plans are all wrong. MRP uses this forecast via the MPS to calculate demand and to create work and purchase orders. Market volatility and fluctuating customer demand in the short-term cause misalignment between such forecasted demand and real customer orders. The consequences are often high inventories of wrong items on one side and expediting, overtime, extra freight costs and even missed shipments on the other.
Full BOM runs	MRP pegs down the full BOM to the lowest hierarchy level independently for each stock-keeping unit (SKU) in cases when available stock is less than exploded demand. The result is many orders and a schedule that can easily change triggered by a small change at an upper level material.
Manufacturing order release	MRP does not check parts availability prior to releasing work orders since only lead-time related criteria is used for making this decision. It is a basic assumption of MRP that all parts are available at the time of work order release. Experience of reality suggests that this assumption is not often true.
Limited early-warning functionality	MRP creates work orders for items that reach the configured safety stock level. There is no visibility of items that are near this level or that might reach this level in the near future due to high customer demand.

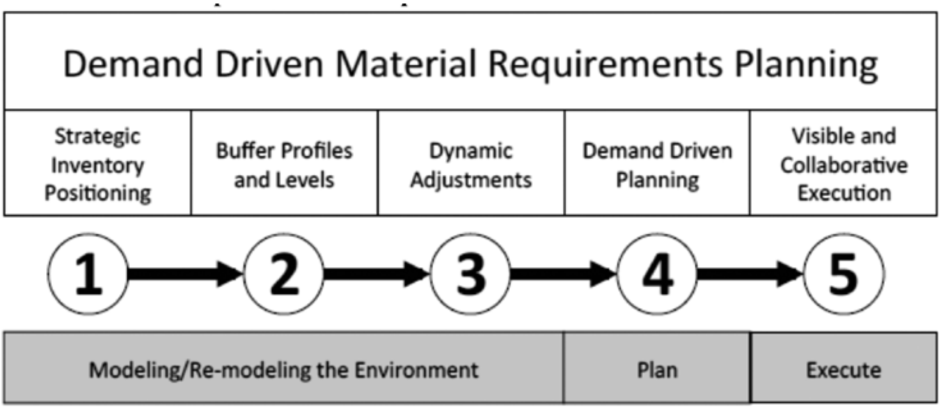
Lead-time ambiguity	MRP can use two different lead-time types. Using manufacturing lead-time often causes orders be released too late while using cumulative lead-time often causes orders to be released too early resulting in work in progress levels being unnecessarily high.

(Source: Mathias Ihme and Roy Stratton (2014), "Evaluating Demand Driven MRP: a case based simulated study")

Based on the above, a more suitable solution is looked for to better help organizations overcome these problems.

Demand-Driven Material Requirement Planning (DDMRP) is a "multi-echelon materials and inventory planning and execution solution" (Ptak et al., 2011). DDMRP is designed to be a framework for production planning and control that incorporates MRP functionality while explicitly addressing its known weaknesses by incorporating ideas such as strategic buffering, replenishment and buffer management.
Ptak et al. (2011) proposed five steps for the implementation of DDMRP, as shown in the below figure.

Chart: DDMRP Implementation Steps



(Source: Ptak et al. (2011) – 5 steps to implement DDMRP)

Ihme & Stratton (2014) summarized the five steps to implement DDMRP proposed by Ptak et al. (2011), which are supposed to be applied jointly, in the below table.

