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Implementation of a Mix DDMRP-Kanban Supply Chain System within a multi-product industrial company: Case of Liban Cables SAL

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Abbreviations

Abbreviation	Description
ADU	Average Daily Usage
APICS	American Production and Inventory Control Society
ASE	Available Stock Equation
ASRLT	Actively Synchronized Replenishment Lead Time
BOM	Bill Of Materials
CIF	Cost Insurance & Freight
CONWIP	Constant Work In Progress
COE	Centers Of Excellence
CRP	Capacity Requirements Planning
CSCMP	Council of supply chain management professionals
DDMRP	Demand Driven MRP
DKS	Dual Kanban System
DSO	Days of Sales Outstanding
ECR	Efficient Consumer Response
EDI	Electronic Data Interchange
ERP	Enterprise Resource Planning
ETO	Engineer To Order
FG	Finished Goods
FOB	Free On Board
JIT	Just In Time
KPI	Key Performance Indicators
LME	London Metal Exchange
LT	Lead Time
MES	Manufacturing Execution Systems
MOQ	Minimum Order Quantity
MPC	Manufacturing Planning and Control

MPS	Master Production Schedule
MRP	Material Requirements Planning
MRP II	Manufacturing Resource Planning
MT	Manufacturing Time
MTO	Make To Order
MTS	Make To Stock
NSP	Non Stock Production
OWC	Operating Working Capital
PAF	Plan Adjustment Factors
QR	Quick Response
RM	Raw Materials
ROP	Reorder Point
ROQ	Reorder Quantity
S&OP	Sales & Operations Planning
SCM	Supply Chain Management
SDKS	Semi-Dual Kanban System
SFC	Shop Floor Control
SKS	Single Kanban System
SKU	Stock Keeping Unit
TPS	Toyota Production System
VMI	Vendor Managed Inventory
WIP	Work In Progress

Introduction

In the last few decades, technological advancements and breakthroughs, as well as the global spread of internet use and social networks, has transformed the world into a one single network, where people are all connected, and well informed, as well as very susceptible and has higher sensitivity to changes in trends, from the political point, to social, to the way of life and individual behaviors.

In addition to that, the world's population has been steadily increasing, putting more and more pressure on governments and organization to satisfy the needs for necessities, like food and water, basic commodities, as well as infrastructure.

Due to this change and rapid evolution in the global environment, competitiveness has been increasing, with many emerging markets gaining knowledge and competitive edge over traditional super powers. Many countries have been heavily investing in promoting and supporting local industries and encouraging them to quickly become global players, by providing incentives to industries in general, like building the infrastructure needed to support successful industries, to passing legislations and law that give tax exemption and advantages to many types of industries, and mostly to industrial innovation, in addition to creating incentive schemes that encourage export and selling products outside the country's borders once the local demand is full satisfied, and trying either directly or indirectly to put entry barriers and obstacles to protect domestic industries against importations.

In such a challenging environment, industrial companies are in constant search for ways to optimize their business models, increase their profit, assure customer satisfaction and increase market share. To do so, a company needs to make sure it maintains its competitive edge against traditional competition, as well as new or surprising competing business models that they have no experience in competing against, either from the innovations and product creation side, or from the business model and market management side.

One of many paths to help 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 optimizes 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 point of view. In such conditions, customer demand would suddenly change in short term periods, both in terms of 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).

By not properly handling those challenges, preparing for it, or by underestimating the impact such challenges could have on its business, a company could quickly lose market share, at a trend and speed that might not be able to come back from or reverse, and transform a very successful business into an insignificant player on its markets, or even put it completely out of business.

A – Empirical Question

Supply chain and supply chain management usually refers to the group of operations or cycle of activities that governs and link a company's operations from the moment a customer order is received, to ordering the raw materials needed, planning and producing the order, or order preparations, to shipment and distribution and delivery to client. It varies from type of business to another, whether it is an industrial operation, or a distribution operation, to different types of services, but in general, it is the link or chain of tasks and activities that connect, coordinate and governs an operation, from the moment it receives a client demand, to the moment this client is delivered, in time and in full.

The concept of supply chain and supply chain management started its development in the military activities in the 1950's, mainly for the coordination of transportation and logistics needed for the military operations. It was later developed for the textile business in the United States, after examining very long delays from buying the raw materials, to delivering the customers, putting a heavy weight on inventories and financing the businesses, which encouraged retailers and suppliers to work closely together to reduce this long supply chain of activities. It was also later developed for the grocery activities in the United States, with the attempt to provide quicker reaction time between production and distribution, and delivering as quick as possible and at the same time as accurate as possible. Later, industrial companies started adopting supply chain strategies to optimize their production and production planning operations, as well as better connecting and performing their distribution channels.

Many theories and concepts were later developed and analyzed to optimize and enhance the supply chain practices, like for example the concept of agility, which focus on flexible manufacturing systems, and the use of automation to provide rapid changes and better responsiveness to changes in requirements, and the concept of lean manufacturing, which is about doing more with less and trying to reach the zero inventories all while providing just-in-time efficiency.

Today, supply chain management is more and more being recognized as key to the growth of organizations, and although it is still relatively new, its transforming the traditional point of views about how markets may be best served, and how significant competitive advantage it could provide if well implemented. It is being segregated into two main angels, (1) the production Planning and inventory control process, and (2) the distribution and logistics process, and at the same time it is supposed to link and orchestrates all processes that affect the efficiency of the system and good implementation of the supply chain strategy, and follow the full cycle of delivering a product to the client, from the purchasing of raw materials, to the production process, to the delivery to the customer.

From the production planning and inventory management aspect, two main approaches stand out from the rest in the academic research as well as in practice, which are the push and the pull strategies, and from each of them several sub-strategies and implementations steps.

Push system is a conventional production method, consisting of pushing a production job or process from one workstation to the next, upon completion. In this method, production schedules are prepared following a certain historical demand as well as a sales forecast, which due to the unpredictability of demand, and the inaccurate nature of forecasts, is subject to many modifications and deviations from the original plan, forcing planners to create higher work-in-progress inventories and safety stocks in order to cover the deviations. Push strategies are usually suggested for products with small demand uncertainty, as the forecast will provide a good direction on what to produce and keep in inventory.

Push management refers to multistage production scheduling and rely traditionally on information systems to calculate components and raw materials needed for a certain production campaign, usually known for relying on the famous concepts of material requirements planning (MRP and manufacturing resource planning (MRP-II). This approach leads to the centralization of all relevant information on central computers and lead to developing and optimizing a strong information system within a company. That is why, companies invested hundreds of millions of dollars on software developments related to MRP and MRP-II, and soon after their release, these types of software were widely demanded and used worldwide by various organizations.

Starting with the early days of industrial evolution, the manufacturing planning and control systems evolved in several steps, marking five major stages of evolution, starting with the reorder point system (ROP), then the material requirement planning (MRP) process, developed later into the manufacturing resource planning (MRP-II), and the manufacturing execution systems (MES), and finally the enterprise resource planning (ERP), all stages were building on top of each other in term of optimization and process evolution, relying as well and following of manufacturing philosophies and technological innovations.

In a Pull system, the job is pulled by the successive workstation, instead of being pushed by the previous one. The flow of parts throughout the product line is controlled by Kanban Cards, as well as others pull-type methods like Kanban cards, based on real demand instead of forecasts. The Pull system primarily helps reduce inventory levels as well as the costs associated to inventories. Pull strategies are usually suggested for products with high demand uncertainty, and hence, the firm would be willing to manage the supply chain based on realized demand.

Pull management was widely famous through the Toyota Production System, which focused on reducing cost by avoiding waste, which was later known as the just in time approach, and the idea and full use of workers' capabilities.

The Toyota just in time approach became famous later as a process to shorten production lead time, and optimize it, while using the minimum necessary inventories. This philosophy relied on four main principles of, (1) withdrawal by subsequent processes, which makes sure all processes can quickly obtain accurate information, and where the last line of production, to acquire the necessary parts at the right time for assembly, would go to the previous line of production to get this part, and in return the previous line would produce immediately and only what was withdrawn by the following line, (2) one piece production and conveyance, where each process can only produce one piece and convey one at a time and have only one piece in stock ready for production, (3) leveling of production, by averaging the monthly production into daily workflow, and arranging production lines to be working in correlation with each other, and by adjusting the monthly and daily production schedules constantly to produce only as much as could be sold and not more, (4) elimination of waste from over producing, by eliminating any kind of excess inventories or workers or even utilized time, between processes and production lines.

To implement such a strategy, Toyota relied on a Kanban cards system for production control, which does not rely on computer systems for its implementation. The Toyota Kanban system relies on physical cards that turns between the company's warehouse, the production control, and production lines, and back to the warehouse, used to control inventory levels, and launch production control. This system helped Toyota reduce the cost of processing information, by excluding the computer systems from the production launch decision making, provided real time control and information for the chain, in addition to rapid and very precise supply of facts and demand signals, and limited surplus capacities, either in the warehouses, or in production stages.

The Toyota Kanban card system consisted of two types of cards, a conveyance card and a production card. The conveyance card would be used to relay the information from one process to the preceding process, to withdraw the necessary part, and the production card is used at the same preceding process to launch the production needed to reproduce the same part that was withdrawn by the following process. Each type of cards will be attached to a container holding part, where a card would represent a certain specific item, in term of description, and in term of quantity to represent.

Many types of Kanban cards were later developed, depending on the needs of organizations and business models, all while following the original concept developed by Toyota, like the single Kanban system, using production Kanban, the dual Kanban system, using two types of kanbans simultaneously, and the semi-dual Kanban system, changing production kanbans and withdrawal kanbans at intermediate stages. The differences between the various types of Kanban systems adopted, was related to differences in the distance between two production stages, the volume of the work in progress inventory between two stages, the speed of turnover of the kanbans, also the speed in the turnover of the work in progress inventory, and the level of necessity of synchronization of production and movement of the work in progress inventories.

Both push and pull strategies present advantages and disadvantages, depending on the way of implementation, and the type of business model and its needs, which is why there were some attempts to create hybrid strategies, that combines both push and pull concepts, trying to optimize the best characteristics of each philosophy.

DDMRP or demand driven MRP is an approach that is supposed to manage manufacturing flows better than the traditional MRP, by adopting some of the pull strategy concepts.

It is argued that DDMRP can address many weaknesses found in the traditional MRP system, mainly in the areas of forecasting and usage of master production schedules, full runs of bill of raw materials for produced items, manufacturing order release, limited early-warning functionalities, and lead time ambiguity, by incorporating ideas such as strategic buffering, replenishment and buffer management.

DDMRP is supposed to be operational following five steps of implementation and execution: (1) strategic inventory positioning, knowing what type of inventory to keep, how much, and at which stage along the supply chain, (2) buffer profiles and levels, know how to set the right buffers in types and volumes, following average consumption and lead time for production, (3) dynamic adjustments, which considers that parameters should be variables and adjusted following changes in internal and external factors to the company, (4) demand driven planning, pushing the traditional forecast planning into a demand driven planning, (5) highly visible and collaborative execution, which manages priorities and set up alerts at the right steps for an optimized decision making and management process.

Literature review and academic articles related to DDMRP are still not that frequent, since the concept is still relatively new, but several consulting firms have started promoting for DDMRP and proposing it in their offered packages to their clients, as a tool for optimizing a company's supply chain cycle, improve business performance, increase customer satisfaction and optimize organizational agility and resilience. Other advantages are also indicated, such as, product movements driven by real demand, real-time demand and supply visibility, inventory management in correlation with dynamic target operating levels, early identification of demand and supply issues before impacting production, and single demand signal shared across the full supply chain cycle.

In this paper, we will try to shed some light on the existing literature related to supply chain management, as well as pull and push production control strategies, mainly the MRP & MRP II (push), the Just-In-Time and Kanban (pull), and the new concept of DDMRP (demand-driven MRP) which is a mix process between push and pull. In addition, we will try to study the implementation of Kanban and DDMPR and possibility of setting up a mix system of DDMRP and Kanban at a multi-product industrial company, showing the advantages and disadvantages of each system compared to each other, as well as the added value, if any, of implementing a mix system within the same company.

Since quantitative studies are usually used for objectivity and through questionnaires that ensure the existence of distance between the observer and the observed, while qualitative studies are more fluid and flexible, and helps discover new or unanticipated findings, by providing more rich and in-depth information, this paper will adopt the qualitative approach for research, as a profound understanding is needed , while examining different types of data, both in quantity and nature of data, while at the same time understanding the root cause behind the findings.

To reach this outcome, a single case study will be examined, which is a method that allows a strong in-depth understanding of the situation, since insights reached from case studies can directly influence policies, practices and future research, as it is associated with the telling of a real or life stories.

The case study will be done at Liban Cables SAL, a company that experienced a transition in its supply chain business model, from forecast driven, to demand driven, and where the researcher was the supply chain director at the heart of that change. Consequently, we will have access to many sources of in-depth information and observations, coming from day-to-day management practices, and change management process, in addition to access to all the company's supply chain reports, and live database, giving access to all related indicators, such as inventory levels changes, sales evolution, customer satisfaction, and all necessary data required to perform a very detailed study in relation to that shift in supply chain model.

Liban Cables SAL is a leader of electrical cables production in the Lebanese market, and part of an international cables producing group called Nexans. Liban Cables produces thousands of cables, for various applications, and comes in different colors, lengths and packing types. The complexity of the operation is highlighted by the fact that from limited types of raw materials, several hundreds and thousands of cable types could be produced, and the variety of the market segments on the local market, as well as its export market, makes the overall supply chain management very complex but also its efficiency vital to the success of the company.

The historical supply chain module at Liban Cables was forecast based, relying mostly on sales monthly forecasts to produce a list of cables throughout a given month. This practice, given that forecasts are wrong by definition, led to inefficient inventory levels, having some finished products with very high inventory levels, much more than needed, and at the same time some finished products were out of stock and in shortage situation, all due to the market trends volatility and demand, which had a negative impact on the company's operating working capital due to the high inventory levels, and at the same time poor customer satisfaction due to the shortages in the items under demand.

To start the implementation of the DDMRP management system for production launch, which is also an inventory management system, followed later by the implementation of the Kanban system, several preparatory steps were needed at the company.

The first step was the creation of a supply chain department, which did not exist before at the company, along with the segregation of duties between this new supply chain department and the sales department and production planning department, since many supply chain functions were previously distributed between the sales department and the production planning department.

This structural change was then followed by a campaign of data collection and cleaning, since a lot of data necessary for the good management of the inventories were either nonexistent, or wrong, and the vocabularies used between departments were not unified when it came to products classification and identification, which is why a crucial step of language unification was necessary between various department, to have all parties in relation to the supply chain management process speaking the same language to avoid miscommunication and making decisions based on misinterpreted information.

Later, the most critical part was the segregation of the company's full portfolio of products, to identify which items could be managed through DDMRP or Kanban, and which items cannot be. The products to be managed by the new systems were defined as stock items, to be produced repeatedly to ensure a certain minimum of inventory level, before receiving any customer order, while the other type of product were considered as not vital, to be produced only after receiving a confirmed customer order.

DDMRP was then implemented as an inventory replenishment system, or production launch system, for a good number of items, representing the most sold and produced items in the company's portfolio of products, following the five steps described earlier, of strategic inventory positioning, buffer profiles and levels, dynamic adjustments, demand driven planning, and visible and collaborative execution, following a customized manner that best suit the context of the company and its portfolio of products and business model.

Kanban replenishment system was also implemented for a selected number of products, using the same global principles, adopting conveyance cards from the warehouse to the production workshop, and production cards within the production floor.

The implementation of the DDMRP and Kanban showed significant improvement in the quality of the inventory, by reducing the overall level of inventory, while at the same time avoiding shortages to maintain a high level of customer satisfaction.

The new mix system showed significant evolution, however, it was obvious that it can only be used for stock items, or inventory management for the items that are required to exist physically in the company's warehouse always. The new system could not be implemented for the products that are only produced on customer demand.

Using DDMRP as inventory replenishment model, showed encouraging results, which we will later examine in details, for managing the full portfolio of stock items, with much improvement compared to the forecast driven system, but with some limitations that might lead to excess inventory levels or shortages in some cases, such as having high economical production lot, or if the minimum order quantity accepted by production to launch a production campaign is high compared to the average monthly sales, in addition to the limitation regarding the reaction time versus receiving sudden elephant orders, with much higher volumes than the average historical sales, which could lead to shortage situations.

The Kanban system also showed very promising results, that seems much more efficient than the DDMRP, in terms of inventory reduction and speed in production, which helps reduce further the inventory level by reducing the production lead time, but only for a limited number of items. Kanban seemed more efficient, and suitable, for high runners, or items with very high level of sales compared to the rest, much higher or equivalent to the production output of the machines needed for its production. Consequently, key machines can be dedicated only to produce these items in their various production steps, which helps reduce the production lead time, since for regular products the steps required during production are shared with other items, so each production step for a certain item needs to wait its turn for the machine to finish producing other items first.

Consequently, as it would seem, for an inventory replenishment system, the Kanban model is more efficient than the DDMRP in terms of inventory reduction and customer satisfaction, but only for a limited number of high runners' items, while the DDMRP is more efficient, or more suitable, than the Kanban for the wider range of stock items. But the combination of both system would be a very interesting manner to optimize the inventory management module, a switch to a demand driven mode much more efficient than the forecast driven management system.

To examine and corroborate these results, we will have access and study Liban Cables data base, and its reports, emphasizing on the evolution of its inventory levels per product, sales evolution, shortages evolution, and global inventory position. We will elaborate how the DDMRP was implemented at the company, then how the Kanban was implemented as well, in addition to showing the evolution of key indicators before and after this implementation, such as inventory level reduction or increase, inventory coverage versus sales, the quality of the inventories as well as the level and number of shortages. We will try to check the full replenishment cycle and if implementing such systems would also impact the stability and volatility of the management cycle of the company.

The expected outcome of this paper would be to explain the differences between the implementation of DDMRP and the implementation of Kanban, along the difficulties encountered by each implementation and its limitation. Then we will try compare the advantages offered by DDMRP with the advantages offered by Kanban, both compared to the forecast management model, along with the disadvantages of each model.

Then the added value that we will try to present is explaining how industrial companies should know if they can implement such models, and how to choose which products to be managed following DDMRP as an inventory replenishment system, and which products to be managed by Kanban, and finally which products cannot be managed by either system.
Furthermore, we will try to give a guideline on which companies can or should implement each type of models, following the company's business model and its portfolio of products.

To that end, this paper will be developed following five main sections.

The first section will be the literature review on the main subjects in question in this paper.
We will start by exploring some of the available definitions of supply chain and supply chain management, followed by tracking how the concept of supply chain was developed over time and in which industries.
We will then explain the concept of agility and lean manufacturing, and the difference between the two, in addition to role of decoupling points in an agile strategy. We will also explain the definition and causes of the bullwhip effect, which impact a lot of companies' strategies and efficiencies.
Then we will explain what is the push management strategy, what is the philosophy behind it, how it started, and in which direction it was developed. That is why, we will discuss the evolution of manufacturing planning, the history of manufacturing planning and control system and its evolution, the manufacturing execution systems and the enterprise resource planning.
Following the push management strategy, we will highlight the definition of the pull management strategy and its relationship to the Toyota production system. That is why, we will explain in details the Toyota production system, from its basic concept and how it was created, to the concept of reduction of cost by eliminating waste, the just-in-time production concept, the Jidoka concept and the idea of full utilization of workers' capabilities.
Toyota used a Kanban system to implement its production philosophy, that is why, we will explain the Toyota Kanban system, from its purpose, to its description and construction, and later try to outline the various types of Kanban systems available in the literature.
The final part of this section will explain the DDMRP concept, from its definition and origin, to its way of implementation and use. In addition, since there is not much academic literature on

DDMRP, we will mention how some consulting companies are promoting for DDMRP and what advantages they promise from its implementation.

In the second section of this paper, we will explain the research question, and the research methodology.

In the research question, we will elaborate what idea are we trying to develop in this paper and what question we will be trying to answer and which outcomes we wish to reach.

In the research methodology, we will explain our epistemological positioning, and then the choice of the research method, which is a qualitative research, why we chose to follow and single case study, and what method we will use for data gathering and analysis.

The third section will elaborate the case study and the core of this paper.

We will begin with a brief description of the company Liban Cables SAL, its previous (historical) supply chain processes, and its inventory situation and key supply chain indicators before the implementation of the new model.

Following that, we will explain what steps were necessary for the implementation of the new DDMRP and Kanban at the company, from the structural changes required, to the data management process, then the unification of supply chain vocabulary, the creation of ABC matrixes for the company’s full portfolio of products, and the setting up of a sales and operation planning tools.

We will then elaborate how DDMRP was implemented as an inventory replenishment tool, by explaining how each step of implementation was customized to the company’s context, from the strategic inventory positioning, to the buffer profiles and levels, the dynamic adjustments, the demand driven planning and the visible and collaborative execution.

We will explain subsequently the observed advantages and disadvantages of implementing DDMRP as well as the limitations found to implement such system.

The implementation of Kanban will be the next step in this section, from the steps and parameters of implementation, to the items chosen to be managed by Kanban, the definition of the number of conveyance cards, also determining the number of production cards, the creation of decoupling points and work in progress inventory for the Kanban cycle, and finally elaborating how the full cycle of Kanban operates within the company.

Likewise, we will later elaborate the found advantages and disadvantages of the Kanban system and the potential limitations for using such system.

We will conclude this section by presenting and explaining the results of implementing and using both DDMRP and Kanban, over a period of four years (2014, 2015, 2016, 2017), while exploring key performance indicators relative to the performance and efficiency of the supply chain process, such as the inventory level reduction or increase, inventory coverage or inventory turn compared to sales volumes, the quality of the inventories, the level of shortages or stock outs per items which is an indirect indication of customer satisfaction, and the impact of these new supply chain models on stabilizing the inventory levels, reducing the volatility in the production process, and inventory movements.

In the fourth section of this paper, we will discuss the outcomes found in this paper and try to come up with a synthesis of the findings to conclude the study and elaborate comparison tables and guidelines that could be useful to other researchers.

We will begin by comparing the differences of implementing DDMRP and implementing Kanban, in terms of preparation, product selection, workflow, buffer levels and replenishment mode, and finally the cycle of each model, and team involvement.

Then we will compare the advantages and disadvantages found for DDMRP to the advantages and disadvantages found for Kanban, both compared to the previous forecast driven model. The same comparison would be done for the limitations of each model.

The next step will be to create a charter that explain how to identify and choose products to be managed by this mix system, from product mapping and classification, to defining which products to be considered as stock items, and which products to be produced only to confirmed orders, then identifying which products are eligible to be managed by DDMRP for inventory replenishment or production launch, and which products can be managed by Kanban.

In the final part of this section, we will try to elaborate which types of companies can implement such systems, either combined, or only DDMRP, or only Kanban, or none of both, depending on the company's structure of products and sales trend and production complexity.

The fifth and final section of this paper will be the conclusion, where we will try to summarize the key findings of the paper, making a synthesis of the most important elements, and try to look for new perspectives for what was discussed and other applications or questions that still needs to be addressed to push this study further.

B – Literature review on Supply Chain, Kanban & DDMRP

Supply chain can be defined as the total set of activities that covers the full cycle of delivering a product or service to a client, from receiving the customer's order, to buying the raw materials, storing it, manufacturing and assembly, then keeping the finished products in warehouses, to shipping and shipment tracking, order entry and order management, and the administration and information system necessary to monitor all these activities.

Supply chain manage and coordinates the various activities of the chain into a unified process, by linking all the internal and external partners and stakeholders, from departments within the same company to external partners, like suppliers, carriers, and service providers.

Efficient managers would look out for the success and interests of all stakeholders within the supply chain, from the internal departments to external companies and partners, since any weakness at one link within the supply chain cycle would be reflected in weakness though all the supply chain, hence the necessity of close coordination and information sharing about production problems and market information and trends, all to make the whole supply chain competitive.

That is why, the supply chain cycle must be regarded as one complete system, not separate processes and activities, and any weakness across the chain, from suppliers to manufacturing to warehousing and even to customers, must be assessed and improved to ensure the full efficiency of the process (R. Lummus, R Vokurka, 1999).

Supply Chain Management was defined by the Council of supply chain management professionals (CSCMP), one of the leading organizations for supply chain academicians, researchers and practitioners, as: *"SCM encompasses the planning and management of all activities involved in sourcing and procurement, conversion, and all Logistics Management activities. Importantly, it also includes coordination and collaboration with channel partners, which can be suppliers, intermediaries, third-party service providers, and customers. In essence, SCM integrates supply and demand management within and across companies"* (Ballou, 2007).

Most importantly, the supply chain management is not an isolated process on its own. Many attempts of supply chain implementation have failed to reach the maximum potential advantages because it was viewed from the supply side or the purchasing side, while in fact supply chain is more than just procurement. Consequently, supply chain is not only, inventory management, logistic management, supplier partnerships, shipping strategy, distribution management, procurement management, a computer system. That is why, for successful and efficient implementation, all nodes or parts needs to be well managed, from supplier's supplier to customer's customer. In addition, a clear understanding of supplier chain perception and the openness to willingly share information between supply chain partners and stakeholders is a necessary first step to making the supply chain a competitive force for the business (R. Lummus, R Vokurka, 1999).

The evolution of theory and practice for the development of supply chain management has continued such that it is now supply chains that compete, not individual companies, and the success or failure of supply chains is ultimately determined in the marketplace by the end-customer (Christopher, 1992).

Supply chain management was defined by some authors around the operational perspective, covering the flow of materials and products, others considered it as a management philosophy, while some viewed it in terms of a management process (Tyndall et al., 1998), and some authors studied it as integrated system. Sometimes authors described supply chain management differently within the same article: as a management philosophy on the one hand, and as a form of integrated system between vertical integration and separate identities on the other hand (Cooper and Ellram, 1993).

According to Christopher (1994), a supply chain is *"a network of organizations that are involved, through upstream and downstream linkages, in the different processes and activities that produce value in the form of products and services in the hands of the ultimate customer."*

The scope of activities of Supply Chain Management was first developed for inventory management operations under the supply chain, but it evolved later to cover the management of all functions within the supply chain cycle. According to Chopra and Meindl (2001), *"Supply*

chain management engages the management of flows between and among stages in a supply chain to minimize total cost".
Consequently, the involvement of upstream and downstream flows of products is necessary for the success of the chain, as well as finance and information through every node of the cycle. In time, businesses with advanced supply chain management efficiency should reach many advantages like radically improved customer responsiveness, optimized customer service and satisfaction, increased flexibility for changing market conditions, improved customer retention and more effective marketing (Horvath, 2001).

Supply chain management was also defined as a concept, *"whose primary objective is to integrate and manage the sourcing, flow, and control of materials using a total systems perspective across multiple functions and multiple tiers of suppliers"* (Monczka, Trent and Handfield, 1994). Stevens (1989) considered that the objectives of supply chain management is to coordinate and create a balance between the customer's requirements and the material flow, and try to manage a harmony between conflicting objectives of maximum customer service, minimum inventory management, and low unit costs.

Supply chain strategy includes *"two or more firms in a supply chain entering into a long-term agreement; the development of mutual trust and commitment to the relationship; the integration of logistics events involving the sharing of demand and supply data; the potential for a change in the locus of control of the logistics process"* (La Londe and Masters, 1994). Manufacturers are able to develop alternative conceptual solutions, select the best components and technologies, and assist in design assessment by involving suppliers early in the design stage, (Burt and Soukup, 1985).

New (1995) and Saunders (1995) considered that there was already an excess of confusing and overlapping supply chain terminologies and definitions, and practices related to supply chain management, including integrated purchasing strategy (Burt, 1985), supplier integration (Dyer et al., 1998), buyer-supplier partnership (lamming, 1993) supply based management, strategic supplier alliances (Lewis et al., 1997), supply chain synchronization (Tan et al., 1998), network supply chain (Nassimbeni, 1998) value-added chain (Lee and Billington, 1992), lean chain approach (New and Ramsay, 1995), supply pipeline management (Farmer, 1996), supply network (Nishiguchi, 1994), and value stream (Jones et al., 1997). Harland et al. (1999) prefer the term “supply strategy”.

Drucker (1998) went as far as claiming there was a paradigm shift within the management literature: *“One of the most significant changes in paradigm of modern business management is that individual businesses no longer compete as solely autonomous entities, but rather as supply chains. Business management has entered the era of inter-network competition and the ultimate success of a single business will depend on management’s ability to integrate the company’s intricate network of business relationships.”*

According to Benita M. Beamon (1998), supply chain is comprised of two basic and integrated processes. The first process is the Production Planning and Inventory Control process, which controls the design and management of the entire manufacturing process, including raw materials procurement and scheduling, production control and scheduling as well as product design, in addition to the management of the storage spaces of raw materials, work in progress and finished products. The second process is the Distribution and Logistics Process, which controls the retrieval of products from warehouses and transportation to customers, depending on the complexity of the distribution network. Both processes interact with one another to produce an integrated supply chain and strive to meet performance objectives.

According to R. Lummus, R Vokurka (1999), in order to be able to start managing transversely the entire supply chain, the plans and execution steps of companies should consider the following guidelines:

1) Supply chain initiatives should be aligned with business objectives, to connect the supply chain strategy to overall business strategy.
2) Set supply chain goals, and make sure each business process can individually help reach those goals, by developing the right plans for execution.
3) Keep an open ear for market trends’ changes, by developing tools and systems that helps track market demand and plan accordingly, including any modifications in ordering patterns and changes in demand impacted by customer promotions.

4) Reducing the cost of sourcing materials, and optimize the receptions in time and in full, by well managing the sources of supply and creating partnerships with suppliers.
5) Tailoring logistic solutions and developing it based on individual customer segment.
6) To support decision making at different levels of the supply chain and provides a clear view of the flow of products, a proper supply chain information system is required.
7) Implement cross-functional and cross-business key performance indicators, which helps link every parameter of the supply chain, measuring both service and financial elements.

B.1) Evolution of Supply Chain Management

Before 1950's, supply chain was only considered as logistics, and logistics was thought of in military terms (Ballou, 1978), it was only considering the aspects of procurement, maintenance and transportation of military materials and personnel. A transformation occurred around the 1950's when the importance of logistics increased considerably and physical distribution management in industrial companies was acknowledged as a separate organizational function (Heskett et al., 1964). What also contributed to the supply chain beginning in the 1950's was the emergence of the notion of holism, that the whole is greater than the sum of the parts (Cavinato, 1992), and the observation that the behavior of a complex system cannot be understood by the segregated analysis of its constituent parts (New, 1997).

The concept of supply chain management was invented in the early 1980's by consultants in logistics (Oliver and Webber, 1982), where it was considered that the whole supply chain must be viewed as a single entity, a perspective later shared by logisticians and channel theorists in marketing (Gripsrud, 2006).

B.1.a) Textile Industry quick response system

In 1984 the Crafted With Pride in the USA Council was created by leaders in the US clothing industry, to try to address strong competition in the textile and clothing industry world-wide (Kurt Salmon Associates, Inc. 1993). In 1985, a supply chain analysis of the clothing industry was done by Kurt Salmon Associates, showing a long delay of 60 weeks from buying the raw materials to delivering customers, out of which warehousing and transit took 40 weeks. This long supply chain led to shortage of having the right product, in the right place, at the right time which translate overall losses related to financing the inventories.

As a result, a partnership between retailers and suppliers was created, under what was called the Quick Response (QR) strategy, to generate a quicker response to consumer needs and share information, leading to the creation of standards for electronic data interchange (EDI) between companies, and the installation of scanning systems at the point of sales, to transfer sales information rapidly to distributors and manufacturers. *"Quick Response maximizes the profitability of inventory by placing the company's dollars where and when they are needed based on point of sale data plus sales history"* (Mullin, 1994).

B.1.b) Efficient Consumer Response in grocery business

In 1992, a working group called Efficient Consumer Response (ECR) was created by grocery industry leaders, charged by examining the grocery business' supply chain, in order to identify potential opportunities which could make the supply chain more competitive. Because of that study, several best practices were identified which could potentially improve the performance of the supply chain. As Kurt Salmon and Associates (1993) found: *"By expediting the quick and accurate flow of information up the supply chain, Efficient Consumer Response enables distributors and suppliers to anticipate future demand far more accurately than the current system allows"*.

The study emphasized on a certain level of flexibility needed, enabling manufacturer to match supply with demand. Inventory deployment was found to be a key element for a company to better use available information, production resources and inventories, adopting a process that closely coordinate and integrate demand management, production scheduling (Weeks and Crawford, 1994).

The concept of continuous replenishment was a supplementary development from Efficient Consumer Response which, based on customer demand, moved from pushing product from inventories to pulling products onto grocery shelves (ECR Performance Measures Operating Committee, 1994).

B.1.c) Supply Chain initiatives at other Manufacturing companies

Hewlett Packard, the computer components manufacturer, started connecting its manufacturing and distribution activities in the early 1990s, (Hammell and Kopczak, 1993), as well as introducing changes in the physical distribution of the product, and adopting a new distribution requirements planning system, used to benchmark customer' orders with forecasts, and serving as the beginning pull in the supply chain.

Whirlpool, the appliance manufacturer, after using the help of a team of executives, started in 1992 the implementation of a supply chain vision, which was entitled *"Winning companies will be those who come the closest to achieving an inter-enterprise pull system. They will be linked in a short cycle response mode to the customer"* (Davis, 1995). To achieve its slogan, Whirlpool started innovating by creating a new position of vice-president of logistics, then putting in place cross-functional teams for key product areas, in addition, by counting on reliability and the ability to assist in product design, they entered single source agreements with suppliers, and connected their cycle by using electronic data interchange (EDI) to communicate daily with suppliers, all as part of their supply chain management program. This successful supply chain mobilization led to increasing product availability to around 90-95 percent range, while at the same time decreasing inventories by 15 to 20 percent and reducing lead times to as low as five days (R. Lummus, R Vokurka, 1999).

Wal-Mart launched Vendor Managed Inventory (VMI), (Johnson and Davis, 1995), by allowing their key manufacturers to manage Wal-Mart's warehouse inventory levels of each manufacturer's products, asking for 100% order fulfillment rates on those products. The same VMI system was already adopted by several other large retailers.

B.2) Agility

According to Christopher (2000), *"Agility is a business-wide capability that embraces organizational structures, information systems, logistics processes and, in particular, mindsets, thus flexibility is the key characteristic of an agile organization"*. The origin of agility as a business concept lies in flexible manufacturing systems, and the route to manufacturing flexibility, was initially thought to be through automation, to enable rapid change and greater responsiveness to changes in product mix or volume, but later the idea of manufacturing flexibility was extended into the wider business context and the concept of agility as an organizational orientation was born.

Christopher (2000) warned however not to confuse Agility with Leanness, and explained that Lean is about doing more with less, which in many cases refers to lean manufacturing and trying to reach a stage of zero inventory and just-in-time efficiency. However, he cynically reflected that many companies who tried to adopt lean manufacturing as a business model, had a supply chain model anything but agile. The Toyota Production System (TPS) was at the origin of the concept of lean manufacturing, focusing on the reduction and elimination of waste.

Nevertheless, the lean approach remained restricted to production and factories, despite the deep impact the TPS principles had on manufacturing practices in various industries, leading to contradicting cases of having extremely efficient vehicle manufacturing processes with throughput time in the factory down to twelve hours or less, while in return having a very high inventory of finished vehicles reaching two months of sales, all while keeping the customer waiting for weeks or even month to get delivered the car of his choice. To that end, the lean approach makes sense in situations, like the conditions in which Toyota developed the lean philosophy, where the demand is somewhat predictable, the requirements for variety is low and the volumes are high. The problems arise however when attempting to implement the lean philosophy into situations where demand is less predictable, the requirement for variety is high and the volumes at the individual stock keeping unit (SKU) level is low.

Thus, Christopher defines agility as the ability of an organization to respond rapidly to changes in demand both in terms of volume and variety, and since the market conditions in which many companies operates are characterized by volatile and unpredictable demand, the urgency of the search for agility becomes high.

B.2.a) The route to agility

Always according to Christopher (2000), an agile supply chain must possess a set of distinguishing characteristics:

a) Market sensitive: enabling the supply chain to read and response to real demand. Many companies have little direct information from the market, and live data on actual customer needs, that is why they base their inventory management strategies on past sales data and sales forecasts, making them forecast-driven rather than demand-driven organizations. The most recent development in efficient customer response and information technology is focusing on companies' ability to hear the voice of the market and respond directly to it, to capture data on demand directly from the point of contact, either point of sale or point of use.

b) Virtual: instead of being inventory based, virtual supply chains are information based. Inventory based systems try to use complex formulas and algorithms, to identify the optimal quantity and locations or position of the inventory. However, it is now considered that with enough visibility of demand through shared information, the foundations of these formulas will no longer be applicable. The wide use of the internet along with numerous information systems have allowed various stakeholders in the supply chain to have access and act upon the same data, real demand, instead of relying on distorted and noisy picture that arises when orders are transmitted from one step to another in the supply chain.

c) Process integrated: process integration can help leveraging shared information between the different partners of a supply chain, by facilitating the collaborative working between buyers and suppliers, joint product development, common systems and shared information. Joint strategy determination works in parallel with process integration, as well as joint buyer-supplier teams, transparency of information and even open-book accounting.

d) Network based: the idea of businesses no longer competes individually, but their full supply chains competing with other supply chains, is at the heart of the fourth ingredient of agility which emphasize the idea of the supply chain as a confederation of partners linked together as a network. When full networks compete against another, success is achieved by the ones that knows how to excel in structuring, coordinating and managing the relationships and links between its partners, all with the commitment to achieve better, closer and more agile relationships with their final customers.

B.2.b) Hybrid strategies mixing lean and agile

In some occasions, neither a pure agile nor pure lean strategy would be appropriate. In that case, the need would be for a mixed hybrid supply chain strategy, recognizing that within a mixed portfolio of products and markets, there will be some products where demand is stable and predictable and some are not. Consequently, and according to Fisher (1997), it is important that the characteristics of demand are recognized in the design of a supply chain. In some cases, the supply chain may need to be lean for part of the time and agile for the rest.

According to Christopher (1998), Zara, the Spanish fashion company provides a good example of this hybrid supply chain strategy.

Zara is a Spanish successful and dynamic company, producing fashionable clothing to appeal to an international target market of 18 to 35 years-olds. It is in direct competition with some of the most skilled operations in the business, including Italian fashion giant Benetton and US-based The Gap and The Limited. To cope and succeed in face of such competition, Zara developed an agile supply chain which still incorporates many lean characteristics, creating of the most effective quick-response systems in its industry.

The process of supplying goods to the stores begins with cross-functional teams, comprising fashion, commercial and retails specialists, working within Zara's design department at the company's headquarters. Zara's team visit fashion shows, competitors' stores, university campuses, pubs, cafes and clubs, in addition to any other event relative to the lifestyles of the customer range, in order to create designs reflecting the latest in international fashion trends. In addition, the team receives regular inflows of data from electronic points of sales and stores from all around the world.

To purchase the required raw materials, the company has purchasing offices in several countries in Europe and the Far East, buying material from more than a dozen countries all around the world. A big percentage of clothes, those with the broadest appeal, are imported as finished goods from low cost production countries, while the rest are produced by quick-response in Zara's highly automated factories in Spain, or small contractors. In addition, great deals of items are stored in semi-finished state, with only few steps to transform them into finished products.

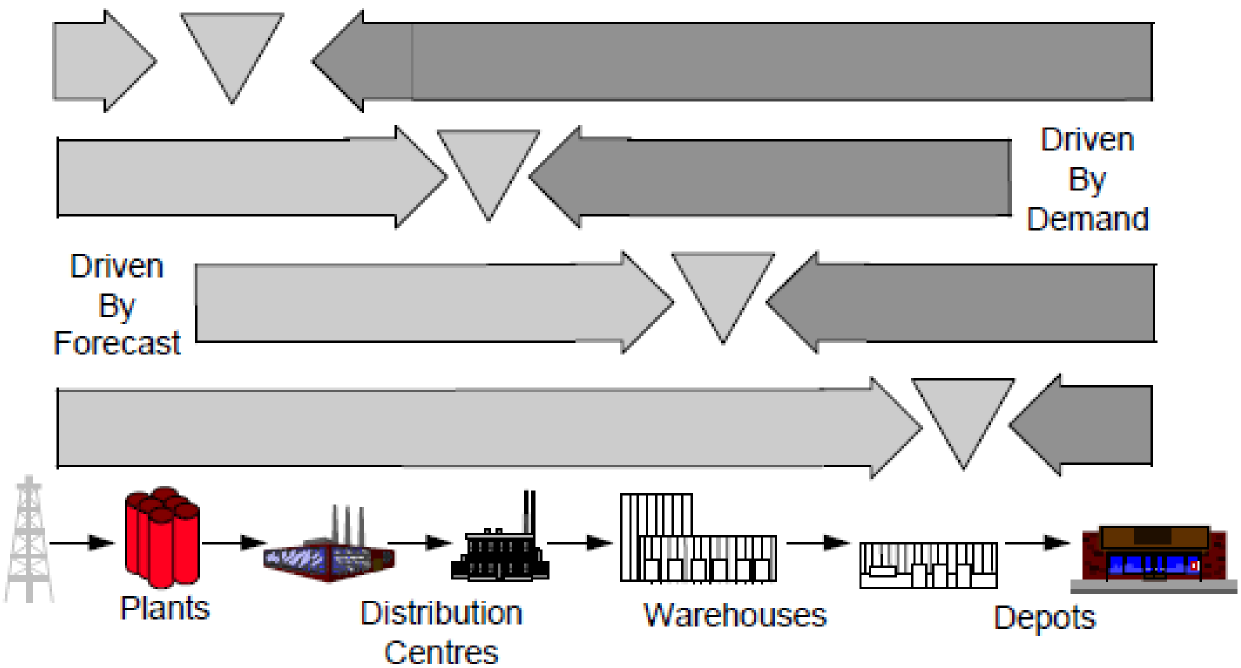
Christopher (2000) concluded that Zara's manufacturing systems are very similar to the successful systems of Benetton, but redefined using ideas inspired by the Toyota model. Only the operations with high cost-efficiency through economies of scale, like dying, cutting, labeling and packaging, are produced in-house. As for the remaining labor-intensive, it is produced by over 300 small subcontractors, each specializing in a particular part of the production process or type of product. These subcontractors work exclusively for Zara's parent company and receive in return the necessary technologies, financial and logistical support required to achieve the required targets in term of timing and quality. The system is flexible enough to cope with sudden changes in demand, though production is always kept at a level slightly below expected sales, to keep stock moving. Zara has opted for undersupply, viewing it as a lesser evil than holding slow-moving or obsolete stock.

B.2.c) The role of the "decoupling point" in an agile strategy

Since many supply chains tends to become prolonged with multiple levels of inventories between the point of production and the final point of sales, limited visibility of real demand becomes a major problem, that is why most supply chains tend be forecast driven instead of demand driven. Christopher (2000) defines the decoupling point as *"the point at which real demand penetrates upstream in a supply chain, the level at which market "pull" meets upstream "push""*. The challenge becomes how far real and accurate demand is made visible, not just how far the order penetrates within the chain. According to Burbidge (1989), customer orders are accumulations of demand, but which are frequently delayed and distorted by the interferences of intermediaries within the chain, while actual demand mirrors the ongoing requirement and trend of the market in a much more accurate and real-time manner.

The decoupling point indicate the state in which inventory is held. In the below picture, the upper level, demand penetrates right to the point of manufacturing, and inventory could be held in form of parts of raw materials. However, in the lower level, demand is only visible at the end of the chain, and the inventory would be held in form of finished products. An agile supply chain would try to implement the concept of postponement, by holding inventories in semi-finished starts, waiting for final assembly.

Chart 1: Decoupling Points



(Source: Material flow Decoupling points – Hoekstra and Romme, 1992)

Christopher (2000) considered that postponement, or the concept of delayed configuration, is grounded on the principle of trying to design products using common platforms, components or modules, and producing common semi-finished items that can be used for multiple finished products, and holding or postponing the final assembly or customization of the product until the requirement or need of the end user is known.

Van Hoek (1998) considered three main advantages to the strategy of postponement:

a) Lower global inventory level would be the result of holding inventory at generic level, meaning fewer stock-keeping variants.
b) Greater flexibility, since holding a generic inventory would contain the same components that would be used for a variety of end products.
c) Forecasting the requirements of products at generic level is much easier than doing the same for finished products, especially for companies working on global level, since forecasting the customers' needs and market trend is much more complex than doing so on a local level.

Christopher (2000) considered the challenge to supply chain management is the challenge of developing "lean" strategies up to the decoupling point, but "agile" strategies beyond that point. He proposed using generic inventories of semi-finished items, and delaying the actual final product, through product standardization, which would help achieve volume-oriented economies of scale. The decoupling point would be the transition point between a forecast driven strategy before the decoupling point and a demand driven strategy after the decoupling point. He added that there are two levels of decoupling points. The first is the material decoupling point, which is the strategy of holding material in generic level as much as possible, and this point should be downstream in the supply chain, as close as possible to the market or the customer. On the other hand, as far away as possible from the point where information of real demand penetrates, lies the second decoupling point, which is the information decoupling point, as much upstream as possible. He confirmed his point by mentioning how Mason-Jones et. al (1997) established, by using simulations, the positive impact of information feedback on reducing upstream amplification and distortion of demand. At the end, he concluded that by managing well these two decoupling points, an agile response can be created, and the notorious Bullwhip effect can be reduced.

B.2.d) Reducing complexity to enhance agility

According to Mills (1991), complexity tends to increase as companies grow and extend market reach, and this increase in complexity is one of the biggest barriers to agility. There are many levels of complexity, from variety of products and labels, to organizational structures and management processes acquired over time.

The reduction of production complexity would become a key challenge for companies working under a wide variety of products or markets, similar to what Procter and Gamble tried to do by focusing on product portfolio rationalization, packing standardization and reduction in promotional activity in an attempt to reduce complexity, since complexity includes not only design issues but also excessive variety that does not contribute much to the bottom line of the company nor to greater customer value.