Table: Five Steps to implement DDMRP

Component	Characteristics
Strategic inventory positioning	Ptak and Smith (2011) found that the question of how much inventory one should hold needs to change to asking where inventory should be positioned. It is necessary to protect the supply chain from fluctuating customer demand and supply variability. Inventory of raw and intermediate items can also help to compress cumulative lead-times and improve overall stability.
Buffer profiles and levels	Buffers are calculated for manufactured, purchased and distributed items. The calculation is based on the average daily usage (ADU), variability and lead-time. Furthermore, minimum order quantities are considered if needed. Ptak and Smith (2011) define three distinct buffer zones (green, yellow and red).Green stands for nothing to do, yellow indicates the rebuild or replenishment zone and red means special attention required.
Dynamic adjustments	DDMRP considers recalculated adjustments, planned adjustments and manual adjustments within the model triggered by external events changing ADUs.
Demand-driven planning	DDMRP separates parts into five distinct categories (replenished, replenished override, min-max, non-buffered and lead-time managed) and parts are allocated to one of the five categories according to their needs.
Highly visible and collaborative execution	DDMRP contains a sophisticated alerting system that circumvents the priority-by-due-date issue of classic MRP by establishing alerts based on buffer states while still considering due dates as a second source of information. Alerts are created based on the buffer state of the part in focus. Collaboration is needed to establish clear rules for decision-making based on these buffer states.

(Source: Mathias Ihme and Roy Stratton (2014), "Evaluating Demand Driven MRP: a case based simulated study")

Although existing literature evaluating DDMRP performance is rare, the description of the DDMRP steps might address major weaknesses of standard MRP.

In another interpretation of Ptak and Smith's (2011) five steps to implement DDMRP, Miclo et al. (2016) explain how the first step deals with "strategic inventory positioning" by evaluating from a financial point of view if there are benefits to position or not a buffer on an article of a Bill of materials. They considered this as the most strategic and original step. The following step of positioning DDMRP buffers will help to implement the method correctly. Consequently, the DDMRP principle would be to pull replenishments between strategic buffers, but to deduce and push plan orders for unbuffered articles. Buffers should control the dispersion of variability in the manufacturing system. Miclo et al. (2016) continue that as soon as the buffers are positioned, it would be possible to define "buffer profiles and levels". Buffers are replenished according to its relative "available stock equation" (ASE) which is the inventory position minus qualified spikes. Huge demand orders whose production have to be anticipated of some production lead-times and consequently made on demand, are considered as qualified spikes. The available stock equation is compared to three buffer alert levels: (1) red which is the safety stock, (2) yellow referring to in-process replenishment quantity, and (3) green the replenishment size. These zones help define on buffer replenishment, anytime the ASE enters the yellow zone a replenishment order is put to reach the green zone upper level. Also the execution the stock buffer is split in these three color zones, but orders can be prioritized and scheduled according to the alert.

The design of the buffer levels for planning and execution is calculated based on the DDMRP formula, which will be explained further below. Average Daily Usage (ADU) is the result of demand forecasting, while ASRLT which is an original concept of DDMRP is the longest unprotected sequence in the bill of material of a buffered article (considering a sum of lead times). As buffers are supposed to control variability, unprotected sequences are considered between buffered articles.

Plan Adjustment Factors (PAF) are percentages used to raise or lower ADU. They enable to model and smooth big seasonal variabilities, promotions, and can be considered as the result of a Rough Cut Capacity Planning. Variability factor is used to protect from uncertainty: it is a part of the red zone and represents the safety stock. Lead-time factor is different for long lead-time or short lead-time products: when the ASRLT is long the lead-time factor is small (in order to often produce long-lead time products with a small order quantity).

Finally Miclo et al. (2016) explained the DDMRP buffer formula as follow:

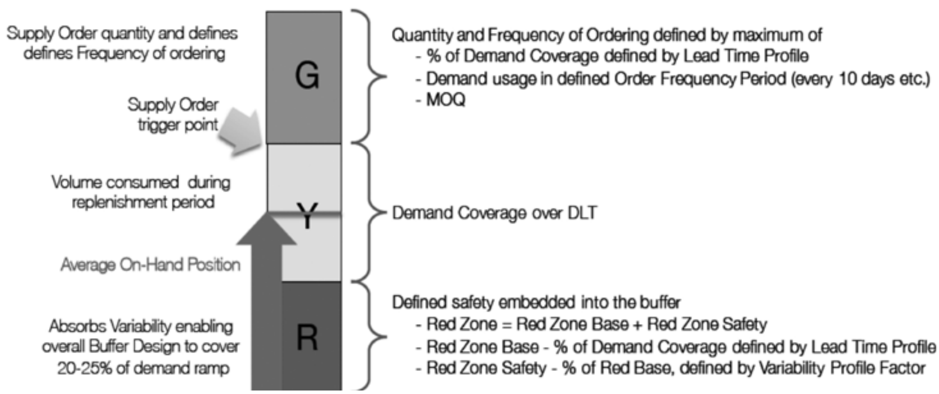
Green Zone = Max (YellowZone. LTFactor; LotSize)
Yellow Zone = ADU. ASRLT. PAF
Red Zone = YellowZone. LTFactor. (1+VariabilityFactor)
TopOfRed = RedZone
TopOfYellow = TopOfRed + YellowZone
TopOfGreen= TopOfYellow + GreenZone

Since DDMRP is not yet well developed in the academic literature, some consulting companies have been publishing training documents to better explain the implementation of DDMPR.

High Impact Coaching & Strategies, published a document called "Demand driven material requirements planning: the next generation MRP standard", where they gave some visual explanation to better understand the concept of DDMRP. They explained the setting of buffer zones as such:

- 3 Buffer Zones indicated by color and representing the state of the inventory system:
  - Green: Part requires no action
  - Yellow: Part requires replenishment
  - Red: Part may require special attention
- Size of Buffer based on:
  - Buffer Profile traits
    - Item Type / Variability / Lead Time
  - SKU traits
  - Average Daily Usage (ADU) / Demand Driven Lead Time / Ordering Policies
- Available Stock is compared against buffer levels to determine Planning and Execution priorities

Chart: DDMRP Inventory Zones



(Source: High Impact Coaching & Strategies, "Demand driven material requirements planning: the next generation MRP standard")

Tompkins International: Demand-Driven Supply Chains

In an article published in February 2012, Tompkins International says that supply chain managers and senior executives across all industries must now react to volatility and unpredictable events even more than ever before. Many relate that their operating plans are impacted even before they reach a steady state, that capacities are either over or under-utilized, that product inventories are either excessive or out of stock, and that flexibility is elusive no matter what they do to prepare for it. Thus they highlight the need for a new approach to demand-driven supply chain, focusing on customer service and providing visibility across the entire chain with neat, real-time availability.

Tompkins speaks of a demand-driven model that is based on a single sales forecast that drives the entire supply chain, leading all trading partners in the supply chain (suppliers, producers, distributors, retailers, and service providers) to operate with one single consensus sales forecast. They describe the demand-chain, and not an individual demand-link, meaning that the single consensus sales forecast is as up to date as possible to reality, knowing what is actually selling, at least daily, and even hourly. Demand-driven takes customer purchase information at the point of sale and provides it in real-time to all trading partners throughout the end-to-end supply chain. This means the entire supply chain sees one set of sales numbers and responds to those numbers in real-time. The key success factor of demand-driven is the timeliness of the data reflecting real transactions.

They speak of several advantages to implementing demand-driven supply chain:

- Organizational Development: Transforming operations to demand-driven provides new ways to improve business performance – for processes, people, and culture – by focusing all efforts on activities and metrics that matter.
- Knowledge and Fact-based Decisions: Basing decisions and choices on facts and intelligence produces more value than on assumptions and intuition.
- Customer Satisfaction: While much of this category can be measured, there are positive and valuable intangibles that result from the power of relationships.
- Self-Assessments: Some companies have established Centers of Excellence (COEs) that house and apply tools, methods, and scorecards to identify needs and opportunities for improvement. Demand-driven supply chains contribute to these for multiple applications.
- Improved Scenario Planning: Scenarios allow the rapid creation and evaluation of alternative plans, which improve the organizational ability to be agile and resilient.