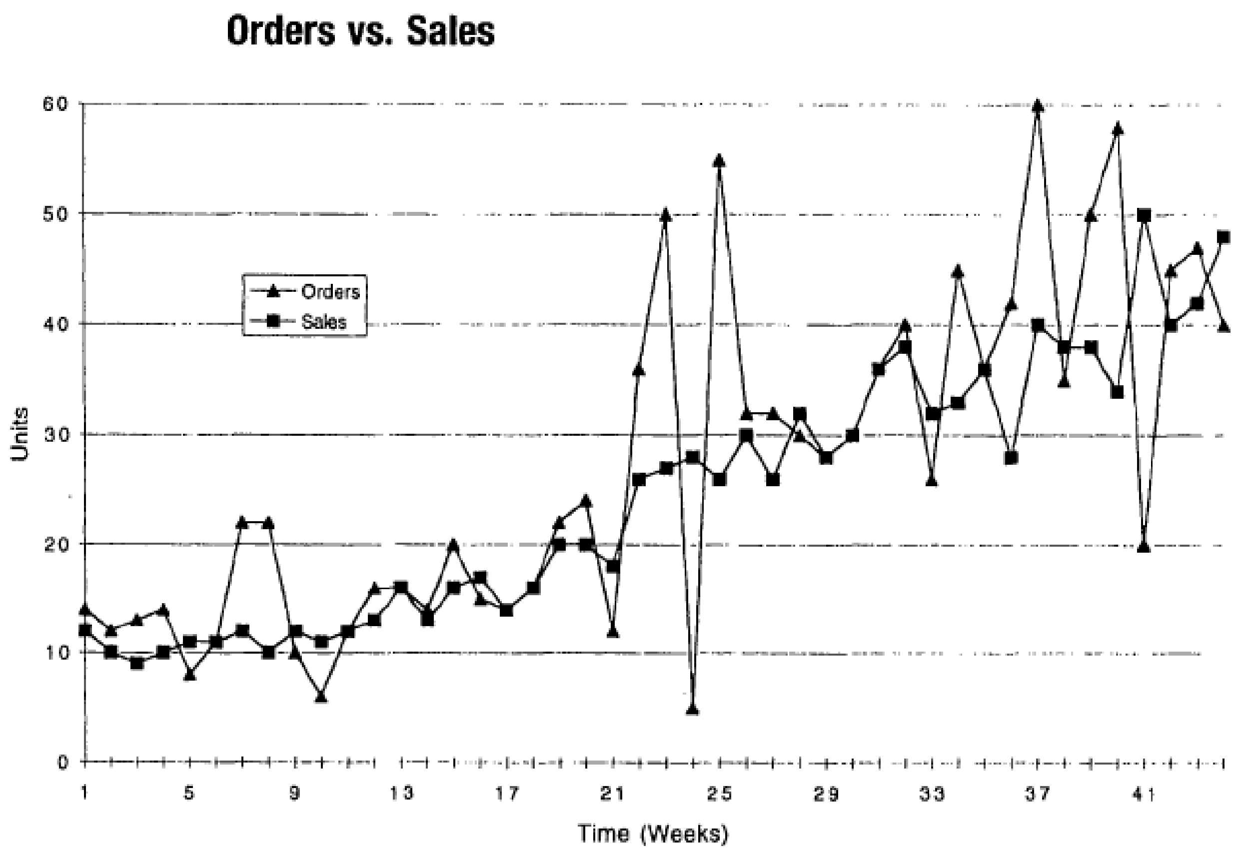
Christopher (2000) considered that complexity is also caused by the way in which organization structures, and management processes are designed, and that there is a need to reduce or eliminate the many non-value activities that are inherent in traditional functionally-based business, and break down functional silos in an effort to regroup around value-creating processes in order to help reduce organizational complexity. He added that the development of a human resource strategy that leads to multi-skilling and encourages cross-functional working would further aid to complexity reduction and hence enhance agility, referring to the team-based management that was demonstrated to be highly effective facilitator of organizational agility by Katzenbach and Douglas (1993).

B.3) The Bullwhip Effect

Consider a series of companies in a supply chain, each of whom orders from its immediate upstream member. In this context, inbound orders from a downstream member serve as a valuable informational input to upstream production and inventory decisions. According to Lee et. al, (1997), the information transferred in the form of orders tends of be distorted, and can misguide upstream members, in their inventory and production decisions. In particular, the variance of orders may be larger than that of sales, and the distortion tends to increase as one move upstream, a phenomenon called “bullwhip effect” or “whiplash effect”.

Consequently, information flow among members of a supply chain is a very important mechanism for coordination, since it has direct impact on the production scheduling, inventory control and delivery plans of individual members in the supply chain. The below figure (based on real data) shows a retail store's sales of a product, alongside the retailer's orders issued to the manufacturer, showing the retailer's orders not coinciding with the actual retail sales. The bullwhip effect could be then defined as the occurrence of having orders or demand with grater variance than actual sales, propagating the same distortions upstream, in a much-amplified way.

Chart 2: Bullwhip Effect



(Source: Hau L. Lee, V. Padmanabhan, Seungjin Whhang (1997), "Information Distortion in a Supply Chain: The Bullwhip Effect")

The distortion of the demand information would mislead manufacturer to observe the amplified demand pattern and produce accordingly, creating a domino effect, since the manufacturer would incurs excess raw materials cost due to the unplanned purchased of raw materials, additional manufacturing expenses created by excess capacity, inefficient utilization and overtime, excess warehousing expenses and additional transportation costs due to inefficient scheduling and premium shipping rates. In return, tremendous efficiency gains can be achieved through improvement of the information flow design.

B.3.a) The causes of the Bullwhip Effect

Lee et. al. (1997) considered four major causes of the bullwhip effect: demand signal processing, the rationing game, order batching, and price variations. These causes lead to systematic distortions of sales information in the order-replenishment transactions of a standard supply chain.

Demand Signal Processing

Distortion of the demand information arises when sales team issue updated forecast, leading the manufacturer to lose sight of the real demand. The distortion gets amplified as the number of intermediaries in the channel increase. A potential solution would be granting the manufacturer access to real data coming out of points of sales.

Another impact of the demand signal processing, would be the multitude of forecasts and differences in forecasting methodologies, which will lead to higher fluctuations in ordering. To eliminate the bullwhip effect in this case, a single member of the supply chain should perform the forecasting and ordering for other members. This way, supply chain can implement centralized multi-echelon inventory control system.

Longer lead time for replenishment and production have an amplified impact on the bullwhip effect, which is why, shortening the lead times, has direct and effective positive impact.

Rationing (Shortage) Game

Information distortion can also arise due to a strategic decision by a retailer, if that retailer would suspect that he is being put on allocation or rationing deliveries by the manufacturer in a certain shortage position, he will then attempt to provide distorted volume needs, higher than his actual needs, in order to ensure he will be delivered his actual needs, and in that case, the order data would have little or negative value to the manufacturer. To avoid this problem, a different rule of allocating supply across retailers in a shortage position can be implemented, by allocating the supply in proportion to the market share and past sales of retailers.

The same distortion can happen if the retailer takes self-protection measures against imaginary shortage, but not real shortage. To avoid such situations, the manufacturer can share production and inventory information with downstream members of the supply chain.

In addition, a more efficient resolution comes in the form of a contract that restricts the buyer’s flexibility, since an unrestricted choice of order quantities, free return and generous order cancellation policies all contribute to more freedom in creating distortion.

Order Batching

Order batching is the result of two main factors: the periodic review process and the processing cost of a purchase transaction. Providing manufacturer access to sell-through data or inventory data at the retail level would solve the demand distortion coming from periodic review process, since it will help the manufacturer to create a production schedule determined by sale as opposed to orders.

Lowering the transaction cost is another way to reduce the need for order batching and mitigate the batching effect, a big portion of which is due to the paperwork and processing requirement in generating an order.

Furthermore, allowing retailers to order an assortment of products to fill a truckload and offer the same volume discount is another tool that manufacturers can use to influence the buyers’ batching decision. Coordinating delivery schedules can also help, since it moves the channel away from random or correlated ordering to balanced ordering. The manufacturer would in that case avoid queuing delays and level deliveries to retailers across time, which will reduce the standard batching effect as experienced by the manufacturer.

Price Variations

Price volatility can be another reason of the bullwhip effect, showing volatility in demand not related to real demand.

To reduce the impact of price variation on the bullwhip effect, one solution could be by reducing the frequency as well as the depth of manufacturer's trade promotion. The use of rationalized wholesale pricing policies further reduces the benefits from forward-buying and diversion.

Buyers' goal to capitalize on the discount offered during a short period of time, would push them to strategic buying, leading to distortion in the real demand information, and creating unnecessary inventory costs. The manufacturer can synchronize the purchases and delivery schedules by signing with the buyer a contract, offering a fixed discount over an extended period of time for a certain large volume, but the goods are delivered in multiple future time points evenly separated, allowing the manufacturer to plan production more efficiently and the buyer can enjoy strategic buying price, while both parties can save inventory carrying costs.

The below table summarizes the various causes and counter-measures of the bullwhip effect, as described by Lee et. al. (1997).

Table 1: The causes & Counter-Measures of the Bullwhip Effect

The Causes and Counter-measures of the Bullwhip Effect

Causes	Contributing Factors	Counter-Measures	State of Practice
Demand Signaling	• No visibility of end demand	• Access sell-thru or POS data	• Sell-thru data in contracts (e.g., HP, Apple, IBM)
	• Multiple forecasts	• Single control of replenishment	• VMI (P&G and WalMart)
	• Long lead-time	• Lead-time reduction	• Quick Response mfg strategy
Order Batching	• High order cost	• EDI & CAO	• McKesson, Nabisco
	• FTL economics	• Discount on assorted truckload, consolidation by 3rd party logistics	• 3rd party logistics in Europe, emerging in the US
	• Random or correlated ordering	• Regular delivery appointment	• P&G
Fluctuating Prices	• High-low pricing	• EDLP	• P&G (resisted by some retailers)
	• Delivery & purchase asynchronized	• Special purchase contract	• Under study
Shortage Game	• Proportional rationing scheme	• Allocate based on past sales	• Saturn, HP
	• Ignorance of supply conditions	• Shared capacity & supply information	• Scheduling sharing (HP, Motorola)
	• Unrestricted orders & free return policy	• Flexibility limited over time; capacity reservation	• HP, Sun, Seagate

(Source: Hau L. Lee, V. Padmanabhan, Seungjin Whhang (1997), "Information Distortion in a Supply Chain: The Bullwhip Effect")

In summary, Lee et. al. (1997) claimed that demand distortion may arise as a result of optimizing behaviors by players in the supply chain. On the normative side, the combination of sell through data, exchange of inventory status information, order coordination and simplified pricing schemes can help mitigate the bullwhip effect. Traditionally, sales data and inventory status data have been considered to be proprietary to retailers with no obligation or reason to share it with others. But the prescription for overcoming the bullwhip effect demands that the manufacturer be given access to these data. In theory, the net benefit from efficient supply chain management can be redistributed among all members of the supply chain. The subject of how to split the gain and cost appears to deserve attention of its own

B.4) 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 launched 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 characterizes of a Just-in-time (JIT) systems, 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; he subtitled his book on the subject 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.

B.4.a) 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 from 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.

B.4.b) Brief history of MPC system evolution

MPC started to take shape at first when, in a manufacturing facility, a group of plant foremen where assigned the task of scheduling production, and ordering raw materials and coordinating shipments for products relative to their areas of responsibilities, all in the simplest manner, and as easy as possible to allow even 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 mainframes 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"*.

B.4.c) 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 emergence 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.

B.4.d) 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 helps in decision making.

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

Table 2: Manufacturing Planning and Control System Stage Characteristics

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).

B.5) Pull Management Strategy

Production control mechanisms that use the actual occurrences of demand rather than future demand forecasts to control the flow of material are known as pull type control mechanism. In contrast to the push approach, the pull type system pull work through the factory, using usually Kanban control systems.

In order to compete with American automakers, Taiichi Ohno in 1940s began evolving a system that would give Toyota a competitive edge, without depending on efficiencies resulting from long production runs that Toyota did not have the volumes to support. This approach was known as the Toyota Production System (TPS), and was designed to make goods as much as possible in a continuous flow (Hopp and Spearman, 2004).

B.5.a) Toyota Production System

The Toyota Production System (TPS) was introduced and developed in reaction to Japan's main two features, the lack of natural resources, and the Japanese concept of work (Sugimori et al., 1977).

The lack of natural resources forces Japanese companies to import most of what is needed in raw materials for production, putting them in a disadvantage position compared to European and American companies. To overcome this disadvantage, Japanese companies had to ensure their survival by producing better quality goods with higher added value, while trying to reduce production cost.

The Japanese concept of work was very particular and different in term of consciousness and attitude than other countries, and included (1) group consciousness, sense of equality, desire to improve and diligence born from a long history of a homogeneous race, (2) high degree of ability resulting from higher education brought by desire to improve, (3) centering their daily living around work. These traits manifested in their companies through customs such as (1) lifetime employment system, (2) labor unions by companies, (3) little discrimination between shop workers and white-collar staff, and (4) chances are available for workers to be promoted to managerial positions, have been a great service in promoting the feeling of unity between companies and workers.

B.5.a.1) Toyota Production System's basic concept

Based on the Japanese traits mentioned, Toyota created its production system based on two main concepts: (1) reduction of cost through the elimination of waste, later known as Just-In-Time, (2) make full use of the workers' capabilities, also referred to as Respect for Humans.

B.5.a.1.a) Reduction of cost by eliminating waste

To execute its main concepts for production, Toyota attached special importance to "just-in-time production and "Jidoka". Ohno identified 7 sources of waste, which are waste of overproduction, waiting, transporting, over-processing, inventories, moving, and defective parts and products (Ohno, 1988). Additionally, the waste of not making use of peoples' potential is mentioned.

B.5.a.1.b) Just in Time Production

In order to avoid unbalanced inventories and surplus use of equipment and workers, there was a need to develop a production system which is able to shorten the lead time from the entry of materials to the completion of the finished products. *"The Just-In-Time (JIT) method is a process that shortens the production lead time, by having all processes produce the necessary parts at the necessary time and have on hand only the minimum stock necessary to hold the processes together"* (Sugimori et al., 1977).

a) ***Withdrawal by subsequent processes***: the first prerequisite for achieving JIT production would be by making sure that all processes can quickly obtain accurate knowledge of the timing and quantity required. To implement this approach, Toyota adopted a reverse method of "the following process withdrawing the parts from the preceding process" (pull) instead of the "the preceding process supplying the parts to the following process". The last line of assemblage, and to acquire the necessary parts at the right time for the vehicle assembly, would go to the previous line in the production cycle to obtain these parts. The previous production process would then produce on the parts withdrawn by the next production process. To produce these parts, the preceding process obtains the necessary parts from the process further preceding it. By connecting all these processes in a connected chain fashion manner, it will be possible for the entire company to engage in just-in-time production without the necessity of issuing lengthy production orders to each single process.

b) ***One piece production and conveyance***: the second requirement of JIT production is that each process can produce only on piece, can convey one piece at a time and have only one piece in stock between the equipment and the processes. By implementing this rule, no process for any reason would be allowed to produce extra amounts and have surplus stock between processes. Toyota tried to implement this rule by reducing the lot size through shortening the setup time, improving production methods by elimination work-in-progress inventories, and improving conveyance.

c) ***Leveling of production*:** since all processes are required to perform small lot production and conveyance, in case of considerable variability in the withdrawal system, the processes within the company will maintain peak capacity or hold excessive stock at all times. That is why, for JIT production to work, it is necessary to level the production at the final assembly line. The leveling of production is achieved through:
    - Averaging the production per day by taking the number of vehicles in the monthly production schedule, segregated by specifications, and dividing by the number of working days.
    - Concerning the daily production sequence, the cycle lead time of each different specification vehicle is calculated, and in order to have all specification vehicles appear at their own cycle time, different specification vehicles are ordered to follow each other.
    - Producing only as much as possibly sold, on the one hand adjusting its production level according to the change in market trends, on the other hand producing as smoothly as possible within a certain range. The monthly production schedule is

constantly changed and reviewed on a daily basis in order to reduce the shock of market fluctuation as much as possible.

A production control system was developed to exercise these general rules is the Kanban system.

d) ***Elimination of waste from over-producing***: in regular or conventional production companies, inventories are kept as a buffer to absorb the problems and volatility in market demand and capacity restrictions. Toyota however saw the inventory as an outcome of over-producing more than required and being the worst type of waste that can raise the production cost, since it hides the causes of waste that should be remedied such as lack of balance between the workers and between the processes, troubles in various processes, workers' idle time, surplus workers, excessive equipment capacity and insufficient preventive maintenance.

B.5.a.1.c) Jidoka

At Toyota, the term Jidoka meant "to make the equipment or operation stop whenever an abnormal or defective condition arises", and the importance is that any line with workers can be stopped by them immediately. This process was important for the following reasons:

- To prevent making too much. Once the requirement is produced, stopping the machine would prevent making excess stock, thus the JIT production can be accurately executed.
- Control the abnormality become easy. When a line is stopped, directing attention to the stopped equipment and the worker who did the stopping will make it easier to make the necessary improvement of the line.

B.5.a.1.d) Full utilization of workers' capabilities

In this second concept, Toyota tried to make the best use of Japan's labor environment, by building a system of respect for human, highlighting the below points:

- ***Elimination of waste movement by workers***: The first of these wastes is workers' movements accompanying the waste of making too much. The movements of material handling operations between the equipment and between the processes due to large inventory are all waste movements. In addition, to prevent waste resulting from waiting time, various improvement were made, such as (1) separating the workers from the equipment by assigning a worker to multiple equipment, (2) concentration of workers' zones at the automatic line, and (3) making up lines that do not require supervisory operations. The second waste is generated from workers performing operations that by nature are not suitable for men. Many processes have been mechanized, automated and unmanned, like monotonous repetitive processes, as well as dangerous operations, which could lead to injuries, or requiring hard physical labor. The third waste is workers' movements coming from troubles or defects. Thorough Jidoka used by Toyota has greatly reduced this kind of waste.

- ***Considerations to workers' safety***: due to the diligence and enthusiasm of the workers at Toyota, some of them might not stop the operation in case of minor trouble or could start working something extra in case the main task is done, all of which would lead to extra activities accompanied by accidents, troubles or defects. That is why, the Jidoka and elimination of waiting time has been further implemented not only to reduce production cost, but also as a measure for safety.

- ***Self-display of workers' ability***: Toyota wanted to create a system where workers can actively participate in running and improving their workshops and be able to fully display their capabilities, and tried to execute that system by laying a set of rules where, (1) all workers at Toyota have a right to stop the line on which they are working, at any sign of abnormality or defect, (2) at all shops in Toyota, the workers are informed of the priority order of the parts to be processed and the state of production advancement, delegating the decision making authority to the foreman, (3) setting a system whereby workers can take part in making improvements, by granting the right to any employee to make an improvement on the waste he finds.

B.5.a.2) Toyota Kanban system

In order to efficiently implement the Toyota Production System, the company implemented a Kanban, pull system, at the core of its execution process.

B.5.a.2.a) The aim of the Kanban system

The Toyota Kanban system is a production control system for just-in-time implementation and making full use of the workers' capabilities, enabling workshops not to rely on electronic computers, with the following advantages compared to computerized systems:

1) Reduction of cost processing information, since implementing a computer system that provides production schedule to all the processes and suppliers as well as its alterations and adjustments by real time control, would come at a huge cost.
2) Rapid and precise acquisition of facts, since by using it, managers of workshops receive continuously all changing facts such as production capacity, operation rate, and manpower without the help of a computer, rendering the data of schedules related to the changes very accurate, and promoting activities for spontaneous improvements.
3) Limiting surplus capacity of preceding shops, since in such multistage production process, the demand for the item becomes progressively more erratic the further the process point is away from the point of the original demand for the finished product.

B.5.a.2.b) Description of the Toyota Kanban System

The Toyota Kanban system was a form of order card called Kanban, with the following description:

1) It consisted of two kinds of cards, one called “conveyance Kanban”, which is used when ongoing from one process to the preceding process, and the other card called “production Kanban” used to order production of the portion withdrawn by the subsequent process. Both types of cards are always attached to the containers holding parts.

2) When content of a container begins to be used, conveyance Kanban is removed from the container. A worker takes this conveyance Kanban and goes to the stock point of the preceding process to pick up this part. He then attaches this conveyance Kanban to the container holding this part.
3) Then, the production Kanban attached to the container is removed and becomes dispatching information for the process. They produce the part to replenish it withdrawn as early as possible.
4) Thus, the production activities of the final assembly line are connected in a manner like a chain to the preceding processes or to the subcontractors and materialize the just-in-time production of the entire processes.

Always according to Sugimori et al., (1977), the equation calculating the number of kanban that play the most important part in this system is as follow:

$Y = [D(Tw+Tp)(1+\alpha)]/a$ where:

Y = number of kanban

D = Demand per unit time

Tw = waiting time of kanban

Tp = processing time

a = container capacity (not more than 10% of daily requirements)

α = policy variable (not over 10%)

The authors further explained the formula as such:

- α is a policy variable which is determined according to the workshop's capability to manage external interference.
- D is determined with a smoothed demand.
- The value of Y is rather fixed despite the variation of D, that is why, when D increases, it is required to reduce the value of (Tp+Tw), that is a lead time. Workshops with insufficient capability of improvement cannot avoid overtime for a while. Incapable shops might have to cope with the situation by increasing α, that is why managers consider the value of α as an indicator of shop capability in improvement.

- In the case that demands decreases, the lead time becomes relatively larger. Consequently, waste of increasing idleness becomes visible, which is an object of improvement, to decrease the number of workers as demand (production) decreases.
- Work-in-process inventory could become much less by conducting an improvement to reduce the value of a, α, and (Tp+Tw).

What Toyota considers as the goal through Kanban System is total conveyor line production system connecting all the external and internal processes with invisible conveyor lines. Because, a set of values of α, a, and Tw is 0, 1, and 0, respectively, its means nothing but attributes of a conveyor line. All the parts that constitute a vehicle are processed and assembled on a conveyor line, raising its added value. Finally, they come out as a completed vehicle one by one. On occurrence of troubles, the whole line may stop, but it begins to move again immediately. *"Toyota Production System is a scheme seeking realization of such an ideal conveyor line system, and Kanban is a conveyer connecting all the processes"* (Sugimori et al., 1977)

B.5.b) Review of the Kanban system

Huang & Kusiak (1996) summarized the main principles for the implementation of Kanban systems as follow:

- Leveling production and achieving low variability of the number of parts from one period to the next.
- Avoiding complex information and hierarchical control systems on a factory floor.
- Withdrawing only the parts needed at each stage.
- Not sending defective parts to the succeeding stages.
- Producing the exact quantities of parts withdrawn

The authors continued by expressing that the Kanban system fulfills the following functions:

1) ***Visibility function***: the information and material flow are combined together as kanbans move with their parts (work-in-progress, WIP)

2) ***Production function***: detaching it from the succeeding stage, the kanban fulfills a production control function which indicates the time, quantity, and part types to be produced.
3) ***Inventory function***: the number of kanbans measures the amount of inventory, allowing to controlling the inventory levels by controlling the number of kanban cards.

Huang & Kusiak (1996) classified five types of Kanban:

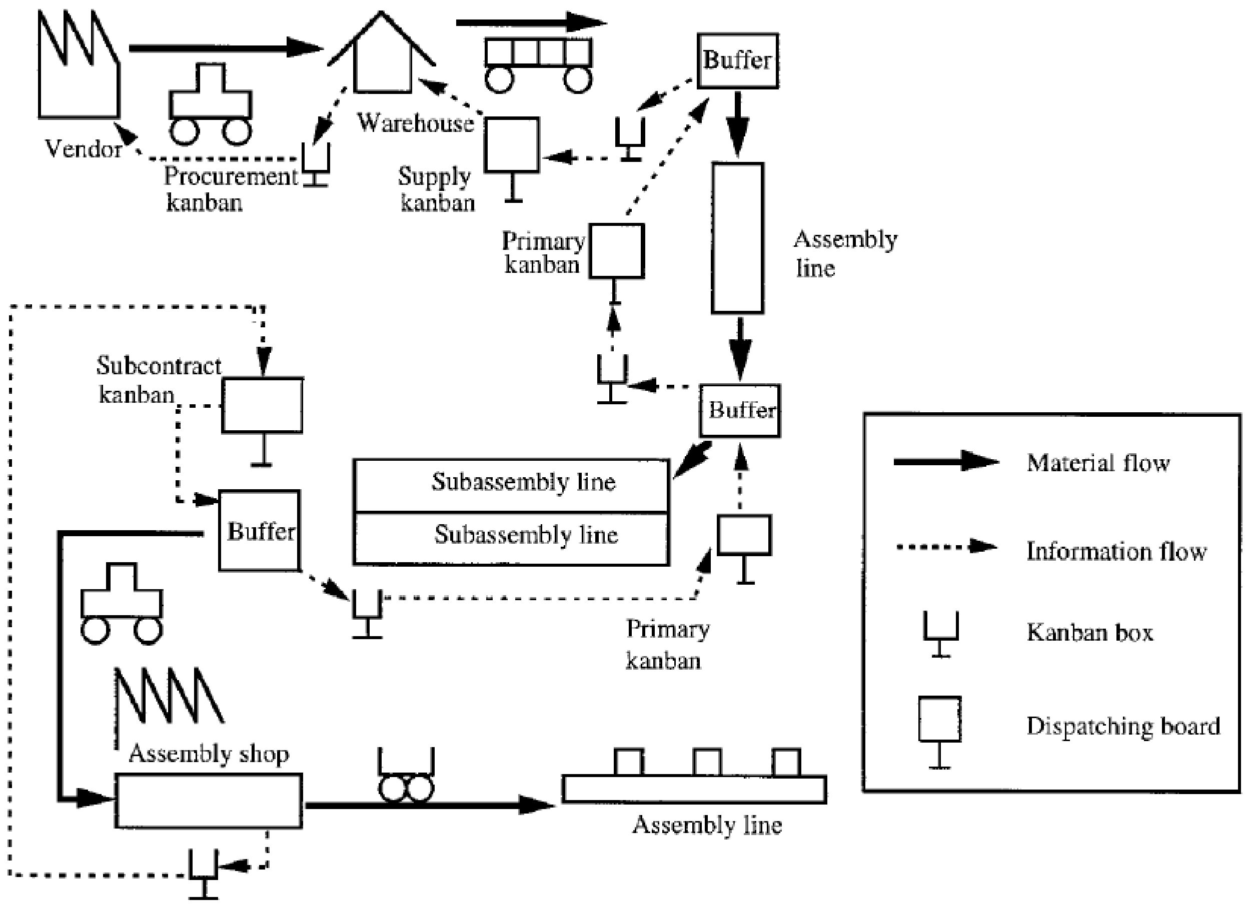
1) ***Primary Kanban***, which travels from one stage to another among main manufacturing cells. This is the main Toyota type, divided into two kinds, (a) the “withdrawal Kanban” (conveyor Kanban) which is carried from one stage to the preceding stage, and (b) the “production Kanban” used to order production of the portion withdrawn by the succeeding stage. Both kinds of primary Kanban are always attached to the containers holding parts.
2) ***Supply Kanban***, which travels from the storage facility to the manufacturing facility.
3) ***Procurement Kanban*** travels from outside of a company to the receiving area.
4) ***Subcontract Kanban*** travels between subcontracting units.
5) ***Auxiliary Kanban*** is an express Kanban or an emergency Kanban or dedicated for a specific application.

The authors provided a summary description of the Kanban operation, being for production stage i, when parts are processed, and demand from its receiving stage i + 1 occurs, the production Kanban is removed from a container and is placed on the dispatching board at stage i. The withdrawal Kanban from stage i + 1 then replaces the production Kanban and the container. This container along with the withdrawal Kanban is then sent to stage i + 1 for processing.

Meanwhile at stage i, the production activity takes place when a production Kanban and a container with the withdrawal Kanban are available. The withdrawal Kanban is then replaced by the production Kanban and sent back to stage i - 1 to initiate production activity at stage i - 1. This forms a cyclic production chain.

The Kanban pulls (withdraws) parts instead of pushing parts from one stage to another to meet the demand at each stage. The Kanban controls the move of product, and the number of Kanbans limits the flow of products. If no withdrawal is requested by the succeeding stage, the preceding stage will not produce at all, and hence no excess items are manufactured. Therefore, by the number of Kanbans (containers) circulating in a JIT system, non-stock-production (NSP) may be achieved. The below chart describes the general flow of a Kanban system.

Chart 3: Kanban Flow



(Source: Chun-Che Huang and Andrew Kusiak (1996), "Overview of Kanban Systems")

B.5.b.1) Kanban Control systems

Huang & Kusiak (1996) talked about three kinds of kanban control systems.

B.5.b.1.a) Single Kanban System (using production kanban)

By using only the production Kanban cards, a single Kanban or single card system blocks material-handling based on the part type, while subsequently the production would be blocked at each stage based on the global queue size. In the single Kanban system, the size of a station output buffer and part mix could alter, and several containers might hold the batches required to be produced, as long as the total number of full containers in the output buffer does not exceed the buffer output capacity. The below conditions are required for the system to function properly:

- The distance between any two succeeding processes should be small.
- The turnover of the kanbans should be fast.
- The work in progress level should be low.
- The turnover of the WIP should be fast and the buffer space should be small
- The speed of material handling and the production rate should be synchronized

B.5.b.1.b) Dual Kanban system *(using two kanbans simultaneously)*

This is a dual kanban system using two cards, the production and withdrawal kanbans to implement both the station and material-handling blocking by part type. There is a buffer for WIP while transporting the finished parts from a preceding stage to its succeeding stage, and the withdrawal kanbans are presented in the buffer area. This system is appropriate for manufacturers who are not prepared to adopt strict control rules to the buffer inventory, with the following conditions for it implementation:

- The distance between two stages should be moderate
- The kanbans' turnover should be fast
- There is a need of some WIP in a buffer
- The production system should have an external buffer
- The speed of material handling and the production rate should be synchronized

B.5.b.1.c) Semi-dual kanban system *(changing production kanbans and withdrawal kanbans at intermediate stages)*

This type of kanban system has the following characteristics:

- The distance between two stages is large

- The kanbans' turnover is slow
- Between succeeding stages, a large WIP is needed
- The work in progress turnover is slow
- The speed of material handling and the production rate are not needed to be synchronized

Table 3: Overview of Kanban Systems

	SKS	DKS	SDKS
Distance between two stages	Small	Moderate	Large
WIP between two stages	Small	Small	Large
Turnover of Kanbans	Fast	Fast	Low
Turnover of WIP	Fast	Moderate	Slow
Synchronization of production and movement of WIP	Necessary	Not necessary	Necessary

SKS: Single Kanban system.
DKS: Dual Kanban system.
SDKS: Semi-dual Kanban system.

(Source: Chun-Che Huang and Andrew Kusiak (1996), "Overview of Kanban Systems")

B.6) Push and Pull

In general, the main distinction between push and pull is related to the manner production orders are released in response to demand. In a push strategy, production orders are created based on expected future demand, being either under the form of existing orders, or forecasts, or both. In pull strategy, however, production orders are released in response to real demand. Current demand is removed from inventory, offsetting upstream production orders to replenish the removed inventory.

In relation to work-in-progress (WIP), taking into consideration that kanban is a pull system and MRP is a push system, a pull production system is one that explicitly limits the amount of work in process that can be in the system. By default, this implies that a push production system is one that has no explicit limit on the amount of work in process that can be in the system (Hopp and

Spearman, 2004). However in the real world implementation, there was no pure push or pure pull, and the implementation or choice of either method is a grey area, as while Kanban system establishes a clear limit on WIP through the production cards, there are almost always circumstances under which this limit will be overridden, and while MRP does not establish a limit on WIP, when WIP reaches certain levels, it will cause management to ignore the planned order releases or revise the production schedule in order to limit the growth of WIP.

Hopp and Spearman (2004) considered that pull can be implemented in a variety of ways, kanban being obviously one way to limit WIP, but there are other systems:

1) MRP is a push system because releases are made according to a master production schedule without regard to system status. Hence, no a priori WIP limit exists.
2) Classic kanban is a pull system. The number of kanban cards establishes a fixed limit on WIP.
3) Classic base-stock system is, somewhat surprisingly, a push system because there is no limit on the amount of work in process in the system. This is because backorders can increase beyond the base-stock level.
4) Installation stock (Q, r) is also a push system as are echelon stock (Q, r) systems, because neither imposes a limit on the number of orders in the system.
5) CONWIP is a pull system because it limits WIP via cards similar to kanban. An important difference between kanban and an implementation standpoint is that the cards are line specific, rather than part number specific. However, from a push/pull perspective, CONWIP cards limit WIP in the same manner as kanban cards.
6) (K, S) systems are pull systems if $K < \infty$ and are push systems otherwise.
7) POLKA systems are pull systems because, like Kanban, CONWIP, WIP is limited by cards.
8) PAC systems are pull systems when the when the number of process tags, which serves to limit WIP, is less than infinity.
9) MRP with a WIP constraint is a pull system.

Krishnamurthy et al. (2004) examined push and pull strategies in multi-product flexible manufacturing systems, by explaining that since pull is a replenishment strategy designed for manufacturing environment producing repetitive products with high demand volumes, which require a minimum inventory of each product to be maintained at the output of each workstation. When one item is removed from downstream workstation, its triggers upstream workstation to begin replenishing this removed quantity. In that case, if the upstream workstation is manufacturing a large number of products specifications with possibly distinct demands, this could lead to proliferation of WIP inventories at each stage of the process. Certain product environments could lead to situations where the time between demands for some products is greater than their average flow time, where pull strategy could lead to inventory replenishments well in advance of their requirements, resulting in excess WIP inventories, potentially leading for inefficient system performance. The authors continued by stating that push strategies however release production orders based on the release times of jobs at each station in the system. These release times are determined by backward scheduling the due dates of orders from the assembly cells using the planned production lead times at each station. To account for the difference between the planned lead time and the actual flow time of an order, push strategies often incorporate safety stocks or safety lead times. Incorporating safety lead times involves inflating the lead time estimates, while incorporating safety stocks involves increasing the target inventory levels in the system.

From the work of other publications, Krishnamurthy et al. (2004) summarized the main issues in modeling push systems, being (1) estimating release lead times for MRP, (2) modeling future requirements for the different products, and (3) determining the safety lead times and/or safety stocks required to guarantee the required service levels for the different products. Furthermore, also from the publications of other authors, they identified the main issues in modeling kanban push systems as being (a) determining the number of kanbans for each product and (b) their allocation among the different stages of the manufacturing system.

Further to their study of the performance of push and pull strategies in multi-product flexible manufacturing systems, Krishnamurthy et al. (2004) found that push outperforms pull in terms of service levels and average inventories. Further, in the pull strategy, if the kanban allocations are not set carefully, despite having high inventories the system could result in large average backorder delays and poor service levels. Their results have shown that pull strategies can perform poorly in certain multi-product environments. Manufacturing departments or suppliers that provide multiple products to assembly lines that share their assembly schedules can achieve better system performance by adopting a push strategy that explicitly considers future requirements when triggering production releases. Ignoring the available information on future requirements and adopting a pure pull strategy that merely replenishes consumed inventories may prove detrimental.

B.6.a) Hybrid Push-Pull systems

Since both push and pull strategies have advantages and disadvantages, depending of the manufacturing system where they are implemented, many authors discussed hybrid systems that combine both push and pull strategies.

Deleersnyder et al. (1992) discussed the main arguments for hybrid systems as follow:

- Due to the centralized nature of the push system’s operation mode, the model excels at information flow, which can readily flow from end to end of the manufacturing system. In case the date was accurate, push systems produce outstanding results. But data is frequently inaccurate in a typical manufacturing environment, resulting in poor decision making abilities.
- On the other hand, pull systems exercise local control which ensures the existence of highly reliable data. However, since information is physically tied to the material flow, it can result in long information lead times.
- The goal of a hybrid system is using local control and the highly reliable local data, but to supplement this selectively with a push system to feed forward information directly to upstream work centers, which bypass the potentially long information lead times.

As an example of a hybrid system, Deleersnyder et al. (1992) studied a general N-stage hybrid push/pull model for the control of manufacturing systems, combining the benefits of pull control systems in reducing inventory levels, and the advantage of push/MRP systems in responding to fluctuating demand. The results of their experiments showed the following results:

1) Under constant demand, the hybrid push/pull approach achieves the same service level but with a lower inventory level compared to the pure pull approach.
2) Under varying demand, both seasonal and step change, the push/pull approach had both a lower inventory level and less fluctuation in the total inventory compared to the pure pull approach.
3) With the push/pull approach there appears to be less need to adjust the number of kanban cards compared with the pure pull systems.

Several hybrid push/pull systems were discussed in the literature, such as the CONWIP (constant work-in-process) model that possesses the benefits of kanban but can be applied to more general manufacturing settings, as well as others.

B.7) 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.

B.7.a) 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 4: 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.

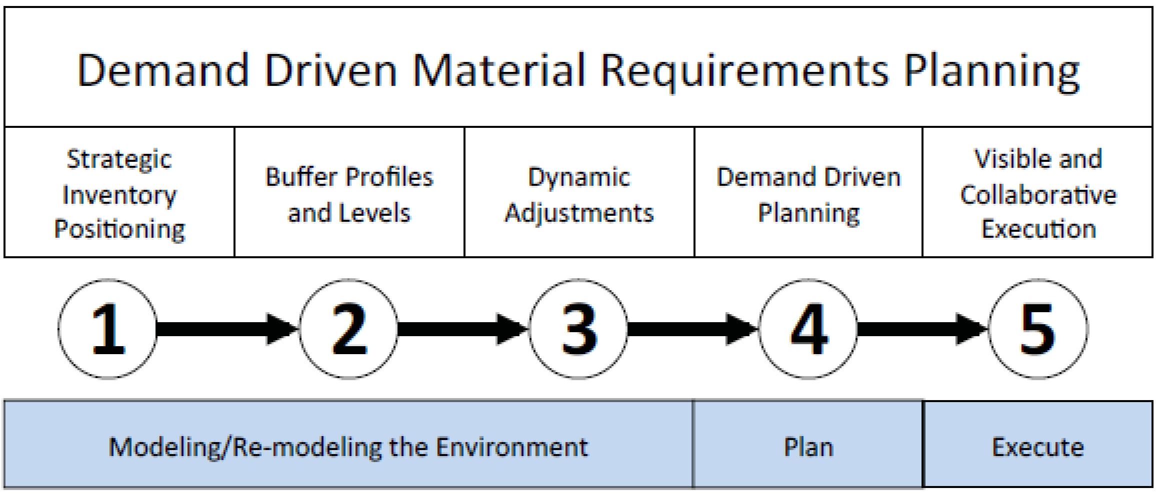
(Source: Mathias Ihme and Roy Stratton (2014), "Evaluating Demand Driven MRP: a case based simulated study")

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 4: 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 5: 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. The demand driven planning refers to the process of generating supply requirements, and this process ends once the recommendation is made and became a pending order for replenishment.
Highly visible and collaborative execution	Demand driven execution is the process of managing and executing pending replenishment orders depending on relative criteria per case. 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) explains 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) continues 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 zone helps 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:

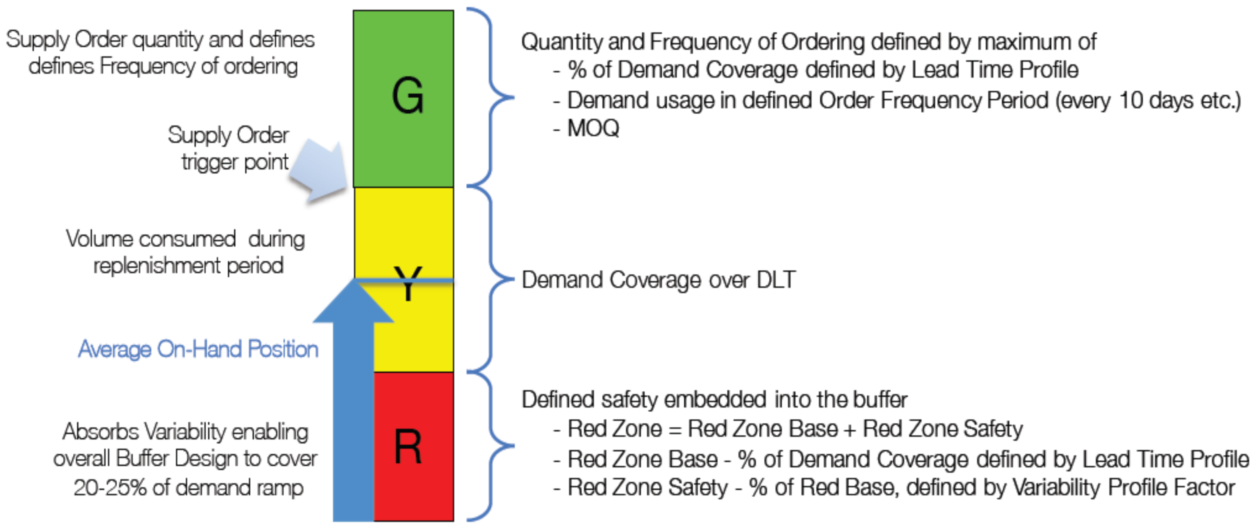
Green Zone = Max(YellowZone. LTFactor; LotSize)
Yellow Zone = ADU. ASRLT . PAF
Red Zone = YellowZone. LTFactor. (1+VariabilityFactor)
TopOfRed = RedZone
TopOfYellow = TopOfRed + YellowZone
TopOfGreen= TopOfYellow + GreenZone.

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: Parts 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 5: DDMRP Inventory Zones



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

In their book, Ptak and Smith (2011), summarized the five components of the DDMRP process as follow:

- Inventory positioning: it is about where to decouple and at which stage to keep inventories, which is the primary question to promoting and protecting the flow of information and materials.
- Strategic buffer: the matter of sizing buffers should not be a matter of rigid or formal equations, but more a logical assessment, and a matter of consideration and organization related assessing the buffer sizes based on a company's profile.
- Dynamic adjustments: recalculated adjustments allow the buffers' levels and base parameters to be recalculated and adjusted in relation to the actual daily usage, allowing it to stay up to date with changes in demand trends.
- Demand driven planning: this process provides a simple, intuitive and visible way to generate supply orders, rendering all components of the supply generation known and containing relatively little variability, reducing nervousness and bullwhip effects.
- Demand driven execution: which creates concepts and alerts for supply order management to establish a highly visible and collaborative execution across the model, with limitless permutations for these concepts based on the circumstances of each environment.

B.7.b) 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 improves 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

B.7.c) 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?

B.7.d) 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 put 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 buffers 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.

C – Research Question

The supply chain concept has been evolving since the 1950's with more intensity after the 1980's and the introduction of the supply chain management concept.
This evolution was following and leading the changes in the market and business environment as well as the evolution in the information systems and new technological innovation, trying to catch up with the new emerging updates and the needs of the market to provide efficient solutions and practices for ever evolving business environment.

To that end many strategies has been developed, to increase agility, trying to become closer to the market place and demand signals, and connecting the various links of the supply chain, by integrating all functions into a seamless process, which meant not following standard theories and moving towards hybrid systems, customized to different situations, industries, or markets, all to insure top efficiency. That kind of strategy meant setting various decoupling points at different sections within the supply chain cycle, to increase responsiveness, in a quick and accurate manner, to become more market sensitive, and at the same time avoid bullwhip effects and distorted information signals.

Push and Pull management strategies were developed, with the terms referring 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 is mainly known for multistage production scheduling, by determining a production schedule for each stage of production. This approach is notorious for adopting the manufacturing resource planning (MRP-II) and the material requirements planning (MRP), for the calculation of component and raw material requirements, in addition to scheduling each work center.

The main advantages of this strategy 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.

On the other hand, the Push approach has some 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.

In contrast to the Push strategy, the Pull type system pull work through the factory, using mostly Kanban control systems. It is a production control mechanisms that use the actual occurrences of demand rather than future demand forecasts to control the flow of material.

The Pull approach was globally famous through the Toyota Production System (TPS), which relied on basic concepts such as reduction of cost through the elimination of waste, the Just-In-Time production process, and making full use of workers' capabilities.

The Toyota Production System was operationally implemented by using a Kanban production system, consisting of two kinds of cards, one called "conveyance Kanban", which is used when ongoing from one process to the preceding process, and the other card called "production Kanban" used to order production of the portion withdrawn by the subsequent process.

The Kanban pulls (withdraws) parts instead of pushing parts from one stage to another to meet the demand at each stage. The Kanban controls the move of product, and the number of Kanbans limits the flow of products. If no withdrawal is requested by the succeeding stage, the preceding stage will not produce at all, and hence no excess items are manufactured. Therefore, by the number of Kanbans (containers) circulating in a JIT system, non-stock-production (NSP) may be achieved.

The Kanban system helps reducing of cost processing information, provides rapid and precise acquisition of facts and demand signals, and limit surplus capacity at each stage of production.

Huang & Kusiak (1996) summarized the main principles for the implementation of Kanban systems as follow:

- Leveling production and achieving low variability of the number of parts from one period to the next.
- Avoiding complex information and hierarchical control systems on a factory floor.
- Withdrawing only the parts needed at each stage.
- Not sending defective parts to the succeeding stages.
- Producing the exact quantities of parts withdrawn

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.

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:

- Strategic Inventory Positioning
- Buffer profiles and levels
- Dynamic adjustments
- Demand-driven planning
- Highly visible and collaborative execution

DDMRP establishes 3 buffer zones, differentiated by color, representing the state of the inventory system:

- Green: Part requires no action
- Yellow: Parts requires replenishment

- Red: Part may require special attention

The literature review on DDMRP is rare however, not much articles has been written on the subject yet, some consulting firms has published presentations pretending to know how to implement DDMRP and promising outstanding results, but not much has been academically validated yet.

Furthermore, DDMRP is presented as a mix management system between Push and Pull strategies, but:

- Could DDMRP be implemented along with a standard Pull system such as Kanban? And how?
- Would both systems compete, coexist, or complement each other?
- In a multiproduct industrial company, how to implement DDMRP and Kanban together?
- What would be the advantages of implementing DDMRP, and Kanban, versus forecast based management systems?
- If such implementation is feasible, which companies could replicate this strategy, and how?

One of the major difficulties companies could face, is knowing if they can implement this mix system or not, and more importantly, which products would be better managed by DDMRP and which by Kanban, as tools for production launch and replenishment systems?
The idea of knowing and deciding the right products to be managed by such system could prove to be a challenge to many companies, especially with historical practices and habits of management practices, in addition to change obstacles and the acceptance to change mindset.
In some cases, companies could have many products eligible to be managed in this system, but they simply would not be aware of it, or haven't thought that replenishment process for finished products could be handled differently.
That is why, we will try to clarify and make a certain charter explaining which products could be managed by such a mix system, by first explaining how to recognize these products and separate them from the company products portfolio, then defining how each type is better managed either by DDMRP or Kanban and why?

To attempt to find an answer to these questions, we will study the implementation of DDMRP and Kanban systems for the replenishment launch of finished products, in a multiproduct industrial company called Liban Cables SAL.

Liban Cables SAL is a Lebanese industrial company, producing electrical cables, with a wide variety of products, (hundreds of products produced repeatedly, and thousands of products within the global portfolio of its capacity, produced when needed). In that wide portfolio of products, some products are engineered or invented upon new demand, some products are produced only following clients' orders, and some products are produced for stock, and kept in the company's warehouses, in various quantities per product type, to be always ready to satisfy customer demand, sold in a continuous manner. So, in summary, it sales history manifest very different sales volumes and frequencies per product.

The scope of the study will study at first the state of the supply chain replenishment process before the implementation of DDMRP and Kanban, then will present how DDMRP was implemented, from the preparatory stages, to the choice of products to be managed by DDMRP, to the implementation, the various parameters, (strategic inventory positioning, buffer profiles and levels, dynamic adjustments, demand driven planning, and visible and collaborative execution) and the added value and limitations of that system.

We will examine as well the implementation of Kanban, which products were managed by Kanban and why, the steps of implementation (defining the conveyance cards, the production cards, and decoupling points), how the process why set, and which were the advantages and limitations of that system.

Once the implementation is studied, we will then examine the results of such systems on the key performance indicators (KPIs) of the inventory management system, comparing these KPIs before and after the implementation of both DDMRP and Kanban.

The main KPIs that we will look at would be the actual inventory level for the chosen products, the inventory turn (or coverage of the inventory versus sales), the quality of the inventory level, customer satisfaction by measuring the shortages of products as well as the excess, and finally the whole process and its impact on stabilizing the volatility of the inventory level and avoidance of bullwhip effects.

Through that study, we hope to shed more light and clarity of the DDMRP implementation process, its coexistence with Kanban, and answer the research questions mentioned above, in an attempt to provide new academically proofed knowledge to that field.

D – Research Methodology

In this section, we will try to explain how to proceed in our attempt to answer the research question, from the epistemological positioning of the paper, to the choice of research method and case, as well as the data gathering & analysis methods.

D.1) Epistemological positioning

Epistemology could be defined as the philosophical discipline that tries to establish the foundations of science (Thietart et al. 2014). It relates to four main dimensions:

- Ontological dimension, related to the nature of the reality that needs to be discovered.
- Epistemic dimension, related to the nature of the produced knowledge.
- Methodological dimension, detailing the manner how the knowledge is produced and justified
- Axiological dimension, checking the added values of the created knowledge.

Chilisa and Kuwalich (2012) explained the main paradigms as following:

- Positivists and post-positivists view reality as being objective and knowable. Such research is value free and based on precise observation and verifiable measurement.
- Constructivists or interpretativists view reality as being socially constructed and hold that there are multiple realities. Knowledge is subjective and idiographic and truth is dependent upon the context. This paradigm is value-laden and emphasizes that values influence how we think and behave, as well as what we find to be important.
- Transformative or emancipatory research focuses on the view that reality is shaped by culture, politics, economics, race, gender, ethnicity, and disability. Values are considered to be important, particularly as values and beliefs differ from one culture to the next. Knowledge and understanding are aimed at critical praxis.

- Postcolonial Indigenous research emphasizes reality as being socially constructed with multiple realities, based on the relationships humans have with each other and the world around them, both living and non-living. Values of reciprocity, respect, and representation are emphasized. Knowledge is derived from relationships and drawn from indigenous knowledge systems.

According to Chilisa and Kuwalich (2012), the paradigms can be compared in the below table:

Table 6: Epistemological Paradigms

	Positivist / post-positivist Paradigm	**Constructivist / Interpretativist Paradigm**	**Transformative / Emancipatory Paradigm**	**Postcolonial / Indigenous research Paradigm**
Reason for doing the research	To discover laws that are generalizable and govern the universe	To understand and describe human nature	To destroy myths and empower people to change society radically	To challenge deficit thinking and pathological descriptions of the former colonized and reconstruct a body of knowledge that carries hope and promotes transformation and social change among the historically oppressed
Philosophical underpinnings	Informed mainly by realism, idealism and critical realism	Informed by hermeneutics and phenomenology	Informed by critical theory, postcolonial discourses,	Informed by indigenous knowledge systems, critical

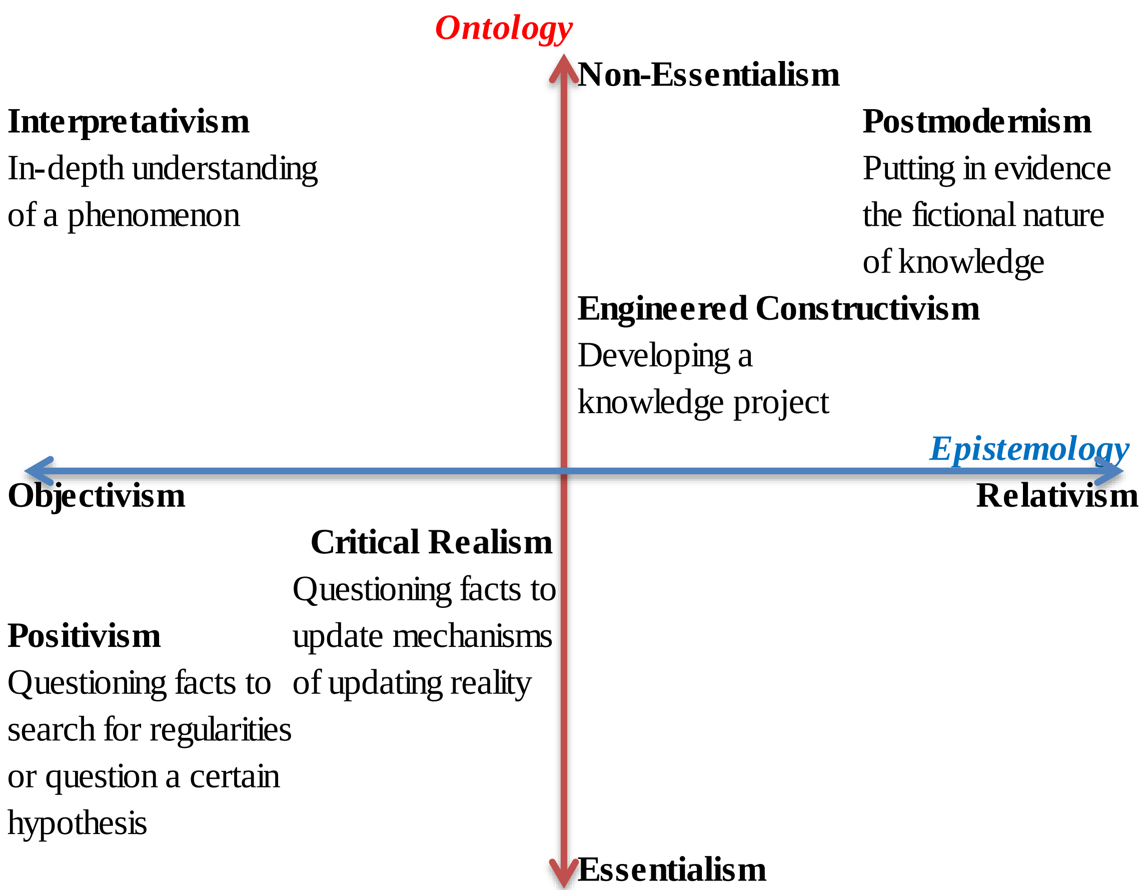
			feminist theories, race-specific theories and neo-Marxist theories	theory, postcolonial discourses, feminist theories, critical race-specific theories and neo-Marxist theories
Ontological assumptions	One reality, knowable within probability	Multiple socially constructed realties	Multiple realties shaped by social, political, cultural, economic, race, ethnic, gender and disability values	constructed multiple realities shaped by the set of multiple connections that human beings have with the environment, the cosmos, the living and the non-living
Place of values in the research process	Science is value free, and values have no place except when choosing a topic	Values are an integral part of social life; no group's values are wrong, only different	All science must begin with a value position; some positions are right, some are wrong.	All research must be guided by a relational accountability that promotes respectful representation, reciprocity and rights of the researched
Nature of knowledge	Objective	Subjective; idiographic	Dialectical understanding aimed at critical	Knowledge is relational and is all the indigenous

			praxis	knowledge systems built on relations
What counts as truth	Based on precise observation and measurement that is verifiable	Truth is context dependent	It is informed by a theory that unveils illusions	It is informed by the set of multiple relations that one has with the universe
Methodology	Quantitative; correlational; quasi-experimental; experimental; causal comparative; survey	Qualitative; phenomenology; ethnographic; symbolic interaction; naturalistic	Combination of quantitative and qualitative action research; participatory research	Participatory, liberating, and transformative research approaches and methodologies that draw from indigenous knowledge systems
Techniques of gathering data	Mainly questionnaires, observations, tests and experiments	Mainly interviews, participant observation, pictures, photographs, diaries and documents	A combination of techniques in the other two paradigms	Techniques based on philosophic sagacity, ethno philosophy, language frameworks, indigenous knowledge systems and talk stories and talk circles

The reference to human and social sciences are assembled under the constructivism label. The interpretativism will highlight the intentional nature and end game of the human activity as well as the interactional factor of social practices. These methodologies aim to understand the sense or meaning, and figure out how this sense is constructed within and by interactions, practices and dialogues (Thietart et al. 2014).

Based on the above, this paper will be positioned under the Constructivism/Interpretativism paradigm, as we will be attempting to understand in depth a certain phenomenon. The below chart highlight the epistemological positioning of in-depth study.

Chart 6: Epistemological Positioning



(Source: Thietart et al. 2014)

D.2) Choice of research method: Qualitative research

Quantitative methodology is routinely depicted as an approach to the conduct of social research which applies a natural science, and in particular a positivist, approach to social phenomena. The paraphernalia of positivism are characterized typically in the methodological literature as exhibiting a preoccupation with operational definitions, objectivity, replicability, causality, and the like (Bryman, 1984). Within this process, the social survey is the preferred instrument of research, mainly through questionnaires, and objectivity is ensured through the distance between observers and observed.

Bryman (1984) described the Qualitative methodology as a commitment to seeing the social world from the point of view of the actor. There is a simultaneous expression of preference for a contextual understanding so that behavior is to be understood in the context of meaning systems employed by a particular group or society. He considered qualitative research to be much more fluid and flexible than quantitative research as it helps discover new or unanticipated findings. Unstructured interviewing and life histories are considered as appropriate methods in this type of research, but most importantly participants' observations, which is a broad term that covers general interviewing, usually unstructured type, the examination of documents, and interviewing of key people, all leading to getting close to the participants and seeing the world from their perspective. That is why, Bryman (1984) considered that qualitative researchers produce data which is called rich, by which is meant data with a great deal of depth.

Since we are trying to reach an in-depth understanding and discover a more subjective reality, this paper will adopt a qualitative research approach in order to better understand the subject in question.

D.3) Choice of Single case study

Ejimabo (2015) considered that although there are many forms of qualitative methods or approaches, the most common types used by most doctoral students and other qualitative researchers include: (1) Grounded theory, (2) Case study theory, (3) Historical research theory, (4) Ethnographic theory, (5) Narrative research theory, (6) Participatory action research, and (7) Phenomenology theory. The below table summarizes the seven methods as described by the author:

Table 7: Research Methods

Grounded theory	This method studies the interactions as they occur naturally and used to generate valid and general explanation that clarifies a process and interaction among people, as well as gaining a better understanding of what is being studied. It is associated with identifying the key variable which explains what is occurring and goes on to develop an emerging theory in the study.
Case study theory	It is a theory that is used to gain an in-depth understanding of the situation and meaning for those involved. The interest is in process rather than outcomes, in context rather than a specific variable, in discovery rather than confirmation. Insights gleaned from case studies can directly influence policy, practice, and future research. It is associated with the telling of a real or life stories.
Historical research theory	This theory is associated with the information of the past events. It seeks to learn and study how the past events are related to or have influenced the present both in values, interest, and meaning while identifying the topic of significant interest to the researcher in relation to the present and future.
Ethnographic theory	It a research method located in the practice of both sociologists and anthropologists, which should be regarded as the product of a cocktail of methodologies that share the assumption that personal engagement with the subject is the key to understanding a particular culture or social setting. Participant observation is the most common component of this cocktail, but interviews, conversational and discourse analysis, documentary analysis, film and photography, life histories all have their place in the ethnographer's repertoire. Description resides at the core of ethnography, and however that description is constructed it is the intense meaning of social life from the everyday perspective of groups members that is sought.
Narrative Research theory	It is a way of understanding experience. It is collaboration between researcher and participants, over time, in a place or series of places

	and in social interaction with milieus, simply stated, narrative inquiry is stories lived and told. This theory is associated with connecting events, actions, and experiences and moves them through time. It is a process of gathering information for the purpose of research through storytelling.
Participatory Action Research	This is a process that simultaneously includes adult education, scientific research and political action, considers critical analysis, diagnosis of situations and practice, as sources of knowledge, while constructing the power of the people. It is associated with people and groups researching their existence, beings, values, culture-natural settings, and experience while examining their goals and objectives as well as their position, interest, needs, motives, vision, values, and shared philosophy in life.
Phenomenology Theory	This theory is centered on essence or structure of a lived and shared experience of the individual or group. It always seeks to answer the critical question - what is it like to have a certain lived or shared experience, and this approach, most often used by psychologists, seeks to explain the structure and essence of the experiences of a group of people. Phenomenology greatly overlap with ethnography, but some phenomenologists assert that they study symbolic meanings as they constitute themselves in human consciousness.

Based on this description, and since we are trying to reach an in-depth understanding of implementing DDMRP-Kanban, and understand the context by examining a real-life story, the case study will be the most suited research tool for our paper.

D.4) Data Gathering & Analysis Method

Based on what we described earlier concerning the constructivist / Interpretativit positioning of this paper and the choice of a qualitative research approach, more particularly a single case study, the most commonly used methods of data gathering and analysis are mainly interviews, participant observation, pictures, photographs, diaries and study of documents.

Since the researcher, is the Supply Chain Manager at Liban Cables SAL, we have access, with management's permission, to all the company's data related to the subject.

So the main source of data will be:

a) The researcher's observation of the implementation and evolution of the DDMRP-Kanban system, and the company's evolution of supply chain model before and after this implementation.
b) In addition to observation, we will be doing an in-depth study of documents, as we will have access to all the company's data in relation to inventory levels, with historical evolution, and main KPI's (key performance indicators) related to inventory level, quality of inventory and operating working capital (OWC).
c) Interviews will be an optional tool that we might use with other stakeholders of the supply chain process in case necessary later in the study, or interviewing informally some stakeholders, as part of the observations, but without documenting the interviews as it will not be the essential part of our data gathering process.

For the analysis part, the observations done will allow us to analyze and describe the implementation and evolution of the mix DDMRP-kanban system, allowing for a better understanding on the process from a descriptive point of view. As for the collected data, it will allow us to compare the evolution of inventory parameters (inventory level in quantity, inventory level in sales coverage) as well as the sales volumes and excess inventory and stock-out items, from month to month and year to year, providing a concrete demonstration of the results of the implementation of DDMRP-Kanban.

This process will be used to compare between DDMRP and Kanban, as well as comparing the mix system of DDMRP-Kanban with the forecast supply chain model.

E – Case Study: Liban Cables SAL

Running a company in Lebanon could be a risky business, and it has been since many years. From 1975 until today, the country is considered at high risk. Many Lebanese citizens chose to leave the country permanently, or temporary until the situation changes. The same applies to businesses; over the years several local and multinational companies opened and soon after closed in Lebanon or relocated to other countries, and the number of failures has been much more important than the success stories.

But at the same time, many firms managed to succeed through all the wars and instability, and harsh conditions to running a business. Several companies experienced even growth during the time of war, by learning to navigate through turbulences and exploit risk and turn it into profit.

This success has been the result of Lebanese creativity, entrepreneurship and even a little chance in many cases, but it was not the result of well-defined scientific approaches well designed for such conditions.

Although the fifteen years old civil war ended in 1990, the political, military and economic situation is far from being stable. After the war, individual weapons were kept in most of the Lebanese houses, and even medium sized weapons remained under the control of many political parties who participated in the civil war. Consequently, today, any political conflict could turn into an armed confrontation in the streets between unorganized armed unofficial militias. That is why, when the political situation is tense, household and overall demand and spending gets down, tourism gets seriously affected and many businesses face tremendous problems just to keep going. On top of that, the country is still officially in a state of war with Israel, with a high possibility of a military confrontation at any time. In 2006, a one month war with Israel caused hundreds of millions of US Dollars in losses to the economy, and many businesses were forced to shut down, especially that Lebanon has only one major commercial seaport and one single airport, which were both blocked by the Israeli army during the period of that war, forcing many industrial companies to reposition their supply chain routes by land through the only country with open borders with Lebanon, Syria. However, with the war in Syria today and the semi-blockade of the traditional land routes, this option is no longer available or extremely risky, which would turn Lebanon into a big prison in case of a new war with Israel.

Industrial companies operating in Lebanon face many challenges that are specific to the Lebanese market:

- Higher Operational cost compared to regional countries, in:
    - Lebanese Wages – higher than surrounding countries, since most industrial companies hire Lebanese workforce, more expensive than the industrial workforce used in surrounding countries
    - Energy Cost – since the public energy production is in constant deficit, the public power grid provides only few constant hours of power per day, which leads the industrial companies to use the public power feed only for marginal use, and generate private power through generators, making the power cost much higher.
- Lack of infrastructure – no railway, limited roads capacity, high traffic, congestions at airport and seaport (since there in only one commercial port and one airport), longer transit time to clear merchandise in both import and export operations.
- Low frequency & higher cost, of sea shipments in and out of the country
- High disruption probability in supply routes, due to limited access points, riots, manifestations and political problems
- High volatility in demand and offer, affected by the overall political situation, country sovereign risk, war risk

In the middle of such environment, Lebanon had many success stories for Lebanese entrepreneurships, in many fields, industry is one of them. Several industrial companies managed to navigate through all the turmoil and managed to grow and excel in a troubled environment.

Liban Cables SAL is one of those companies that managed to grow thanks to the hard work and ambitions of its management, and dedication of its employees, creating a well-known and respected brand name both in Lebanon and surrounding countries.

E.1) Brief description of the company

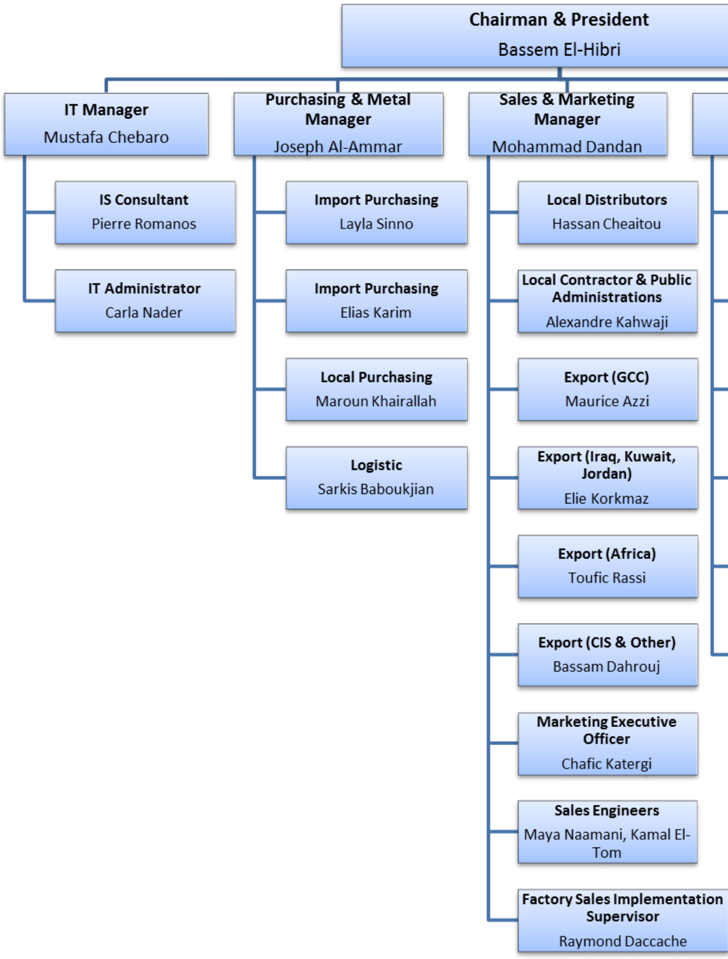
Liban Cables SAL is a leading Lebanese company for the manufacturing of electrical and telecom cables (with 85% market share), part of the leading international group Nexans.

The company was established in 1967, in a partnership between a French Company, an American company, and few Lebanese investors. At a later stage, the American company sold its shares during the civil war, and in 2004 the French company bought most of the shares to increase its ownership of Liban Cables to 95%.
The French company was called Cable de Lyon, and then the company’s structure changed to become Alcatel Cable, and finally became Nexans.
In 2004, at the time of the takeover, Nexans was the worldwide leader in cable manufacturing, with an industrial presence in around 30 countries around the world.
In 2016, Liban Cables had a headcount of around 525 employees, and over the past few years had 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 found locally, that is why all raw materials are imported from all around the world. On top of that, 15% to 25% 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.

Before the creation of a supply chain department, the company’s structure was divided into four main departments, Sales, Purchasing, Factory, Finance, in addition to one support department of IT.

Chart 7: Liban Cables SAL Organization Chart 2011



*(Liban Cables SAL Organization Chart **2011**)*

E.2) Supply Chain model used before changing

The supply chain cycle was implemented in an informal way between the various departments. The Sales department would receive clients' orders, after coordinating with the technical department for the construction of the cables, and transfer those orders to the Planning department to prepare delivery delays and production schedules. Based on the cables needed, the planning department would send production orders to the factory, and would send raw materials purchase requests for the purchasing department, based on the cables constructions.

The company kept a certain minimum level of raw materials in stock, since all the materials needed for the production are imported from many countries around the world, almost nothing is produced locally, and the average lead time to import material is around two months from the date of placing orders. Consequently, when a certain type of material is needed for a cable, some or all the needed quantity could be in stock, and the planning department would order a replenishment, or bigger quantities in case of bigger orders.

Since Liban Cables held most the Lebanese market for cables, a big part of the production planning was done following forecasts, in other words, the cables that were sold repeatedly were produced to a certain stock level, even if there was no client order. The cables that were produced to forecast represented over 60% of the company's total sales, and the remaining cables were special cables that were produced only following a confirmed client demand.

Consequently, at the end of each month, the sales department would send to the planning department a production request, which contains a certain number of cables to be produced for clients' orders, and a certain number of cables to be produced to forecast, with the goal to have a certain finished goods stock level. This production order was repeated at the end of each month, with some modification during the month in case of reception of sudden client requests that could be produced during the same month, but in general the production department would have a monthly visibility.

Liban Cables does not have a distribution channel in the local market. Produced cables are kept in stock for local clients to pick them up. All local sales are done on ex-works basis. For export orders, some of them are also sold on ex-works basis, some on FOB, and some on CIF basis (Incoterm 2010). But what helped is the limited numbers of clients, since locally the company would sell directly only for certain assigned distributors and local utilities, and the export clients were also less than the local clients.

This kind of business cycle led to having a high level of inventories, both in raw materials and finished good, with a high sensitivity to wrong forecasts. Since more than 60% of the production was done based on forecast, inaccurate forecasts, since all forecast are inaccurate, led of having high levels of stock in certain items of raw materials and finished goods, and at the same time shortages in other items.

E.2.a) Inventory situation (reference Nexans 2014 Internal Audit)

In 2014, following the sharp increase in total inventories, and Operating Working Capital (OWC) in Liban Cables, the company received an internal audit team from Nexans Headquarters to investigate the reason of such inventory increase and the best ways to reduce it.

We will discuss information retrieved from 5 main slides from the Confidential Internal Audit Report that concerns this study.

The first slide (Annex Slide 1) shows a spike in the OWC from 24% to 40% in one year. Although the 24% was considerably low, below average, but still the 40% was also a historical high. The inventory turn in weeks of sales also increased from 13 to 21 weeks, which means that Liban Cables had an inventory level that could sustain 21 weeks of sales (over 5 months) without production.
This result shows that the inventory management was not very well controlled under the forecast driven replenishment system, allowing the inventory levels to increase to very high levels.

In the second slide (Annex Slide 2), Liban Cables' Management listed the key reason for the spike in inventories, mainly indicating to:

- Increase in Production, of 20,500 tons compared to a budget of 15,400 tons only, which increased all types of inventories: Raw Material (RM), Finished Goods (FG), and Work in Progress (WIP)
- Increase of the receivable level, or the days of sales outstanding (DSO), due to the change of the structure of a market segment from working directly with the local electricity utility to four private companies instead.
- Dedicating a certain level of inventories for key clients (DSP), <u>without visibility of the time of delivery (no forecast).</u>
- Sales of first three months of 2014 were <u>below forecast</u> (showing the low accuracy rate of sales forecast and impact on inventories) – this also contradicts with the fact of increasing production, versus a decrease in sales below forecast.

The given justifications, although understandable, shows the company's reliance on sales forecasts. However, all forecasts are eventually wrong, or in other word had a certain level of inaccuracy, and in case the level of inaccuracy is high, the impact on inventories and Operating Working Capital would be very detrimental to a company's financial position.

The third slide (Annex Slide 3) speaks of how the limited visibility of sales forecast (which is highly inaccurate), impact the inventory levels of RM, with only one month forecast of sales versus two months needed to source any type of raw material. In addition, this creates unnecessary levels or types of raw materials, shown in the age of some types of raw materials over 4 months in stock.

The slide mentions the creation S&OP process; however, this process was newly defined in 2014 after the creation of the supply chain department, as part of the new supply chain tools, which will be detailed in later pages.

The report mentions also of the MTS products, which refers to the Make to Stock products, which is also a segregation done after the creation of the supply chain department, as part of the new supply chain management process, which will be explained in later pages.

The fourth slide (Annex Slide 4), as well as the previous one, mentions the ABC matrix of RM and FG, which is also a tool created by the new supply chain management tools in 2014, to be detailed in later pages.

This slide indicates the age of the finished goods items, which highlight the impact of inaccurate forecasts. MTO means Make to Order products. The segregation of the FG items between MTS and MTO is also a process established by the new supply chain department in 2014, to be explained later, but MTO are products that are produced for specific orders and not for stock.

Category	MTO

Stock($) @ std	Year				
	2011	2012	2013	2014	Total
Total	28 868,22	204 747,28	944 370,59	517 831,14	1 695 817,23

This small table mentioned in the slide shows the value of the MTO products which were produced in 2011, 2012, 2013 and 2014. Having in stock MTO items older than one year could indicate clients' orders that were produced but not delivered, either due to cancellation of the order by the client, or producing the items based on expected order which was never confirmed later, or for orders that are confirmed but delayed or postponed by the client.

The fifth slide (Annex Slide 5) mentions how the minimum order quantity is done at sub-family level, and not at SKU level (Stock keeping unit), where the demand can vary in a same sub-family depending on the color, which may lead to the production of excess stock in some colors and not enough stock in order colors, all in the same sub-family.

The main conclusions of this slide were later adopted and developed by the new supply chain tools.

The first recommendation considered that the replenishment process must take into consideration the real demand in order to adapt purchasing and production planning accordingly, instead of relying on demand based on history and forecast. This will be the main breakthrough done by the supply chain department by moving from a forecast driven production program to a demand driven production program.

The second recommendation was to define the MOQ at the SKU level, which was also adopted later by the new supply chain tools as a foundation of the demand driven management tools.

As a conclusion, the production / inventory management process of Liban Cables was done based on experience and key people's input and decisions, which was somewhat acceptable since it was based on the long years of experience and successes and failures of each individual, but it was not done based on systematic / scientific approach aiming to reduce the impact of instinct and gut feeling and personal reaction to market volatility, creating bullwhip effect, and bad quality of finished goods inventory. The result was high unsold inventories of certain items (high OWC) and shortages of other items (low customer satisfaction). Thus, the need was clear for a new approach to inventory and production management.

Based on the existent business model, the company was lacking a clear process of handling the full cycle from the time of receiving a customer request to the time of delivering the final product. The success was achieved based on the personal experience and vigilance of key managers and employees, since most employees had an average experience of 30 years with the company. Liban Cables had been the leader and almost a monopole of the Lebanese market since its creation in 1967, and that is why, the company had a high acceptable margin of error in its business model regarding customer and market satisfaction, which clouded many inefficiencies in the full supply chain cycle.

But that type of business model had exposed the company to severe bullwhip effects and reduced its business model's efficiency regarding the optimization of its operating working capital (OWC), along with confusing segregation of duties and incomplete synergies between various functions, and lack of transparency on inventory level management and health.

That is why, the company's management decided to create the Supply Chain function, to create clear separation between some functions, for better management, and increasing visibility and transparency of inventory management. The eventual goal was to protect the company as much as possible from the bullwhip effect, to increase customer satisfaction by reducing as much as possible the stock-out items, and at the same time reduce the inventories from high unsold inventory, which will optimize the overall OWC.

But at that time, the whole concept of supply chain was not clear for all stakeholders, nor which model to implement to best reach the aspired goals. Nevertheless, the process of creation of a Supply Chain Department started anyway.

E.3) Structural changes – Creation of a Supply Chain Department

At the beginning of 2013, the term Supply Chain was first introduced to the company. The Purchasing Manager was named then Supply Chain, Purchasing & Metal Manager, adding to his responsibility the raw materials warehouse. Before that, the raw materials warehouse was under the control of the Plant Manager.

The purpose of this change was to create a clear separation between the production role of the Plant Manager and the process of inventory management and control, as well as raw material planning for the production needs.

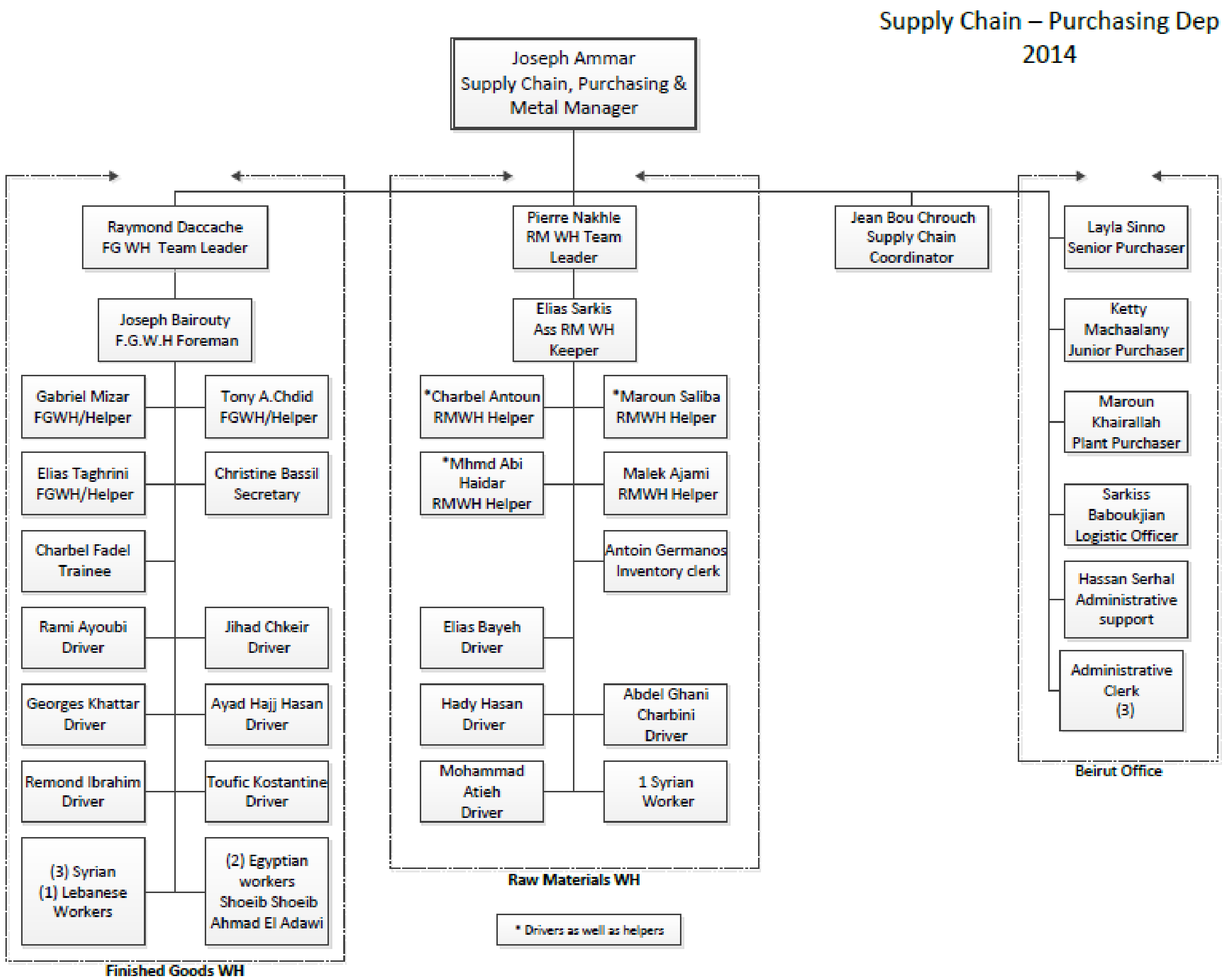
One year after that, once the change was proven to be useful to the overall efficiency of the company, at the beginning of 2014, the responsibility of the Finished Goods warehouse was also transferred from under the Plant Manager to the Supply Chain Manager, with the same goal of better segregation of duties and control and better management.

In addition, one employee was then added to the supply chain team in 2014 as coordinator and later in 2015 another was added as well.

Consequently, and since the logistic functions at the company were already under the purchasing Manager long before 2013, in 2014 the supply chain department was controlling the whole logistic functions of the company, along with the purchasing side, and the raw materials and finished goods management side.

Below we will show the new organization chart of the supply chain department in 2014.

Chart 8: Liban Cables Supply Chain Department's Organization Chart 2014



(Liban Cables Supply Chain Department's Organization Chart 2014)

E.3.a) Data Collection / Cleaning

After controlling both warehouses, it was the time to start creating reports and tools that helps better manage the operations and have better visibility of the flow of materials.

That turned out to be a very challenging task, since the database of the raw materials and finished goods warehouse was all done by hand, on excel files, not in the company ERP system, which is Navision. That is why; there was no easy historic feedback, but most importantly no reliable information to use.

The most basic data extraction, which shows the inventory quantities and values as well as the raw materials consumption and finished goods sales, was not available through Navision. Consequently, more than six months of work was needed between the supply chain department and the company's IT department to create a clean and useful database.

The Supply Chain department defined the required reports in terms of form and content, and the IT department created it. However, upon the first data extraction, the whole results turned out to be completely wrong, which was not evident to the IT department. So, it was the role of the supply chain people to check the reports and point out the errors and give the relative feedback to the IT in order to check what were the reasons of wrong data, and then update the programing of the required reports accordingly.

Since this task was time consuming for both concerned parties, and the results were wrong after many attempts, it took a little more than six months to extract correct information from Navision about the most basic data, which were the inventory movement and levels of raw materials and finished goods at the end of each month.

E.3.b) Unification of language between departments

The next challenge before creating management tools was alligning all concerned departments to speak the same language, regarding the finished goods classification and management style.

Liban Cables was producing a very wide diversity of cables, and the management of the finished goods inventory level was indirectly controlled by the sales department, since they were launching the production process. However, the process was done based on historical experience and market forecasts, while keeping in mind that they needed to provide a certain minimum order quantity for the Production Planning department in order to have sufficient production load for the machines and the labor force available. So, the production orders were a translation of inaccurate sales forecasting, without an actual need, and sometimes just a process of satisfying production gaps, without a real need for the requested cables. That is why, there were no clear segregation between the cables that were supposed to be produced for stock and the cables that will be produced for specific orders.

To set up new management tools, a clear segregation for finished goods items was mandatory, to separate which products would be labeled Make to Stock (MTS) items, and which products would be labeled Make to Order (MTO) items.

MTS items are the products that were sold and produced in a repetitive mode. The production lead time would be short or easy, and the sales of these products would be repetitive either on a daily or monthly frequency. To better serve the market, and since Liban Cables' clients were historically accustomed to finding certain products available in stock whenever requested, a certain level of MTS items was needed to be always available in stock to satisfy demand and to be used as a buffer whenever the production lines would be producing special cables and unable to produce MTS items.

MTO items are the products that were rarely sold each year, or not sold at all. These items were produced upon customer's request only, but producing it would occupy part of the production capacity away from MTS items. Thus, it is important to identify which items to be labeled MTO, since it would mean that the company would have no inventory levels of these items, and the clients would have to wait a certain lead time before receiving the orders. The labeling would be easy for items that were designed on client demand (Engineer to Order – ETO) or sold once each two or three years, or even sold once or twice per year, but the difficult segregation would be for items historically sold once per month or once each two month, with long production lead time.

To do so, a list of all sold items was prepared, showing the inventory level per item and yearly sales volumes, and repetitive meetings were performed between the supply chain department and the Sales Manager as well as the Planning Manager, in order to better define each item, based on the sales vision and future perspectives from one side, and the production lead time from the other side, especially that in many cases, there were conflicting point of views between the sales department and the planning department on which items should be considered MTS and which

MTO, and that is why several meetings were needed to bring all parties into one vision and position for the list of the products.

After those meetings, a clear segregation was done for all the company's products, labeling them either MTS or MTO.

With this segregation done, as well as the creation of the clean database in ERP system, the Supply Chain department became ready to start creating reports and management tools automatically from the ERP system, and launch the DDMRP tools.

E.3.c) Creation of ABC Matrix

ABC analysis is an analysis of a group of items that have different levels of significance and should be handled or controlled differently. It is a form of Pareto analysis in which the items (such as activities, customers, documents, inventory items, and sales territories) are grouped into three categories (A, B, and C) in order of their estimated importance. "A" items are very important, "B" items are important, "C" items are marginally important.
Inventory classification using ABC analysis is one of the most widely employed techniques in organizations.

Zimmerman (1995) noted that most firms use the annual dollar usage ranking of inventory items in its application of the ABC principle, consequently, the A items are the ones that represent 70% of the total values, the B items represent 20% of the total value, and the C items represent the remaining 10%. This is commonly known as the 80-20 rule, although these percentages may vary from firm to firm.

Flores and Whybark (1987) recommended consideration of one or more other criteria, such as lead time, criticality, commonality, obsolescence, substitutability or reparability. The firm can create super categories, subcategories or lower categories based on its established inventory management policies, systems, and control methods. In some cases, categories such as AB, AC, BA, BC, CA and CB can and possibly should be created.

In Liban Cables, the ABC classification did not exist before the creation of the supply chain department.

The ABC matrix is not directly related to the demand-driven process, however it is an important support tool for the monitoring of the inventory evolution in both raw materials and finished goods. That is why, it was created before putting in place the demand driven management tools, in order have a clear visual picture of the inventories, and to start monitoring the evolution.

For the implementation, a mix classification system was used between value of the inventory and frequency of entries from one side and between consumption-sales and frequency of use. This led to an ABC classification per inventory, and an ABC classification per consumption, which created a mix classification per item: AA, AB, AC, BA, BB, BC, CA, CB, CC. This classification was then simplified by regrouping in the following categories:

- A: regrouped the categories of AA, AB, and BA
- B: regrouped the categories of CA, BB, and AC
- C: regrouped the categories of BC, CB, and CC

The result showed what was the value (and percentage) and segregation of existing inventories and how much coverage (inventory turn) these values represented in weeks of sales of finished goods or in weeks of consumption of raw materials.

The first ABC analysis was done in January 2014, and it became a standard report followed up on monthly basis since then.

The below table shows an example of a raw materials ABC classification, where items A represent a value of USD 1,189,933 – out of which USD 602,403 cover over 8 weeks of consumption, and USD 298,147 cover less than two weeks of consumption.

Table 8: Liban Cables Raw Materials ABC Matrix – Stock matrix, January 2014

ABC Matrix ABCx (USD)			Total inventory =		7,709,589	$
Values (USD)	**< to 2 weeks**	**from 2 to 4 weeks**	**from 4 to 6 weeks**	**from 6 to 8 weeks**	**> to 8 weeks**	**TOTAL**
A	298,147	96,461	96,461	96,461	602,403	**1,189,933**
B	108,555	104,476	101,453	101,140	1,112,086	**1,527,710**
C	95,294	93,572	91,024	86,733	2,629,609	**2,996,232**
MTS	**501,995**	**294,509**	**288,938**	**284,334**	**4,344,098**	**5,713,875**
ROD CU	845,806	73,829	-	-	-	**919,635**
ROD ALU	194,327	194,327	194,327	34,243	444,069	**1,061,292**
O	-	-	-	-	3,856	**3,856**
TOTAL	**1,542,128**	**562,665**	**483,265**	**318,577**	**4,792,023**	**7,698,658**

(Source: Liban Cables Raw Materials ABC Matrix – Stock matrix, January 2014)

The second below table shows the same analysis of the same month, but instead of showing the inventory in ABC segregation, it shows the big families of products for better in-depth analysis.

Table 9: Liban Cables Raw Materials ABC Matrix – Family matrix, January 2014

ABC Matrix ABCx (USD)			Total inventory =	7,709,589	$	
Values (USD)	**< to 2 weeks**	**from 2 to 4 weeks**	**from 4 to 6 weeks**	**from 6 to 8 weeks**	**> to 8 weeks**	**TOTAL**
Copper	860,218	87,414	13,585	13,585	95,233	**1,070,035**
Aluminium	194,327	194,327	194,327	34,243	444,510	**1,061,733**
PVC	169,741	13,456	13,456	13,456	372,603	**582,712**
Al Tape	6,081	6,081	6,081	6,081	358,996	**383,318**
Cu Tape	24,089	24,089	24,089	24,089	122,584	**218,941**
PE	88,724	88,678	88,121	87,320	657,161	**1,010,004**
MB	9,828	9,828	9,828	9,828	389,998	**429,308**
XLPE	54,143	7,291	7,291	3,800	239,548	**312,072**
Steel	57,180	56,647	56,152	56,152	772,532	**998,663**
Others	5,155	5,155	5,155	5,155	334,602	**355,220**
Other Tape	14,169	11,663	8,453	8,140	369,731	**412,156**
Lead	-	-	-	-	223,585	**223,585**
LSF	31,810	31,810	31,810	31,810	254,441	**381,682**
Yarn	26,664	26,227	24,920	24,920	152,643	**255,374**
Obsolete	-	-	-	-	3,856	**3,856**
TOTAL	**1,542,128**	**562,665**	**483,265**	**318,577**	**4,792,023**	**7,698,658**

(Source: Liban Cables Raw Materials ABC Matrix – Family matrix, January 2014)

The third below table shows the ABC segregation of the finished goods items, showing for example an inventory of USD 522,789 of the B items, out of which USD 105,256 represent less than two weeks of sales.

Table 10: Liban Cables Finished Goods ABC Matrix – Stock matrix, January 2014

ABC Matrix ABCx (USD)			Total inventory =		8,127,967	$
Values (USD)	**< to 2 weeks**	**from 2 to 4 weeks**	**from 4 to 8 weeks**	**from 8 to 16 weeks**	**> to 16 weeks**	**TOTAL**
A	869,587	803,324	1,267,516	861,748	323,981	**4,126,156**
B	105,256	101,145	110,354	121,216	84,818	**522,789**
C	160,479	152,195	251,645	298,037	1,097,079	**1,959,435**
MTS	**1,135,321**	**1,056,664**	**1,629,516**	**1,281,000**	**1,505,878**	**6,608,379**
M	57,778	53,413	95,105	131,324	780,191	**1,117,810**
DSP	77,436	77,056	104,720	100,503	42,063	**401,778**
O	-	-	-	-	-	**-**
TOTAL	**1,270,535**	**1,187,132**	**1,829,341**	**1,512,827**	**2,328,131**	**8,127,967**

(Source: Liban Cables Finished Goods ABC Matrix – Stock matrix, January 2014)

And the final below table shows the same analysis of the finished goods, but by family of products for a more detailed analysis, showing for example that for the EC (Energy Copper) family, out of the total inventory, USD 278,417 represented less than 2 weeks of sales and a big amount of USD 838,251 represented over 16 weeks of sales (which means a high inventory).

Table 11: Liban Cables Finished Goods ABC Matrix – Family matrix, January 2014

ABC Matrix ABCx (USD)			Total inventory =	8,127,967	$	
Values (USD)	**< to 2 weeks**	**from 2 to 4 weeks**	**from 4 to 8 weeks**	**from 8 to 16 weeks**	**> to 16 weeks**	**TOTAL**
EA	104,756	97,997	96,156	74,919	343,495	**717,322**
EC	278,417	268,017	460,194	449,197	838,251	**2,294,075**
D	329,909	329,909	497,138	400,321	141,254	**1,698,530**
F	324,646	264,848	370,416	308,119	148,110	**1,416,139**
MA	118,065	118,065	236,130	28,533	58,193	**558,987**
MC	32,441	31,333	56,679	103,783	237,414	**461,650**
S	8,583	7,279	13,099	22,976	111,726	**163,664**
T	30,527	28,154	30,473	26,775	69,711	**185,640**
HA	-	-	-	-	-	**-**
HC	-	-	-	-	117,669	**117,669**
C	10,837	9,540	6,944	2,506	26,467	**56,294**
A	32,355	31,990	62,113	95,697	235,842	**457,997**
TOTAL	**1,270,535**	**1,187,132**	**1,829,341**	**1,512,827**	**2,328,131**	**8,127,967**

(Source: Liban Cables Finished Goods ABC Matrix – Family matrix, January 2014)

As a conclusion, the creation of the ABC analysis for raw materials and finished goods was a cornerstone in the creation later of the demand driven management tools, since it showed a clear "visual" picture of the situation of the company's inventory, which is a very important tool of management and transparency that never existed before at the company. That is why, ever since the launch of the tool in January 2014, this analysis became part of the monthly management practices of the supply chain department.

E.3.d) Creation Sales & Operation Planning (S&OP) file

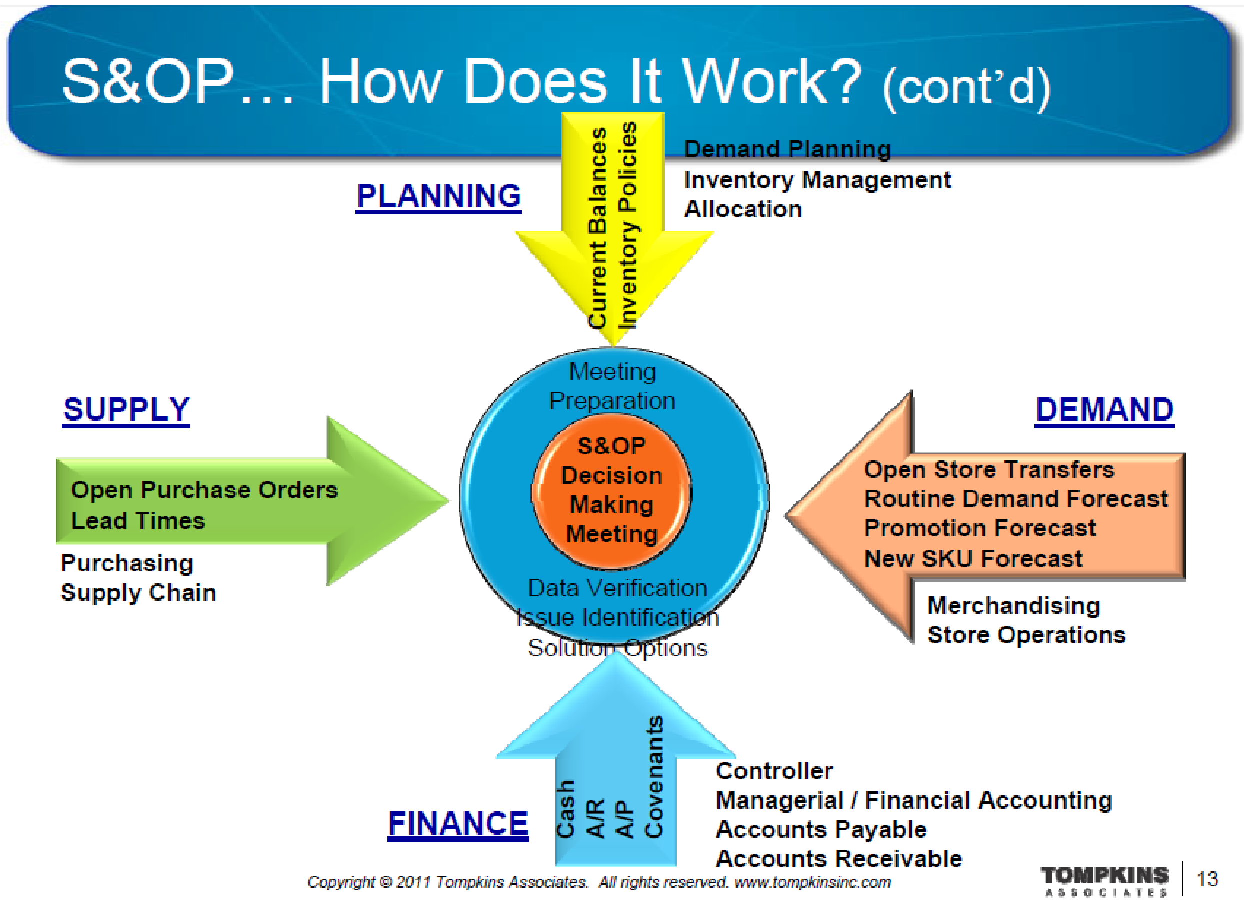
Sales and operations planning (S&OP) is an integrated business management process through which the executive/leadership team continually achieves focus, alignment and synchronization among all functions of the organization. The S&OP includes an updated forecast that leads to a sales plan, production plan, inventory plan, customer lead time (backlog) plan, new product development plan, strategic initiative plan and resulting financial plan. Plan frequency and planning horizon depend on the specifics of the industry. Short product life cycles and high demand volatility require a tighter S&OP than steadily consumed products. Done well, the S&OP process also enables effective supply chain management.