Tompkins International proposes a 3 steps road to achieve demand-driven supply chain:

STEP 1: Prepare the Operation for a Pilot Test.

The objective in this first step is to streamline the strategy and business processes such that a pilot test can be conducted.

- Challenge the operations strategy. (Does it enable the business strategy? Does it give priority focus to demand or to supply?)
- Determine the right product category and supply chain to be tested.
- Determine the pilot test conditions – objectives, metrics and time period.
- Ready the processes and data sets for the pilot test
- Ready the solution sets. (Remember processes, people, and tools are the foundation of the company.)

STEP 2: Conduct the Pilot Test

- Operate the pilot test on true demand data and other actuals.
- Orchestrate change by designing, collaborating and co-managing with the retailer/customer and suppliers/service providers.
- Monitor the results and measure the performance of the four flows of product, cash, information, and work.

STEP 3: Roll-out to other Categories and Trading Partners

- Reformulate the new operations strategy.
- Refine the business processes based on learning from the Pilot.
- Prioritize the categories and supply chains.
- Implement change management programs from the beginning.
- Set the right business-wide financial and service targets and performance measures.
- Integrate and scale the solution sets: processes, people, and tools.
- Provide for continuous improvement

KPMG: Demand-Driven Supply Chains

In a published article on their website in 2016, KPMG considered that demand-driven supply chains align planning, procurement, and replenishment processes to actual consumption and consumer demand, allowing companies to be more responsive to consumer needs while increasing profitability.

In their article, demand driven supply chain involves transforming the traditional supply chain into an integrated multitier supply network, eliminating information latency and unnecessary touch points, thereby reducing operating costs and improving profitability and customer service, through the following main characteristics:

- Product movements driven by actual demand / consumption
- Real-time demand / supply visibility across partner tiers
- Inventory managed to dynamic target operating levels
- Early identification of demand / supply continuity issues before they impact production
- Single demand signal shared across partner tiers – one version of the truth

They claim that their model of demand-driven supply chain would change the business model from supply chains to supply network, in which all tiers of partners have visibility to changes in the end-consumer demand and all material movements and inventory decisions are driven by demand signals as close to the consumer as possible, capturing actual consumption and changes in demand patterns.

In addition, they speak of achieving balanced cash flow, through increased sales, reduced operating expenses, and working capital improvements:

- Improved fill rates and reduced out-of-stocks drive increased revenue and recoverable sales.
- The reduction in information latency requires fewer inventories to be carried as demand uncertainty in reduced.
- Real-demand visibility to the complete demand / supply picture and continuity issues reduces supply disruptions.
- Process automation reduces operating expenses, allowing buyers / planners to manage by exception

KPMG asks five questions to assess a company's supply chain position:

1) Do you have visibility to your total demand and supply picture at any point in time? Does this visibility extend beyond your first-tier partners?
2) Are all material movements driven by actual demand or by forecasted demand?
3) Does it take longer than a day for demand changes to propagate to your second-tier suppliers?
4) How quickly can you identify and respond to a potential supply continuity issue?
5) Does your entire supply chain function as one virtual organization with everyone working with the same information, processes, and metrics?

Supply Chain Magazine Article

In an article called "The MRP is dead, Long live the DDMRP", Thierry Bur (2015) considered the DDMRP (demand driven material requirement planning) as an innovative solution, for the problems of low service level, inadequate levels of finished and semi-finished products, and shortages in raw materials, which combines the lean approach (pull system, visual management) as well as the theory of constraints (optimizing bottlenecks and decoupling points to optimize capacity and reduce lead times).

According to Bur, the secret of DDMRP is to set in place buffer stocks at various points within the supply chain, before determining the required level of inventories and replenishment strategy. The process is not based on forecasts, which are always wrong, but on actual demand from the clients, in order to avoid unnecessary high inventories, but have just enough level that is actually needed. He continues that the DDMRP is well adapted to situations where we have long delays to source materials, high demand diversity, and high complexity of products. It is a complete process of planning and execution, through five consecutive steps:

1) Good positioning of buffer stocks (semi-finished) at various steps within the supply chain.
2) Deciding the right inventory level to absorb the volatility of demand and processes.