A properly implemented S&OP process, routinely reviews customer demand and supply resources and "re-plans" quantitatively across an agreed rolling horizon. The re-planning process focuses on changes from the previously agreed sales and operations plan, while it helps the management team to understand how the company achieved its current level of performance, its primary focus is on future actions and anticipated results.

In their book, Operations Management – Processes and Supply Chains (2013), Krajewski, Ritzman and Malhotra, defined Sales and operations planning is a decision-making process, involving both planners and management. It is dynamic and continuing, as aspects of the plan are updated periodically when new information becomes available and new opportunities emerge. It is a cross-functional process that seeks a set of plans that all of a firm's functions can support. For each product family, decisions are made based on cost trade-offs, recent history, recommendations by planners and middle management, and the executive team's judgment.

In a 2011 document, Tomkins Associates defined Sales & Operations Planning as a process for bringing the management of supply chains, ensuring coordination between demand and supply, as close to real-time as needed, and in the process, ensuring execution in alignment with the business strategy. They illustrated it in the below chart.

Chart 9: Sales & Operational Planning



(Source: "The Latest in Sales & Operations Planning: Demand-Driven Processes", Tompkins Associates, Nov 2011)

In Liban Cables, a habit of partial Sales & Operations Planning (S&OP) meeting existed for many years, and consisted of a monthly meeting between the Production Planning team, the Sales Manager and the General Manager to discuss the production program of the month. The visibility of this meeting was only the one month, with the absence of the supply side and the finance side.

Part of the change management process, the Liban Cables' supply chain team, , created a S&OP file and started actively participating at the regular monthly meeting.

Instead of only the one month view, the new S&OP file complied a much longer vision, by showing few months of actual historical data, the current month, and the upcoming months' expectations, showing a long vision of several months at the same time.

The below image show a typical vision of the S&OP file as created. It showed, “in white” the actual situation for three month back, then “in yellow” the backlog of the actual month (April 2014) and rolling forecast of two more months, and “in green”, a tentative forecast for the following months.

Table 12: Liban Cables S&OP file, April 2014

Domestic	Jan-14	Feb-14	Mar-14	Apr-14	May-14	Jun-14	Jul-14	Aug-14	Sep-14	Oct-14	Nov-14	Dec-14
Sales Forecast				220	230	250	240	240	235	230	220	200
Actual Sales	235	200	238									
Production Plan				220	230	250	240	240	235	230	220	200
Actual Production	270	176	270									
Stock Forecast				287	287	287	287	287	287	287	287	287
Actual Stock	544	520	287									

(Source: Liban Cables S&OP file, April 2014)

This file shows the situation of the “Domestic” family of finished products. The historical data would be gathered by the supply chain team from the actual figures of the company, then the three yellow months would be communicated by the sales team, and the later green months would represent a statistical forecast by the supply chain team, just for the purpose of creating a certain possible scenario. In this example:

- Actual Sales of March 2014 were 238 tons
- Actual production of March 2014 was 270 tons
- Inventory of Domestic Family products at end March 2014 was 287 tons
- Expected Sales of April 2014 would be 220 tons
- Production Plan of April 2014 would be 220 tons
- Expected Inventory of Domestic Family products at end April 2014 would be 287 tons.
- The inventory two months back was 544 tons, compared to 287 in March 2014.
- The production in February 2014 was 94 tons less than the production of March 2014.

This S&OP file does not represent a demand-driven process, but it represents an important monitoring tool for better visibility and follow up, since during the chaos of monthly meetings and the pressure of the sales and problems of the production, all stakeholders would be focusing on the month at hand, not paying attention to where the company is coming from in the past few months, and what certain decisions would impact on the months to come.

All this preparatory work from creating a clean database, to unifying language and vocabulary between departments, to monitoring inventories through the ABC matrix and S&OP, was necessary before embarking on setting up DDMRP and Kanban tools.

E.4) 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.

E.4.a) 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 a. (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.

E.4.a.1) Strategic Inventory Positioning

While the original definition of strategic inventory positioning is knowing what to keep as buffer, and at which stage of the full production cycle, from supplier's orders, to raw materials, to semi-finished and finished products, Liban Cables' business model did not require such positioning. The cables produced at the company needs mostly the same products, which are the inside conductors of the cables, either copper or aluminum, and the cover of the cables which is mostly few types of PVC or Polyethylene materials. To better illustrate, two or three types of the same raw materials, and the same semi-finished products related to them, could be used to produce several hundreds if not a thousand different products.

That is why, Liban Cables historically kept always a certain minimum buffer of incoming orders from suppliers, a minimum level of key raw materials in their warehouses, as well as a constant minimum level of semi-finished products inside the factory and around the production lines, that can be used to produce most of it cables, or most its high runners' cables.

Those kinds of buffers were built taking into consideration the internal and external factors surrounding it, like the supplier lead time, internal lead times to replenishment, and production complexity, which will ensure an acceptable level of uninterrupted chain of supply.

Consequently, the company's management found that the strategic inventory positioning was only needed at the stage of finished products, since buffers are kept at all previous steps of production in acceptable volumes, and the challenge was to define which finished products should have a constant buffer in the finished products warehouse, and which products should only be produced on demand.

The addition to the strategic inventory positioning step was defining which finished products 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 are 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 was kept 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 it will not change later.

The cables classified as MTO cannot be listed, since the portfolio of products 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, divided as follows:

Table 13: Liban Cables Make-To-Stock Items

Cable Family	Total number of items	Code name	Number of items (sizes) per Code	Number of Colors used
Energy Aluminum Cables	8	EAXT	8	1 (N)
Energy Copper Cables	87	ENYY	21	1 (N)
		ENYA	16	8 *
		EX	13	1 (N)
		ENYM	37	1 (N)
Domestic Cables	92	DNYA 1	8	8
		DNYA 3/0.029	8	8
		DNYA 1.5/3	8	8
		DNYA 2	8	8
		DNYA 2.5	8	8
		DNYA 3	8	8
		DNYA 4	8	8
		DNYA 6	8	8
		DNYA 10	8	8
		DNYA 16	8	8
		DNYA 25	7	7
		DNYA 25/T	1	1 (VJ)
		DNYA 6/T	1	1 (VJ)
		DNYA 16/T	1	1 (VJ)

		DNYA 10/T	1	1 (VJ)
		DNYA 4/T	1	1 (VJ)
Flexible Cables	148	FNYAF 0.75	8	8
		FNYAF 1	8	8
		FNYAF 1.5	8	8
		FNYAF 2	8	8
		FNYAF 2.5	8	8
		FNYAF 3	8	8
		FNYAF 4	8	8
		FNYAF 6	8	8
		FNYAF 10	8	8
		FNYAF 25	8	8
		FNYAF 16	8	8
		FNYAF 35	8	8
		FNYAF 50	1	1 (N)
		FNYAF 70	1	1 (N)
		FNYAF 95	1	1 (N)
		FNYAF 120	1	1 (N)
		FNYAF 150	1	1 (N)
		FNYAF 185	1	1 (N)
		FNYAF 240	1	1 (N)
		FNYLHY	9	1 (B)
		FNYMHY	15	1 (B)
		FNYMHY	11	1 (N)
		FNYZ	10	2 (B + RN)
Telecom Cables	34	TDWIRE 2*0.8	3	1 (N)
		TLIBBEL 2*0.5	5	5
		TLIBTEL	26	1 (G)

* 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.

The parameter of how much inventory should be kept as buffer 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 crosses 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.

E.4.a.2) 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 if no additional quantities were 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. The value in meters per week are different between products, depending the of sales volumes per product, 1 week could represent 1000 meters for item A, or 5000 meters for item B.

As an example, if item A has a manufacturing time (MT) of 1 week, then its production lead time would set at 2 weeks, and if its average weekly sale is 1000 meters, then DDMRP parameters would become as follow:

Table 14: DDMRP zones conversion to meters of cables

Item A (LT = 2 weeks)	Number of weeks	Conversion into meters of cables
Red Zone	2+1 = 3	3*1000 = 3000
Yellow Zone	2	2*1000 = 2000
Green Zone	2	2*1000 = 2000
Replenishment threshold	3+2 = 5	5*1000 = 5000

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 as per the below outlook:

Table 15: DDMRP zones conversion to number of weeks of sales

MT (weeks)	**LT (weeks)**	**Red zone (weeks)**	**Yellow zone (weeks)**	**Green zone (weeks)**	**Re-Order Point (weeks)**	**Max level (weeks)**
1	2	3	2	2	**5**	7
1	3	4	3	3	**7**	10
1.5	3	4	3	3	**7**	10
1.5	3.5	4.5	3.5	3.5	**8**	11.5
2	4	5	4	4	**9**	13
1.5	4.5	5.5	4.5	4.5	**10**	14.5
2.5	5	6	5	5	**11**	16
2	6	7	6	6	**13**	19
3	6	7	6	6	**13**	19

The totality of the MTS items was positioned as such:

Table 16: Stock Items DDMRP positioning

Code name	**Number of items (sizes) per Code**	**Safety Stock – Red Zone level in weeks**	**Yellow Zone level in weeks**	**Green Zone level in weeks**	**Top of Yellow – Re-Order Point in weeks**
EAXT	2	4	3	3	**7**
	3	5	4	4	**9**
	3	5.5	4.5	4.5	**10**
ENYY	5	5	4	4	**9**
	16	7	6	6	**13**
ENYA	16	5	4	4	**9**
EX	6	5	4	4	**9**
	7	7	6	6	**13**
ENYM	12	3	2	2	**5**
	16	4	3	3	**7**
	9	5	4	4	**9**
DNYA 1	8	5	4	4	**9**

DNYA 3/0.029	8	3	2	2	**5**
DNYA 1.5/3	8	3	2	2	**5**
DNYA 2	8	3	2	2	**5**
DNYA 2.5	8	4	3	3	**7**
DNYA 3	8	4	3	3	**7**
DNYA 4	8	4	3	3	**7**
DNYA 6	8	3	2	2	**5**
DNYA 10	8	3	2	2	**5**
DNYA 16	8	3	2	2	**5**
DNYA 25	7	3	2	2	**5**
DNYA 25/T	1	3	2	2	**5**
DNYA 6/T	1	3	2	2	**5**
DNYA 16/T	1	3	2	2	**5**
DNYA 10/T	1	3	2	2	**5**
DNYA 4/T	1	4	3	3	**7**
FNYAF 0.75	8	3	2	2	**5**
FNYAF 1	8	3	2	2	**5**
FNYAF 1.5	8	3	2	2	**5**
FNYAF 2	8	3	2	2	**5**
FNYAF 2.5	8	3	2	2	**5**
FNYAF 3	8	3	2	2	**5**
FNYAF 4	8	3	2	2	**5**
FNYAF 6	8	3	2	2	**5**
FNYAF 10	8	3	2	2	**5**
FNYAF 25	8	3	2	2	**5**
FNYAF 16	8	3	2	2	**5**
FNYAF 35	8	4	3	3	**7**
FNYAF 50	1	4	3	3	**7**
FNYAF 70	1	4	3	3	**7**

FNYAF 95	1	4	3	3	**7**
FNYAF 120	1	4	3	3	**7**
FNYAF 150	1	4	3	3	**7**
FNYAF 185	1	4	3	3	**7**
FNYAF 240	1	4	3	3	**7**
FNYLHY	5	5.5	4.5	4.5	**10**
	4	7	6	6	**13**
FNYMHY	4	4	3	3	**7**
	3	4.5	3.5	3.5	**8**
	5	5.5	4.5	4.5	**10**
	3	6	5	5	**11**
FNYMHY	2	4	3	3	**7**
	5	5.5	4.5	4.5	**10**
	4	7	6	6	**13**
FNYZ	10	3	2	2	**5**
TDWIRE 2*0.8	3	3	2	2	**5**
TLIBBEL 2*0.5	5	7	6	6	**13**
TLIBTEL	26	7	6	6	**13**

In summary, the number of items per inventory position would be:

Table 17: Summary of Items per Zone Positioning

Number of Products	Safety Stock – Red Zone level in weeks	Yellow Zone level in weeks	Green Zone level in weeks	Top of Yellow – Re-Order Point in weeks
172	3	2	2	**5**
64	4	3	3	**7**
3	4.5	3.5	3.5	**8**

47	5	4	4	**9**
18	5.5	4.5	4.5	**10**
3	6	5	5	**11**
62	7	6	6	**13**

E.4.a.3) 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 lead 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) was set to be 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 seasonality 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 seasonality, 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.

The following example explains how the adjustment on the average is done:

Table 18: Seasonal Adjustment Example

Seasonality	**Average last 12 months' sales**	**Average last 3 months' sales**	**Adopted value to calculate the Replenishment level**
High demand	4000	3000	4000
Regular demand	4000	3000	3500
Low demand	4000	3000	3000

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 buffer profiles, 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 of sales, or inventory turn. This allows the buffer profiles to follow dynamically the demand changes, as well as seasonality of demand.

E.4.a.4) Demand Driven Planning

The demand driven planning refers to the process of generating supply requirements, and this process ends once the recommendation is made and became a pending order for replenishment.

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.

The process of demand driven planning was customized using 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.

At the company, the excel files used to manage the whole process is called “Norm of Stock” as per the below example format.

Table 19: Liban Cables Norm of Stock December 2016 – Flexible Cables Family

Flexible cables																
Family	Color	Stock (m)	Allocated stock (m)	Average Monthly sales (m)	Month to date actual sales (m)	Coverage (weeks)	Re-Order Point (weeks)	Remaining Planned Production (M)	Projected coverage (weeks)	Week 1 (M)	Week 2 (M)	Week 3 (M)	Week 4 (M)	Week 5 (M)	Projected coverage (weeks) with Rajouts
FNYLHY 2*0.5	B	32,630	0	47,244	33,376	3.0	10.0	70,000	9.4	0	0	0	0	65,000	15.4
FNYLHY 2*1	B	228,226	0	112,875	74,432	8.8	13.0	0	8.8	0	0	105,000	0	0	12.8
FNYLHY 4*0.75	B	11,242	0	3,364	1,280	14.5	10.0	0	14.5	0	0	0	0	0	14.5

(Source: Liban Cables Norm of Stock December 2016 – Flexible Cables Family)

Each column of this file shows different information necessary for the visual management process:

- Family: this column shows the item description and code
- Color: since some same items are different from color to color, this shows different colors per item
- 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: this column 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: this column 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: the columns of weeks 1 to 5, are 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: this final column 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.

The unit of measure (m) used in the file refers to "meters" of cables.

To better explain how the file works, we will detail each of the three cases shown in the picture above:

- FNYLHY 2*0.5:
    - at the time of updating the file, the physical inventory level at the warehouse was 32,630 meters of cables.
    - No reserved stock, meaning that nothing was booked to be delivered.
    - The average monthly sale was 47,244 meters
    - Month to date sale was 33,376 meters.
    - The inventory coverage was only 3 weeks of sales
    - The Re-order level is 10 weeks
    - 70,000 meters of cables were ordered to be produced, but not delivered yet
    - The inventory level and the ordered quantity would together represent 9.4 weeks' inventory coverage
    - During Week 1, 2, 3, 4, nothing was ordered, which means that in the past 4 weeks, the Projected Coverage was still above 10 weeks
    - At week 5, once the inventory coverage slipped below 10 weeks to 9.4, a production order was launched for 65,000 meters.
    - The new production order done at week 5 would increase the final inventory coverage to 15.4 weeks.
    - The quantity ordered would correspond to economical production lets, which is different per product
- FNYLHY 2*1:
    - The same logic applies to this item, however, there was no pending production orders from previous months.
    - The inventory coverage was higher than the Re-Order point for the first two weeks of the month.
    - In week 3, the inventory coverage level decreased below the Re-Order point, which means that either there were no sales during the first two weeks and there was a big withdrawal in week 3, or there were small sales in the first two weeks,

and after the third week the inventory level decreased below the Replenishment threshold.
    - At week 3 a production order was requested for 105,000 meters.
    - During week 4 and 5 no big withdrawals were made.
    - At the end of the month, the expected inventory coverage would be 12.8 weeks.
- FNYLHY 4*0.75:
    - The same logic applies to this item; however, the total sales of the month did not drive the inventory coverage below the Re-order point, that is why no production order was launched during the month, and at the end of the month, the inventory level represented 14.5 weeks of sales.

Based on the results coming from this excel file, the supply chain department prepare 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, ensuring demand driven planning and generation of replenishment requirements.

E.4.a.5) Visible and Collaborative Execution

Demand driven execution is the process of managing and executing pending replenishment orders depending on relative criteria per case.

The process was not however implemented as described by Ptak and Smith (2011), using automatic buffer alerts and synchronization. In Liban Cables, the demand driven collaborative execution was rather achieved through regular weekly meetings between different stakeholders, to discuss the on-hand position of production orders requested.

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 pending replenishment requests not produced yet, the newly 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 exceeds the average monthly sales per MTS items, to avoid any unforeseen surprises that could lead to shortages in certain products. 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.

E.4.b) Added value of the DDMRP system compared to the old

The implementation of the DDMRP management system brought an added value to the global business module and overall business cycle of the company, providing a more dynamic and live inventory management and production control system, directly connected to the actual demand and market trends, with quick reaction time of a week or less compared to a monthly reaction cycle existing historically at the company through the forecast driven production launch model.
But also, like any management model, along with its advantages, it had some disadvantages, as there are no optimal of ideal system that can 100% cover all the parameters and requirements of all stakeholders of the supply chain cycle.

E.4.b.1) Advantages

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, reduce 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.

Segregation of duties:

In the previous forecast based management system for production planning, there was a sole reliance on the sales department to prepare the sales forecast for the next month, and the sales department would coordinate with the planning department to prepare a feasible production plan. Consequently, the sales team, driven by the concern of having no shortages in stocks, but never so concerned by the excess inventories, and the planning team driven by the concern of having all machines running and the labor manning fully utilized (avoid having idle machines or labor), would both have an interest in preparing a production forecast that could ease these mentioned concerns. However, these concerns, despite their legitimacy and positive impact on certain links on the supply chain, had a very negative impact on the inventory levels as well as the quality of the inventories.

Switching to a demand driven production planning through the DDMRP management style removed the power of controlling the production planning from Sales and Planning departments and trusted it to the Supply Chain department, allowing a very efficient segregation of duties between functions, putting aside the bias impact of Sales and Production on the production plan. The Supply Chain department, relying on the weekly demand driven production launch, would request production orders only to the items that were impacted by real demand, thus improving the level as well as the quality of the inventory.

Live monitoring:

Preparing the weekly production plans, required some time for preparation, including monitoring the reception of finished goods into the warehouse, and the deliveries of finished goods to the clients, in addition to the delay in production and pipeline of items expected to be produced and delivered to the warehouse. All this information needed to be checked each Tuesday for the

weekly team meeting between supply chain and production planning and sales, and later re-checked on Thursday before the launch of the production order by supply chain.
This follow up, during three days each a week, and then repeating it each week, allowed a live and more accurate monitoring of the evolution of inventory levels, compared to the monthly snapshot taken only at the beginning on the month when using the monthly forecast system, allowing consequently a better and more accurate management and decision making.

Quicker reaction time:

Live monitoring allows for change signals of inventories and market trends to quickly reach the decision-making people in supply chain, triggering a much quicker reaction time, within hours or maximum a day or two from any sudden movement. This is supported by weekly adjustments to the production plans, allowing the impact on the company's production plan to be triggered within just few days from the change signals.
The forecast based monthly management system required much longer time for a market signal to reach the decision-making employees, since the monitoring was not on day to day basis, and even after the signal reached its destination, it used to take a longer time to make changes to the production plan since it was adjusted on monthly basis.

Reduce the overall cycle of production lead time:

Combining the impacts of live monitoring and quicker reaction time, allowed for the overall cycle of production lead time to be reduced.
The overall cycle of production lead time is not just the time that a product is spending on the production machines, it is the time from receiving the customer's order, to passing the order to the supply chain and production teams, to the actual production process, and finally the delivery to the client.
This overall cycle was mainly reduced by the shortening of lead time for any demand signal reaching the different stakeholders and being diffused within the organization. Since the supply chain team is following up the changes constantly, they are the first contacts for change signals to all stock items, while the sales team remained the first contact for all items produced on

demand. Once the change signals of stock items are known, a decision for replenishment is taken immediately within a minimal amount of time delay, which diffuses the knowledge and impact of those signals within the organization very quickly. The supply chain team would be the first party to detect change signals, and at the same time they are now the decision makers for replenishment and the launch of production orders, making the information cycle lead time, between the contact with the client and the production decision making process, the shortest possible.

The overall cycle of production lead time is also reduced by avoiding bottlenecks of unnecessary production on the machines.

When producing to monthly forecasts, the production lines would be busy most of the month by producing, in some occasions, items that are not needed for the current market trend for a given week or situation, and thus when the signal of real demand reaches the production team, they will not be able to produce what is needed before finishing the already scheduled production orders. This fact used to extend the production lead time eventually, while when switching to the demand driven cycle, only needed items were produced, and in case of no need, nothing was produced, keeping the machines idle and on standby for any new order coming in, reducing the actual time needed to launch a new production order.

<u>Precise inventory management:</u>

Managing the inventory levels, through the production order replenishment, using the DDMRP process was a complete change from the previous forecast based replenishment process.

Since in forecast mode, the actual need is not known, the order for replenishment used to be made for full groups of items, or item family, or item size, but never going in details into item colors. The replenishment orders were simply made for groups of items that could be required in the market following a certain trend, which would be true from a general perspective, for example when detecting increasing demand for domestic cables, or the 2.5 mm domestic cable, the forecast mode replenishment would either order more quantities for the total domestic family or just order the domestic 2.5 mm for all colors. This kind of actions would be in line with a certain market trend, but not precise enough for inventory management, as within the domestic 2.5 mm, there are several colors, meaning several products, and ordering all colors would result at the end of the month with some colors being over-sold and resulting in shortages and negative customer satisfaction, while some colors would be over-produced and not sold resulting in excess inventory levels.

The precise inventory management style of DDMRP allowed to better manage the production orders for replenishment, ordering only the items that were sold, which helped reduce inventory levels and shortages at the same time.

Enhanced interdepartmental communication:

Enhanced communication was achieved through the repetitive meetings held between various stakeholders of the supply chain cycle.

In addition to the monthly meeting historically held between all departments around production, the creation of the DDMRP process came with a new type of weekly meetings, organized each Tuesday, two days ahead of the weekly DDMRP replenishment order on Thursdays, between the supply chain team, the production planning teams and the sales team.

This weekly meeting, which was new to the company's business model, came out of necessity to fill any missing gaps in communication between the different stakeholders, since the party controlling production orders, supply chain, was not in direct contact with clients, sales, or production, production planning.

During this meeting, each party would bring its concerns and input to flair a very insightful and oriented discussion, where new needs are discussed, production delays and breakdowns, priority setting between regular stock item production, and MTO products for special clients, with minutes of meetings taken and distributed to all attendees for follow up and monitoring.

Inventory reduction and operating working capital improvement:

Ordering only the necessary items, following demand, instead of ordering full groups of items and doing so on weekly intervals instead of monthly, allowed to reduce the level of inventory per item. More so, when ordering less quantity of finished goods, it also means requiring less production time, less labor cost, and less raw materials needed for production. Consequently, the full cycle of production from raw materials to finished products is optimized, which improved the operating working capital of the company, which means for the same amount of business, the company used less resources, by keeping lower inventories of raw materials, lower inventories of semi-finished items on the production floor, and eventually lower inventories of finished products, and the capital needed to fund the same volume of business and to keep the company operational is reduced, thus optimizing the operating working capital.

We will show in the section (E.6) the quantitative evolution of the inventories in full details, comparing the situation before and after the implementation of the DDMRP.

Optimizing the quality of the inventory:

The quality of the finished products inventory of stock items is measured by how much of the inventory is considered at healthy levels and how much at bad levels.

The healthy level of the inventory is referred to the levels of stock within the yellow and green zone of the DDMRP chart, which means the level of inventory above the safety stock (top of red zone), and below the excess levels (top of green).

The bad level of the inventory is referred to the instance when the inventory level is either in the red zone (the safety stock, below the top of red), or above the top of green zone, being in a situation of excess inventory levels.

Using the DDMRP replenishment system helped the company push its inventory levels as much as possible over the safety stock, and at the same time, not too high to be considered as excess inventory levels, and that by ordering only what is required by the real demand, to avoid excess inventory level coming from producing items that are not sold in enough volumes, but at the same time ordering in weekly repetitive mode and as quick as possible to avoid having critical inventory levels in the red zone, and thus optimizing the quality of the inventories.

We will show in the section (E.6) the quantitative evolution of the quality of the inventories in further details, comparing the situation before and after the implementation of the DDMRP.

Increasing customer satisfaction by reducing the shortages of products:

Once the quality of the inventory is optimized, the shortages of products is automatically reduced, since the goal would be to avoid reaching the red zone of safety stock, thus trying not to reach a situation of zero inventory level for all stock items.

Consequently, avoiding shortages improved customer satisfaction, by making sure client’s need is always available when needed.

However, avoiding a situation of zero inventory is almost impossible, due to many variables, like unexpected huge orders, or delay in production due to machines breakdown, or priority for other types of products in production, but the number of shortages has been seriously reduced and monitored much closely as one of the KPIs of the new implemented system.

We will show in the section (E.6) the quantitative evolution of inventory shortages in further details, comparing the situation before and after the implementation of the DDMRP.

Reducing the bullwhip effect:

One of the results of the segregation of duties implemented with the setting up of the DDMRP management style is the reduction of the bullwhip effect.

As explained in the literature review, the bullwhip effect comes from overestimating certain market movements or trends, either in situation of demand increase of decrease, which is traditionally communicated by the people in direct contact with the clients and the market, the Sales people. Before using DDMRP, this overestimation would be translated into the previous monthly forecasts, with a long waiting period of one month before checking if the change signal is accurate or not, or as important as expected or not.

When setting up the DDMRP and creating the filter, which is the supply chain department, between the sales people and the production people, the risk of creating a bullwhip effect was reduced significantly. The supply chain team would follow the market trends with two objectives in mind, to avoid shortages, and at the same time to avoid excess inventories, and completely removed the influence of the sales team on the production plan of the company for all stock items.

The management of the production planning would only follow the DDMRP system, using the moving average explained in part (E.4.a.3), which allows to follow market trends, but with very strict limits and follow ups, to avoid falling under the bullwhip effect.

Increasing transparency and visibility of market trends and historical evolution:

Setting up a detailed management system, create several positive side effects, among other is the increase of transparency and visibility of market trends and historical evolution of the demand and the inventory level with it.

The gathering and analysis of the data allowed to detect market seasonality in case there was, and at the same time to prove the absence of market seasonality when there is none.

It simply provided the possibility of making much more informed and smart management decision in close relation with any given situation and created a much better maturity in the decision-making process.

E.4.b.2) Disadvantages

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.

Risks of negative impacts of low interdepartmental communication level:

The impact of segregation of duties enforced after the implementation of DDMRP, separating the authority on production control between the sales department, the production planning department, and the supply chain department, could lead to detachment and working in silos.

At the early stages of putting in place the system, the sales department and the production planning department, not so used nor happy to not be involved in the production replenishment decision, withdrew completely from the process and stopped even sharing vital information for the overall fluidity of the business cycle.

This withdrawal was detrimental to the full success of the process, since key information about sudden changes in market trends or unexpected big orders under negotiations or being confirmed are essential information from the sales side, while production bottlenecks, machines breakdowns, scheduled maintenance campaigns and overall production problems and delays are also essential information from the production control side.

That is why, in the event of low interdepartmental communication level, there is a major risk of problems and delays that would impact the overall efficiency of the system.

This issue was very clear and visible to the management of the company after the early stages of implementation, and that is why, just few weeks after the launch of the new system, a regular weekly meeting was set in place between the sales department, the production planning department, and the supply chain department to make sure the mentioned departments will not be working in silo mode, and provide a high level of communication within the supply chain cycle.

Repetitive production orders:

Setting up a weekly replenishment system, means that each week a production order is launched, which should contain different products, but also could contain the same products each time, depending on the sales, demand, movement.

From the production side, the bigger the production order is, the better it is, as it would mean less setup time, and less scrap and higher efficiency of the machines, so they would prefer receiving one production order for item A for example for 4000 meters, instead of receiving 4 production orders of item A of 1000 meter, with one week apart.

However, since real demand is never stable, the same item A could be requested 4 times a month, with similar volumes or different volumes, or this same item might not be requested at all, or only ordered once a month, following market trends.

This behavior created some perturbation at the early stages of the system implementation, when the production team would have nothing to produce of some group of items, while they would have the historical habit of producing it regularly, and preparing the machines and the manpower accordingly.

A phrase that was repeated many times at the beginning from the production side was *"we have nothing to produce this week on those machines, what shall we do with our manpower? It is not healthy for the factory to have nothing to produce, the supply chain should order something! This system doesn't work!"*. This statement was true to some extent, since the focus was previously on creating a balanced production order that would cover all the factory's machines and manpower, making sure the factory's capabilities fully utilized, regardless of the real demand, which eventually led to the state of excess inventories and bad inventory quality.

In time, however, the production team learned to cope with the new system by allocating idle machines to produce other products, and by training the manpower to operate other machines, but the fact of having repetitive production orders remained a complaint from the production side, it was simply a price to pay for improving the inventory management system and overall company's inventory levels.

Lower visibility for the production teams:

Compared to having a monthly production plan for the whole month, enabling the production team to prepare the raw materials, the machines, and the manpower accordingly, switching to a weekly replenishment program reduced this visibility for the next 30 days.

At the beginning of the month, the production planning department would have a ready production plan for the month that covers only the make to order (MTO) products, following confirmed production orders, in addition to pending MTS items that were requested for replenishment the month before, but haven't been produced yet.

Since the average volume of MTS items is around 65% of the company's total production, the orders on hand at the beginning of the month, between MTO, and pending MTS, would represent around 60% of the monthly production, while the balance production orders would follow later during the month.

This reduced visibility had some impact on the efficiency of raw material preparations, machines, and manpower coordination during any given month, which is why, close and daily follow up was needed to adjust and modify following the updates of the new incoming production plans launched by supply chain.

Challenge of economical production lot sizes:

To maximize production efficiency, an economical lot size was defined by the production team for each type of cables, which represent the minimum quantity produced per item, at which the setup time, scrap level, and production efficiency would be optimal.
At the time of implementing the DDMRP system, many of these economical lot sizes turned out to be very large quantities per product, that would represent in volume the average sales of several months, not just few weeks, and in some cases, the production economical lot per item would represent almost a year's sales volume.
But with the focus on reducing inventory levels and optimizing it through DDMRP, the supply chain department was forced in many cases to launch production orders, with quantities per item representing less than the economical production lot.
This issue also raised complaints with the production team, but middle grounds and solutions were adopted in order not to reduce significantly the factory's efficiency, but at the same time avoid having excess inventories that were not needed for months ahead.

E.4.c) Limitations of the DDMRP system

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.

Furthermore, for the system to work efficiently, a company's database needs to be clean and live in a transparent and easy to use ERP system, enabling the live and quick extraction of sales and inventory moments, allowing the efficient and quick reaction necessary for the system to work. That is why, for companies that have no live ERP system or accurate live database on inventories and sales, implementing such process would not be possible.

Interdepartmental communication, especially between sales, supply chain, and production planning is essential for the efficiency of DDMRP. In case such efficient communication is not well established within a certain company, this would create a major obstacle for the smooth implementation of DDMRP.

E.5) Implementation of Kanban

The implementation of a Kanban replenishment system was done as a complementary to the DDMRP process, and it was implemented in a customized manner as well, following the context of the company.

E.5.a) Steps & Parameters of Implementation

The implementation of Kanban was done in two types of cards, like the TPS model, one conveyance card, and one production card, however the full system was customized as well and implemented for only few items of the MTS range.

E.5.a.1) Steps of Kanban Implementation

The implementation of the Kanban production system was set in place several months after the implementation of the DDMRP process, and based on the analysis of the DDMRP data and results.

E.5.a.1.a) Items chosen for the Kanban

After a value stream mapping of the production process of different cables, the Kanban system was implemented for the items that shows continuous repetitive sales, which helps predict certain volumes of demand, and required dedicated machines in production. Due to the diversity of cables produced at the company, most of the machines are used in producing several cables types, and thus, since the Kanban process requires the availability of the production machines, most machines were not available on spot demand, which means that in the case of implementing Kanban, the production order of a Kanban product would be delayed waiting for the production process to finish producing other cables, which will delay the production cycle and create different production delays per product, which completely destroy the Kanban process. That is why, having the possibility to dedicate certain machines only to produce the same items is key to implement the Kanban, and without this possibility, the Kanban should not work as intended.

Consequently, the Kanban production process was implemented only on the following items, from the Domestic MTS family:

Table 20: Domestic Kanban Items

Family	Color	Stock (m)	Average Monthly sales (m)	percentage of total family sales	Re-Order Point January 2016 (weeks)
DNYA 2.5	B	347,594	290,147	2.79%	7
DNYA 2.5	BE	637,241	413,507	3.98%	7
DNYA 2.5	G	536,061	405,247	3.90%	7
DNYA 2.5	J	481,312	335,082	3.22%	7
DNYA 2.5	N	1,003,663	714,917	6.88%	7
DNYA 2.5	R	781,744	574,099	5.52%	7
DNYA 2.5	V	176,768	137,922	1.33%	7
DNYA 2.5	VJ	696,468	544,922	5.24%	7
Sub Total DNYA 2.5 mm		**4,660,851**	**3,415,843**	**32.86%**	
DNYA 3	B	250,162	144,368	1.39%	7
DNYA 3	BE	328,492	233,058	2.24%	7
DNYA 3	G	252,995	201,564	1.94%	7
DNYA 3	J	348,782	197,023	1.90%	7
DNYA 3	N	480,033	341,841	3.29%	7
DNYA 3	R	476,194	324,871	3.13%	7

DNYA 3	V	188,284	152,156	1.46%	7
DNYA 3	VJ	189,107	58,499	0.56%	7
Sub Total DNYA 3 mm		**2,514,049**	**1,653,380**	**15.91%**	
DNYA 4	B	116,444	72,748	0.70%	7
DNYA 4	BE	445,484	200,277	1.93%	7
DNYA 4	G	346,954	146,190	1.41%	7
DNYA 4	J	316,701	145,146	1.40%	7
DNYA 4	N	657,897	320,459	3.08%	7
DNYA 4	R	612,106	276,362	2.66%	7
DNYA 4	V	165,982	76,375	0.73%	7
DNYA 4	VJ	431,499	155,882	1.50%	7
Sub Total DNYA 4 mm		**3,093,067**	**1,393,439**	**13.41%**	
Jun-2015	***Sub Total***	***10,267,967***	***6,462,667***	***62.18%***	

These items showed historical repetitive sales, ranging between 60% and 65% of the total sales of the Domestic Products Family, and it was possible to dedicate machines only to produce these items and nothing else, due to the volume of production versus the capacity of the dedicated machines.

In addition, the production steps of these items are much simpler than other cables, requiring fewer steps of production, and less complexity, which allows production completion without interfering with the production processes of other items.

The first two items used to test the Kanban system were the DNYA 2.5 and DNYA 3, and quickly after the good results the DNYA 4 was added. A year later, one more item was added to the Kanban process, and another was examined as well, but the choice of managing through Kanban was subject to the volume of production per item and the simplicity of production process. For this study, we will examine only the three items mentioned above.

E.5.a.1.b) Defining the number of conveyance cards

The DDMRP parameters were used to decide the number of cards, indicating the maximum inventory per item.

Following the value stream, it was deducted that setting up a semi-finished quantity for the three DNYA items in question, and the fact of delivering the needs on daily instead of weekly basis, would enables quicker response and shorter production time. That is why, the previous Re-order point of these items used in the DDMRP process was set to become the maximum inventory. In other words, instead of waiting an inventory level of 7 weeks before launching new production campaign, which means that the actual inventory would be reduced below 7 weeks waiting for the new production, but would also soon spike much over 7 weeks since the production campaign was for a certain minimum order quantity, the maximum inventory level was set at 7 weeks of sales, and the inventory level would vary between 7 weeks and the delay needed to replenish.

The inventory level of 7 weeks, was then transformed into number of cards.

The items were small cable coils of around 10 cm width and around 30 cm diameter (the size of the coil varied per item), packed on pallets. The number of coils per pallets was not stable, since the deliveries to the clients were not done in multiple of pallets, but by individual coils.

But to launch the system, the number of coils per pallets needed to be fixed. Each pallet was then set to contain 250 coils of DNYA 3 and DNYA 4, and 300 coils of DNYA 2.5. Once the capacity per pallet was set, it was easier to transform the 7 weeks' inventory level into number of pallets, and each pallet was attached to a Kanban conveyance card.

Below we show the design and shape of individual conveyance cards, as well as the number of cards per item.

<u>DNYA 2.5 mm</u>

8 Colors for DNYA 2.5:

Table 21: DNYA 2.5 Conveyance Cards

Color	Number of Pallets	Number of conveyance Cards
White	36	36
Blue	50	50
Grey	50	50
Yellow	40	40
Black	90	90
Red	70	70
Green	20	20
Green / Yellow	70	70
Total DNYA 2.5 mm	**426**	**426**

An example of DNYA 2.5 Red conveyance card can be found in Annex Picture 1.

DNYA 3 mm

8 Colors for DNYA 3:

Table 22: DNYA 3 Conveyance Cards

Color	Number of Pallets	Number of conveyance Cards
White	24	24
Blue	36	36
Grey	30	30
Yellow	30	30
Black	50	50
Red	50	50
Green	24	24
Green / Yellow	12	12
Total DNYA 3 mm	**256**	**256**

An example of DNYA 3 Yellow conveyance card can be found in Annex Picture 2.

DNYA 4 mm

8 Colors for DNYA 4:

Table 23: DNYA 4 Conveyance Cards

Color	Number of Pallets	Number of conveyance Cards
White	10	10
Blue	26	26
Grey	22	22
Yellow	20	20
Black	42	42
Red	38	38
Green	12	12
Green / Yellow	18	18
Total DNYA 4 mm	**188**	**188**

An example of DNYA 4 Yellow conveyance card can be found in Annex Picture 3.

Each of these conveyance card was physically attached to each relative pallet, when stored inside the warehouse. The card would only be removed once the pallet is completely emptied (sold).

E.5.a.1.c) Defining the number of production cards

The conveyance cards, transferred from the warehouse to the production workshop, were transformed into production cards. To launch a production campaign, one card (one pallet of coils) was not enough to be considered as economical production lot. Consequently, the conveyance cards were grouped within the production workshop, until reaching a certain number of cards enough to launch production.

The Picture 4 in the Annex show how the production cards were gathered, showing the actual shape and size of the cards. The large cards are the conveyance cards, per item, per color. While the very small square cards are the production cards.

The below table shows how much conveyance cards were necessary to create a production card, per type of item, and per color.

Table 24: Domestic Kanban Production Cards

Cable type	Number of conveyance cards required to launch production = 1 production card	Equivalence of a production card in meters of cables
DNYA 2.5 White	5	137,100
DNYA 2.5 Blue	6	164,520
DNYA 2.5 Grey	6	164,520
DNYA 2.5 Yellow	5	137,100
DNYA 2.5 Black	9	246,780
DNYA 2.5 Red	7	191,940
DNYA 2.5 Green	4	109,680
DNYA 2.5 Green / Yellow	9	246,780
DNYA 3 White	4	91,400
DNYA 3 Blue	5	114,250
DNYA 3 Grey	5	114,250
DNYA 3 Yellow	4	91,400
DNYA 3 Black	7	159,950
DNYA 3 Red	7	159,950
DNYA 3 Green	4	91,400
DNYA 3 Green / Yellow	4	91,400
DNYA 4 White	5	114,250
DNYA 4 Blue	6	137,100
DNYA 4 Grey	6	137,100

DNYA 4 Yellow	5	114,250
DNYA 4 Black	9	205,650
DNYA 4 Red	7	159,950
DNYA 4 Green	4	91,400
DNYA 4 Green / Yellow	9	205,650

Based on the above, for example, 9 conveyance cards of DNYA 4 Green / Yellow are needed to launch a production campaign, equivalent to 205,650 meters of cables. Consequently, once the production workshop receives a total of 9 conveyance cards, they will issue one production card of this item and sends it into the production process.

E.5.a.1.d) Setting WIP decoupling points

To explain at which stage the decoupling point was defined, we will begin first with a brief explanation of the production steps of DNYA cables:

a) The DNYA cables are made of a copper core, of a certain diameter (like 2.5 mm or 3 mm or 4 mm …), covered by a plastic colored sheath. The inner core is made of several copper wires assembled together to reach a certain overall diameter, as per international specifications.
b) The copper, which is the heart of the cables is received at the company in big coils of 3 to 4 tons each, with a wire diameter of 8 mm.
c) The 8 mm copper rod is passed through a rod breakdown machine, in order to reduce its diameter to required cable types. In case of DNYA, the copper is drawn down to less than 1 mm diameter.
d) To reach the inner cable core required of DNYA cable, 7 wires are assembled together, to reach the required inner diameter.
e) DNYA 2.5 mm requires assembling 7 wires of 0.678 mm diameter each, DNYA 3 mm requires assembling 7 wires of 0.71 mm diameter each, DNYA 4 mm requires assembling 7 wires of 0.856 mm diameter each, the wires are assembled together through a stranding machine.

f) After stranding, the cords (assembled wires) are insulated with a colored outer sheath, depending on the need, and produced in large quantities on big drums, by color.
g) These drums are then cut, through a coiling machine, into small coils, covered in polyethylene cover, labeled, and stacked on pallets.
h) The pallets will be sent to the finished goods warehouse for storage.

Setting decoupling point requires the capacity of dedicating specific machines to produce only one item, enabling the uninterrupted production process of the same item.

The first part of the decoupling point setting was assigning dedicated machines to perform the stranding operation only for the DNYA cables to be managed through Kanban.
To that end, 3 stranding machines, each with the stranding capacity close to the monthly average sales of each item was dedicated to the stranding operation of only the set item and nothing else, as per the below table:

Table 25: Kanban Machines' Capacity

Machine dedication per item	Machine type + Stranding capacity	Monthly average sales (June 2015)
DNYA 2.5 mm	SAMP 14 – 3,120 km / month	3,416 km
DNYA 3 mm	SAMP 12 – 2,000 km / month	1,653 km
DNYA 4 mm	LESMO 14 – 1,800 km / month	1,393 km

Each of the above machines will only produce (assemble) the copper core for the specific cable it was dedicated for, since its monthly production capacity is very close to the average sales, or average production needs, of each item.

The second step of setting the decoupling points was the preparation of a fixed quantity of semi-finished items, or work in progress, which will always be available whenever needed to launch production. This quantity will be set after the stranding operation, but before the insulation, since

the stranding operation per size is the same for all 8 colors, and after the stranding, the same item could be used for the insulation of any of the 8 colors.
Based on the average sales, the drum content per size, and the actual physical space available, the buffer WIP per item was decided as such:

Table 26: Kanban Semi-Finished Buffer Quantity

Buffer WIP per item	Buffer quantity	Buffer quantity % of Monthly average sales (June 2015)
DNYA 2.5 mm	630 km	18%
DNYA 3 mm	468 km	28%
DNYA 4 mm	210 km	15%

The third step was by dedicating an insulation machine, which insulate the stranded copper core by the colored plastic cover, transforming the semi-finished items into an actual electrical cable. The specific machine called Pioneer 62 was dedicated for the insulation of the three items (DNYA 2.5, 3 ,4), with 7,500 km per month of insulation capacity, while the average monthly sales, and production need, of the three items was around 6,500 km.
This machine would transform the stranded copper cores into cables, in all 8 colors, and deliver the cables on big drums, which is still not the final stage of production.

The final stage of production would be to transform the cables from the drums into small coils. To do so, two coiling machines would be used. The first machine with the coiling capacity of 4,500 km per month was fully dedicated to the Kanban system, while a second coiling machine with the same capacity was only half-time dedicated to the Kanban system, and half time to other items produced within the company.

All these actions, of fully dedicating machines to the Kanban management system, from standing machines, to insulation machine, and coiling machine, as well creating a buffer WIP semi-finished inventory inside the production workshop, were essential to setting up a Kanban system since it help ensure an un-interrupted production cycle and quick response time and reactivity to the production signal related to each product managed by the Kanban system, which reduces the production lead time and increase efficiency.

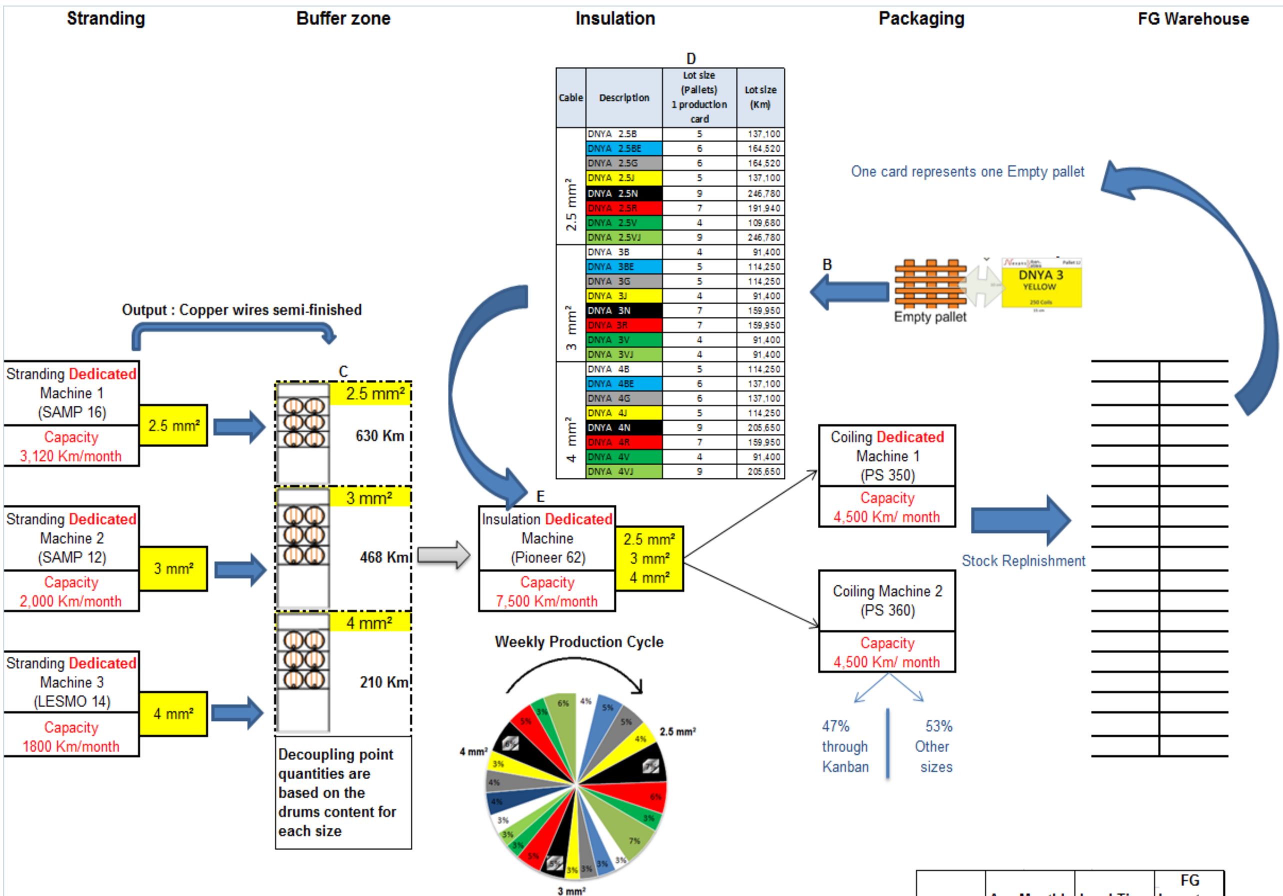
E.5.a.2) Kanban Process

The Kanban process begins and ends at the finished goods warehouse. The same process applies for all three items of DNYA 2.5 mm, DNYA 3 mm, DNYA 4 mm, which will be referred to as the Kanban items.

The Kanban process is done without any administrative or management interference, except for monitoring, it is a flow process executed directly by the workers on the shop floor in direct contact with each operation throughout the process.

The below picture shows the overall cycle of the Kanban process, which we will explain in further details:

Chart 10: Liban Cables Kanban Cycle



Cable	Description	Lot size (Pallets) 1 production card	Lot size (Km)
2.5 mm²	DNYA 2.5B	5	137,100
	DNYA 2.5BE	6	164,520
	DNYA 2.5G	6	164,520
	DNYA 2.5J	5	137,100
	DNYA 2.5N	9	246,780
	DNYA 2.5R	7	191,940
	DNYA 2.5V	4	109,680
	DNYA 2.5VJ	9	246,780
3 mm²	DNYA 3B	4	91,400
	DNYA 3BE	5	114,250
	DNYA 3G	5	114,250
	DNYA 3J	4	91,400
	DNYA 3N	7	159,950
	DNYA 3R	7	159,950
	DNYA 3V	4	91,400
	DNYA 3VJ	4	91,400
4 mm²	DNYA 4B	5	114,250
	DNYA 4BE	6	137,100
	DNYA 4G	6	137,100
	DNYA 4J	5	114,250
	DNYA 4N	9	205,650
	DNYA 4R	7	159,950
	DNYA 4V	4	91,400
	DNYA 4VJ	9	205,650

Cable	Avg Monthly sales (Km)	Lead Time (Weeks)	FG Inventory level (Weeks)
DNYA 2.5	3,477	3	7
DNYA 3	1,714	3	7
DNYA 4	1,386	3	7

A) One Kanban card represents one Pallet.
B) When one pallet is sold, the associated card will be sent from the FG warehouse to production.
C) A buffer stock of stranded copper conductors is managed through a supermarket system waiting to be insulated following the real demand.
D) Every item has a minimum lot size to be produced; the cards coming from the FG warehouse will be cumulated to reach the required lot size in order to be produced.
E) Once the lot size is reached, the stranded conductor will be insulated, packed into pallets and delivered to the FG warehouse with each associated card.
F) Then the cycle B => E is repeated

We will proceed in explaining each of the steps mentioned in the above picture for better understanding.

<u>Finished Goods Warehouse</u>

At the finished goods warehouse, finished products for the Kanban items are stored on pallets, and each pallet is coupled with a Kanban conveyance card. Once a pallet is sold, or emptied, a designated worker removes the conveyance card relative to the empty pallet, and store it separately from the finished goods racks. At the end of each day, all cards removed from the racks are sent by the same worker to the production workshop.

Picture 5 in the Annex shows the inside the of finished good warehouse, where the Kanban item and stored and how, as well as a picture of the conveyance card in real.

Production shop floor – Insulation stage

Conveyance cards are received by the production workers, and stored together on a board of cards (Annex Picture 3), waiting to reach enough cards for an economical production campaign. By production campaign, we are referring to the insulation process of transferring the semi-finished copper cores into colored electrical cables. Once reached, the conveyance cards are transferred into production cards.

Picture 6 in the Annex gives a better idea of the regrouping of the cards showed in the above Kanban cycle.

The insulation process withdraws semi-finished cable cores from the buffer zone, which is constantly replenished by the dedicated stranding machines, and managed in a supermarket system, constantly producing to keep the buffer zone full.

Buffer Zone Withdrawal

Picture 7 in the Annex gives a better idea of the buffer zone section showed in the above Kanban cycle, and how the supermarket system withdraws automatically from the buffer zone, keeping the semi-finished buffer always replenished (as much as possible).

Insulation process

The actual insulation process is done by the dedicated insulation machine for the Kanban process, which only produces for the Kanban process. The production is done in a weekly cycle per color, to ensure more smoothness and efficiency, dedicating a certain percentage of production per color and type of cable. If the relative cable does not have enough production cards, it will be skipped to the next cable. The cables are produced on big drums, containing one color per drum.

Picture 8 at the Annex shows an illustration of the insulation process for better explanation.

Coiling process

At the coiling process, the cables produced on drums, are cut, transformed into coils, covered, labeled and stacked on pallets, in fixed quantities per pallet, as it was defined at the beginning of the Kanban process.

Picture 9 of the Annex shows the machines dedication at the coiling stage.

Finished Goods Warehouse

Once the coiling stage is done, each pallet is linked again with a conveyance card, and sent back to the finished goods warehouse, with its relative conveyance card, where it will be stored back on the warehouse racks, and the card along with it, ending the Kanban cycle.

E.5.b) Added value of the Kanban system compared to the old

Putting in place the Kanban system was a drastic move and change in mentality to the management team, allowing production launch without the interference or the control of any administrative party, with skepticism and reservations to its implementation.

In parallel, it was also a change for the operators and the people on the floor, engaging them and empowering them with direct impact on the production launch mechanism, which they never had before.

The whole process brought many added values and advantages compared to the historical forecast driven replenishment system, as well as compared to the DDMRP system, but at the same time it had some disadvantages and limitations, since the implementation of any production launch system would operate well in certain ideal conditions, and not good at all in other conditions and situations.

E.5.b.1) Advantages

Implementing the Kanban proved to bring many added values to the production process, like reducing the overall production lead time of some article, prompt reaction to demand, launch production without management interference, empowerment of people, smooth flow of production, reduction of inventory and improvement of the quality of the inventory.

Reducing the overall production lead time

The overall production lead time of a certain product, would usually start from the management side, by studying the demand and deciding if a production order needs to be issued or not, then issuing a production order to the production team, then the production team would combine the production orders of several items and decide what and how to produce, waiting for the machines or production lines to finish producing what is already programmed to be produced, in order to start the production process of the new demand.

Each of the mentioned steps would usually take few days, from the administrative side to receive the demand signals from the sales team or warehouse team, to analyze the reduction in inventories versus sales, and decide what to produce and how much, taking into consideration what other items are already being produced and the production lines availability and pending production orders, this process does not happen promptly depending on the maturity of the teams. Then the time to prepare the necessary paperwork and send it to the production team, just the cycle of sending and receiving papers between the departments, along with getting the necessary approvals, would not be done at the same day. Later when the production team receives the production orders, they would need to figure out what is required and what they can produce quickly and what must be postponed waiting for production line availability. All that before proceeding with the actual production process, which has its own lead time.

Implementing the Kanban system completely removed all those steps, connecting the warehouse movement directly to the production workshop, and issuing automatically the production order, reducing the production cycle by many days.

In addition, the fact of dedicating machines only to producing the Kanban items meant that when a production step is needed, the operation would not be postponed waiting for the production lines to be available from producing other items, as it will only be producing or waiting to produce the Kanban products.

Also, preparing a semi-finished quantity at the production workshop, and setting a decoupling point for the Kanban items, reduced the manufacturing time, which previously needed to start the production process few steps before the decoupling point, while after, the production process would be reduced by few steps, already done through the decoupling point.

Consequently, implementing the Kanban process allowed for the overall production cycle of the chosen items to be reduced and optimized, by reducing both the administrative and paperwork delays to the absolute minimum, and at the same time reducing the actual manufacturing time of the Kanban items.

Prompt reaction to demand

The Kanban process ensure an optimal speed of reaction to real demand, since as soon a quantity is sold and removed from the warehouse racks, the demand signal is transferred to the production workshop during the same day. Consequently, during the same day when a demand signal is materialized, all concerned parties for demand replenishment are informed within only few hours.

Along with the quick transfer of information, the actual production process is also launched quickly, with no blocking administrative work, or pending production orders of other items, following the Kanban weekly production cycle.

This combination of prompt transfer of information and launch of production process produces a very quick reaction to actual demand, allowing the replenishment of the sold items at a very high speed.

<u>Launch production without management interference</u>

As previously highlighted, the Kanban replenishment mechanism allows the launch of production without passing through an administrative process. The traditional management habit of a mandatory administrative decision required to launch production, including the various influences on such decision, from internal politics to bureaucratical approvals and bias to certain angles within the company, was all isolated and removed from the decision-making process.

This new demand driven replenishment model allowed the production launch of the Kanban items to be driven solely by demand and market trends, cleansing the production process and inventories from bias positions.

<u>Empowerment of people</u>

The Kanban replenishment model requires the direct involvement of the people on the floor for its successful implementation, from the finished good warehouse employees handling the reception of finished products from the factory and the delivery to the clients, to the production team handling the reception of production orders and proceeding with the execution of these orders, packaging and delivering back the products to the warehouse.

With the Kanban process, these employees will no longer remains only receivers of orders and decisions, but they would become part of the decision making and execution process, putting within their hands the power of successful implementation or failure of the full replenishment cycle.

This empowerment raises the awareness and vigilance of the employees and increase their sense of responsibility and discipline, improving the level of self-satisfaction, motivation, usefulness and sense of partnership in the management process, which they were completely blind to before.

Smooth flow of production

The weekly production cycle set for the Kanban items was a drastic change from the previous habits of production within the company.

The production team used to receive different production orders, for different items, in different quantities and volatile frequencies, which made the prediction or preparation of any production campaign not possible as it would be a wild guess. To that end, they would have to wait to receive the new production orders, and analyze its contents and requirements, and check what and how to produce, before setting up the machines and dedicating the manpower accordingly.

By creating a regular weekly routine that administrates the production cycle of the Kanban items, it was no longer possible to produce other items, and the production process on the workshop dedicated for the Kanban operation became entirely dedicated to that operation, which provided visibility and capacity to plan ahead the resources, time and manpower, and changed the flow of production in that section from a volatile and unpredictable operation, to a very smooth flow of production, requiring less effort, less overtime, and less problems, increasing the overall efficiency of the production team and process, indirectly increase the speed and capacity of production.

Reduction of inventory level

Putting in place the different features of the Kanban management system, from reducing the overall lead time for producing, to prompt reply to demand, to the empowerment of people, the dedicating of machines to the Kanban process and setting ready to use semi-finished work in progress materials at decoupling points, all allowed the supply chain team to reduce the inventory level of the Kanban items, since the overall quick response ensured no shortage of inventory while maintaining a lower level of inventories.

That is why, after putting in place the Kanban system, the inventory level of the chosen items was set to be lower than the previous one, consciously due to the efficiency of the system. While the replenishment threshold used previously for the chosen item by DDMRP was set at 7 weeks of inventory, which means that when reaching 7 weeks, a production order is launched to go back over the level of 7 weeks, usually reaching between 9 and 12 weeks, depending on the minimum production lot size per item, putting in place the Kanban system allowed to set the maximum inventory level, through the number of cards, at only 5 weeks of inventory, which means that the inventory level would go up and down below the level of 5 weeks, which is a big reduction of the inventory level compared to the previous one.

That is how putting in place the Kanban system allowed to maximize the inventory level for the chosen item, ensuring the right level of inventory is available in stock while avoiding to reach a shortage position.

<u>Improvement of the quality of the inventory</u>

The quality of the inventories is optimized when no excess inventories are kept in stock and at the same time no shortage position is reached.

The Kanban management process is the ideal tool to optimize the inventory quality, as it is simply not possible when using it to reach a low quality of stock. The number of conveyance cards in the warehouse is setting a mandatory cap on the maximum inventory level, which is the maximum number of available cards, set at a maximum of 5 weeks of inventory coverage. At the same time, the quick reaction time in production, maintained by the dedication of machines and decoupling point, ensures a shortage of materials in never reached (except in extreme situations).

That is why, using the Kanban process, if properly implemented, would simply provide an optimal level of inventory quality, as it is simply not possible to have a bad inventory quality under the cards management system.

E.5.b.2) Disadvantages

The Kanban system had some weak points and disadvantages which were detected after the implementation, like the lack of visibility for the management team, machine dedication in case of lower demand, human error risk.

<u>Lack of visibility for the management team</u>

Unlike the previous forecast based system which provide monthly production backlog to the production planning team, and unlike the DDMRP system that provide weekly production orders to the production planning team, both in paper form, analyzed by the planning team and transferred later to the production workshop, which gives them the opportunity to prepare the raw material needed for production as well as the manpower and machine setup ahead of time, the Kanban production cycle provides no such information or visibility.

The production planning team has no possibility of knowing ahead of time nor monitoring how many items are produced by the Kanban process, or how much materials are needed for it. They can only know after the fact, not before.

The information signals come to the planning team only after the products are produced and ready to be delivered to the warehouse, and they would be replenishing the raw materials drawn from the Kanban process in the production floor, but without detecting that these materials were withdrawn by the Kanban process until after the delivery.

The overall lack of visibility to the management team makes it difficult to predict and make forecasts of the requirements of raw materials or manpower for the Kanban process, which forces the planning team to become more vigilant and follow the changes of the flows within the factory floor much closely and accurately.

Machine dedication in case of lower demand

The machines that were dedicated to producing the Kanban items has a production capacity close to the average sales volumes of the Kanban items, which means that on average, these machines would always be producing close to their maximum output with high efficiency.

However, in case of reduction in sales, and consequently demand for the Kanban items, the dedicated machines would not be producing at a good efficiency level, since they will remain dedicated to the Kanban process, but without enough production volumes, which will in return increase the cost of production due to the reducing of efficiency and low utilization of manpower and resources accordingly.

This scenario would lead to high production cost, and higher waste level of materials, time and resources.

In some occasions, when the demand of the Kanban items was low, and the company had other orders to produce that requires to pass through similar machines, some items other than the Kanban items were produced on the Kanban machines, in order not to delay the production time of those other items and at the same time maintain a higher utilization of the machines and maintaining higher efficiency.

But this is not a permanent solution, nor a very encouraged one, as in case of new demand for the Kanban items, and the machines were busy producing something else, it will delay the Kanban production cycle, and potentially lead of shortages as it will halt the system’s efficiency.

Human error risk

The efficiency and vitality of the Kanban system is solely relying on human efficiency, on the discipline and vigilance of the workers on the warehouse and production floors, who historically were never used to being empowered as such or being in a semi-decision-making position.

That is why, human errors and misconduct or recklessness, could completely halt and sabotage the system and make it utterly useless. These results could come out of seemingly innocent behaviors of carelessness, like forgetting to remove the conveyance cards from a sold item, or forgetting to delivering it back to the production team the same day, or overconfidence at the production floor for not following the weekly production cycle as it was set. This kind of behavior, as harmless as it may seem, could lead to completely blocking the healthy cycle of the Kanban process.

To avoid this outcome, several trainings were made for the employees in direct contact and influence with the Kanban cycle, to increase their vigilance and awareness to the system.
In addition, some statistics were followed by the supply chain team that follows daily the number of Kanban cards delivered, the inventory levels related, and the speed and response time to the launch of Kanban, and the inventory level of each Kanban item is closely followed on weekly basis to make sure no shortage position is reached.

E.5.c) Limitations of the Kanban system

The Kanban system is not an absolute system, and cannot be implemented to all manufacturing companies, nor any type of products.

The system can only be implemented for manufacturing process which has a steady flow of demand with important volumes vis-a-vis the machine capacities and production lines.

In other words, at Liban Cables, which produces thousands of products, the Kanban system was only possible to be implemented on few dozens of items, which manifest high volumes of regular sales.

In case of low volumes of sales, the produced quantities would not be enough to operate the dedicated machines at full capacity, which will reduce the machine and production efficiency.

In case of irregular or none constant sales or demand, the dedicated machines would operate full time on certain days and be completely idle on other days, which is a loss opportunity of production that can be used to produce other items.

The successful implementation requires as well a disciplined work force, since the implementation requires the direct involvement of the people on the floor, from the warehouse operators to the production operators, who needs to be well informed and disciplined and able to understand and ensure smooth implementation.

So, in summary, in a multiproduct manufacturing operation, the Kanban system, can be used to optimize the production flow for the company's top runners stock products, showing stable sales volumes on regular basis, which could only represent a small fraction of the total number of products a company produces.

E.6) Using Mix DDMRP-Kanban

Liban Cables began the preparation to implement the DDMRP management system in 2014, and the actual implementation of the tools began in January 2015, followed few months later by the Kanban implementation.

Before 2014, inventory evolution was not monitored and followed in the same manner, neither the same vocabulary was used nor segregation and classification of items, like it was done through the DDMRP implementation.
That is why, comparisons and benchmarks to the period before 2014 is not possible, since the data simply does not exist.

To examine the impact of implementing DDMRP and Kanban, we will compare and analyze the evolution of several key performance indicators, from January 2014 until December 2017, which will give us benchmarking data of one year before the implementation of the mix system (2014), and three years after the implementation (2015, 2016, 2017).

The main parameters we will study are the inventory evolution in tons and value, the inventory coverage representing the weight of inventories compared to sales, the level of shortages of items and customer satisfaction, in addition to the quality of the inventories.
Furthermore, we will simulate the evolution of the inventory levels through DDMRP charts, tracking the inventories versus sales within the three sections of the DDMRP chart (Red, Yellow, Green).

To do so, we will use some of the official reports coming out of Liban Cables' Supply chain department, in addition to creating some charts and tables using those reports.

To note that a simulation comparison between the results of DDMRP and Kanban, and the results of keeping the forecast driven system, during the same years of 2015, 2016, 2017, cannot be executed, since the forecast driven system had no parameters to follow and use in a simulation, as it relied solely on the estimation and personal impressions of key people making the forecasts, not following any particular set of rules, which is why, no simulation of forecast decisions could be charted to compare its results with the outcomes of the demand driven implemented tools.

E.6.a) Inventory level reduction

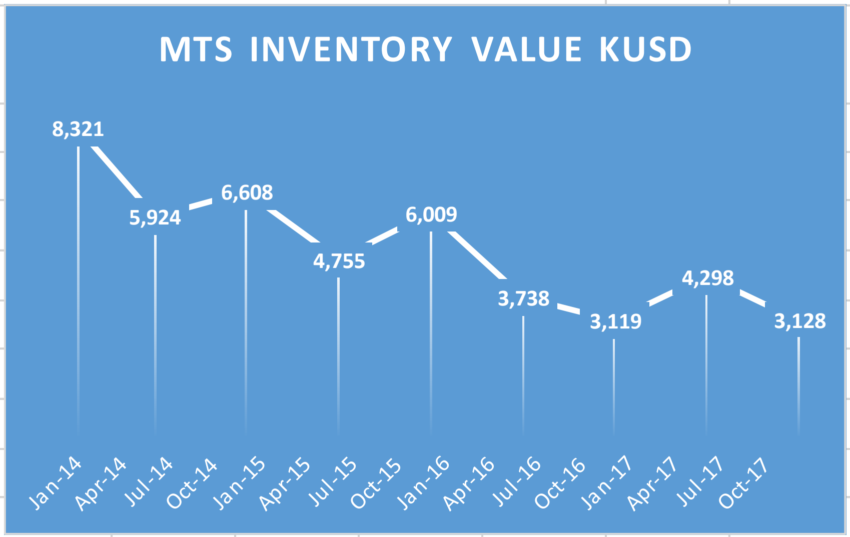
One of the results of implementing the mix system was the reduction in inventory level.

By analyzing the "Liban Cables' Finished Goods ABC Matrix in USD", copy shown in Annex Report 1, we can see how the inventory value in US Dollars decreased from 2014 to 2017 for the stock items (MTS) managed by the mix system. The below table and chart shows a summary of the evolution, in KUSD which is by thousands of US Dollars (i.e. January 2014 MTS inventory level was eight million three hundred twenty-one thousand dollars).

Chart 11: Liban Cables' Stock Items Inventory Evolution (value)

Liban Cables' Stock Items Inventory evolution in value (USD)

Month	MTS Inventory Value KUSD
Jan-14	8,321
Jun-14	5,924
Dec-14	6,608
Jun-15	4,755
Dec-15	6,009
Jun-16	3,738
Dec-16	3,119
Jun-17	4,298
Dec-17	3,128



(Source: "Liban Cables' Finished Goods ABC Matrix in USD", Annex Report 1)

Although the decrease is clear in the above chart, however it does not reflect the real evolution of the inventories, since the value of the inventories are linked to the value of the materials used to produce the cables. As copper and aluminum are the main ingredients of electrical cables, the cost of the finished products would be highly impacted by the copper and aluminum price fluctuation on the stock exchange. This chart show however a trend of decrease, which sums up to a 62% reduction of the value of the stock items inventories between January 2014 and December 2017.

This decrease certainly helped the company improve its operating working capital and cash flow, but to measure the impact of the implemented tools on the actual inventories, we will study the evolution of copper and aluminum prices on the stock exchange to make sure that the decrease in inventory values is not only related to a decrease of metal prices, in addition, we will look at the decrease in inventory tonnage to also benchmark.

Table 27: London Metal Exchange Price Evolution

Copper LME Average prices				Aluminum LME Average prices		
Month	**USD**	**% vs Jan14**		**Month**	**USD**	**% vs Jan14**

Jan-14	$7,295			Jan-14	$1,726	
Jun-14	$6,806	-6.70%		Jun-14	$1,834	6.25%
Dec-14	$6,423	-11.95%		Dec-14	$1,913	10.82%
Jun-15	$5,834	-20.03%		Jun-15	$1,683	-2.49%
Dec-15	$4,629	-36.54%		Dec-15	$1,494	-13.45%
Jun-16	$4,631	-36.52%		Jun-16	$1,592	-7.78%
Dec-16	$5,666	-22.33%		Dec-16	$1,731	0.24%
Jun-17	$5,699	-21.87%		Jun-17	$1,887	9.28%
Dec-17	$6,801	-6.77%		Dec-17	$2,071	19.94%

(Source: London Metal Exchange (LME) official site)

The above table show the evolution of copper and aluminum prices on the London Metal Exchange (LME), at the same months we are studying.
All the prices are in US Dollars, and the prices displayed are the average cash official settlement prices of the LME for the full month, for example, if we add all the daily cash settlements of copper at the LME for the month of January 2014, the average price of all the settlements would be $7,295 per ton for the month.

By examining the evolution of copper and aluminum prices, we can detect a clear reduction in copper prices, but not as steep as the inventory reduction, while on the other hand aluminum prices increased compared to January 2014.
However, the decrease in metal prices does not follow the same trend of the inventory reduction, which means that there was in fact an inventory reduction, but to understand better the evolution of the inventories, we should look at the reduction in the weight of the inventory, not the price.

Inventory levels in Liban Cables are measured either in value, or in weight. However, by weight its means weight of metal, since other raw materials on the cables are very different from once cable to another, either in terms of volumes and spaces and weight, or in terms of price of other raw materials. That is why, for benchmarking purposes, the company does not measure the level of its operations (production, sales, inventories) in weight of cables, but only does it in weight of metal (copper and aluminum) within the cables.

To note that the weight of metal inside each cable, varies from once cable to another, which means that for the same length of cable, once cable type could contain double or triple or even ten times more metal than another type of cable.

To continue with the comparison in tonnage, we referred to the Liban Cables report “Evolution of MTS families”, copy shown in Annex Report 2.

The difficulty in the comparison was the absence of data for all families of products since 2014, in fact, only the Domestic family has data going back to 2014, since it was the first family of products to be managed by the DDMRP system, quickly followed by the Flexible family in February 2015, while the other families followed either in the middle of 2015 or the beginning of 2016. From that Report 2, we extracted the below inventory evolution per tons’ table per family of products. The tonnage mentioned is the weight of metal, copper or aluminum, inside the cables, it is the metal weight of the cables.

Table 28: Liban Cables Inventory Evolution Per Family, in Tons

	DOMESTIC	**FLEXIBLE**	**EAXT**	**ENERGY COPPER**	**E(NYM)**	**TELECOM**
	Stock (Tons)	**Stock (Tons)**	**Stock (Tons)**	**Stock (Tons)**	**Stock (Tons)**	**Stock (Tons)**
Dec-14	512					
Jun-15	419	339				
Dec-15	237	241		372	86	
Jun-16	322	298	66	356	97	20
Dec-16	270	259	117	211	83	25
Jun-17	364	347	146	500	128	31
Dec-17	277	224	114	345	91	28

In the above table, we can clearly monitor the inventory evolution per family, where the inventory reduction is very clear in the domestic family, from 512 tons in December 2014 to 322 tons in June 2016, and 277 tons in December 2017.

The same inventory reduction is clear in the flexible family, although not as steep as the domestic family, 339 tons in June 2015, to 298 tons in June 2016, and 224 tons in December 2017.

The unavailability of data for certain families since December 2014 is due to the fact that the DDMRP analysis and management tools where not used to manage all the families from the start, rather the implementation started family by family, first managing the domestic family, then closely followed by the flexible family, while the other families' management through DDMRP were delayed further in time, waiting to use and test the system on fewer families first, and also to make the preparatory data analysis and steps to implement it on more families.

The other families, however, does not reflect the same inventory reduction levels, rather a stability or slight increase is manifested. This evolution would be linked to the management of the items inside each family, since DDMRP system provide equal management techniques for all items, and increase the inventory level of items that has lower levels than required, and decrease the inventory levels for items with high levels. That is why, it is normal to see some items' inventory levels increasing instead of decreasing in case it did not have the adequate levels.

In addition, one more aspect to consider, which is the metal weight inside the cables that is different from one family to the other, like for example the copper weight inside one meter of the energy copper cables is much more important that the weight inside the same length of domestic cable. That becomes a very affecting factor when the minimum order quantity for production is also high compared to the sales volume, where for some items, the minimum order production quantity, also called economical production lot, represent several weeks or months of sales. This creates high volatility in the inventory levels, as big quantities would be received at the warehouses that would need a long time to be sold.

The supply chain department tried to reduce the impact of such factor by trying to reduce the minimum order quantity, or sometimes ordering lower than the economical production lot, even though it creates lower efficiency in production, to try to keep the control on the inventory levels.

In the same table, we could see an increase in inventory levels in all families in June 2017. This is an example of management conscious decision to increase the inventory levels due to a certain specific circumstance. In the summer of 2017, the sales levels were increasing for the company, and some orders requiring products that are not managed by the DDMRP, rather MTO items, were creating bottlenecks in the productions workshop. The company's production capacity was not enough to produce at the same time the incoming big orders of MTO items, while keeping the production of MTS items managed by DDMRP in the same continuity and without interruption. That is why, it was decided to increase the inventory levels of the MTS items for a short period, to have enough inventory levels to cover the sales needs, during the period when the production team would not be producing MTS items, as they would be giving priority to the MTO items needed for the incoming orders.

That is an exceptional case, when MTS levels are pushed up, through the DDMRP system by increasing the base of replenishment to the higher end, but once this period ends, it is as simple and easy to reduce back the inventory levels to normal, which we can see in the reduction of inventories between June 2017 and December 2017, going back to normal levels compared to the trend in previous periods.

Consequently, the DDMRP system, backed by the Kanban where applicable, can consciously reduce the inventory levels when needed to correct levels, while also can increase the inventory levels when needed, following specific rules and provide the adequate method of doing so.

E.6.b) Inventory coverage reduction

Inventory levels evolution cannot be examined as an isolated indicator, since it is not possible to judge if an inventory level is good or bad, without comparing it to the level of demand or sales, since the purpose of the inventory is to ensure the continuity of sales and customer demand.

A business cannot usually increase sales without increasing inventory levels in an equivalent level, and in case the sales level were decreasing, the inventory level should decrease simultaneously. Thus, examining the inventory level evolution alone does not give any indicator of good or bad management practices of the inventories, without looking at sales evolution, and all depending on the company strategy of how much and in what state they intend to hold inventories.

That is why, the more adequate key performance indicator (KPI) to measure the inventory level is the inventory coverage. The inventory coverage measure how much time could an inventory level cover the demand or the sales. For example, if the inventory level of item A is 100 units, and the average sales of item A per month is 50 units, then the inventory coverage is 100/50 or 2 months. This means that the inventory coverage of item A is two months of sales.
The inventory coverage, or inventory turn, could be measured in months or weeks or days, depending on the type of products and type of business.

Liban Cables’ supply chain department measured the inventory coverage in number of weeks of sales, since it was more adequate than measuring in number of days, or number of months, taking into consideration the production delays to produce the items and the sales trends.

To study the inventory coverage evolution, we will examine two files, first the Liban Cables Finished Goods ABC Matrix in percentage of inventories, copy in Annex Report 3, to monitor the overall inventory evolution of MTS items, and then we will use again the Report 2 in the Annex to the extract the inventory coverage per family.

The ABC matrix evolution below (extract from Report 3 in the Annex) shows how the company’s inventory is segregated and what does it represent in weeks of sales.

Table 29: Liban Cables Finished Goods Segregation January 2014

January-2014					
Values	< to 2 weeks	from 2 to 4 weeks	from 4 to 6 weeks	from 6 to 8 weeks	> to 8 weeks	TOTAL
A	9.6%	8.9%	8.0%	6.2%	23.8%	**56.5%**
B	0.6%	0.6%	0.5%	0.3%	7.6%	**9.5%**
C	0.2%	0.1%	0.1%	0.1%	4.5%	**4.9%**
MTS	**10.4%**	**9.6%**	**8.5%**	**6.6%**	**35.9%**	**71.0%**
MTO	2.2%	2.1%	2.0%	1.9%	20.7%	**29.0%**
DSP	-	-	-	-	-	-
TOTAL	**12.6%**	**11.7%**	**10.6%**	**8.5%**	**56.6%**	**100.0%**

For example, in January 2014, the MTS products represented 71% of the total company's inventories, while the MTO represented 29%. In addition, within the MTS products, the A products represented 56.5%, the B products 9.5% and the C products 4.9%.
Then we can see how MTS items are spread versus weeks of sales, for example, 10.4% of the MTS products presented less than 2 weeks of sales, while 35.9% represented over 8 weeks of sales.

From that report, we will isolate the MTS products from the MTO products, and study the evolution of coverage within the MTS family to study the evolution of inventory coverage within MTS products. The below table shows that evolution.

Table 30: Liban Cables MTS Inventory Coverage Evolution 2014-2017

MTS Inventory Coverage Evolution within MTS family						
Month	**< to 2 weeks**	**from 2 to 4 weeks**	**from 4 to 6 weeks**	**from 6 to 8 weeks**	**> to 8 weeks**	**TOTAL**
Jan-14	**14.7%**	**13.5%**	**12.0%**	**9.2%**	**50.6%**	**100.0%**
Jun-14	**21.0%**	**16.0%**	**16.8%**	**12.6%**	**33.6%**	**100.0%**
Dec-14	**17.2%**	**16.0%**	**24.7%**	**19.4%**	**22.8%**	**100.0%**

Jun-15	**22.4%**	**19.3%**	**27.4%**	**20.8%**	**10.2%**	**100.0%**
Dec-15	**42.6%**	**24.3%**	**18.4%**	**7.5%**	**7.2%**	**100.0%**
Jun-16	**23.3%**	**22.6%**	**33.9%**	**19.6%**	**0.6%**	**100.0%**
Dec-16	**29.7%**	**27.6%**	**28.8%**	**13.4%**	**0.5%**	**100.0%**
Jun-17	**19.9%**	**19.8%**	**32.6%**	**26.6%**	**1.1%**	**100.0%**
Dec-17	**27.7%**	**26.1%**	**31.1%**	**12.8%**	**2.3%**	**100.0%**

Based on the level of sales, 14.7% the total inventory level of MTS items covered less than 2 weeks of sales in January 2014, 12% represented from 4 to 6 weeks, and 50.6% of the MTS inventory represented over 8 weeks of sales. That means that more than half of the inventory level of MTS would only be used for sales after 8 weeks, in case production was halted in January 2014. The “over 8 weeks” column represents high inventory levels beyond the needs of sales for the next 8 weeks, which translate in high inventory level to the management.

From this table, the improvement in inventory coverage for MTS is very clear, the 22.8% of inventory over 8 weeks at December 2014 was reduced to 7.2% in December 2015 and 2.3% in December 2017. We can see how the weight of the inventory coverage shifted from high levels to low levels of coverage, the inventory weight representing less than 2 weeks of sales increased from 17.2% in December 2014, to 42.6% in December 2015 and 27.7% in December 2017.

The implementation of the DDMRP in 2015 shows significant improvement in the inventory coverage within the MTS family, as we see a clear shift in the inventory overage from high level, representing over 8 weeks of sales, to more reasonable levels, manifested in the increase of the inventory coverage percentage in the columns representing less than 2 weeks of sales and 2 to 4 and 4 to 6 weeks of sales, and decrease of the percentage of the inventory in the over 8 weeks’ coverage level.

The above study however shows the evolution of the total group of families of MTS, in a global picture. To better understand the evolution, we will examine the evolution by family of products. We will use again the Report 2 of the Annex to extract the below table of coverage evolution per family of cables within the MTS group.

Table 31: Liban Cables Inventory Coverage Evolution per Family of MTS

	DOMESTIC	FLEXIBLE	EAXT	ENERGY COPPER	E(NYM)	TELECOM
	Coverage (weeks)	**Coverage (weeks)**	**Coverage (weeks)**	**Coverage (weeks)**	**Coverage (weeks)**	**Coverage (weeks)**
Dec-14	9.4					
Jun-15	7.6	8.4				
Dec-15	4.4	6.3		14.7	7.6	
Jun-16	6.2	7.8	2.5	12.3	8.3	9
Dec-16	5.3	6.8	4.9	8.5	7.7	9.9
Jun-17	7.2	8.6	6.7	13.3	9.5	14
Dec-17	5.9	6.5	5.6	11.7	8.1	15.3

In this benchmark, we can clearly see an improvement, reduction, in the inventory coverage (inventory turn) level for some items, stability for others, and increase for some.

The domestic family had a decrease in inventory coverage from 9.4 weeks in December 2014, to 6.2 weeks in June 2016 and 5.9 weeks in December 2017. This means that the inventory level in December 2014 could cover 9.4 weeks of sales, while in December 2017, the inventory level represented only 5.9 weeks of sales. This improvement of inventory coverage translates the reduction of inventory level in parallel with the sales evolution, showing the real improvement of stocks versus sales, since the target is to improve the inventory level, either by decreasing or increasing, in relation to the sales needs.

The sale trend of coverage reduction is visible in the flexible family as well as the energy copper family, while we can see an increase in the inventory coverage for the families of EAXT and telecom and rather stability in the E(NYM), both the decrease and increase of coverage are considered an improvement based on the sales levels. Reducing the inventory coverage means that we had too much inventories compared to the sales levels and needed to the reduced to more reasonable levels, and increasing the inventory coverage means that we had low inventory levels compared to sales and it was necessary to increase the inventory to more reasonable levels.

A reasonable inventory coverage level is different for each product family, since for the families that requires less production lead time, the inventory coverage was reduced as we can produce faster and no need to keep that much inventories in stock, while for the items that requires higher production lead time, the inventory coverage was increased as the production process is slower and thus more stock should be kept to cover sales while waiting for new products to be produced.

The decision to increase inventory levels in June 2017 by the management, explained earlier, is also translated in a momentary increase in the inventory coverage for all families of the MTS, like 7.2 weeks for the domestic family in June 2017, versus 5.3 weeks in December 2016, and reduced back to 5.9 weeks in December 2017.

In summary, we can clearly see how implementing the DDMRP management system improved the inventory coverage versus sales, either by decreasing or increasing or even maintaining the same level when necessary, since improving the inventory does not only mean to decrease, as a reasonable level is needed to maintain sales and customer satisfaction. The DDMRP management system allowed to push towards having the correct level of inventory and inventory coverage compare to sales and demand needs.

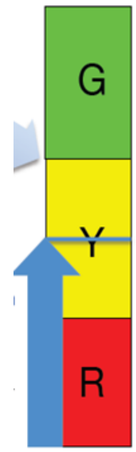
E.6.c) Improving the quality of inventories

The quality of the inventory is a ratio that measure how much good inventory and how much bad inventory represent out of the total inventory level.

The notion of good or healthy inventory level is determined in relation to the DDMRP threshold segregation, already explained in the DDMRP literature review, as such:

- Below the top of red, the inventory level is in danger zone, and thus considered as bad or unhealthy inventory level, since there is strong probability of getting in shortage position leading to negative customer satisfaction.

- Above the top of green, the inventory level is in excess zone, and thus also considered as bad or unhealthy inventory level, since there would simply be too much stocks, more than needed to run the business, increasing the company cost and damaging its operating working capital.
- Based on the above, when an item's inventory level is moving between the top of red and the top of green, or simply within the yellow and green zone, it is then considered as good inventory level, as it will neither be within the safety zone and risk of shortage, nor in excess position, rather it will be within normal limits to satisfy customers' needs, as well as in acceptable levels enough to relaunch production campaign without shortage risk, all while maintaining the overall operating working capital of the company within acceptable limits.



- The quality of inventory ratio measures how many products within each family are within good inventory levels, in percentage of the total weight of the family. For example, if the quality of inventory of a family of products is 60%, it means that 60% of its products have inventory levels within the yellow and green zone of their DDMRP classification, while 40% of products of that family are either in excess inventory or in danger zone. The ultimate objective would be to increase the quality of inventory as much as possible by having most inventory levels within the yellow and green zones, and avoid having inventory levels outside these zones.

Based on the data available in Report 2 Annex, we can extract the below evolution of the quality of inventory per family of products.

Table 32: Liban Cables Quality of Inventory Evolution per Family of MTS

	DOMESTIC	FLEXIBLE	EAXT	ENERGY COPPER	E(NYM)	TELECOM
	Quality (%)	Quality (%)	Quality (%)	Quality (%)	Quality (%)	Quality (%)
Dec-14	43					
Jun-15	46	29				

Dec-15	67	49		67	61	
Jun-16	82	41	4	76	43	27
Dec-16	83	57	32	77	70	78
Jun-17	77	24	57	49	38	60
Dec-17	81	49	63	84	63	44

The above benchmark shows what was the quality of the inventory per family in the early stages of DDMRP implementation, and how it evolved in time.

By examining the domestic family, the quality of the inventory was 43% in December 2014, which means that 43% of the products within the domestic family were at inventory level within the yellow and green zone in December 2014, while 57% of the products of the family had inventory levels either in the rod zone (danger zone), or in excess (beyond the green zone). The quality of the inventory started improving with the implementation of DDMRP and Kanban, reaching 67% in December 2015, and 81% in December 2017, which means that, in December 2017, 81% of the domestic family products had inventory levels within the yellow and green zones and only 19% of its products had inventory levels either in danger zone or in excess. This evolution shows strong improvement in inventory management over time after the implementation of new system, which is a much more indicative ratio to measure, compared to only the level of the inventories. Its shows how well and accurate the inventories are managed.

The quality of the inventory however is very much related to the economical production lots of each item, and how much an economical production lot represent out of the average sales or demand of that product. That is why, there is a limit to how much the quality of the inventory can be improved. By examining the quality evolution of the flexible family, the improvement is clear from 29% in June 2015, which means that 71% of the flexible products were either in the danger zone or in excess levels, to an average of 50% in the period following the implementation of DDMRP. The quality of the inventory however did not reach as high as the domestic family, due to the high volume of the economical production lot, which upon production would increase the inventory levels beyond the top of green and into the excess zone. This situation would not be changed for all items that has high economical production lots compared to the average sales volumes, unless somehow the production team succeeded to reducing the minimum order quantity for production in relation to the average sales volumes.

Similar improvements in quality of inventories is clear in the rest of the families, each in relation to its economical production lot and sales volumes and frequencies, but the improvement of the quality of stock is visible. The evolution shows how the implementation of the DDMRP and the Kanban (for some items) helped move big parts of the inventories out of danger zones, and below the excess zones, into more reasonable inventory levels within the yellow and green zone.

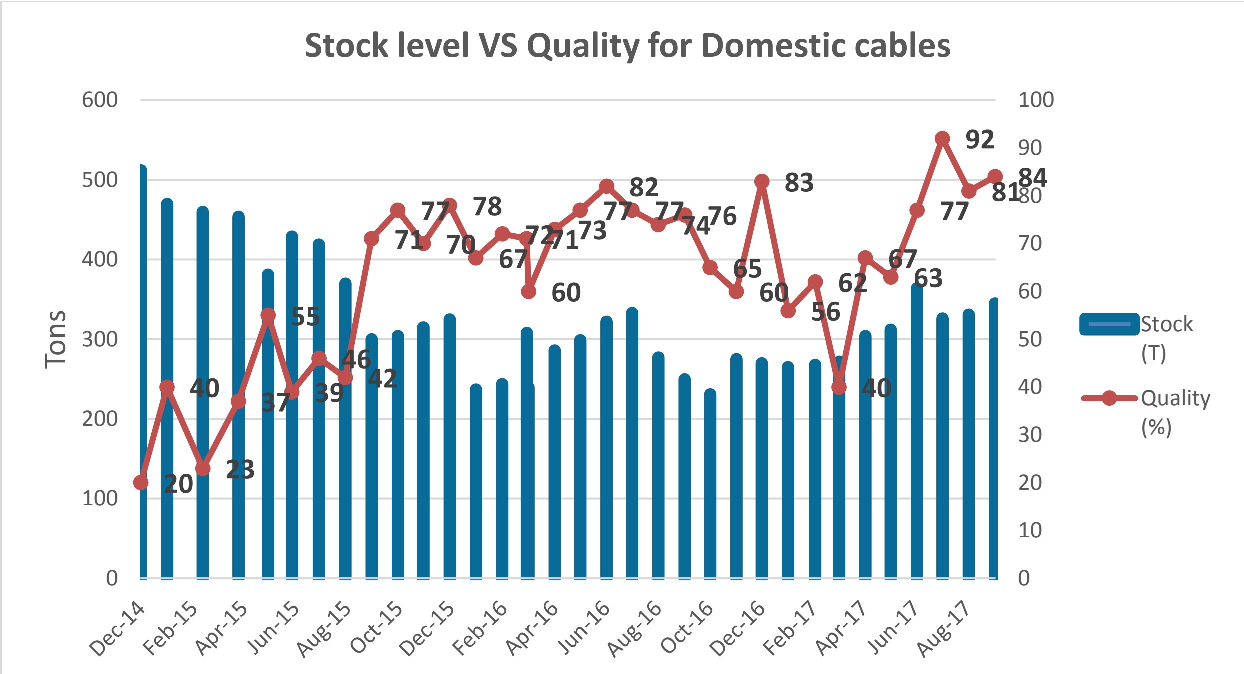
We can see as well how the quality of inventory was damaged almost for all families in June 2017, further to the management decision to increase inventory levels to cover the company's risk of shortage due to the bottleneck in production and large orders in hand. The quality was however improved back from June 2017 to December 2017 for almost all families once the temporary bottleneck situation was over, showing the flexibility of the DDMRP management system, allowing to make exceptions when necessary, and push back inventory to better levels when needed.

For the telecom family, the quality was not improved as quickly as the other families from June 2017 to December 2017, since the sales were not as continuous as the other families, which means that the quantities that was kept in stock as buffer in the bottleneck period were not all sold as quickly as the other families, keeping certain excess levels in stock, due the low quality of inventory at 44% only.

To shed more light on the quality of inventory evolution, we will use the data available from Report 2 in the Annex to examine closely the evolution of the domestic family.

The below chart shows the evolution of the inventory level of the domestic family versus the evolution of the quality of the same inventory.

Chart 12: Domestic Evolution of Inventory Level versus Quality of Stock



As we can see in the chart, most of the bad quality of inventory for the domestic family was coming from excess inventory levels, since the stock levels at the beginning were much higher, and started decreasing during 2015, and at the same time of stock decrease the quality increased to the average of 70% and moved in a more stable manner after that.

There is a strong decrease in the quality at some point during 2017, which was due to selling of big quantities compared to normal, or what is referred to as elephant orders sales, which means that there were unexpected big order sales, specifically in march 2017, selling a total of 265 tons of metals of products, compared to only 147 tons in February 2017 and 185 tons in April 2017. This large demand reduced the inventory levels of certain products into the red zone, compared to the increase of sales level, which reduced the overall quality. The lower quality of the inventory was quickly improved in the following months by increasing back the stock, but with the correct level of increase all while avoiding excess inventories, and avoiding falling under a bullwhip effect, which increased back the overall quality of the inventory.

By examining the evolution of the quality of the inventory and the reaction of the implemented system to bottlenecks in production and unexpected huge orders, we can witness the efficiency of the mix DDMRP and Kanban system in providing stable inventory management practices and production replenishment campaigns, with quick reaction and correction capabilities to changes, while avoiding over producing and over reacting, or falling under a bullwhip effect, keeping the company's inventories under steady control.

E.6.d) Inventory KPIs Consolidation

In this section, we will try to consolidate the information shared in the previous sections, and look at it all at once to see how each indicator was evolving compared to the others for each family.

All the tables will be extracted from Report 2 in the Annex, and for comparison purposes, we will only check the same months checked in the previous sections.
The data that we will be looking at are:

- Inventory level, referred to as "Stock", in Tons of metal in products.
- Sales volumes, referred to as "Sales", in Tons of metal in products.
- Inventory coverage, in weeks of sales, referred to as "Coverage".
- Quality of the inventories, referred to as "Quality", in percentage.

Below we can see the evolution of the domestic family indicators.

Table 33: Liban Cables Domestic Family Indicators' Evolution

DOMESTIC Family				
	Stock (Tons)	**Sales (Tons)**	**Coverage (weeks)**	**Quality (%)**
Dec-14	512	158	9.4	43
Jun-15	419	159	7.6	46
Dec-15	237	203	4.4	67
Jun-16	322	212	6.2	82
Dec-16	270	180	5.3	83
Jun-17	364	221	7.2	77
Dec-17	277	154	5.9	81

In the first two months examined, it was clear that the inventories were higher than needed, compared to the sales volumes, and the low quality of the inventory was mainly due to excess inventories more than shortages, although some shortages may have been also found.

In December 2015, we could deduct that there was an excessive reduction of the inventories compared to before, but at the same time it was accompanied with an increase in the sales compared to before, which drove the coverage down, while increasing the quality of the inventories, but not to optimal levels, which means that probably due to the spike in sales, there were some shortages, and the system needed time to adapt.

In the following months, the inventory level was more stable, as well as the sales evolution, while at the same time maintaining a stable level of coverage and quality of inventories, which emphasize the stability of the management system through DDMRP.

The conscious inventory increase in June 2017 had clear negative impact on the coverage as well as the quality of the inventory, but quickly corrected by the end of 2017.

In total, we could clearly examine how the key indicators of the domestic family, from inventory level, to inventory coverage and quality of stock, were constantly improving, in parallel with an increase of sales, which means that we were not experiencing shortage of items and negative customer satisfaction in general. This evolution of the indicators translates the added value and positive impact of implementing the DDMRP management system, in addition to the Kanban, compare to the previous management tool, and the change from the forecast driven replenishment process to the demand driven replenishment process.

Below we can see the evolution of the flexible family indicators.