3) Continuous and dynamic modification of the buffer stocks based on the evolution in demand and clients profiles.
4) Continuous (daily or weekly) replenishment of material based on real demand.
5) Transparent execution and collaboration of processes once confirm demand requirements enter the system.

Using the DDMRP leaves the business model based on forecasting and follows only real demand; however a small level of forecasting remains necessary in order to determine the right level and position of the buffer semi-finished inventories within various levels of the supply chain, make vital industrial plans and manage products life cycles.

Brief description of Liban Cables

Liban Cables SAL is a leading Lebanese company for the manufacturing of electrical and telecom cables (with 85% market share).

Established in 1967, Liban Cables had a headcount of around 525 employees in 2016, with a turnover between 100 and 125 million US Dollars per year. The company's factory is located in the area of Nahr Ibrahim, 45 km north of Lebanon's Capital, Beirut, where the port and airport of Beirut are located.

Almost nothing of the raw materials needed for production could be founds locally, that is why all raw materials are imported from all around the world. On top of that, 30% of the company's sales are exported to foreign countries. Thus the availability of an accessible and safe seaport and airport is essential to the existence of Liban Cables SAL.

Implementation of DDMRP

DDMRP was implemented at Liban Cables out of necessity, as an experimental project at first, without fully knowing the impact of such tools on the overall supply chain system of the company. The expected results were mostly based on guessing, and the process was facing a lot of resistance and skepticism from experienced planners who were used to forecast based planning for tens of years, while many were waiting for the process to just fail and not deliver any added value.

Steps & Parameters of Implementation

The implemented DDMRP process at Liban Cables was executed under the global description made by Ptak et al. (2011), but in a more adapted manner to the specificities of the company, and the whole system was created and managed outside the existing ERP system. The management of the system was done through basic excel files, and the existing ERP system at Liban Cables (Navision) was only used to extract data such as inventory levels and movements.

The implementation followed the general 5 steps described by Ptak et al. (2011), which are: (1) Strategic Inventory Positioning, (2) Buffer Profiles and levels, (3) Dynamic Adjustments, (4) Demand Driven Planning, and (5) Visible and Collaborative Execution, modified to the context of Liban Cables.

Strategic Inventory Positioning

The strategic inventory positioning step deals with defining which items should be kept in inventory, and what level of inventory should be maintained, and why.

At Liban Cables, the first preparatory step of defining MTS and MTO items, as described earlier, was used to define which items should have a standby inventory level at the company's warehouse, and which items will not, and will be produced only based on specific demand.

The decision was based on the volumes of sales as well as the frequency, stock items (MTS) were sold on repetitive basis, even if the volumes were different from item to item, but if the frequency was high, the item was considered as MTS. In addition, the decision was made on the family level and type of items. Cables, the company's products, are produced in different types, sizes, and also in different colors per size, so if a size of cable is considered MTS, then all the colors of this size are considered MTS, even if the volume and frequency of sales is different between colors. The segregation was not considered as final or strict, since depending on the variation of client demand and market trends, some cables' classification could change from MTO to MTS and vice versa, and at the same time some items' classification remained questionable or under debate between the sales team and the supply chain team, whether to consider it MTS or MTO, since it was requested in some sort of repetitive form, but not necessarily on yearly basis or in sufficient volumes. In other words, the whole classification is in a variable state rather than fixed. That was the original intent, but after the original segregation between MTS and MTO, the classification was never changed afterwards until this date, but that does not mean that is will not change later.

The cables classified as MTO cannot be listed, since the portfolio is very large, and could at the same time merge with ETO (engineer to order) status, since it was produced or assembled or engineered on special demand.

In this study, we will focus on the MTS items, which are managed more easily with specific production planning tools like DDMRP and Kanban, or others.