Table 34: Liban Cables Flexible Family Indicators' Evolution

FLEXIBLE Family				
	Stock (Tons)	**Sales (Tons)**	**Coverage (weeks)**	**Quality (%)**

Jun-15	339	172	8.4	29
Dec-15	241	148	6.3	49
Jun-16	298	170	7.8	41
Dec-16	259	167	6.8	57
Jun-17	347	175	8.6	24
Dec-17	224	137	6.5	49

For the flexible family, the inventories were reduced in general, except for June 2017, but due to the large economical lot of production compared to the sales volume, the optimization was limited to around 50% of quality of stock, and around 6.5 weeks of inventory coverage.

In fact, compared to the domestic family, which had a target replenishment level between 5 and 9 weeks with most weight around 5 weeks, the flexible family has more diversity in term of replenishment threshold, starting in 5 weeks, but also going up to 11 and 13 weeks.

What we can examine, repeatedly in December 2015 and December 2016 and December 2017, is a reduction in inventory level, following a reduction in sales volumes, which simultaneously reduced the inventory coverage and improved the quality of the stock compared to the other periods. This correlated reduction in inventory to a decrease in sales and improvement of the coverage and quality, shows flexibility and reactivity of the system, as if a replenishment system is operating based on monthly forecast, or not flexible enough, once the sales volume decrease, it usually lead to an increase in inventory levels and deterioration in other inventory indicators, since the reaction time is usually slower and management got taken by surprise when sales decreases, and don’t have the time or conviction to reduce inventories simultaneously.

However, with the DDMRP management system, the cycle is flexible and reactive enough to closely follow the sales evolution and adjust accordingly, as quickly and accurately as possible, taken into consideration all other parameters related to various products.

Below we can see the evolution of the EAXT family indicators.

Table 35: Liban Cables EAXT Family Indicators' Evolution

EAXT Family				
	Stock (Tons)	**Sales (Tons)**	**Coverage (weeks)**	**Quality (%)**
Dec-14				
Jun-15				
Dec-15				
Jun-16	66	133	2.5	4
Dec-16	117	41	4.9	32
Jun-17	146	64	6.7	57
Dec-17	114	65	5.6	63

The evolution of the EAXT family were in a different direction compared to the domestic and flexible family. The implementation of DDMRP management system in EAXT was at a later stage than the other families.

For this family, the struggle was to have enough inventories to cover sales and not to reduce over inventories. In fact, the company's production capacity was not flexible enough or large enough to cover the sudden changes in demand.
The sales evolution of this family could easily double up from month to month, and then decrease in half the following month. During 2016 and 2017, we witnessed a maximum sales volume of 173 tons of metal, and a minimum sales volume of 41 tons of metal. A further example was a sales volume of 64 tons in June 2017, followed by 147 tons in July 2017, then 81 tons in August 2017.

The replenishment process through DDMRP was trying to catch up the high volatility of sales, through the moving average sales basis of the replenishment threshold, in addition to the using the weekly meetings with Sales representatives to try to get a feeling of market trends and expected sudden order or increase in demand.

But at the end, due to the market nature of this family of products, the key indicators of this family were not optimized as it should have been, through the automatic replenishment system.

To try to smooth the demand volatility, it was communicated to the sales representatives to try to split the deliveries and big orders, and not to give immediate delivery delay for orders that are larger than usual.

If we only examine the evolution of the above table, we can clearly see an improvement of the indicators of the inventories, by improving the quality of the inventories, through increasing the inventory levels and inventory coverage levels.

Below we can see the evolution of the energy copper family indicators.

Table 36: Liban Cables Energy Copper Family Indicators' Evolution

ENERGY COPPER Family				
	Stock (Tons)	**Sales (Tons)**	**Coverage (weeks)**	**Quality (%)**
Dec-14				
Jun-15				
Dec-15	372	97	14.7	67
Jun-16	356	141	12.3	76
Dec-16	211	127	8.5	77
Jun-17	500	147	13.3	49
Dec-17	345	80	11.7	84

The replenishment threshold of the energy copper products is not as diversified, with high threshold levels varying between 9 and 13 weeks, due to a longer production lead time for these cables, but with enough production capacity to cover the requirements for sales.

That is why, the quality of the inventory was acceptable from the initial time of implementation of the DDMRP system. In other words, before the DDMRP implementation, this family was somewhat well managed through the monthly forecast system, since the long lead time for production for most of the products, justified providing similar long delivery delay for sales demand, which provided more accurate forecasts of incoming requirements, and allowed the production to reaction with reasonable delay compared to demand requirement and offered lead time offered to clients.

Implementing the DDMRP system, allowed to further optimize the key performance indicators of inventories as shown in the above comparison.
Between December 2015 and June 2016, the sales volume increased, while at the same time the quality of the inventories improved in addition to a decrease in the coverage, all which means the existence of a slight excess of stock in certain items. Moving with the same concept to December 2016, the quality of the inventory remained high, while the actual inventory level decreased along with sales level and coverage.

The spike in stocks in June 2017 clearly had its negative impact on the coverage and quality of the inventory, but it was quickly corrected by the end of 2017 to a higher level in quality of the inventory, despite a sharp reduction in sales.

In summary, although this family was relatively well managed under the monthly forecast system, due to its long lead time in production and offered sales orders' delivery time to clients, the implementation of the DDMRP allowed to further optimize the key indicators of its stocks and provided further flexibility of reaction to changes in trends.

Below we can see the evolution of the ENYM family indicators.

Table 37: Liban Cables E(NYM) Family Indicators' Evolution

E(NYM) Family				
	Stock (Tons)	**Sales (Tons)**	**Coverage (weeks)**	**Quality (%)**
Dec-14				
Jun-15				
Dec-15	86	42	7.6	61
Jun-16	97	45	8.3	43
Dec-16	83	39	7.7	70

Jun-17	128	65	9.5	38
Dec-17	91	32	8.1	63

The E(NYM) family manifest the most stability in the evolution of its inventory indicators.

The inventory levels for almost all months was more or less stable, in parallel with a similar stability in sales volumes, which explains similar stability in the coverage of the inventory versus sales. This same stability was also visible in the quality of the inventory, expect June 2016, which is the result of the slight increase in stock and coverage more importantly than the variation in sales.

The change in June 2017 in inventory levels, which was the result of the management decision to increase, was more important than the need in sales, which had a clear impact on the increase in coverage and reduction in the quality of the stock, due to excess inventories.

Overall, we did not see much improvement in the inventory indicators of this family, but rather stability, while not reaching higher quality of the inventory. That cap on quality increase would be the presence of excess inventories in some items that does not have much frequency in sales, but once produced it would require some time to be turned.
Aside for that, implementing the DDMRP brought simply stability to the inventories' turn of this family, as well as flexibility and reactivity, which is clear by the ability to improve back all indicators from June 2017 to December 2017, once the exceptional needs experienced in the summer of 2017 were over, the system manage quickly to get back to normal level of inventories and inventory indicators.

Below we can see the evolution of the telecom family indicators.

Table 38: Liban Cables Telecom Family Indicators' Evolution

TELECOM Family				
	Stock (Tons)	**Sales (Tons)**	**Coverage (weeks)**	**Quality (%)**
Dec-14				

Jun-15				
Dec-15				
Jun-16	20	8	9	27
Dec-16	25	9	9.9	78
Jun-17	31	7	14	60
Dec-17	28	5	15.3	44

The telecom family represent very few products, with not much stability in sales, mostly not enough volume of sales. This is a family of products that would have been treated as MTO or MTS with not much impact on inventories or sales.

Consequently, implementing the DDMRP did not have much impact on the inventory indicators, except improving the quality, but had in return an increase in the coverage. However, the variations on the indicators does not mean much, taking into consideration the weight of the family's figures.

The increase in the inventory in June 2017, like what was done for the other families, was not quickly corrected by December 2017 like the other families, due to the low frequency in sales and weight.

In short, the impact of implementing the DDMRP management style would bring as much added value, as important as the products are compared to the total portfolio of the company. For products with less impact on the total portfolio, the results of the DDMRP would be as limited, but at least it would bring some stability in the reactions and help avoiding bullwhip effects.

E.6.e) Reducing Shortages

The purpose of improving inventory management is not to reduce the inventory level, but to reach the right level of inventory, which is not high enough to damage the company's operating working capital, but also not low enough to damage its sales and customer satisfaction.

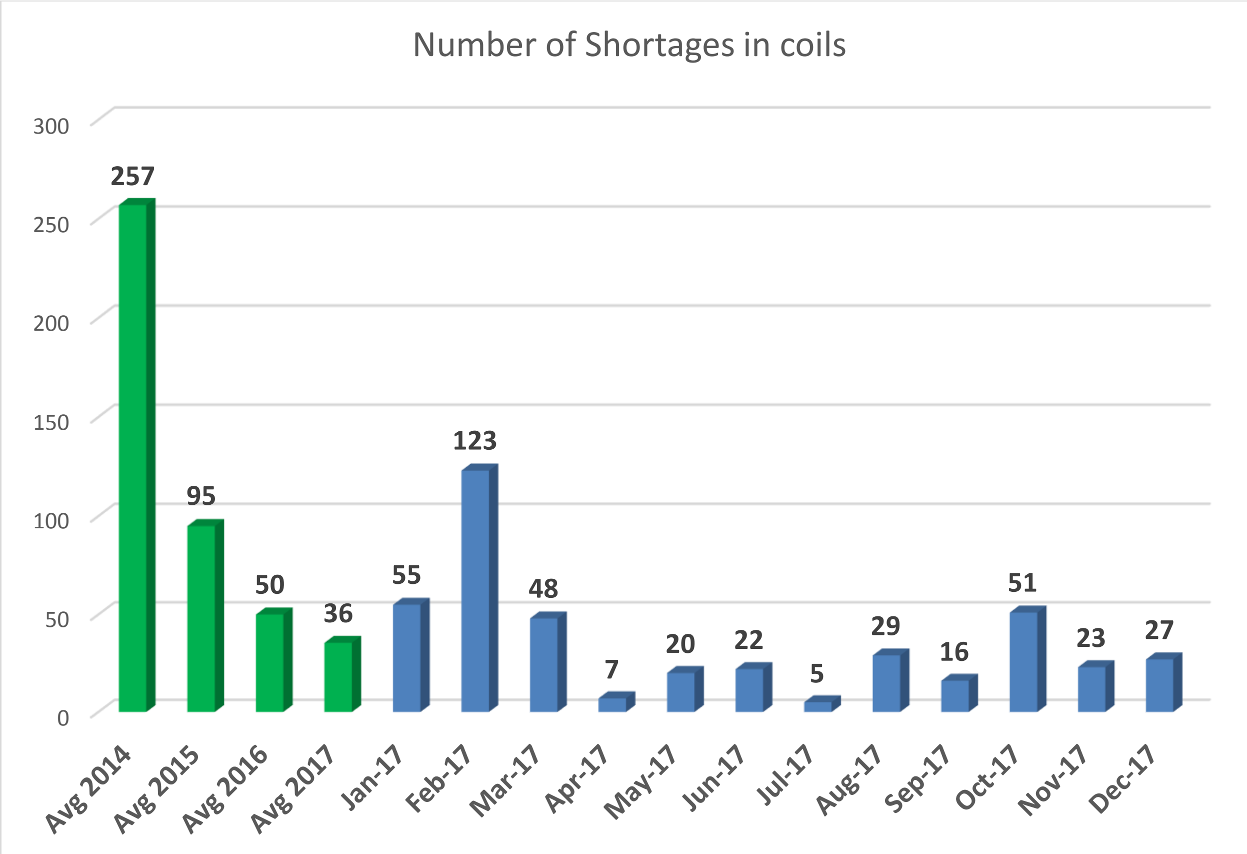
That is why, it was important to measure in the previous sections the coverage of the inventory and the quality of the inventory, more than the level of the inventory itself.

Furthermore, to measure the customer satisfaction, once more indicator was followed, which is measuring the number of shortages of items.

To do so, an employee in the finished goods warehouse was responsible of registering how many times the sales people inquired about an item, and that same item was out of stock. This process would mostly apply for products sold in coils, as the products sold in drums are mostly produced on demand, while most of the stock items are in coils.

This data was all gathered in a supply chain dashboard, example shown in Annex Report 4, along with other relative data to the supply chain department. From this dashboard, we will gather the shortages in coils and study the evolution, in the below chart.

Chart 13: Liban Cables Coils Shortage Evolution



Based on the above recap, the average number of shortages of coils in 2014 (before the implementation of the DDMRP and Kanban systems) was 257 shortages per month. After the implementation of the new system, the average number of shortages became only 95 shortages per month in 2015, then continuously decreased to 50 shortages in 2016 and 36 shortages in 2017.

Through 2017, the highest number of shortages experienced was 123 shortage in February, probably due to elephant orders or unexpected demand, while the lowest number of shortages was in July 2017 with only 5 shortages.

The impact of the management's decision to increase the inventories during the summer of 2017 is manifested with a very low level of shortages during the same period, but at the same time, after this period was over and the inventory levels were reduced back to normal levels for the rest of the year, the number of shortages did not increase much.

In general, this study of shortages shows how implementing the DDMRP and Kanban to manage the inventory replenishment helped reduce the shortages in the inventory, which improve the customer satisfaction and boosts sales, all while reducing the inventory levels and improving the coverage and quality of the inventories at the same time.

E.6.f) Stabilizing inventory levels & volatility

To examine the impact of DDMRP implementation and Kanban implementation, compare with the previous replenishment method, and check its impact on stabilizing the inventory levels and avoid bullwhip effects under market volatility, we will make an in-depth study on few products, from January 2014 until December 2017.

We will select different products, from different families, having different criteria, from the volume & frequency of sales, to replenishment cycle, both in speed of replenishment and quantity (minimum order quantity). Some items will have the implementation of DDMRP only, and some others will be subject to the DDMRP and Kanban implementation.
The chosen products are:

- DNYA 1.5 (3) Noir (black)
- DNYA 2.5 Gris (grey)
- DNYA 3 bleu (blue)
- DNYA 4 rouge (red)
- FNYZ 2*1.5
- FNYAF 240
- E(NYM) 3*10+6
- TLIBTEL2P05

The parameters that we will look at are:

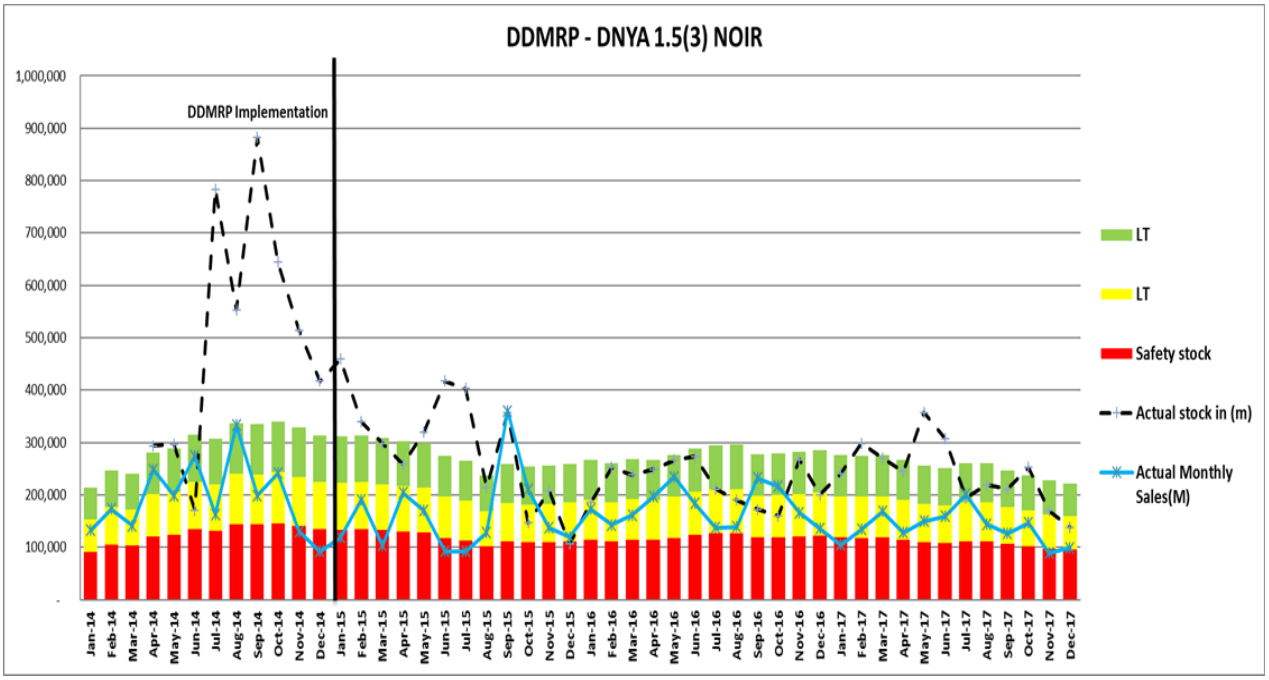
- The inventory level of the product, referred to in the chart as “Actual stock in (m)”, “m” being meters of cables, and displayed in the chart as a dotted black line.

- The sales level of the product, referred to in the chart as "Actual Monthly Sales (M), "M" being meters of cables, and displayed in the chart as a straight line, sometimes in blue color and sometimes in green color.
- We will see a horizontal line separating the chart, between the period before the implementation of DDMRP and the period after the implementation, the line will have next to it the phrase "DDMRP implementation".
- We will see a horizontal line separating the chart, between the period before the implementation of Kanban and the period after the implementation, the line will have next to it the phrase "KANBAN".
- We will illustrate on the chart the three zones of DDMRP for each product:
    - The Red Zone
    - The Yellow Zone
    - The Green Zone

    To follow the inventory evolution compared to the three zones
- The data will be examined monthly, and in meters of cables
- In some cases, the inventory level for some product is missing at the early stages of the study (the first few months of the year 2014) due to the absence of accurate data in the company's database.

We will start examining the products by order, as mentioned above, and continue one by one. The first chart below shows the evolution of the parameters of the product DNYA 1.5 (3) Noir.

Chart 14: DNYA 1.5 (3) Noir DDMRP Parameters Evolution



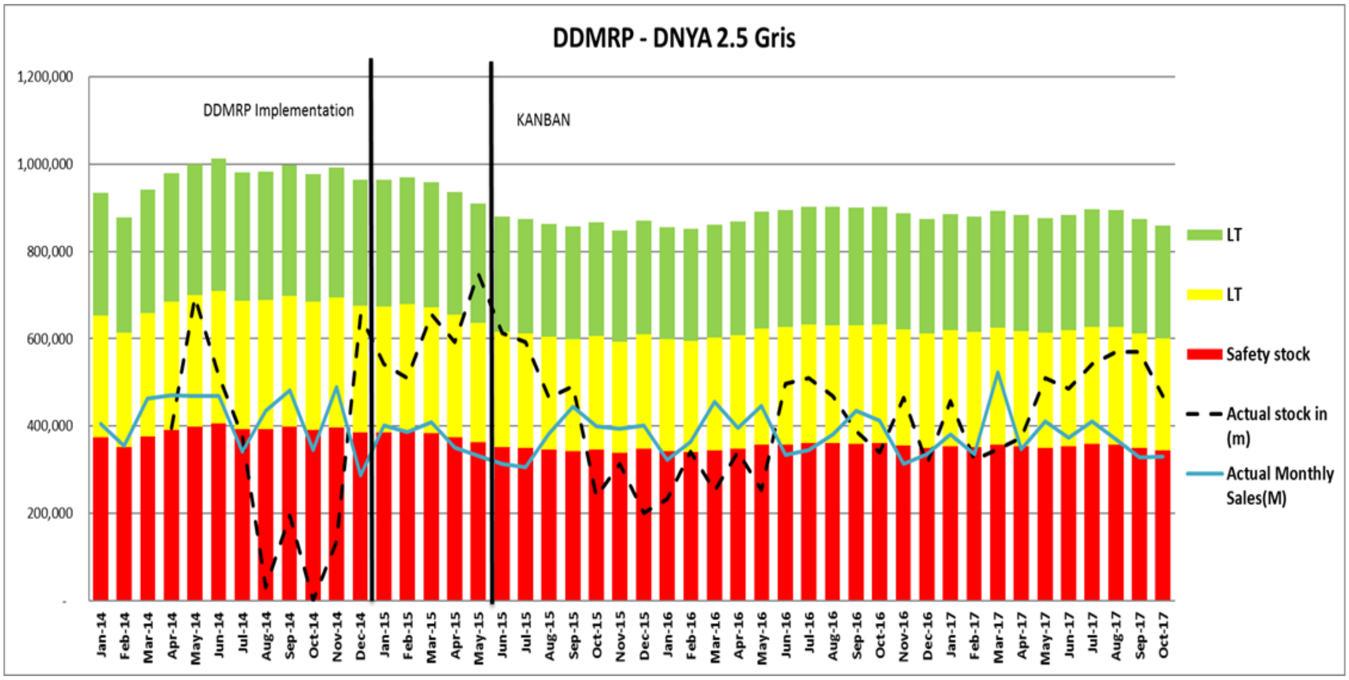
From the DNYA 1.5 (3) Noir chart, we can observe the following:

- The implementation of DDMRP started in January 2015.
- Kanban was not implemented for this item.
- The sales volume is not stable; we could see that it could double and even triple within few months.
- The DDMRP zones are not fixed, due to the usage of moving average to calculate the replenishment threshold, the DDMRP zones were increasing and decreasing, reaching a high of around 300,000 (all three zones together) some months, and were reduced to around 220,000 by end of 2017.
- The inventory level before the implementation of DDMRP started at an acceptable level in the middle of 2014, but then incredibly increased to very high levels, much more than needed. However, after the implementation of DDMRP, the inventory level started decreasing after few months of implementation, and then in most of the period between the year 2015 and end of 2017, the stock was hovering within the DDMRP correct zone, not falling into the red (danger) zone, and not increasing too much about the top of green zone.

These observations show how using the DDMRP management system brought stability to the inventory levels, keeping it from skyrocketing like before to very high levels, following the volatility of sales, and at the same time insuring the customer satisfaction indicator by avoiding shortages, since the inventory level never reach a zero level, or in this case, it never even went down into the safety zone.

The next chart would examine the parameter evolution of the DNYA 2.5 Gris product.

Chart 15: DNYA 2.5 Gris DDMRP Parameters Evolution



From the DNYA 2.5 Gris chart, we can observe the following:

- The implementation of DDMRP started in January 2015.
- The implementation of Kanban started in June 2015.
- The sales volume is not stable; but it follows a clear trend with some stability
- The DDMRP zones are not fixed, due to the usage of moving average to calculate the replenishment threshold, but we can see a relative stability in the zones, in relation to the relative stability in sales.
- The inventory level before the implementation of DDMRP witnessed sharp variations, with a high of over 600 meters in May 2014, but then reaching very critical levels, and

shortage levels in august 2014 and October 2014, before going back up by the end of the year 2014, all while having relative stable sales. This means that the forecasts that were giving for replenishment at that time were not accurate, even wrong, which led to producing less than needed and reaching shortage levels of inventory.

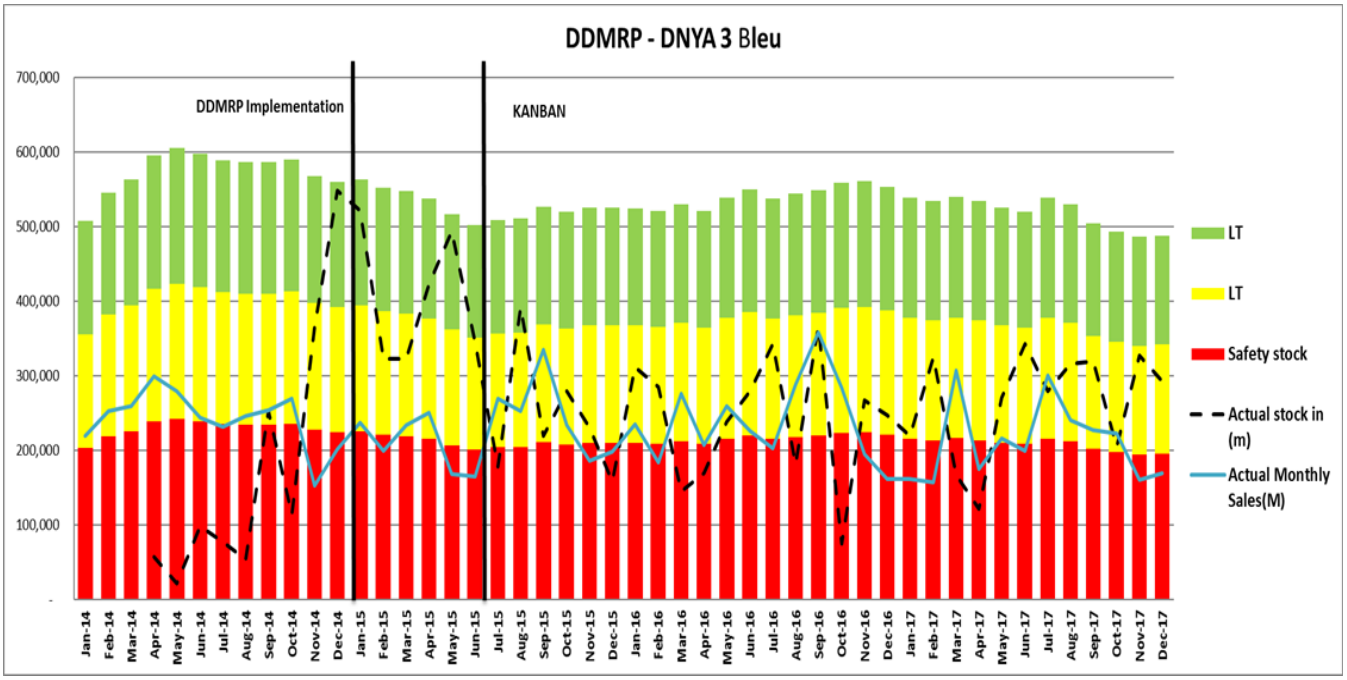
After the implementation of the DDMRP, the inventory level increased and remained within the normal zone (between yellow and green), never going down to the red zone.

After the implementation of Kanban, the inventory levels became constantly below the “top of yellow” which was set as the maximum inventory level through the number of Kanban cards, but at the same time, the inventory level never reached shortage situations, it became coherent with the level of sales; the line of sales and line of inventory became intertwined, moving in harmony.

In these observations, it was clear how by using the forecast replenishment model the inventories were not experiencing stable level, although the sales evolution was somewhat stable, and after implementing the DDMRP the inventory level increased to healthy levels. Later by implementing the Kanban, the inventory levels were better optimized, reduced further than the DDMRP phase, but not going down to dangerous levels, and maintaining a good evolution with sales.

The next chart would examine the parameter evolution of the DNYA 3 Bleu product.

Chart 16: DNYA 3 Bleu DDMRP Parameters Evolution



From the DNYA 3 Bleu chart, we can observe the following:

- The implementation of DDMRP started in January 2015.
- The implementation of Kanban started in June 2015.
- The sales volume is not stable; but it follows a clear trend with some stability
- The DDMRP zones are not fixed, due to the usage of moving average to calculate the replenishment threshold, but we can see a relative stability in the zones, in relation to the relative stability in sales.
- The inventory level before the implementation of DDMRP witnessed sharp variations, with a low close to zero and shortage level, and high close to the excess level. This volatility was coupled with relative stability in sales, which means that the forecast management for inventory replenishment was not as stable or accurate.

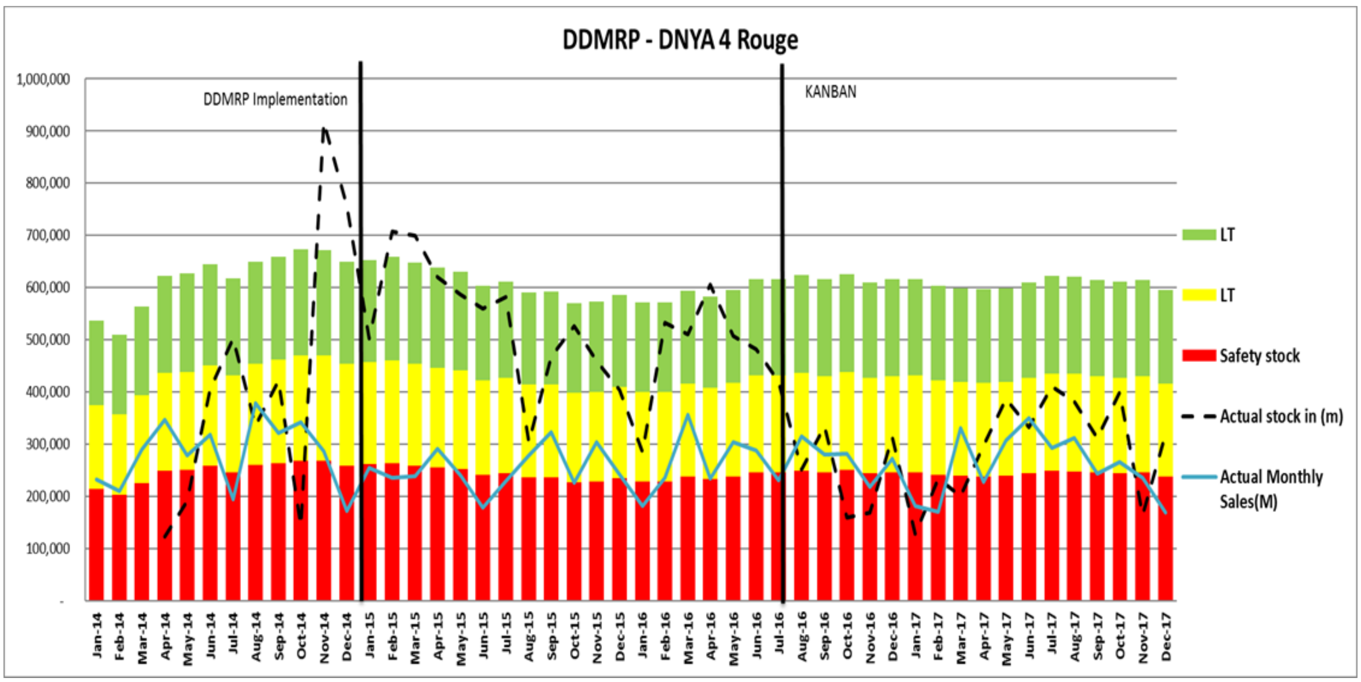
  After the implementation of the DDMRP, the inventory level was stable and remained within the normal zone (between yellow and green), never going down to the red zone.

  After the implementation of Kanban, the inventory levels became constantly below the "top of yellow" which was set as the maximum inventory level through the number of Kanban cards, but at the same time, the inventory level never reached shortage situations, it became coherent with the level of sales; the line of sales and line of inventory became intertwined, moving in harmony.

In these observations, it was clear how by using the forecast replenishment model the inventories were not experiencing stable level, although the sales evolution was somewhat stable, and after implementing the DDMRP the inventory level moved to healthy levels. Later by implementing the Kanban, the inventory levels were better optimized, reduced further than the DDMRP phase, but not going down to dangerous levels, and maintaining a good evolution with sales.

The next chart would examine the parameter evolution of the DNYA 4 Rouge product.

Chart 17: DNYA 4 Rouge DDMRP Parameters Evolution



From the DNYA 4 Rouge chart, we can observe the following:

- The implementation of DDMRP started in January 2015.
- The implementation of Kanban started in January 2016.
- The sales volume is not stable; but it follows a clear trend with some stability
- The DDMRP zones are not fixed, due to the usage of moving average to calculate the replenishment threshold, but we can see a relative stability in the zones, in relation to the relative stability in sales.

- The inventory level before the implementation of DDMRP witnessed sharp variations, decreasing to the red zone, and immediately climbing over the excess level, by far. This volatility was coupled with relative stability in sales, which means that the forecast management for inventory replenishment was not as stable or accurate.

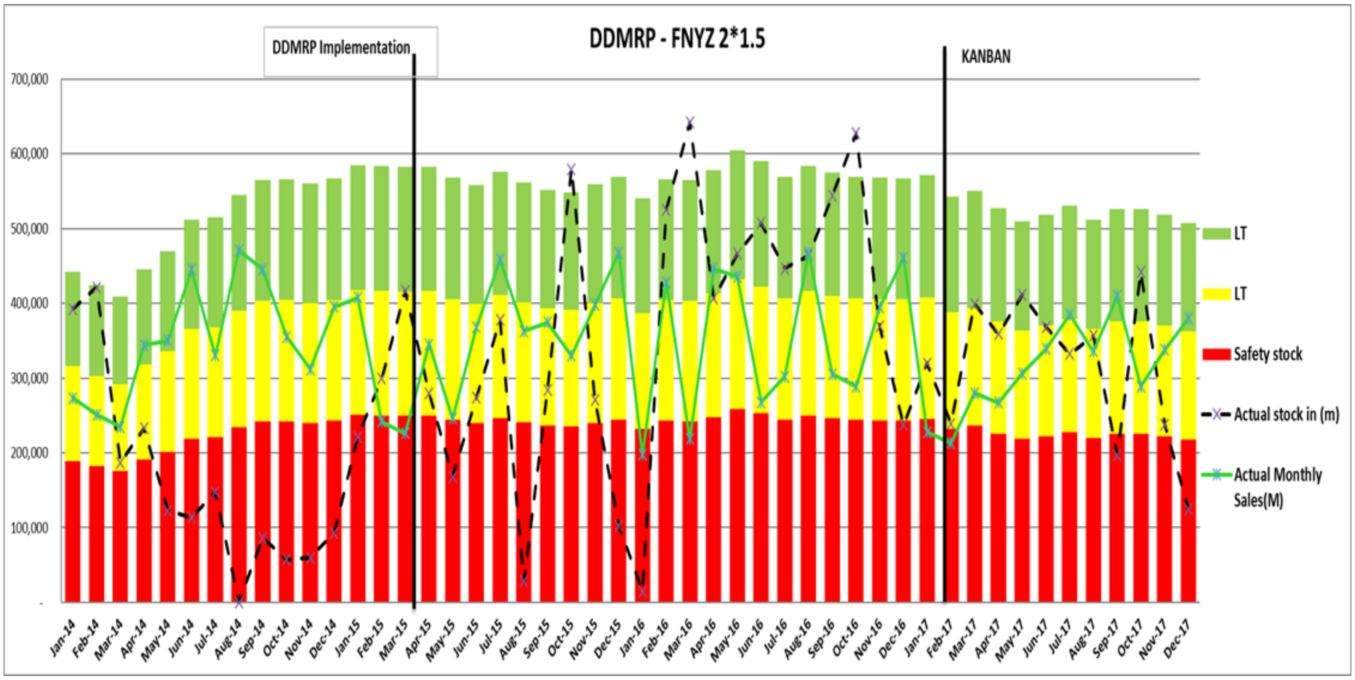
  After the implementation of the DDMRP, the inventory level remained within the normal zone (between yellow and green), never going down to the red zone, which shows the stability in replenishment management.

  After the implementation of Kanban, the inventory levels became constantly below the “top of yellow” which was set as the maximum inventory level through the number of Kanban cards, but at the same time, the inventory level never reached shortage situations, it became coherent with the level of sales; the line of sales and line of inventory became intertwined, moving in harmony.

In these observations, it was clear how by using the forecast replenishment model the inventories were not experiencing stable level, although the sales evolution was somewhat stable, and after implementing the DDMRP the inventory level moved to healthy levels. Later by implementing the Kanban, the inventory levels were better optimized, reduced further than the DDMRP phase, but not going down to dangerous levels, and maintaining a good evolution with sales.

The next chart would examine the parameter evolution of the FNYZ 2*1.5 product.

Chart 18: FNYZ 2*1.5 DDMRP Parameters Evolution



From the FNYZ 2*1.5 chart, we can observe the following:

- The implementation of DDMRP started in March 2015.
- The implementation of Kanban started in February 2017.
- The sales volume is not stable; with sharp variations from month to month, with volumes doubling from month to month, and them going back to half the following month.
- The DDMRP zones are not fixed, due to the usage of moving average to calculate the replenishment threshold, but were kept relatively stable, since the sharp variation in sales, although very different from month to month, provided a global trend.
- The inventory level before the implementation of DDMRP was mainly in the red zone, even reaching a shortage position in August 2014.

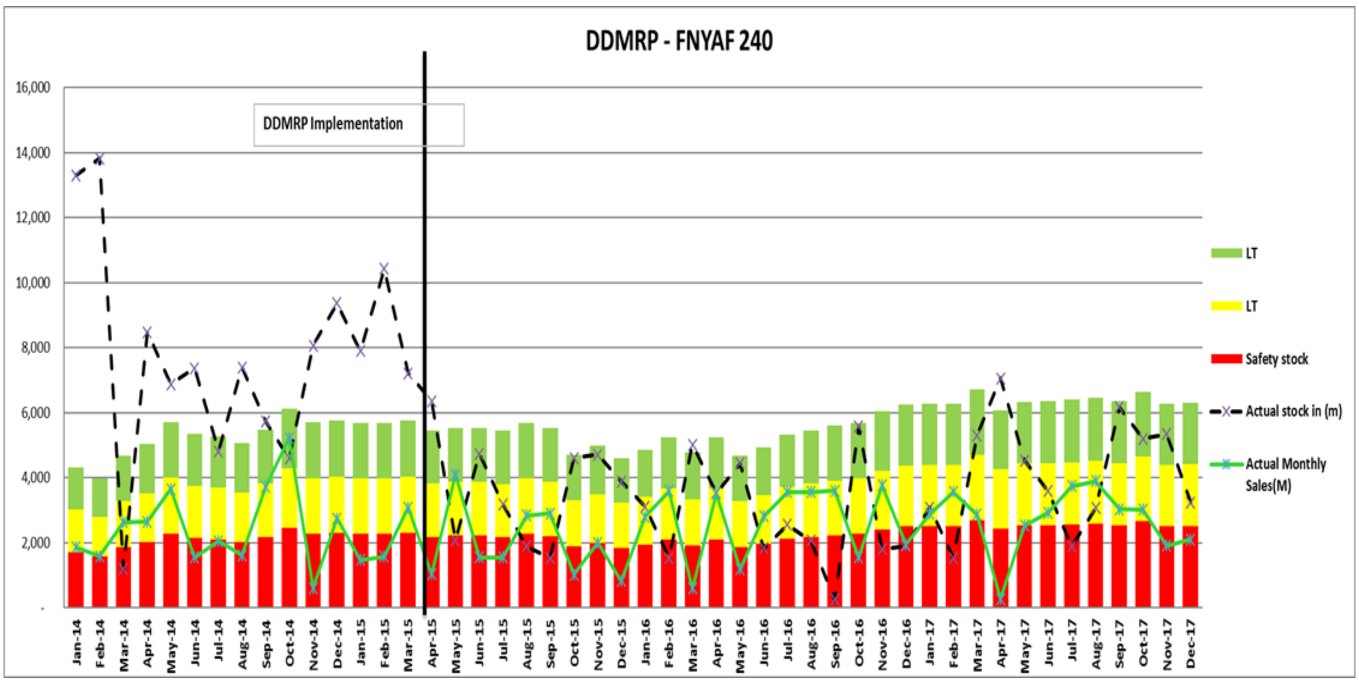
  After the implementation of the DDMRP, the inventory level followed a sharp trend of ups and down, following the sharp variations in sales, in addition, the large “minimum order quantities” for production, made the variation of inventories as sharp as the sales.

  After the implementation of Kanban, the inventory levels became constantly more stable, not reaching the excess levels reached before, but at the same time, never reached shortage situations, it became coherent with the level of sales; the line of sales and line of inventory became intertwined, moving in harmony.

In these observations, we could deduct how the inventory levels were within dangerous zone for most of the previous period. After the implementation of DDMRP, the inventory level followed the variation of sales, but still reached shortage level twice, and at the same time exceeded the excess level three times, all due to the longer lead time for production and large minimum order quantities. However, after the implementation of Kanban, it was possible to reduce the lead time for production, as well as the minimum order quantity, which helped provide quicker reaction to demand, and at the same time with smaller and adequate production quantities, providing harmonious evolution of inventories with sales.

The next chart would examine the parameter evolution of the FNYAF 240 product.

Chart 19: FNYAF 240 DDMRP Parameters Evolution



From the FNYAF 240 chart, we can observe the following:

- The implementation of DDMRP started in April 2015.
- Kanban was not implemented for this item.
- The sales volume was somewhat stable, with some sharp variations.

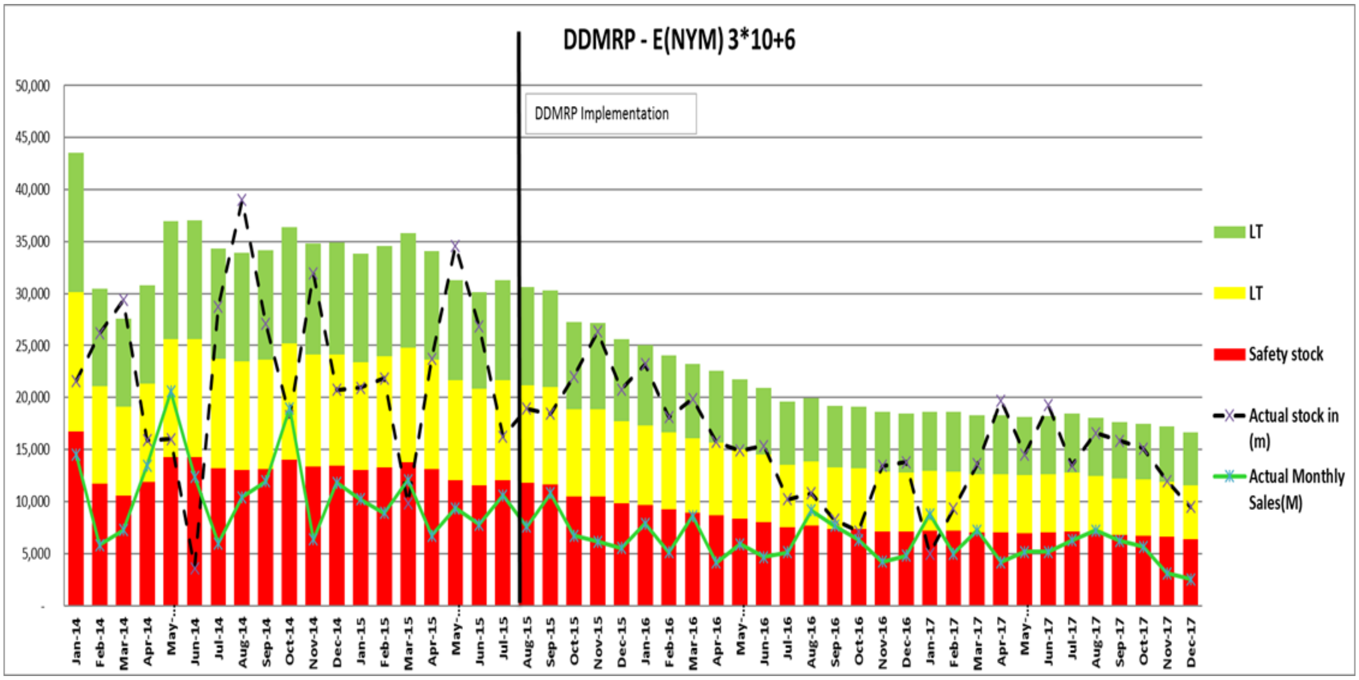
- The DDMRP zones are not fixed, due to the usage of moving average to calculate the replenishment threshold, but were kept relatively stable, since the sales evolution provided a global trend.
- The inventory level before the implementation of DDMRP was constantly in excess position, always above the top of green, except few exceptions, but the global trend was a position of excess inventory level, which could be interpreted as excess sales volume forecasting as well as large production quantities.

  After the implementation of the DDMRP, the inventory level drop within the DDMRP management zone, reducing the inventory levels to below the top of green, with one single exception, and reaching a shortage position once in September 2016.

In these observations, we could deduct how the forecast management model lead to excess inventory levels, way more than needed, and probably as well the correct inventory level for this item was not measured or properly assessed with the minimum order quantity for production. However, after the implementation of DDMRP, the inventory level was reduced to below the excess levels, which means that the minimum order quantity for production was revised to more logical levels, as well as the management style of DDMRP allowed for inventory to closely follow the sales evolution and show the same trend.

The next chart would examine the parameter evolution of the E(NYM) 3*10+6 product.

Chart 20: E(NYM) 3*10+6 DDMRP Parameters Evolution



From the E(NYM) 3*10+6 chart, we can observe the following:

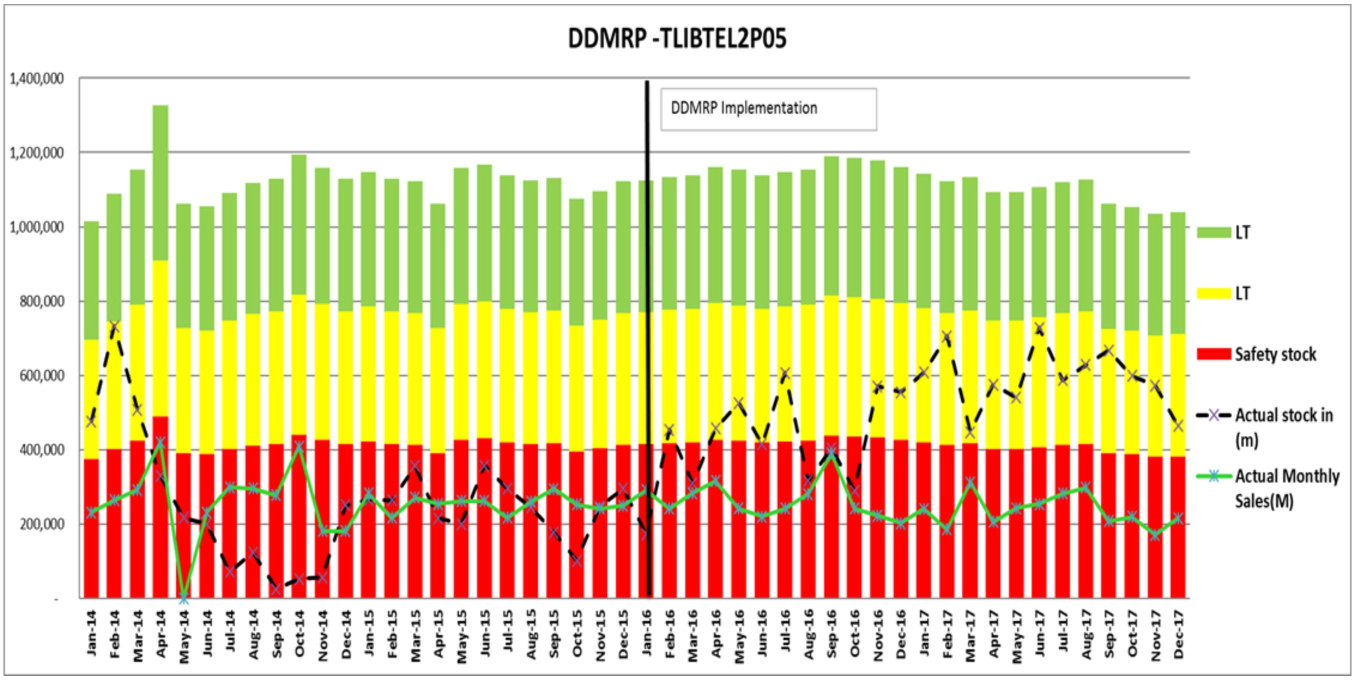
- The implementation of DDMRP started in April 2015.
- Kanban was not implemented for this item.
- The sales volume was very volatile before the implementation of DDMRP, but more stable after it.
- The DDMRP zones were moving in a decreasing mode. The use of the moving average for setting the DDMRP zones followed the evolution of sales, and reduced the parameters which were set very high compared to what is needed. This correction was not done immediately at the beginning of the implementation, but gradually following the evolution.
- The inventory level before the implementation of DDMRP was volatile, but within reasonable levels compared to the standards set at that time, but if we compare if with the inventory levels after the implementation of DDMRP, we can see that it was much higher.