The main families of products considered as MTS were:

- Energy Aluminum Cables
- Energy Copper Cables
- Domestic Cables
- Flexible Cables
- Telecom Cables

Defining these families of cables as MTS does not mean that all cables related to these families would be considered automatically as MTS, since MTO and ETO items would exist as well in each of the families.

The total number of items chosen to be MTS was 369 items.

The 9 cable colors used at the company are:

- N: Black
- B: White
- BE: Blue
- G: Grey
- J: Yellow
- R: Red
- V: Green
- VJ: Yellow-Green
- RN: Red-Black

The average sales of the MTS items represented around 65% of the company's total sales, varying between 55% and 75% depending on demand variation.

Concerning how much inventory should be kept as buffer, this was calculated based on the average monthly (and weekly) sales per item, in addition to the lead time required to produce each item. The amount of inventory kept would represent enough to cover the expected sales volumes during the delay of producing new batches, once the actual inventory level becomes below a certain threshold, making sure that the material would never be out of stock.

In the next section, we will explain how buffer profiles and levels were defined and implemented.

Buffer Profiles and levels

The buffer profiles and levels were implemented in line with the model described by Ptak et al. (2011), but more adapted to the context of Liban Cables' needs and complexity, by having three levels of inventory monitoring levels, being:

- Green: Part requires no action
- Yellow: part requires replenishment
- Red: part requires special attention

The threshold of each color was set at different levels for each MTS item, depending on the average sales and the time needed to produce an economical production lot of the product. Economical production lot refers to the minimum order quantities which represent the optimal state of production, or the quantity that minimizes the loss times and scrap rate generated during production.

The main unit of measure, or variable, used was the Lead Time (LT), which refers to the time needed to produce one economical lot per item.

LT was calculated based on the standard manufacturing time multiplied by two. Manufacturing time (MT) refers to the time span from the beginning of the production process of an item until its end.
In other words, taking as a hypothesis that the machine needed to produce an item is always booked in a production process, and that it needs some time to finish producing and needs a certain setup time to start producing again, the management of the company, based on experience, considered that the production lead time of any item should be calculated as double the manufacturing time.

The DDMRP zones were consequently built in multiple of LT, as such:

- Red Zone – Safety stock = 1 LT + 1 week (buffer)
- Yellow Zone = 1 LT
- Green Zone = 1 LT
- Top of Yellow – Replenishment level (Re-Order point) = Red + Yellow = (1 LT + 1 week) + 1 LT = 2 LT + 1 week
- Top of Green – Maximum stock = Red + Yellow + Green = (1 LT + 1 week) + 1 LT + 1 LT = 3 LT + 1 week.

The LT's unit of measure used was "weeks".
The item unit of measure used was "meters" of cables.
The inventory turn, or inventory coverage in weeks, refers to how many weeks of sales could a certain inventory lasts, for example, if the average weekly sales of item A is 1000 meters, and the inventory level is 3500 meters, then the inventory coverage (turn) would be 2.5 weeks, meaning that the existing inventory would last 2.5 weeks if the sales remained constant, and nothing new was produced.

The inventory levels in weeks are translated into values (meters) by multiplying it by the weekly (deducted from monthly) average sales in meters. So, if an item's safety stock should be 3 weeks of sales, then the actual inventory value would be 3 multiplied by the average sales (in meters) per week.

In some exceptional cases, however, due to the complexity of the production process of certain items, the lead time was calculated as 3 times the manufacturing time, instead of 2. This exception was based on a decision by the production control department in coordination with the supply chain department.

This process of setting the LT and parameters was done for all MTS items, which led to setting the replenishment threshold (referred to as Re-order point in the company files), and indirectly the inventory level for all items.

Dynamic Adjustments

Based on what was explained, the inventory level of each MTS item is under control by the replenishment threshold (Re-order point – top of yellow) set, which leads to controlling the total level of inventory variations, in number of weeks of sales.