  After the implementation of DDMRP, the inventory level gradually decreased, catching up closely with the level of sales, remaining within the healthy zone of inventory level (between the yellow and green), and almost never going down to red.

In these observations, we could clearly see how the implementation of DDMRP drastically changed the parameters of this item, reducing the replenishment threshold to normal levels, since it was very high before the implementation. The variation of inventories before the implementation was very sharp, and much higher than the sales volume, which shows a style of nervous reaction mode in the forecast replenishment system. This sharp variation of inventories was smoothed after the implementation of the DDMRP.

The next chart would examine the parameter evolution of the TLIBTEL2P05 product.

Chart 21: TLIBTEL2P05 DDMRP Parameters Evolution



From the TLIBTEL2P05 chart, we can observe the following:

- The implementation of DDMRP started in January 2016.
- Kanban was not implemented for this item.
- The sales volume is showing a very stable and clear trend, with few exceptions in 2014.
- The DDMRP zones were moving with the moving average, but the variation is not important since the variation in sale is not as important, that is why the DDMRP zone are relatively stable.

- The inventory level before the implementation of DDMRP was constantly in the red zone, which means that the sales forecasts was constantly less than the reality, always underestimating the real demand, and probably as well underestimating the correct level of inventory to keep in stock for that demand.

  After the implementation of DDMRP, the inventory level gradually moved up out of the red zone, and remained steadily in the yellow zone. There were no sharp reactions to increase the inventories from the red zone, the increase was just right as needed, but not nervous enough to increase the stock too high.

In these observations, we could deduct that in the forecast model, the sales team responsible for the demand signal was underestimating the demand level, as well as the correct level of inventory to cover sales. After the implementation of DDMRP, the management team learned how to set the correct or right level of inventory to cover sales demand, and the inventory level was pushed up to remain in a healthy situation, all while maintaining a steady evolution in parallel to the sales evolution.

The below table shows a comparison summary of the 8 examined products.

Table 39: 8 Products DDMRP vs Kanban Results

Product	**Start of DDMRP**	**DDMRP Zone (inventory positioning)**	**DDMRP impact on Inventory level**	**Start of Kanban**	**Kanban impact on Inventory level**
DNYA 1.5 (3) Noir	January 2015	Variable – continuous corrections	Reduction from excess levels to Yellow & Green zone	Not done	Not applicable
DNYA 2.5 Gris	January 2015	Variable – continuous corrections	Increase to Yellow & Green zone, compared to dangerously low	June 2015	Reduction below Top of yellow, relative stability at the edge of

			levels before		Red – very close to sales level
DNYA 3 bleu	January 2015	Variable – continuous corrections	Stability within the Yellow & Green zone, compared to dangerously low levels before	June 2015	Reduction below Top of yellow, relative stability at the edge of Red – very close to sales level
DNYA 4 rouge	January 2015	Variable – continuous corrections	Stability within the Yellow & Green zone, compared to excess & low levels before	January 2016	Reduction below Top of yellow, relative stability at the edge of Red – very close to sales level
FNYZ 2*1.5	March 2015	Variable – continuous corrections (increased compared to previous)	Increased to compared to very low levels before – but we could notice points of excess & dangerously low levels due to strong volatility in sales volume	February 2017	Reduction below Top of yellow, we could no longer see sharp changes to excess or shortages – variation much closer to sales level
FNYAF 240	April 2015	Variable – continuous corrections	Reduction from excess levels to Yellow & Green zone	Not done	Not applicable
E(NYM) 3*10+6	April 2015	Variable – sharp decrease of	Stability of inventory within the Yellow & Green	Not done	Not applicable

		inventory positioning levels, which was much higher than needed	zone – but decreasing in parallel with the decrease of inventory threshold, moving closer to sales levels		
TLIBTEL2P05	January 2016	Variable – continuous corrections	Increase of inventories & relative stability within the Yellow zone, compared to very low inventories, always in the red zone before.	Not done	Not applicable

In summary, it was clear by studying the monthly evolution of key parameters for 8 products through the long period of 4 years how the implementation of DDMRP and Kanban helped optimize the inventory management and stabilize it.

Before the implementation of these two methods, the forecast management system was unable to predict the correct level of sales and it was not able to set the right level of inventory to cover that sales, and the replenishment threshold to launch production accordingly. That is why, we witnessed volatility in the inventory levels, excess quantities for some items and very low quantities for other items, all due to the lack of proper management system for inventory replenishment. In addition, the monthly replenishment lead to sharp changes in the inventory levels, as the reaction to missing quantities would come delayed, for many days or weeks after the withdrawal from inventories. This delay, waiting for a full month for the information and demand signals, was the main reason for sharp reaction, and excess reaction in replenishment, when the production capacity can respond to the need, and when it cannot, the inventory level would remain in the danger zone for several months, unable to catch up the evolution of sales.

After the implementation of DDMRP, the most important change was the proper setting of inventory levels and replenishment threshold to cover the expected demand, in addition, the weekly replenishment cycle provided very quick response to demand signals, launching replenishment process within only few days (maximum 5 days, and minimum 1 day) from the time of withdrawal from the inventory, in case the threshold level was reached.

This process allowed for the replenishment cycle to closely follow sales and stay up to date with any new demand signal, and created just the right reaction to the level of sales, avoiding excess reaction and bullwhip effects.

The result was the improvement of the inventory quality, reducing the inventory from excess levels, and increasing it from dangerously low levels, to proper levels that covers the needs of sales and its evolution. That is why, it was important to adopt the moving average of replenishment threshold, and inventory positioning, following the sales evolution, which was clear in the chart, moving all three DDMRP zones (red, yellow, green) in line with the evolution of sales, to follow market trend and maintain proper response level, in terms of speed of response, and volume of response.

The implementation of Kanban brought further optimization to the replenishment process.

It was clear in the presented charts how the inventory variations after the implementation of Kanban became less volatile, and more in line with the sales evolution.

That was due to the daily launch of the replenishment process adopted by the Kanban system, allowing daily reactions to demand signals and removal of items from the inventories.

Adopting Kanban allowed to reduce the inventory levels further down than the DDMRP, since the preparation of semi-finished items in the production zones, decoupling points, allowed to reduce the producing cycle. In addition to that, the daily launch reduced the replenishment launch cycle, which in total reduced the full cycle of replenishment for the items managed by Kanban. That allowed the management of the company to set lower inventory replenishment threshold for the items in question, by reducing further than the levels adopted by DDMRP. That is why, the Kanban allowed the optimization of the inventory management system further than the DDMRP, but only for the items eligible to be managed by Kanban, improving the inventory levels as well as the reaction time and good tracking of sales signals, which is why it was obvious from the charts how the inventory level after the implementation of Kanban was moving very closely and intertwined with the variation of sales, stabilizing the inventories as much as it could get.

After examining the above 8 products, the below table show a comparison between DDMRP and Kanban, in implementation, results, and explanation in which circumstance each can work, and in which cannot, and why?

Table 40: 8 Products DDMRP vs Kanban Summary

	DDMPR	Kanban
Implemented for all 8 items?	Yes	No
Why / why not	Items with enough regular sales, are considered as stock items, and thus can be managed by DDMRP	A certain minimum volume of sales / production is needed to launch Kanban management
Production capacity utilization	Multiple items (hundreds) managed by DDMPR can use the same production capacity, in turn of priority	Require dedication of production capacity, specific machines, to a single product, or less than a handful of products
Replenishment order launch	Weekly	Daily
Management involvement in production launch	Required to prepare and launch the production orders	Not required, production order launched and executed at workers' level
Production Order launch / product delivery	Few weeks / depending on machines availability	Weekly – few days, maximum 7
Decoupling points at Production workshop – semi finished products ready to use	Not needed to be coupled for specific products, only prepared for big groups	Mandatory required

Impact on Inventory level	Correction by increasing or decreasing toward the Yellow and Green zones	Decreasing below the Top of Yellow, and maintaining between the Top of Yellow and Top of Red
Products with recurrent sales, with volumes much below of the production capacity of a single machine	Can be managed by DDMRP, improving inventory levels compared to forecast management system	Cannot be managed by Kanban
Products with recurrent sales, with high volumes & frequency equal or near the production capacity of a single machine	Can be managed by DDMRP, improving inventory levels compared to forecast management system	Can be managed by Kanban, providing more optimized inventory levels compared to DDMRP

F – Discussion

In this section, we will try to analyze the results presented in the case study, and the lessons learned from the implementation of DDMRP and Kanban at Liban Cables SAL.

From the presented results, and the observations made, we will compare the implementation process of DDMRP to the implementation of Kanban, and then try to highlight the advantages and disadvantages of each system compared to the other, in addition to advantages and disadvantages of the mix DDMRP-Kanban compared to the old Forecast system used at Liban Cables SAL previously.

We will later try to shed some light on the limitations of this new system, when it can be used, and when it cannot be used, and in which companies.

Furthermore, we will try to map which products can be managed by such model, how to identify them, and how to put in place the management tools and follow up for it.

F.1) Comparison between implemented DDMRP and Kanban (implementation)

The setting up and implementation of DDMRP management style and Kanban were completely different one from the other, starting with the preparatory phases, to the communication, to the implementation and follow up.

The below table compare both implementation in each step.

Table 41: DDMRP versus Kanban implementation

Description	DDMRP	Kanban
Preparation & Data collection	The first step during the DDMRP implementation was the data collection and analysis, to decide which products could be managed by DDMRP for production replenishment cycle. That is why, all the items produced should be examined to decide which products should be labelled as make to order (MTO) and which products labeled as make to stock (MTS) – so the first step is the analysis and classification of all the company's products portfolio., with a wide-angle overview	The first step in Kanban is checking the company product portfolio of only MTS products, so there is no product analysis and classification like DDMRP, in this step, it is only the study of the MTS items, to understand the scale of sales and production, as well as the frequency of production and sales per product, to try to decide which specific items could be managed by Kanban for production replenishment management
Product selection	All MTS items are selected to be replenished through the DDMRP system, only the MTO items are left to be produced only on new clients' order, and all the company portfolio of MTS items would be replenished by DDMRP tools.	Very few MTS items are selected, the ones that manifest very high volumes of sales and production, as well as frequency, enough to be worth managing them on daily basis, and dedicate specific machines only to producing these items
Work flow	An analysis of the products replenishment process is made, from an administrative level, checking the replenishment cycle through excel files, studying the production lead time, delays on machines, historical production habits and problems.	A detailed analysis of the replenishment flow of the relative items is done, studying the steps of production, the capacity of the machines needed in production, to check the feasibility of managing by Kanban or not.

	Following this analysis, the DDMRP replenishment process would begin for all items simultaneously. The analysis is done by administrative people mostly.	The analysis is done jointly between administrative people and production responsible.
Buffer	Buffer levels are kept at the finished products levels, in order to maintain a good level of inventory within the yellow and green zones of DDMRP segregation, in line with each product sales needs and production lead time, to avoid shortage between production launch, and delivery of finished products to the warehouse.	Two buffer inventories are kept, the first at the finished products stage, linking it with the conveyance cards, and the second buffer is kept at the production level, in semi-finished stage, as decoupling points to help increase the production speed of the selected items and at the same time avoid shortages.
Replenishment	Replenishment is done by working on excel files, to generate inventory levels, sales levels, and needs for replenishment by product, based on the data extracted in the workflow.	Replenishment is done following the extraction of Kanban cards from the warehouse to the production workshop, transforming the conveyance cards into production cards.
Cycle	Replenishment cycle is launched on weekly basis, by updating inventory levels and sales (demand) level.	Replenishment cycle is launched on daily basis, whenever a product lot is sold, its relative conveyance card is sent to the production workshop on the same day.
Team involvement	Replenishment cycle is coordinated between supply chain administrative employees, preparing the replenishment needs, and production planning administrative employees, consolidating the needs and launching	Replenishment cycle starts with warehouse employees, gathering the conveyance cards, and sending them to production workshop, to production employees who consolidate conveyance cards and

	production orders, depending on products priorities and machines capacities and bottlenecks. The cycle is handled by white collar people (administrative employees).	transforms them into production cards, and launch production immediately. The cycle is handled by blue collar people only.
Follow up	Weekly meetings between supply chain people, production planning people, and sales people are done to coordinate the priorities and machines capacities, since various items are produced on the same machines, which creates the necessity to give priority to producing some items before others, depending on the needs, and that is why constant coordination and adjustments of production plans are needed.	No follow up meetings are needed, since the production of Kanban items is done on dedicated machines producing only the Kanban items, in a structured manner, thus no bottlenecks are experienced or adjustments to production priorities are needed, except in the case of machines breakdowns or mandatory maintenance campaigns.

This table highlighted the main differences in the implementation steps between DDMRP and Kanban, but we will check in a later part the main differences and methods of choosing which items can and should be managed by DDMRP or Kanban, why and how?

F.2) Advantages & Disadvantages of DDMRP versus Kanban compared to the forecast model

Various advantages and disadvantages of DDMRP and Kanban were discussed in the previous section, that is why, we will provide a consolidation and summary of it, and compare one model against the other in the below tables.

The first table will compare the advantages of the DDMRP and the advantages of Kanban compared to the forecast system.

Table 42: Advantages of DDMRP versus Advantages of Kanban

Description	DDMRP	Kanban
Segregation of duties	Ensuring separation of tasks between Production Control, Sales, and Supply Chain departments, putting control over product replenishment out of the hands of Sales and Production Control, keeping it only for Supply Chain.	Same impact on the departmental and structural level.
Enhanced interdepartmental communication	Enhanced communication achieved through repetitive meetings held between various stakeholders of the supply chain cycle, both periodic monthly and weekly meetings	No meetings are required to manage the Kanban replenishment cycle.
Empowerment of people	No blue collars employees are involved in the decision-making process, decision making remains on an administrative level	Blue collars employees (shop floor workers in warehouses and production lines) are no longer receivers of orders and decisions, but became part of the decision making and execution process, putting within their hands the power of successful implementation or failure of the full replenishment cycle
Launch production without management	Production replenishment process remains in administrative control.	Various administrative influences on decision-making, from internal politics to bureaucratical approvals and bias to certain angles within

interference		the company, is all isolated and removed from the decision-making process
Live monitoring	Constant monitoring of the reception of finished goods into the warehouse, and the deliveries of finished goods to the clients, in addition to the delay in production and pipeline of items expected to be produced and delivered to the warehouse, all examined on daily basis, before the weekly coordination meeting and the weekly production launch	No such monitoring needed or done, except making sure the flow has no blocking obstacles – and on periodical basis, checking if the number of Kanban cards is still covering markets trend's changes.
Quick reaction to demand	In monthly forecast system, demand signals would take weeks before reaching decision making stage, and production launch would also be delayed. But in weekly production launch and update, demand signals required only few days (maximum 5) to reach decision making process, and the production launch would also be launched within days, depending on machine load	Kanban ensure even quicker reaction to demand, with demand signals transferred daily and directly to the production workshop by the conveyance cards, and production is launched within hours or maximum couple of days from receiving the demand signal
Precise inventory management	In forecast mode, the actual need is not known, the order for replenishment used to be made for full groups of items, or item family, or item size, but never going in details into item colors. The	Kanban provide a more accurate tool for more precise inventory management than DDMRP, as it allowed the replenishment of smaller volumes per item, the smaller a production order is, the

	DDMRP allowed more precise management, replenishing the economical production lots of only sold items in the past few days	more precise and accurate it would be in reaction to demand
Reducing the overall cycle of production lead time	The overall production cycle was mainly reduced by the shortening of lead time for any demand signal reaching the different stakeholders and being diffused within the organization. The time needed for demand signal to reach decision-making process was reduced from weeks to days, and the time from the decision-making process to the production process was also reduced from weeks to days.	Kanban reduced the overall cycle of production much further than DDMRP, since the delay of transfer of the demand signal from warehouse to production would be done at the same day, and by making benefits of the decoupling points and semi-finished items at production level, the production process was also reduced further, allowing the full cycle from the creation of the demand signal to the return of the produced items to the warehouse to be reduced to just few days
Smooth flow of production	Production flow for DDMRP is not as smooth as Kanban, since several products are produced on the same machines, and thus, production orders needed to be prioritized as well as capacities, and sometimes the order first received is not first produced, depending on priorities, which created some volatility in the production process, but it remains much smoother than the monthly production planning	Dedicating machines and setting up weekly production cycle for Kanban products provided visibility and capacity to plan the resources, time and manpower, and changed the flow of production in that section from a volatile and unpredictable operation, to a very smooth flow of production, requiring less effort, less overtime, and less problems, increasing the overall efficiency of

		the production team and process, indirectly increase the speed and capacity of production
Inventory reduction and operating working capital improvement	Ordering only the necessary items following demand, instead of ordering full groups of items and doing so on weekly intervals instead of monthly, allowed to reduce the level of inventory per item, while previously, many items would be produced based on monthly sales expectation, but many of them would not be sold, thus increasing the company’s inventory levels	Putting a ceiling of the maximum volumes of production, by coupling the maximum level of inventory to the number of conveyance cards, prevented any spikes in inventories, and reduced inventory levels even further than DDMRP
Optimizing the quality of the inventory	DDMRP replenishment process helped push inventory levels to more healthy situations, by launching production when reaching the Top of Yellow threshold, which allows inventory level to go down within the yellow zone, and sometimes to the red, before going back up to the green zone, depending on the economical production lot size per item, but in general, the inventory level would be moving within the yellow and green zone, of the DDMRP inventory segregation	Following the DDMRP inventory level segregation, or red, yellow, and green zones, Kanban model set the ceiling of the inventory level to the top of yellow, and the shortened production cycle allowed the inventory level to be replenished before plunging into the red zone, that is why items managed by Kanban had an inventory level moving mostly within the yellow zone, which is even more optimized than DDMRP
Increasing customer satisfaction by	Both models resulted in optimized inventory levels, with slightly better results in the Kanban system, pushing inventory levels higher than the red zone, reducing shortages, which improved customer satisfaction, by	

reducing the shortages of products	making sure the client's demand are mostly available when needed, and replenished as quickly as possible once executed
Reducing the bullwhip effect	Both models helped reduce the bullwhip effect, which is mostly the result of wrong forecasting and over-reacting to market trends, since forecasts are not followed for products replenishment, rather following real demand signals
Increasing transparency and visibility of market trends and historical evolution	By using both models, company's management team could get the feeling of the market trends and shifts in requirements on rather daily intervals, allowing them to make more accurate decision and adjustments to master production plans, as well as sales and marketing strategies and product development & optimization campaigns

The second table will compare the disadvantages of the DDMRP and the disadvantages of Kanban, compared to the forecast system.

Table 43: Disadvantages of DDMRP versus Disadvantages of Kanban

Description	DDMRP	Kanban
Risks of negative impacts of low interdepartmental communication level	In the absence of weekly meetings or coordination between key departments or functions within the supply chain cycle, many obstacles could damage the fluidity and efficiency of the process, like machines bottlenecks and breakdown, or incoming big orders or change in sales priorities	No such communication or meetings are required for the Kanban process, as it is run entirely by blue collars, management intervention is only needed in case of maintenance scheduling or change in the number of Kanban cards
Lack of visibility for the management	This case does not apply to the DDMRP process, since even if the launch of the replenishment process	The overall lack of visibility to the management team makes it difficult to predict and make

team	is done by the supply chain team, but the information passes to the production planning team to consolidate and filter the demands, and proceed following priorities, and hold the backlog of orders waiting to be produced later, once machine capacity is available	forecasts of the requirements of raw materials or manpower for the Kanban process, which forces the planning team to become more vigilant and follow the changes of the flows within the factory floor much closely and accurately
Lower visibility for the production teams	Since replenishment requests are done on weekly basis, production teams have less visibility, to prepare machines, and manpower allocation and raw materials for a prolonged period compared to monthly production programs, and would need to make more adjustments and changes throughout the month based on the changes in priorities and demand	Kanban has no such problems, since the production team has complete visibility over the production plan, as it is done with simple continuity and repetitiveness of the same items, without any major exceptions from week to week
Repetitive production orders	Weekly production orders, instead of monthly, means that some items, per type and volumes, are repeated each week sometimes, or not at all, depending on demand, but in terms of production efficiency and reduction of set up time and labor, bigger orders for longer spans are better than smaller orders repeated on weekly basis, so production resources in general cannot be allocated and planned for a longer period, rather	This case is not applicable in Kanban management, since even if the production cycle is done on weekly basis, but it is repeating exactly the same items in general, removing or adding some colors, but producing the same production steps, which is an optimal allocation for production resources and visibility

	shorter periods with many corrections and adjustments	
Challenge of economical production lot sizes	Producing to cover sales demand, while trying to maintain a low inventory turn, or coverage compared to sales, meant producing quantities that covers the quantity of weekly or monthly production volume. However, for some items, the economical production lot is much higher, corresponding to several months of sales or even a year's sales volumes. That is why, replenishment would be launched with quantities lower than the economical production lot, which decrease the production efficiency (increased setup time, labor, scrap rate…)	Dedicating machines, producing in cycles, and repeating the same production campaign on weekly basis (with minor changes), is the best way to creating the optimal economical production quantities and process. That is why Kanban actually helps set, define and follow optimized production lot sizes
Machine dedication in case of lower demand	DDMRP does not required the dedication of machines for certain products, many products managed by DDMRP are produced on the same machines, that is why, in the case of lower demand on some products, the same machines would produce other products, to keep the company's production teams and resources fully utilized and optimized as much as possible	In case the sales demand for the items managed by Kanban is low, lower than usual, the dedicated machines would not be producing at a good efficiency level, since they will remain dedicated to the Kanban process, but without enough production volumes, which will in return increase the cost of production due to the reduction of efficiency and low utilization of manpower and resources accordingly, and this

		would make the company miss production capacity in the Kanban machines
Human error risk	Human error risk does exist in DDMRP system, but not with the same severity of Kanban, since decision making is filtered many times before reaching the production workshop, first by the supply chain employees launching the replenishment process, then the production planning team, receiving the requests, consolidating and launching the production orders, and finally the production managers receiving the production orders, before launching the production orders at the workshop level	Seemingly innocent behaviors of carelessness, like forgetting to remove the conveyance cards from a sold item, or forgetting to delivering it back to the production team the same day, or overconfidence at the production floor for not following the weekly production cycle as it was set, could completely block the Kanban cycle. This kind of behavior, as harmless as it may seem, could lead to completely blocking the healthy cycle of the Kanban process, since it is relying on the discipline and vigilance of blue collar workers, who historically were never empowered in such position

Based on the above, mixing both models together would optimize a company's production flow, managing each item, in its relative optimal way, depending on its context, from sales volumes, frequencies of sales, production steps and capacities, either with DDMRP or Kanban.

F.3) Limitations of DDMRP compared to the limitations of Kanban

Since DDMRP and Kanban are different management systems, each has different limitations related to the implementation and the operational side.

Table 44: Limitations of DDMRP vs Limitations of Kanban

DDMRP	Kanban
The system can operate efficiently with the type of products that shows repetitive sales frequencies, and should be managed on stock base. These items could be identified by having some overall repetitive historical sales to be used as base parameters for the launch of production orders. DDMRP cannot be used for non-stock items products, produced only on customer demand. DDMRP cannot be used in the absence of clean and live database and ERP system, providing continuous and live data, which is vital for the launch of the replenishment decision-making process. Periodic interdepartmental communication is needed for the follow up and smooth continuity of the process. The absence of such communication would limit the efficiency of the process.	Like DDMRP, Kanban can only be used for stock items, with repetitive sales volumes and frequencies, but the difference is that Kanban can only be used for stock items that have such a large volume of sales that covers the production capacities of the needed machines for its production. Stock items with lower demand than production capacities of the relative machines cannot be managed by Kanban. Successful implementation does not require interdepartmental communication, its rather require an empowered and well disciplined, since the implementation requires the direct involvement of the people on the floor, from the warehouse operators to the production operators. Reckless or not disciplined workers would make the implementation very difficult, if not even impossible.

F.4) How to identify & choose items to be managed by the mix system

As previously explained, implementing DDMRP and Kanban for the inventory replenishment management cannot be used to any type of product that a company produces.

We could identify three types of products that a multiproduct industrial company produces. The inventory replenishment management of the first type products can never be managed by either DDMRP nor Kanban, the second type of products can be replenished by DDMRP, and the third type of products by Kanban.
DDMRP system can be used for both the second and the third type of products, as the items that can be managed by Kanban could also be managed by DDMRP, but the opposite is not true, only a few number of items, with specific characteristics, of the second type of products can be managed by Kanban.

In this section, we will create a charter or mapping system that explain how to identify each type of the three products, that could be useful for similar companies, producing a wide variety of products, with different sales volumes and frequency of sales, as well as different production lead time and steps, per product.

F.4.1) Products Mapping

The key task for any company before launching any new inventory replenishment system, which is indirectly a production launch model, is to having a full mapping and classification of its complete portfolio of products. Some companies do not have this kind of product classification, and thus, do not have clear visibility of its products, which hinders any efforts for efficient replenishment management.

The two-main products classification that could be done are "Make to Order", or MTO, and "Make to Stock", or MTS. There are other classifications as well, like "Assemble to Order", or "Engineer to Order" and others, but the MTS and MTO remains the key classifications to follow and use for the replenishment systems described in this paper.

F.4.1.1) A, B, C Classification

To be able to identify the MTS from the MTO items, a company needs to understand the importance and weight of each item within its portfolio of products.

To do so, an ABC classification should be done to determine which are the company's A products, which are B products, and which are C products; A being the most important products to follow and manage, B the lesser items to follow and manage, and C the least important items to follow and manage.

In Liban Cables, the A, B, C grid was determined as such, by weight of products:

Table 45: ABC Classification Grid

ABC Grid	Weight by Top importance intervals	
A	0%	80%
B	80%	95%
C	95%	100%

In other words, the top 80% of products are classified as "A", the next 15% are classified as "B" and the least important 5% of products are classified as "C".
Other companies could change this interval for ABC classification, depending on its business type and products complexity.

Once the grid is determined, the ABC classification is extracted by working on the inventory levels and movement. Based on the inventory levels and movements over a certain month, or several months, a double ABC classification is extracted:

- ABC over Quantities Available on Stock, per item, at the end of the chosen period
- ABC over the Frequency of Sales from Stock, per item, during the chosen period, or how many times this item was sold (requested) during the period

The dual ABC grids are then combined as such:

Table 46: Dual ABC Grid Consolidation

ABC Classification for Quantities in	ABC Classification for Frequency of	Joint ABC Classification	Final Consolidated ABC Classification

Stock	**Sales**	**Inventory level + Frequency of Sales**	
A	A	AA	**A**
A	B	AB	**A**
B	A	BA	**A**
C	A	CA	**B**
B	B	BB	**B**
A	C	AC	**B**
C	B	CB	**C**
B	C	BC	**C**
C	C	CC	**C**

The above table would be explained as follows:

- Items with highest quantities in inventory levels (A), and highest frequency of sales (A), are considered as "A" products.
- Items with highest quantities in inventory levels (A), but lower frequency of sales (B), are considered as "A" products.
- Items with lower quantities in inventory levels (B), and highest frequency of sales (A), are considered as "A" products.
- Items with lowest quantities in inventory levels (C), and highest frequency of sales (A), are considered as "B" products.
- Items with lower quantities in inventory levels (B), and lower frequency of sales (B), are considered as "B" products.
- Items with highest quantities in inventory levels (A), and lowest frequency of sales (C), are considered as "B" products.
- Items with lowest quantities in inventory levels (C), and lower frequency of sales (B), are considered as "C" products.
- Items with lower quantities in inventory levels (B), and lowest frequency of sales (C), are considered as "C" products.
- Items with lowest quantities in inventory levels (C), and lowest frequency of sales (C), are considered as "C" products.

The result of mixing two ABC matrixes results together, produced a hybrid result, slightly different than the general grid of 80% to “A” products, 80%-95% to “B” products, and 95%-100% for “C” products. The below table give an example of the result on Liban Cables inventories on December 2017 (the total company portfolio of products was at 6,487 products):

Table 47: Dual ABC Matrix results

ABC Products	% of Total company portfolio of Products	% versus total inventory level (value)	% frequency of sales versus total
A	1.82%	70.49%	55.51%
B	1.51%	22.15%	30.48%
C	96.67%	7.36%	14.01%

This dual ABC matrix, relying on both the inventory levels and the frequency of sales, is the cornerstone to identifying which products would be considered as MTS, kept in stock and managed for continuous availability, and which products as MTO to be produced only on demand.

F.4.1.2) Make to Stock

Make to stock, as the term states, are products that are produced to be placed in stock, without waiting for client direct demand for the products.

Based on the historical demand trend and sales experience, a company would choose to start producing products, and keep them in stock, in order to deliver them directly from stock to clients upon demand.
Products that are classified as MTS should be sold repeatedly, otherwise a company’s inventory levels would grow beyond control, as well as its need of operating working capital.

The other factor that governs the MTS status is the production speed, or lead time for replenishment, as well as the minimum production quantity required, or economical production lot, but this factory is not as crucial as the volume and frequency of demand.

So, the purpose of producing to stock is to be able to provide quicker service to clients, delivering them their needs immediately, without waiting the usual production lead time to produce an item, a client could place an order for MTS products, and physically receive it in the same day.

The ABC classification previously discussed is used as a platform to identify which items to be produced to stock, and which will not, following as well the frequency of demand or sales of the items. The below table shows an example of the MTS products of Liban Cables in December 2017:

Table 48: Make-To-Stock weight

MTS	**% Total Nb of company's items**	**% total Value in Inventory $ compared to the company's inventories**	**% Frequency of Sales out of company's total sales**
A	1.40%	41.18%	50.87%
B	0.69%	4.07%	28.80%
C	0.60%	1.46%	2.93%
Total MTS	**2.70%**	**46.70%**	**82.60%**

As visible in the above table, the MTS products are not only A products, but we can find as well B and C products within the global MTS portfolio. The reason of this mix is that is why very difficult to manage a very big portfolio of products of thousands on items, on item level, the global management of the items is done on products family levels and type.

For example, for a product X that comes in 8 different colors, if the sales volumes and frequency defines it as "A" product, then item X is classified as MTS, even if between the 8 colors, some colors are not sold as much as others, and thus within the various colors of item X, some colors could be classified as A products within the company's global ABC matrix, and some colors as B and some others as C, the global item X, with all its 8 colors, would be managed as A and thus MTS, as it makes more sense to manage the item classification at item level and not at color level. That is why, within the above table of MTS products we can see B and C products.

The above table shows the following information:

- The total number of the MTS products represent only 2.7% of the total number of products (6,487 products) in the company's portfolio: this ratio shows how little the MTS number of products is, compared to the total number of products managed by the company, so we are discussing about only a small fraction of the total items.
- The value in US Dollars of the MTS products represented 46.7% of the total value of the company's inventory at end of December 2017: this ratio shows that the value of MTS in the inventory represented a little less than half the inventories, meaning that many other products are produced for specific orders and kept in stock for various reasons, but not managed as MTS.
- The frequency of sales, or how many times an item has been sold or delivered, of the MTS products represented 82.6% of the company's sales during December 2017: this ratio shows how much MTS products are sold during the month, shows that clients are repeatedly asking to be delivered and withdrawing these items constantly at a very high rate compared to the other products of the company – in other words, the warehouse staff spent more than 80% of their time working to deliver only these 2.7% number of MTS items.

In summary, the MTS products are the very few number of items that are sold repeatedly, and frequently, representing most of the company's sales turnover and volumes, and thus requires the special attention to be managed more meticulously and in a special way, in order to maintain a healthy inventory level that allow the maximum customer satisfaction and product availability to spot and unplanned demand.

Based on such or similar analysis, a company can define which products to manage it as MTS, but at the same time, the formula is not rigid or unchangeable, since business intelligence should be coupled with statistics for the final decision. In some cases, a company's management could decide to manage some items or family of items as MTS, even if the demand volumes or frequency is not as high as required, for strategic reasons, either to keep a certain quantities of the selected items in stock for key high profile customers or projects, or for production capacity concerns if the production lead time it too long, or if producing some items take away the same production capacity of other high runners items, then a batch would be produced and kept in stock in order to free the production capacity or bottleneck for other production needs.

F.4.1.3) Make to Order

Make to Order, also as term states, are products that are produced only following a customer's firm order.

This classification englobes all other products produced within a company that does not fall under the MTS classification, which based on historical sales volumes and frequency, a company's management would decide not to keep a stock of the MTO products, and launch a production campaign for any incoming demand, after the confirmation of the need by the client. In other words, these are the products that are too slow to sell, and not worth keeping some standby inventories for it.

Table 49: Make-To-Order weight

MTO	% Total Nb of company's items	% total Value in Inventory $ compared to the company's inventories	% Frequency of Sales out of company's total sales
A	0.42%	29.31%	4.64%
B	0.82%	18.09%	1.68%
C	96.07%	5.90%	11.08%
Total MTO	**97.30%**	**53.30%**	**17.40%**

The above table shows the MTO products of Liban Cables in December 2017.

The above table shows the following information:

- The total number of the MTO products represent as much as 97.30% of the total number of products (6,487 products) in the company's portfolio: this ratio shows how much the MTO number of products is, compared to the total number of products managed by the company, so the range covers most of the company's products.
- The value in US Dollars of the MTO products represented 53.30% of the total value of the company's inventory at end of December 2017: this ratio shows that the value of MTO products in the inventory represented a little more than half the inventories, which does not mean that these items should be managed as stock items, but rather that these items were produced for certain clients' orders, and in large volumes, but not yet delivered, for various reasons, but the orders represents big volumes, delivered in big quantities, which explain the large values in stock.
- The frequency of sales, or how many times an item has been sold or delivered, of the MTO products represented only 17.4% of the company's sales during December 2017: this ratio shows how rare MTO products are sold during the month, showing that clients are rarely asking to be delivered, and withdrawing these items unfrequently and at a very low rate compared to the other products of the company – in other words, the warehouse staff spent only 17% of their time working to deliver a range of product representing 97.3% of the company's total number of products, highlighting how insignificant and scarce these deliveries are, but at the same time, how large the quantities must be per single delivery, to represent high values of inventories.

Like the MTS, within the MTO range we can see some A products and some B products, but mostly the range of MTO would be grouping C products.

The existence of A and B products would be the result of high sales of certain colors within a global product classified as C (like the case of product X described in the previous MTS section, but in an opposite way), or the company's management would decide to classify some products as MTO, despite the fact that they show high rates of sales in certain periods, since it would be known that these products are only requested occasionally for very particular projects, but will never be requested again except for similar non-repetitive project, that is why, production would be launch only upon the confirmation of such demand.

In summary, a company would define as MTO all products that are not sold frequently, following the ABC classification, representing less than 20% of frequency of sales. In addition, specific product identified as related to very specific and restricted projects or needs, even if the sales would spike up in some periods, would also be classified as MTO.

F.4.2) How to identify & choose items to be managed by DDMRP

Using the DDMRP zoning and concept as a finished products inventory replenishment tool, or production launch tool, can be adopted for products with recurrent movement of sales (demand), as well as repetitive production campaigns, as we have discussed in the previous sections of this paper. Such items would require a minimum inventory level available to satisfy the clients' immediate demand, based on historical and moving market trends.

Such management process, would consider historical sales trend, production lead time, updated recurrent demand versus historical, and based on it define a minimum quantity to keep in stock, as well as an inventory threshold to launch production campaigns.

Consequently, such process would not be effective for products that are only produced based on customer demand, and never kept in stock for other requirements, but rather for products that would be produced indirectly based on customer demand and based on demand trends, directly following an automatic production launch system, and needs to be kept in a company's warehouses for spot demand.

In other words, and based on the MTS and MTO classifications discussed in the previous sections, the DDMRP replenishment process cannot be used for MTO products, but can be used for all MTS products.

All company's products that are managed on stock based, produced to be kept in stock, can be managed by the DDMRP process.

The main challenge, or preparatory work, is for a company to know how to define its MTS products and separate its MTO products, and once done, all MTS production launch can be managed following the DDMRP guidelines.

F.4.3) How to identify & choose items to be managed by Kanban

As explained in previous sections of this paper, the Kanban process required continuous production cycle, and a steady flow of the Kanban cards from the warehouse of finished products, to the production workshop, productions lines and back to the warehouse.
That is why, and like the DDMRP requirements, Kanban cannot be used for MTO products that shows no continuous production need, nor steady historical trends to follow, but rather the Kanban replenishment process can only be used for MTS products.

However, while DDMRP can be used for all MTS products, Kanban cannot be used for all or any MTS product. The Kanban replenishment process can only be used for a limited number of MTS products, with specific characteristics.

To define which MTS products can be replenished using Kanban, a company needs to perform a value stream mapping for its top runners, for all its products that show high volumes of sales as well as high frequency of sales. The value stream mapping should show the following information per product:

- Production lead time, from production launch to delivery to warehouse
- Production steps and complexity per item
- How many machines are used to produce the item
- Machines capacity (for the machines concerned in the product’s production steps)
- Obstacles, bottlenecks and potential delays in the production process

Following the results of the value stream mapping, and the volumes and frequencies of sales per products, Kanban can be used to manage the replenishment process of MTS products with enough sales volumes to occupy the full production capacity of certain machines, during the production steps, with minimum complexity and deviations. The usage of the machine capacity could be for individual products, or for groups of products that has similar production steps.

Consequently, the related machines to the production of the Kanban items would be completely dedicated to their production, and no other product would be produced, to ensure a smooth production flow, as well as availability of production capacity, always ready to satisfy the requirements of the sales needs of these items.

If one product has enough sales volumes to occupy the machines capacities through its complete production cycle, then those machines would be dedicated only to producing that product. In addition, if not one single product can occupy the production capacity, but rather a group of products, like for example several colors of the same products, or few sizes of the same products, then the machines would be dedicated to producing this group of products only, and the production cycle would be done in turn between the items to ensure continuity of output per product.

In summary, Kanban can be used for high runners MTS products, with enough volumes to completely occupy the full production capacity of the production lines needed to produces these products, either individually, or per small groups of similar products.

F.4.4) Conclusion on Product Identification & Classification

In a multiproduct industrial company, various products are produced, with different types, different production steps and complexity.

To implement a mix DDMRP-Kanban inventory replenishment system, or production launch system, the full portfolio of products must be well identified and managed into three main categories:

a) Make to Order products, representing the majority of a company’s portfolio in terms of number of products, but at the same time the minority in terms of volumes and frequency of sales. These products can only by produced following confirmed customer demand, in exact quantities to satisfy the demand, and completely sold without keeping any excess quantities in the company's warehouses. DDMRP and or Kanban cannot be used to manage the replenishment process of those items.

b) Make to Stock products, representing a small part of the full company's products portfolio in number of items, but at the same time representing most of the company's activities in terms of volume and frequency of sales, and indirectly in terms of production activity. DDMRP can be used to manage the replenishment process of all MTS items, without exception. Kanban however cannot be used for all MTS items, but only for a select few items.

c) Make to Stock Items Top Runners, representing only a select few items of the MTS portfolio, but with the highest volumes of sales and highest frequency of sales as well, to the degree that producing these items would continuously occupy the full capacity of complete production lines, or main machines, either individually or per small groups of similar items. These top runners MTS can be managed by DDMRP, but it would be recommended to managed them by Kanban to better optimize the production flow and efficiency.

This type of product segregation would ensure an optimized method of product management, using the more convenient method for inventory replenishment, following the type and nature of each product.

F.5) Which companies can implement mixed DDMRP-Kanban

DDMRP and Kanban are not exclusive to companies similar to the one studied in this paper, but it could be implemented in many other companies, depending on the company's business model and type of activity.

To do so, a selected company needs to have products that would be eligible to be managed in this mixed system of inventory replenishment and production planning and launch.

Based on what we have described, a company that is producing items only on customer demand, and keeping no inventories of finished products that are not produced to orders, or not keeping unrestricted finished products in its warehouses, cannot use this mix system.

This mixed model can be implemented for companies that are producing to stock, or keeping stock items in their warehouses, regardless of the customer direct demand. A company could be producing its entire portfolio for stock, or part of its portfolio for stock.

The number of produced products, or its complexity, is not a blocking factor, as long as the management of the replenishment process is done as required.

The choice between implementing DDMRP or Kanban would follow the product types and volumes and frequencies of sales, as well as production lead time and steps.

A company that produces a limited number of items, all produced to stock, and sold repeatedly and in high volumes, as much as, or more than its machines and production lines' capacities, can implement only Kanban, which will provide maximum efficiency in terms of smoothness and speed of the replenishment and production process.

A company that produces a larger number of items, all produced to stock, and sold repeatedly, but in various volumes and frequencies, depending on the products, can implement DDMRP for the majority of the items as an inventory replenishment tool, as well as using Kanban for its high runners with sales and production volumes as high or higher than its machines capacity, which allow managing the replenishment cycle of each product in the more suitable manner.

A company that produces a large number of items, all produced for stock, and sold repeatedly, but in various volumes and frequencies, and none of its products shows high volumes and frequencies of sales to cover its machines capacities required for the production of those items, can only use DDMRP as a replenishment tool, without using Kanban.

A company that produces a very high number of products, some are produced to stock, and some are produced following only customer demand, can use DDMRP and Kanban, if suitable following the previously described conditions, for its products that are manufactured for stock, and not use neither DDMRP nor Kanban for the other products that are only produced following clients' firm orders.

The below table summarizes the various possibilities of inventory replenishment options, following the various inventory positioning strategies per company:

Table 50: Inventory Replenishment Strategies

Business Type / Inventory Replenishment Strategy	Produce to Customer Confirmed Orders	DDMRP	Kanban	Mix DDMRP-Kanban
Producing items only on customer demand, and keeping no inventories of finished products that are not produced to orders	X			
Limited number of items, all produced to stock, and sold repeatedly and in high volumes compared to production lines capacity			X	
Large number of items, all produced for stock, and sold repeatedly, but in various volumes and frequencies, and none of its products shows high volumes and frequencies of sales to cover its machines capacities		X		
Large number of items, all produced to stock, and sold repeatedly, but in various volumes and frequencies,		X	X	X

some products with high volumes compared to production lines capacities, and some with much less volumes				
Producing a very high number of products, some are produced to stock, and some are produced following only customer demand, and the stock items have various volumes, some higher and some lower than production lines capacities	**X**	**X**	**X**	**X**

Conclusion

Finding the most appropriate supply chain strategy is a challenge many companies face.
It is difficult to say if there is one single right answer or one ultimate strategy that optimizes a business's supply chain cycle, but rather different strategies and approaches could be adopted depending on a company's business model, its mode of operation, and its internal and external environment. In addition, the optimal strategy might change and evolve for the same business and same conditions, following the changes in market trends and competitive landscape.

For multiproduct industrial companies, inventories and buffers are needed at each main link of the supply chain to maintain a fluid and efficient flow of business, but if not properly managed, inventories could become a huge liability that would hinders financial efficiency as well as customer satisfaction and operations.

That is why, one of the paths that could help accomplishing business excellence through supply chain is the inventory management strategy, for finished products replenishment, which is at the same time a production launch strategy.

The proper inventory replenishment strategy could help reduce inventories to reasonable levels, which optimizes a company's need of working capital, reduce its operational inefficiency by producing only what is needed at the right time, and maintain healthy levels of products to ensure customer satisfaction and retention.

Several approaches were tested and used in the attempt to find the optimal manner of inventory replenishment process, and the optimization of the flow of production and cycle from the finished goods warehouse to the production workshop and then back to the finished goods warehouse. Among the most known and used approaches are the push and pull strategies.

Push and Pull explain the way a production order is released into the production workshop.
Companies that used a push strategy at the core of their production model, adopted a flow consisting of pushing a production job or process from one workstation to the next, upon completion. They achieved this through multistage production scheduling, relying traditionally on information systems and computers to calculate the needs of components, mostly famous for implementing MRP and MRP-II.
While in a pull system, the job is pulled by the successive workstation, instead of being pushed by the previous one. This approach was famous by following the Toyota production system, using Kanban cards to control the flow of information and production process.

DDMRP or demand driven MRP is an approach that is supposed to manage manufacturing flows better than the traditional MRP, by adopting some of the pull strategy concepts. The concept is still novice to the academic literature, but it is said to have many advantages of optimizing inventory levels and related key performance indicators, as well as product movements driven by real demand, real-time demand and supply visibility, inventory management in correlation with dynamic target operating levels, early identification of demand and supply issues before impacting production, and single demand signal shared across the full supply chain cycle.

In this paper, we tried to explore the literature review, in search of methods to optimize the flow of production and products replenishment process. We examined existing literature regarding supply chain and supply chain management, as well as research done around push and pull management strategies, the Kanban production system and the DDMRP model.
We did not find however literature review that elaborates implementing a mix system of Kanban and DDMRP for finished goods inventory replenishment, neither its advantages nor disadvantages, compared to traditional forecast replenishment system, and a comparison between Kanban and DDMRP explaining the differences between each system, expected outcomes, and which products are better managed through DDMRP instead of Kanban and vice versa.

To shed some light on implementing DDMRP and Kanban within the same company, we proceeded with an in-depth case study of such implementation within a multiproduct industrial company, that has thousands of products in its portfolio, with different production steps and complexity per product, as well as different management strategies per product.

The study was done at the company Liban Cables SAL, an electrical cables producer in Lebanon, leading the market since 1967, with over 80% of the local market share, and part of an international cables producing group called Nexans. To maintain its leadership position, the company produces most of the Lebanese market's needs of electrical and telecommunication cables, holding a portfolio of thousands of products, with a large variety of applications, different designs and cables constructions, as well as different production complexity per product.

Liban Cables used to adopt a forecast-driven inventory replenishment management style for many products, without clear classification or identification of a defined method explaining what was the strategy per product type. The process relied of receiving monthly forecasts from the sales department for a list of cables that they expect to sell during a certain month, per type and quantity, and then relative production campaigns would be launched accordingly.
The forecast would mostly rely on guessing and the personal experience of a handful of people, which made the forecasts inaccurate to a large degree, and consequently, not reflecting actual demand during the month of production. The correction between the forecast and actual demand would be done the following month, but in the process, many products would reach a level of excess if not sold as expected, and other products would be out of stock if oversold.

The implementation of DDMRP and Kanban at Liban Cables was preceded by many preparatory steps of data cleaning for the information coming out of the company's ERP system, then by the unification of vocabulary between various departments affecting the replenishment cycle, as well as creating many reports that would be used in parallel to monitor the key performance indicators around the inventory replenishment process.

The implementation of DDMRP was done in line with the global guidelines found in the academic literature regarding its implementation, following the general 5 steps described by Ptak et a. (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, but in a customized manner, adopted to the company's business model and it needs for an inventory replenishment system.
Following the lessons learned from DDMRP implementation, Kanban management system was adopted for items that could be better managed by Kanban compared to DDMRP, and Kanban was used as close as possible compared to how it is described in the academic literature, adopting Kanban conveyance cards from the finished goods warehouse to the production floor, and Kanban production cards to launch production campaigns.

Based on what was described in this paper, implementing the DDMRP management style provided many advantages compared to the forecast management system, as it helped improve the segregation of duties between departments, it provided live monitoring and quicker reaction time to real demand, helped avoid bullwhip effects, which allowed for a more precise inventory management and reduced ultimately the full production cycle's lead time. Consequently, inventory levels for products managed by this new model were reduced, accompanied by an optimization of the quality of the inventory, reduction of shortages (or stock-outs) and improvement of customer satisfaction and retention.