However, the value of the inventory in meters of cables (and indirectly in currency value) is under constant adjustments depending on the market trends and seasonality.

The value (in meters) of the Re-Order point is calculated by multiplying (a) the number of weeks of inventory coverage by (b) the average weekly sales. And since the number of weeks is constant following the DDMRP formula, the adjustment factor will be coming from the value of the average sales.

The average sales that was used to evaluate the inventory level (when multiplying it by the number of weeks) had two variable features and was calculated as such:

a) Calculating the monthly average sales of the last 12 months, and translating it into weekly sales. In this case, the average will always be changing since each new month, the average 12 months' sales would change as well, as it will always be the average of M – 12 to M, so with each new month up, a month would be removed from the bottom.
b) Another figure is also used which is the average of the last 3 months, since the 12 months' average might not reflect the spike or decrease in demand in a more recent period.

These two averages of sales are always leveraged one against the other, and to ensure a dynamic adjustment and stay tuned to market seasonality, which is never in the same periods each year, the following practice is adopted:

a) In a period of high demand, or high season of sales, the 12 months' average is compared to the 3 months' average, and the highest figure between the two is used to calculate the value of the Re-Order level.
b) In a period of regular demand, or regular season, the 12 months' average is compared to the 3 months' average, and the average of the two figures is used to calculate the value of the Re-Order level.
c) In a period of low demand, or low season, the 12 months' average is compared to the 3 months' average, and the lowest figure between the two is used to calculate the value of the Re-Order level.

Based on this process, the inventory replenishment threshold is never constant in value (meters of cables), and thus will always be changing following the change in market trends.

In addition, the full scale of DDMRP, from the Red level, to the Yellow level, to the Green level, is always changing in terms of value (in currency or in unit of measure of cables – meters), while staying constant in terms of weeks.

Demand Driven Planning

Demand driven planning was a major shift in the company's culture, which was relying on monthly planning, based on monthly sales forecast. Monthly planning allowed the production control department to have a monthly visibility on machine setup, labor and man-hour needed to achieve the required production program.

To implement the DDMRP process, the supply chain department completely stopped using the monthly forecast, and changed to weekly replenishment. The level of inventory per MTS items would be benchmarked versus the Re-Order level once a week, and once the threshold is breached a replenishment order is launched to replenish the missing quantities and increase back the inventory level above the re-order level. This threshold breach would only happen in case of real demand, or actual sales, being delivered during the previous week, and physically being removed from the warehouse, reducing the inventory level below the Top of Yellow threshold.

In the absence of demand, and the inventory level per items remaining above the threshold, no production is launched, following only actual demand or sales instead of forecast, changing the supply chain model of the company from a (monthly) forecast driven production planning to a (weekly) demand driven production planning.

The difficulty for the production planning department was in the lack of monthly vision of the needs in machines and labor force, but the upside in improving the quality of the inventory was much more important to pursuit.

Visible and Collaborative Execution

The visible execution of the DDMRP process is done through excel files per family of products. The excel files are updated with information from the ERP system, concerning the change in inventory level, which indirectly gives withdrawal (sales) and the input (production) information, but the management of the system and the decision-making process are done manually by the supply chain team.

The file would show the following information for the visual management process:

- Family: the item description and code
- Color: since some same items are different from color to color
- Stock: shows the actual inventory level at the time of the update of the file (weekly).
- Allocated: shows how much of the available physical inventory is reserved for an order, for example if the inventory level was 100, and the allocated file mentioned 40, it means that 40 is reserved to another order, and only 60 is free at the inventory, so the calculation for the inventory management would be done based on the availability of 60.
- Average Monthly Sales: shows the average monthly sales, as per the previously explained formula, which is the basis of the inventory coverage calculation.
- Month to date actual sales: this is a benchmark information, not used in the formulas of the file, but it shows, during a month, the actual sales level from the beginning of the month until the time of the update of the file. The purpose is to check if the actual monthly sales is much higher

or much lower than the average monthly sales, which could affect the decision-making process in case the inventory coverage is very near the Re-order level.

- Coverage: shows the inventory turn in weeks of sales, which is deducted by dividing the information from the Stock column by the information in the Average Monthly Sales column, showing how many weeks of sales could the actual inventory last.
- Re-Order Point: this is the replenishment threshold, or Top or Yellow level per item, indicating at which level of inventory coverage per item the replenishment process should be launched.
- Remaining Planned Production: here we can see if a launched production order is still pending, meaning that the order has been sent to execution, but the actual finished products hasn't been delivered to the warehouse yet.
- Projected coverage: shows the expected inventory coverage after the reception of all pending production orders. In other words, this information is deducted from adding the Remaining Planned Production to the Stock, and dividing the sum by the Average Monthly Sales.
- Week: showing the 4 or 5 weeks of each month. Since this file is updated on a weekly basis, after each update, a decision is made either to launch a production order or not per item, and this decision (in quantity) is added in the relative week column.
- Projected Coverage with Rajouts: shows what would the final inventory coverage becomes with the replenishment quantity decided. In other words, to get this information, the information from the Stock column added to the information from the Remaining Planned Production added to the information from the Week columns, and the sum of the three is divided by the Average Monthly Sales to shows the expected inventory coverage.

Based on the results coming from this excel file, the supply chain department prepares a list of items that should be replenished, showing the item description, and requested quantity, and sends it to the planning department for execution. This process is repeated each Thursday of each week.

The collaborative execution is done through regular meetings between different stakeholders.

On a weekly basis, each Tuesday, a meeting between the supply chain team, the production control & planning team, and the sales team is done. The purpose of the meeting would be to discuss the requested production orders for MTS items, the priorities, the delays and bottlenecks. In addition, the choice between producing MTS or MTO items is also discussed, based on the capacity of the machines, the inventory level per MTS item, and the delivery delay offered to clients for the MTO items.

This meeting ensure that all stakeholders of the production cycle are well aligned, and provide a high level of visibility and coordination, and shared ownership of the decisions taken.

In addition, once a month, a dialogue is done between the supply chain team and the sales team to discuss the market trends, seasonality of demand, and expected big orders that exceed the average monthly sales per MTS items, to avoid any unforeseen surprises that could lead to shortages in certain products. In addition, the sales team has been encouraged to communicate daily with the supply chain team about any incoming elephant orders (the expression "elephant orders" is referred to orders with larger quantities of sales than usual, higher that the monthly average sales), to ensure the quickest reaction possible for products replenishment.

CONCLUSION

In this article, we have described how DDMRP was implemented in a Lebanese multiproduct industrial company, as a demand driven inventory replenishment system.

Compared to a forecast replenishment model, many advantages were detected after the active execution of the DDMRP management style, regarding several aspects of the business, like segregation of duties, live monitoring, quicker reaction time, reducing the overall cycle of production lead time, precise inventory management, enhanced interdepartmental communication, inventory reduction and operating working capital improvement, optimizing the quality of the inventory, increasing customer satisfaction by reducing the shortages of products, reducing the bullwhip effect, increasing transparency and visibility of market trends and historical evolution.

Along with the numerous advantages detected, there were as well some disadvantages, since there is no such thing as an ideal system, but the disadvantages were far less than the advantages, with minimal impact on the company's performance and efficiency, such as the risks of negative impacts of low interdepartmental communication level, repetitive production orders, lower visibility for the production teams, challenge of economical production lot sizes.

The DDMRP management style is not an absolute management system that can manage the inventories and production launch of the full product portfolio of a company. The system can operate efficiently with the type of products that shows repetitive sales frequencies, and needed to be kept in stock. These stock items should have overall repetitive historical sales to be used as base parameters for the launch of production orders.

However, the system cannot be implemented, and should not provide any added value or positive results for products that are produced only on customer demand or designed and engineered on customer demand.

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