Some disadvantages were detected from the DDMRP implementation, 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 Kanban system as well offered several advantages like reducing the overall production lead time of some article, prompt reaction to demand, launch of production without management interference, empowerment of people, smooth flow of production, reduction of inventory and improvement of the quality of the inventory.

As for the disadvantages of the Kanban system, it was somewhat marginal, like the lack of visibility for the management team, machine dedication in case of lower demand, which would impact the capacity of the company's output, and the risk of human error.

Compared to the forecast-driven management, the new demand-driven management system displayed many advantages to the main key performance indicators related to inventory management and production launch, depending on the type of products, construction complexity and lead time in production.

Some families of products experienced around 40% reduction in the inventory levels, while at the same time maintaining the same level or higher sales, which reduced the inventory coverage or inventory turn also by 40% to 50%, and ultimately boosted the quality or health of the inventories held.

Other families showed similar improvements, but not with the same intensity, since its production complexity and lead time, as well as the minimum production quantity compared to the level of sales, did not allow for the same improvements.

By examining 4 years of data for certain items, we could clearly see how the implementation of this new management system, pushed inventory levels within the normal zones of DDMRP, which are the yellow and green zones, and how the implementation of Kanban pushed inventory levels below the top of yellow zone, when the number of cards was set to reflect a maximum inventory level equivalent to the top of yellow for the chosen items.

What was also interesting to show, was the movement of the values of the DDMRP zones (red, yellow, green), increasing or decreasing in value of unit of measure, depending on the moving average of actual demand, making it in direct correlation with market trends, rendering the system up to date and live as much as possible, and avoiding the trap of launching production campaigns following historical non-moving values.

Based on all the observations discussed and the data examined, it was clear how changing from a forecast-driven to a demand-driven replenishment model helped the company optimizes its main relative efficiency ratios, optimize its working capital, avoid bullwhip effects and increase customer satisfaction.

Within the implemented demand-driven system, the DDMRP model and Kanban were different one from another, either from the implementation aspect, to the advantages and disadvantages of each system compared to the forecast-driven.

From the implementation side, DDMRP requires a management follow up, for order generation and execution, using an information system that provide necessary data for the decision-making process, while Kanban does not require any administrative involvement, nor an information system, since the order generation and execution are both done on floor level by direct workers, without administrative involvement. The administrative input for the Kanban system is in the process of setting up the system and its relative parameters, but once done, it would be out of the control of administration.

The product selection mechanism is different as well between DDMRP and Kanban.

Buffers profiles and levels are also different between DDMRP and Kanban, since the parameters and type of buffers are different, as well as the position of the buffers along the supply chain.

In Liban Cables, the DDMRP replenishment cycle was repeated on weekly basis, while with the Kanban, the order generation was done daily, providing quicker reaction to demand.

When considering the advantages these two new models offered compared to the forecast-driven model, we found that the weekly meetings related to the DDMRP execution system enhanced interdepartmental communication, which was not the case in Kanban, as no meetings are required for executing replenishment orders. In return, Kanban allowed for production launch to be decided and executed without management or administrative interference, which was not the case for DDMRP, that is why, employees working under the Kanban system were more motivated and empowered once they were given these new responsibilities and decision-making powers, that they were not used to before.

Both models, compared to the forecast-driven system, provided quicker reaction time to demand, more precise inventory management system, a reduction of the overall production cycle lead time, a smoother flow of production, as well as inventory reduction and optimization of inventory quality, but with better results coming from the Kanban system compare to the DDMRP, only when applicable, as it was not possible to use Kanban as vastly as DDMRP which can be used for a much wider diversity of items.

When considering the disadvantages, DDMRP and Kanban showed different elements when compared to the forecast-driven model, as in case the execution meeting is not well followed, the

DDMRP model could be hindered, while the Kanban system is not affected by this practice. The Kanban system give higher visibility to the production team, but lower visibility to the management team, while the DDMRP system provide lower visibility to the production team (compared to Kanban, but better visibility compared to forecast-driven) and higher visibility to the management team, and the risk of human error deeply impacting the replenishment process is much higher in the Kanban model than DDMRP.

The choice however of which demand-driven strategy to adopt, would vary from company to company and from type of product to another, that is in case a demand-driven strategy could be adopted or not.

For a multiproduct industrial company with big diversity of product types and sales behaviors as well as production processes, the decision of moving to demand-driven should be preceded by a full mapping of its portfolio of products, to identify the nature of each product and its proper management strategy, and recognize if certain products could be managed through a demand-driven strategy or not.

Based on this case study, the first step of products mapping should start with a clear segregation showing which items should be managed as stock items (MTS), to be produced to stock, and which products to be produced on demand (MTO).

Identifying MTS products could be done by establishing an ABC matrix which classifies a company's products according to their weight in the inventory (and activity), in addition to their frequency of movement (sales). This ABC classification should be the cornerstone in defining the MTS and MTO families, but at the same time, management's feedback and experience could be used to handpick certain items and manage them as MTS and MTO depending on their status.

Once the MTS-MTO segregation is done, the DDMRP replenishment model for finished products can be implemented for all MTS items without exception. DDMRP cannot be used to manage MTO products, which would be only produced following confirmed clients' orders.

Kanban replenishment system cannot be used as well for MTO products. As for the MTS products, in contrast to the DDMRP, it cannot be all managed by Kanban. Only MTS products with relatively high volumes of sales and production, that can cover the dedication of certain machines or productions lines to its production, should be managed by Kanban.

This kind of strategy could be adopted by many companies, depending on their business model and portfolio of products.

Companies that produce only to customers' orders and keep no standby inventories cannot use this mix demand-driven management system, which will have no added value to its finished products replenishment cycle, unless it was used to manage its semi-finished and various buffers along the supply chain.

Companies that produces only to stock, with a small number of items, sold continuously in large volumes, larger than its production lines' capacity, can implement Kanban for its replenishment cycle, without the need of any other management system.

Companies that try to diversify and customize its products' portfolio following market trends, and maintain a wide diversity of products in its portfolio, with different production designs and delays, as well as different sales behaviors, should adopt a mix system, where MTO are managed separately, and MTS partially managed by DDMRP and partially by Kanban, depending on the conditions surrounding each product.

Based on all what was presented, and coming back to our research questions, we could deduct and conclude with the following observations:

DDMRP could be implemented alongside a Pull management system of Kanban, within the same company, depending on the types of products, since the replenishment strategy could be different by product type, and consequently, the two management systems could be implemented, in addition to possibly many more management systems, depending on the diversities of products, their nature, and sales habits.

DDMRP and Kanban complemented one another, without conflict in the implementation nor the processes between the two, since DDMRP was used for the clear majority of MTS products, while Kanban was implemented only for fewer products, with much more stable and higher sales volumes. DDMRP provided inventory optimization to a certain degree, but Kanban offered a much more precise management to demand, quicker reaction time, and steeper inventory optimization for the products with the possibility to be managed by it.

In a multiproduct industrial company, the path to implement DDMRP and Kanban would begin by a wide communication to the various stakeholders of the supply chain, explaining the concepts and potential added values of each system, followed by cleaning and setting up and useful database through the company's ERP system, and putting in place the management reports enabling to monitor and follow up the evolution of all inventories' key performance indicators. Once done, the DDMRP model would be implemented following the 5 steps described for its creation, but customizing each step to better suit a company's business model and requirements. Based on the results of DDMRP implementation, and after testing the routing and production flows of key runners, with full value stream mapping, Kanban could be implemented for those runners, by putting in place conveyance cards and production cards that translate the desired level of inventories and the production complexity, while in parallel training the labor force that would manage and execute the Kanban flow.

Compared to a forecast-driven management system, both DDMRP and Kanban presented many advantages regarding reducing the inventory levels, reducing the inventory turn versus sales, improving the quality of the inventories held in relation of sales, reducing shortages of products or stock-outs, which would increase customer satisfaction and subsequently increase the sales volumes. In addition, this management style would reduce a company's need for operating working capital, protect it against bullwhip effects, and provide a better visibility and stability for the production operation. Kanban however would provide better and more aggressive results than DDMRP, but only for the products that could be managed by Kanban, while DDMRP could be implemented for a far wider product range than Kanban.

In a multiproduct industrial company, not all products could be managed by a demand-driven management style, only make-to-stock products. MTS products could all be managed by DDMRP, and only some of them could be managed by Kanban, as described earlier.

Any multiproduct industrial company could implement such demand-driven management system, provided that it has products that are manufactured to be held as standby in stock; the degree of implementation would depend on the nature of each product. Companies that produces only to customer orders, and does not hold a level of standby inventories, cannot use such model for its finished products management system.

The next step forward for this kind of management system would be to look for ways to enhance it and optimize its positive effects in the future.

Based on the observations made, and attempts to improve the efficiency of the system tested within the company Liban Cables, the mix DDMRP-Kanban management system can be improved following the below steps:

- Add or remove products to the portfolio managed by the DDMRP system:

  The purpose of implementing a demand-driven management system is to create the best reaction to demand signals and market trends, and consequently any changes in customers' behaviors should be translated into changes related to certain products' nature and replenishment strategies.

  In addition, the installation of new machines that changes the company production capacity and output, or production speed, could change the strategy required to manage certain products, either by increasing a product's manufacturing time or decreasing it.

  Production lead time is also affected by bottlenecks on certain productions lines. The manufacturing lead time of a certain product could change, even if this same product still maintains the same demand behavior (sales volumes and frequency), and the same production time, it might be affected however by changes in the sales volumes and frequencies or production lead times of other products that requires the same production capacity to be manufactured, hence indirectly prolonging or reducing production lead times of all products manufactured on the same production lines.

  Based on such evolutions, the company's management must remain vigilant to detect which products are shifting in nature from MTS to MTO, or used to be MTO and in time should be moved to MTS. Consequently, when necessary, new products should be added to the portfolio managed by DDMRP to insure better management strategy and efficiency of the company's global performance indicators, and in return some products removed, to avoid the waste of time and the unnecessary effort of managing as MTS.

- Add or remove products to the portfolio managed by the Kanban system (transfer in product management from DDMRP to Kanban and vice versa):

  We observed how the Kanban management system provides advanced optimization to the inventory replenishment management compared to the DDMRP, which is why, more products should be managed by Kanban for a further company global efficiency level, in case those products has the required characteristics allowing them to be managed by the Kanban replenishment model.

  To move in that direction, a more in-depth study should be done on all the MTS portfolio of products, and their production flows, through a thorough value stream mapping of their production cycle, to identify which new products could be managed by Kanban.

  In case a large number of products could be managed by Kanban, much more than the company's capacity to dedicate machines and designate an independent replenishment flow of Kanban cards, the company could move to assessing the weight of each product within the full portfolio, and its impact on the company's profitability, before deciding which products to add to the Kanban management system and which product to keep under DDMRP. On the other hand, if the number of items was considerably high and the expected benefits from moving them all to Kanban management system is very high in relation to the company's global profitability, the other possibility to explore would be to make new investments and add new machines to the total production capacity, in case the expected benefits from implementing Kanban is greater than the cost of making such an investment in fixed assets.

  Following market trends is also a factor, since with increasing sales, new products could reach the volume threshold of demand that makes them eligible to be managed by Kanban, and vice versa, some items should stop being managed by Kanban when their sales volumes or trends are crucially reduced. This transfer would be done within the MTS portfolio of items, between DDMRP and Kanban management per product, and in extreme case of market shifts, some products could be moved from under the Kanban managed portfolio, directly to become MTO products.

- Change the parameters of DDMRP:

  The parameters of DDMRP buffer levels are correlated with the average sales (or average demand) and the lead time for production and replenishment cycle per product.

  The average sales is not fixed, but it is variable by design, following the continuous adjustment factor, as described earlier. That is why, this factor should not be adjusted manually, but kept moving following only market behaviors.

  However, the lead time for production is constant in the model we observed.

  In that case, the optimization opportunity of the DDMRP parameters, and buffers zones levels, would be accomplished by changing the production lead time, which was defined at the early stage of DDMRP implementation, and not revised later. This element should be reviewed periodically, following the real-time observations and changes in the production environment, and modified accordingly.

  In some cases, the lead time could be set at higher than needed compared to actual production lead time, which lead to excess inventory levels compared to real sales, and in some other cases, the lead time could be estimated lower than the reality, which might lead eventually to shortages compared to demand.

  That is why, the lead time factor in the DDMRP buffer zone calculation must be periodically reviewed, since it is the key element to optimizing the full model, and keep it updated, compared to changes in demand versus the historical trends, and following changes in the production landscape and machines availability, since installing new machines or adopting new production practices would change the production lead time. Furthermore, even without adding machines and production physical capacity, the production team must be challenged constantly to optimize its processes and production efficiency (setup time, labor manning, accidents levels, scrap rate…), which will decrease the overall production lead time for manufacturing, impacting the DDMRP system's parameters and making a huge difference to the overall inventory levels and efficiency.

- Change the parameters of Kanban:

The key parameter of Kanban, that impact directly the inventory levels and efficiency of the system, is the number of Kanban cards, which set the limit to avoid excess inventory levels and should protect against shortages to sales requirement.

That is why, once a Kanban system is implemented, the number of cards should be reviewed, in-line with the actual production lead time and replenishment cycle within the Kanban replenishment model, and reduced in case there is room for reduction, which will reduce inventory levels, or increased in case it was not enough to protect the company against shortages and maintain customer satisfaction.

Installing new production capacity or optimizing production processes, as suggested for the DDMRP parameters' optimization, would as well impact the Kanban parameters since it would allow to reduce the Kanban cards.

In addition, production efficiency related to the Kanban buffer semi-finished work-in-progress inventory levels and its replenishment speed would also impact the overall production lead time, which would help reducing the number of Kanban cards, and directly reducing the inventory levels for the products managed by Kanban.

On top of developing and optimizing the existing practices, other factors and paths could be used to optimize this replenishment system in the future, like the use of artificial intelligence in the order generation process, or the use of blockchain in the production and supply chain flow.

Although still novice, artificial intelligence could positively impact several links in the supply chain, like order management, customer service, logistics, inventory management, procurement, and various analysis, which could help make decisions faster and make use of the full set of data possible and in real time.

Researchers considers that artificial intelligence, which has been around for around 20 years, supplements rather than replaces supply chain traditional processes, since it can analyze data, way quicker than people can analyze excel spreadsheets, or any other order replenishment system, leading to faster decision making, and with more accuracy since it will be based on facts rather than gut feeling or inaccurate data interpretation.

For most organizations, acquiring the right data could be a challenge, since it is crucial that the obtained data for decision-making comes in the needed quality to start helping automate tasks, or give people insights or training them, since regardless of the advancement and sophistication of any ERP system, if the acquired data is wrong, the decision-making outcomes will be wrong; in other words, garbage in is garbage out.

Artificial intelligence should be able to offer a big assistance because it learns form outcomes that weren't chosen manually, and since it functions on real-time data, it enables an increased demand and spend visibility, as well as velocity and offering recommendations to supply chain managers which enables them to make decisions quicker and develop contingency plans. It can also help in making decisions related to how to move inventories faster and more cost effectively, as well as fixing a problem before it occurs or before affecting the supply chain.

Consequently, organizations should start thinking how artificial intelligence could help or affects their businesses, by looking at where, at which processes, the organization could use automation, better decision-making, increased learning capabilities and smart platforms.

In the case of our demand-driven replenishment model, artificial intelligence could be a very useful tool for data analysis and order generation.

To launch the DDMRP replenishment cycle, inventory and sales data is extracted manually from the ERP, then analyzed on excel spreadsheets, followed by a decision-making process handled by experienced supply chain employees, once a week.

Artificial intelligence could extract the inventory and sales data from the ERP system, analyze it, and propose replenishment order solutions, extremely accurate as per predefined requirements, all in a matter of minutes, each day and each hour of each day if necessary, which would optimize the process to unprecedented levels.

The Kanban process could also be optimized through artificial intelligence if the Kanban conveyance cards are transformed into electronic cards, detected and read by the system, and replenishment signals would be sent to the production floor each minute, and transforming the conveyance signals coming from the system to electronic production orders, substituting the Kanban production cards.

The other tool that could be adopted to optimize the demand-driven replenishment system and push it to the next level into the future is the Blockchain.

The blockchain technology was first created to support the cryptocurrency Bitcoin, by allowing many users to trade values between each other, over the internet, without the need of a third party, usually a bank, to verify the transaction.

A blockchain is a ledger of facts replicated across several computers assembled in a distributed peer-to-peer network, forming a chain of blocks, where each user of the blockchain can review the entire blockchain. however, the update of the blockchain can only be done by the consensus of most users, and any information registered into the blockchain can never be erased.

Facts are assembled in blocks, with only one single chain of blocks, which is replicated through the entire network. In each block, there will be a reference to the previous block, by using the hashing cryptography which connects the blocks. When new nodes in the chain of blocks create a new block with pending new facts, this block is sent to all the other nodes in the network. All the nodes in the network would then run a check to verify if the block is correct, then add it to their copy of the chain and attempt to build a new block with new pending facts.

According to the consulting firm Deloitte, blockchain has been considered as an information game changer, because of its unique capabilities and advantages in providing superior information transparency.

Blockchain is basically a distributed digital ledger, that lives on the internet, or an internal local network, and records transactions and events. The recorded information is shared through a peer-to-peer community. Within this network, all participants maintain their own copy of the ledger, called a node, and they validate new records or entries to the chain by using a consensus protocol, ensuring transparency and collaboration.

In a supply chain, a restricted blockchain could be used, dictating different user's ability to read and write to the blockchain, providing different access rights per user, and it could remedy some of the supply chain headaches of (1) Traceability, by providing a full audit trail of data and creating an everlasting means of record keeping along the supply chain, (2) Compliance, since all transactions made on the blockchain are timestamped and tamper-proof which provides a single source of data integrity, (3) Flexibility, by facilitating continuous real-time tracking of data through the use of smart contracts across the supply chain, and (4) Stakeholder Management, since blockchain enables trusted peer-to-peer interactions based on digital signatures.

This new blockchain technology could be used to optimize the production flow within the demand-driven replenishment system described in this paper, by better connecting all stakeholders of the supply chain cycle, and ensuring transparency and visibility to all parties, as well as rapid transmission of information, accurately and promptly, which optimizes the full demand-driven flow of production execution and follow up, from the time a production replenishment order is launched to the time the related products physically arrives to the finished products' warehouse.

Furthermore, both technologies of artificial intelligence and blockchain could be implemented simultaneously to support and complement each other, the first ensuring quicker and more accurate decision making process and replenishment order launch, and the second optimizing the flow and execution of order processing and production.

Other possible technics or technologies might be useful as well to upgrade and optimize the demand-driven mixed system of DDMRP and Kanban, as long as those new technics or practices would ensure better decision making processes and a more optimized flow of production within the supply chain.

References

A

Adrian Done, (2011), ***"Supply-Chain Evolution: Knowledge-Based Perspectives",*** IESE Business School, University of Navrra, Working Paper, WP-899, January, 2011

Alan Bryman, (1984), ***"The Debate about Quantitative and Qualitative Research: A Question of Method or Epistemology?"***, The British Journal of Sociology, Vol. 35, No. 1. (Mar., 1984), pp. 75-92.

B

B. E. Flores and D.C. Whybark, (1987), ***"Implementing multiple criteria ABC analysis"***, Journal of Operations Management, Vol. 7, pp. 79-86

B. E. Flores, D. L. Olson, and V. K. Dorai, (1992), ***"Management of multicriteria inventory classification"***, Math Comput Modelling, Vol. 16, No 12, pp.71-82

Bagele Chilisa, Barbara Kawulich, (2012), ***"Selecting a research approach: paradigm, methodology and methods"***, In book: Doing Social Research: A global context, Chapter: Selecting a research approach: Paradigm, methodology and methods, Publisher: McGraw Hill, Editors: C. Wagner, B. Kawulich, M. Garner, pp. 51-61

Ballou, R., (1978), ***"Basic Business Logistics"***, Prentice-Hall, Englewood Cliffs, NJ, 1978

Benita M. Beamon, (1998), "***Supply Chain Design and Analysis: Models and Methods"***, International Journal of Production Economics (1998), Vol. 55, No. 3, pp. 281-294

Burbidge, (1989), ***"Production Flow Analysis"***, Oxford, UK: Oxford University Press

Burt, D.N. and Soukup, W.R. (1985), ***"Purchasing's role in new product development"***, Harvard Business Review, Vol. 64 No.5, pp. 90-7

C

Carol Ptak & Chad Smith, (2011), ***"Orlicky's Material Requirements Planning",*** 3rd Edition, McGraw Hill Professional, 2011.

Cavinato, J. L., (1992), ***"A total cost/value model for supply chain competitiveness"***, Journal of Business Logistics, Vol. 13, No. 2, pp. 285-301.

Chopra, S. and Meindl, P. (2001), ***"Supply Chain Management",*** Prentice Hall, NJ

Christopher, M.G., (1992), ***"Logistics and Supply Chain Management",*** Pitman Publishing, London, UK.

Christopher, M., (1994), ***"Logistics and Supply Chain Management",*** Pitman Publishing, New York, NY

Christopher, (1998), ***"Logistics & Supply Chain Management"***, London: Pitmans (Zara case written by Helen Peck)

Chun-Che Huang and Andrew Kusiak, (1996), ***"Overview of Kanban Systems"***, International Journal of Computer Integrated Manufacturing, 1996, Vol. 9, No. 3, pp. 169-189

D

Davis, D., (1995), ***"State of a new art: manufacturers and trading partners learn as they go"***, Manufacturing Systems, Vol. 13, No. 8, pp. 2-10.

Drucker, P.F., (1998), ***"Practice of Management"***, Butterworth Heinemann, Oxford

Dyer, J. H., Cho, D. S. and Chu, W. (1998), ***"Strategic Supplier Segmentation: The next best practice in supply chain management"***, California Management Review, Vol. 40, No. 2, pp. 57-77.

E

ECR Performance Measures Operating Committee, (1994), ***"Performance Measurement: Applying Value Chain Analysis to the Grocery Industry"***, Joint Industry Project on Efficient Consumer Response, Kurt Salmon Associates Inc., Washington, DC.

F

Farmer, D., (1996), ***"Creating World Class Suppliers"***, International journal of purchasing and materials management, vol. 32, No. 3, pp.52.

Fisher, (1997), ***"What is the right supply chain for your product?"***, Harvard Business review, March/April 1997

G

G.W. Zimmerman, (1975), ***"The ABC's of Vilfredo Pareto"***, Production and Inventory Management, Vol. 16, No 3, pp. 1-9

Gene Tyndall, Ralph Cox, (2011), ***"The Latest in Sales & Operations Planning: Demand-Driven Processes"***, Tompkins Associates, Nov 2011

Gripsrud, Geir, (2006), ***"Supply chain management-back to the future?"*** International Journal of Physical Distribution & Logistics Management, Vol. 36 No. 8, pp.643-659

H

Hammel, T.R., Kopczak, L.R., (1993), ***"Tightening the supply chain"***, Production and Inventory Management Journal, Vol. 34, No. 2, pp. 63-70.

Harland, C. M., Lamming, R. C. and Cousins, P.D., (1999), ***"Developing the concept of supply strategy"***, International journal of operations and production management, vol. 19, No. 7, pp. 650-666.

Hau L. Lee, V. Padmanabhan, Seungjin Whhang, (1997), ***"Information Distortion in a Supply Chain: The Bullwhip Effect"***, Management Science, Vol. 43, No. 4, Frontier Research in Manufacturing and Logistics, pp. 546-558

Heskett, J., Ivie, R. and Glaskowsky, N., (1964), ***"Business Logistics, Management of Physical Supply and Distribution"***, the Ronald Press Company, New York, NY

High Impact Coaching & Strategies, ***"Demand driven material requirements planning: the next generation MRP standard"***, www.myhicoach.com

Hokey Min, Gengui Zhou, (2002), ***"Supply Chain modeling: past, present and future"***, Computer and Industrial Ingineering, Vol. 43, pp. 231-249

Hopp & Spearman, (2004), ***"To Pull or no to Pull: What is the Question?"***, Manufacturing & Service Operations Management, Spring 2004, Vol. 6, No. 2, pp. 133-148

Horvath, Laura. (2001). ***"Collaboration: the key to value creation in supply chain management"***, Supply Chain Management: An International Journal, Vol. 6 No. 5, pp. 205-207

J

Jean-Luc Deleersnyder, T. Hodgson, R. King, P. O'Grady, A. Savvay, (1992), ***"Integrating Kanban type pull systems and MRP push systems: Insights from a Markovian Model"***, July 1992, IIE Transactions, Volume 24, Number 3

Johnson, M.E., Davis, T., (1995), ***"Gaining an edge with supply chain management"***, APICS - The Performance Advantage, Vol. 5, No. 12, pp. 26-31.

Jones, C., Hesterly, W. and Borgatti, S., (1997), ***"A general theory of network governance; Exchange conditions and social mechanisms"***, Academy of management review, vol. 22, No. 4, pp. 911-945.

K

Katzenbach Jon, Douglas Smith, (1993), ***"The wisdom of teams"***, Boston, Mass: Harvard Business School Press.

KPMG, (2016), ***"Demand-Driven Supply Chains"***, www.kpmg.com

Krishnamurthy et al., (2004), ***"Re-examining the performance of MRP and Kanban material control strategies for multi-product flexible manufacturing systems"***, International Journal of Flexible Manufacturing Systems, June 2004.

Kurt Salmon Associates Inc., (1993), ***"Efficient Consumer Response: Enhancing Consumer Value in the Grocery Industry"***, Food Marketing Institute, Washington, DC.

L

La Londe, Bernard J. and James M. Masters, (1994), ***"Emerging Logistics Strategies: Blueprints for the Next Century,"*** International Journal of Physical Distribution and Logistics Management, Vol. 24, No. 7, pp. 35-47

Lamming, R. C. (1993), ***"Beyond Partnership: Strategies for Innovation and Lean Supply"***, Prentice-Hall, Hemel Hempstead.

Lee, H. L. and Billington, C., (1992), ***"Managing Supply Chain Inventory: Pitfalls and Opportunities"***, Sloan Management Review, Spring, pp. 65-73.

Lee J. Krajewski, Larry P. Ritzman, Manoj K. Malhotra, (2013). ***"Operations Management – Processes and Supply Chains"***, Tenth Edition, Pearson, pp. 536-540.

Lewis, J. C., Naim, M. M. and Towill, D. R. (1997), ***"An Integrated Approach to Re-Engineering material and logistics control"***, International Journal of Physical Distribution and Logistics Management, Vol. 27, No. 3, pp. 197-209.

M

Mamun Habib, (2011). "***Supply Chain Management (SCM): Theory and Evolution, Supply Chain Management - Applications and Simulations"***, Prof. Dr. Md. Mamun Habib (Ed.), ISBN: 978-953-307-250-0, InTech, Available from: http://www.intechopen.com/books/supply-chain-management-applications-and-simulations/supply-chainmanagement-scm-theory-and-evolution

Mark Spearman and Michael Zazanis, (1992), ***"Push and Pull production systems: issues and comparisons"***, Operations Research, May-June 1992, Vol. 40, No. 3.

Martha C. Cooper Lisa M. Ellram, (1993), ***"Characteristics of Supply Chain Management and the Implications for Purchasing and Logistics Strategy"***, The International Journal of Logistics Management, Vol. 4 Iss 2 pp. 13 – 24

Martin Christopher, (2000), ***"The Agile Supply Chain: Competing in Volatile Markets"***, Industrial Marketing Management, Vol. 29., No.1., pp. 37-44

Mason-Jones, Rachel, Mohammed Naim and Denis Towill, (1997), ***“The impact of pipeline control on supply chain dynamics”***, International Journal of Logistics Management, Vol. 8, No. 2.

Mathias Ihme and Roy Stratton, (2014), ***“Evaluating Demand Driven MRP: a case based simulated study”***, a paper for Nottingham Trent University.

Mills, (1991), ***“Rebirth of the Corporation”***, New York: John Wiley

Monczka, Robert, Robert Trent, and Robert Handfield. (1994). ***“Purchasing and Supply Chain Management”***, Cincinnati, OH: South-Western College Publishing, Chapter 8

Mullin, T., (1994), ***"A new frontier"***, Stores, 76, 7, 10.

N

Nassimbeni, M., (1998), ***“The information society in South Africa: from global origins to local vision”***, South African Journal of library and information science 66(4): pp. 154-160

New, S. J. (1995), ***“Supply Chain Integration: Results from a Mixed method pilot study”,*** In Fourth International IPSERA Conference, Birmingham.

New, S. J. and Ramsay, J., (1995), ***Supply Chains- corporate path of economic disaster?”***, In Fourth international IPSERA conference, Birmingham.

New, S. J., (1997), ***“The scope of supply chain management research”***, Supply Chain Management, Vol. 2, No. 1, pp. 15-22.

Nexans Internal Audit Report, (2014), “***Management of the OWC in Liban Cables”,*** April 30, 2014 – Issued on July 1, 2014, P13-14 23

Nick Obioma Ejimabo, (2015), ***“The effective research process” unlocking the advantages of ethnographic strategies in the qualitative research methods”***, European Scientific Journal August 2015 edition vol.11, No.23 ISSN: 1857 – 7881

Nishiguchi, T, (1994), **“*Strategic Industrial Sourcing: the Japanese advantage”***, Oxford University Press, Oxford.

O

Olinger, C, (1998) ***“The Issues Behind ERP Acceptance and Implementation.”,*** APICS—The Performance Advantage 8, no. 6 (June 1998): pp.44–48.

Oliver, R. K. and Weber, M. D., (1982), ***“Supply chain management; Logistics catches up with strategy”***, In Christopher, M. L. (Ed), Logistics: The issues, Chapman & Hall, London, pp. 63-75.

Orlicky, J., (1975), ***Material Requirements Planning***. New York: McGraw-Hill, 1975.

R

R. Miclo, F. Fontanili, M. Lauras, J. Lamothe, B. Milian, (2016), ***“An empirical comparison of MRPII and Demand-Driven MRP”,*** 2016, IFAC (International Federation of Automatic Control) Hosting by Elsevier Ltd.

Raymond-Alain Thietart et al. (2014), ***“Methods of research in management”***, Dunod, Paris

Rhonda R. Lummus, Robert J. Vokurka, (1999), ***“Defining supply chain management: a historical perspective and practical guidelines”***, Industrial Management & Data Systems, Volume 99 Number 1 1999 pp. 11-17

Ronald H. Ballou, (2007), ***"The evolution and future of logistics and supply chain management",*** European Business Review, 2007, Vol. 19 Iss: 4, pp.332 – 348

Rondeau, Patrick and Litteral, L. A., (2001), ***"The evolution of manufacturing planning and control systems: From reorder point to enterprise resource planning."*** Scholarship and Professional Work - Business. Paper 41.

S

Saunders, M. J. (1995), ***"Chains, Pipelines, Networks and Value Stream: the role, nature and value of such metaphors in forming perceptions of the task of purchasing and supply management"***, In First Worldwide Research Symposium on Purchasing and Supply Chain Management, Tempe, Arizona, pp. 476-485

Skinner, W., (1985) ***"The Taming of the Lions: How Manufacturing Leadership Evolved, 1780–1984."*** In The Uneasy Alliance: Managing the Productivity-Technology Dilemma, edited by Clark, Hayes, and Lorenz, pp. 63–110. Boston, Mass.: The Harvard Business School Press.

Stevens, Graham C. (1989), ***"Integrating the Supply Chains,"*** International Journal of Physical Distribution and Materials Management, Vol. 8, No. 8, pp. 3-8

T

Taiichi Ohna, (1988), ***"Toyota Production System: Beyond Large-Scale Production"***, Diamond Inc., Tokyo, Japan

Tan, K. C., Kannan, V. R. and Handfield, R. B. (1998), ***"Supply Chain Management: Supplier performance and Firm performance"***, International Journal of purchasing and materials management, Vol. 34, No. 3, pp. 2-9.

Thierry Bur, (2015), ***"The MRP is dead, long live the DDMRP"***, Supply Chain Magazine, Vol. 93, April 2015, pp. 80

Tompkins International, (2012), ***"Demand-Driven Supply Chains"***, www.tompkinsinc.com

Tyndall, Gene, Christopher Gopal, Wolfgang Partsch, and John Kamauff. (1998), ***"Supercharging Supply Chains: New Ways to Increase Value Through Global Operational Excellence",*** NY: John Wiley & Sons

V

Van Hoek, (1998), ***"Reconfiguring the supply chain to implement postponed manufacturing"***, International Journal of Logistic Management, Vol. 9, No. 1.

W

Weeks, D., Crawford, F.A., (1994), ***"Efficient consumer response: a mandate for food manufacturers?"***, Food Processing, Vol. 55, No. 2, pp. 34.

Y

Y. Sugimori, K. Kusunoki, F. Cho & S. Uchikawa, (1977), ***"Toyota production system and Kanban system Materialization of just-in-time and respect for human system"***, International Journal of Production Research, Vol. 15, No. 6, pp. 553-564,

Annex

Slide 1

Evolution of the Operational Working Capital March 2013 – March 2014

Nexans Evolution of the Operational Working Capital March 2013 – March 2014

Value in KUSD *Source: HFM*	MAR 2013	JUN 2013	SEP 2013	DEC 2013	MAR 2014
Annual (last 12 months) Sales @actuals	154 755	153 797	154 862	153 453	149 310
@ Actuals					
Raw Material Inventory - Gross	8 615	10 526	13 925	10 852	12 940
Work in Progress Inventory - Gross	4 982	4 880	4 773	4 204	5 267
Finished Goods Inventory - Gross	16 600	18 497	21 024	23 175	23 690
Gross Inventory	30 198	33 903	39 722	38 230	41 897
Acc. Receivables, Net (Work. Cap)	22 030	28 377	34 733	35 275	28 772
Accounts Payable, Net (Work. Cap)	-14 519	-15 878	-17 037	-15 683	-11 287
Operational Working Capital	37 710	46 402	57 419	57 822	59 381
Operational Working Capital	37 710	46 402	57 419	57 822	59 381
OWC/Sales (%)	**24%**	**30%**	**37%**	**38%**	**40%**
Average SDC (3 months)	9 866	11 044	9 843	9 340	8 647
Inventory Turn - Weeks	13	13	17	18	21
Acc. Receivables, Net (Work. Cap)	22 030	28 377	34 733	35 275	28 772
Quarterly sales (3 months)	37 195	42 308	38 664	35 287	33 051
DSO - Total customers Days	**53**	**60**	**81**	**90**	**78**
Accounts Payable, Net (Work. Cap)	-14 519	-15 878	-17 037	-15 683	-11 287
DPO - - Total Suppliers Days	- **44**	- **43**	- **52**	- **50**	- **39**

OWC has deteriorated in all areas as highlighted above.

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Slide 2

Main Justifications of OWC increase – Liban Cables

Nexans

Main justifications for OWC increase – Liban Câbles

OWC increase from March 2013 to early 2014 is due to:

-Production increase starting June 2013 resulting in total production 20,500 MT Versus 15,400 MT Budget. This required additional raw materials, WIP and Finished goods.

- The Decision to create a finished good stock specifically for DSP in order to insure that the government doesn't lift the ban on cable imports for DSP.

- 2014 Budget 18,500 Tons requiring us to build a level of raw material, finished goods, and DSP stock to reach the Budget.

- First 3 months of 2014 were below forecasted sales volume due to security problems. Forecasted sales volume was not reached causing increase in stock.

- Due to the lack of AGS production capacity we had to import over 400 tons based on DSP needs forecast. Due to the security problems in Lebanon deliveries slower than planned.

- Before DSP companies we were working with EDL against letter of credit with payment terms of 15 days, which was replaced with the DSP.
contractors to become 60 to 90 days, in addition, the settlements of dues by DSP were excessively delayed due to lack of government and funding.

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Slide 3

Inventories – Sales & Operations Process (1)

Nexans

Inventories

1. Sales & Operations Process

- **Key Points:**
- S&OP tool was launched in March 2014. S&OP minutes of meeting will be available in June 2014.
- Sales Forecasts are defined by the Sales department at a detailed level (cable, packaging, color) with a visibility of one month and communicated to the planning department in a document called "Ebauche". However, the purchasing department cannot source RM (whose leadtime is over 2 months) based on the sales forecast that covers a period of only one month. This contributes in building safety stock in order to prevent any potential shortage. The RM level increased by 50% between March 2013 and March 2014.
- For the MTS products, the Sales Forecasts defined by the Sales department at a product level are based on historical data (sales of products recorded on the last 3 year and sales recorded over the 3 last months).
- 50% of the RM value (standard) is older than 4 months, which seems excessive. The first ABC matrix for RM was established in March 2014.
- Typical lead time for copper is 1 month and 2.5 month for aluminum.
  RM needed for the programmed orders are bought on a monthly basis according to the monthly RM meeting.

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Slide 4

Inventories – Sales & Operations Process (2)

Nexans

Inventories

1. Sales & Operations Process

- **Key Points:**

- The first ABC matrix for FG was created in March 2014 but has not been used by the Sales to drive stock demand and commercial actions, as it was not communicated.
- There is no identified commercial actions or scrapping of Finished Goods aiming at the reduction of the slow-moving and obsolete MTS stock and aged MTO.
  - The average age of the Finished Goods on hand at the end of March 2014 is 101 days.
  - 1. 2MUSD of MTO were produced in 2013 and prior years.
  - The MTS/MTO classification was defined by the Unit in January 2014.

Category	MTO

Stock($) @ std	Year				
	2011	2012	2013	2014	Total
Total	28 868,22	204 747,28	944 370,59	517 831,14	1 695 817,23

As per the Lebanese Accounting Law, scraping any material (FG or RM) is considered as Tax evasion and consequently a 15% Tax is imposed on the value of any scrapped material.

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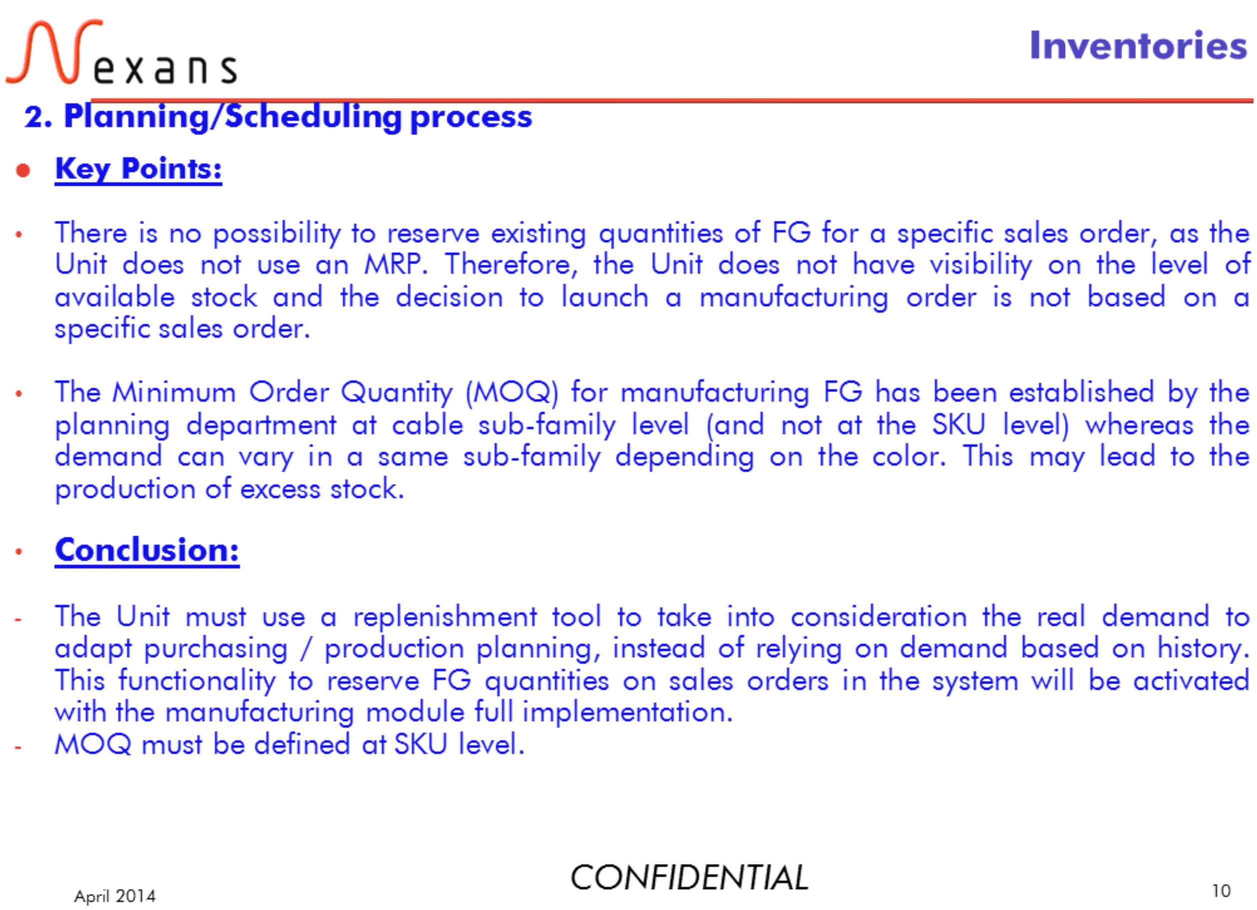
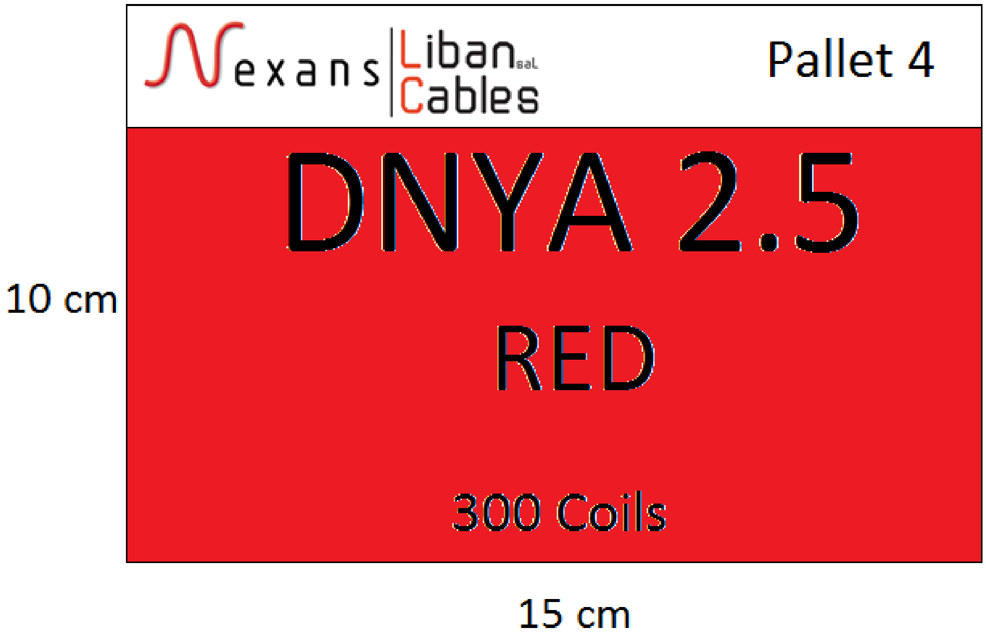
Slide 5

Inventories – Planning / Scheduling Process



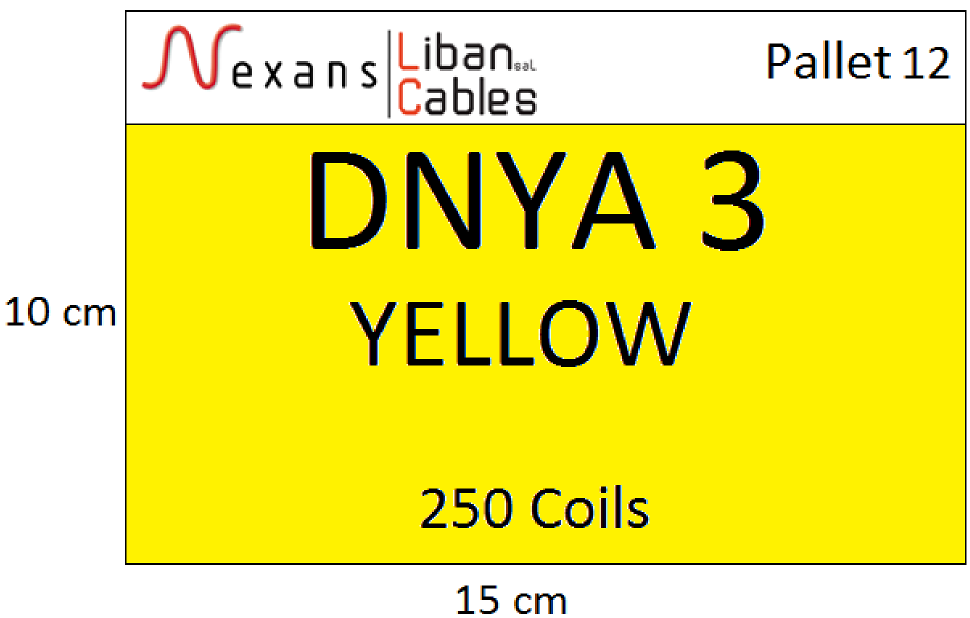
Picture 1

Example of DNYA 2.5 Red conveyance card



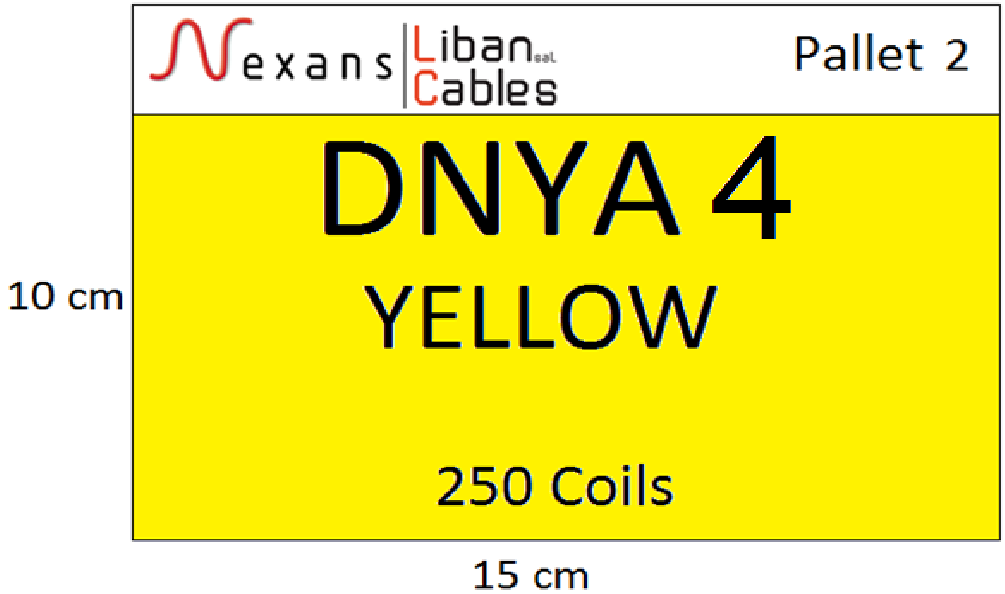
Picture 2

Example of DNYA 3 Yellow conveyance card



Picture 3

Example of DNYA 4 Yellow conveyance card.



Picture 4

Picture taken inside Liban Cables production workshop – Cards' Regrouping Board

Picture 5

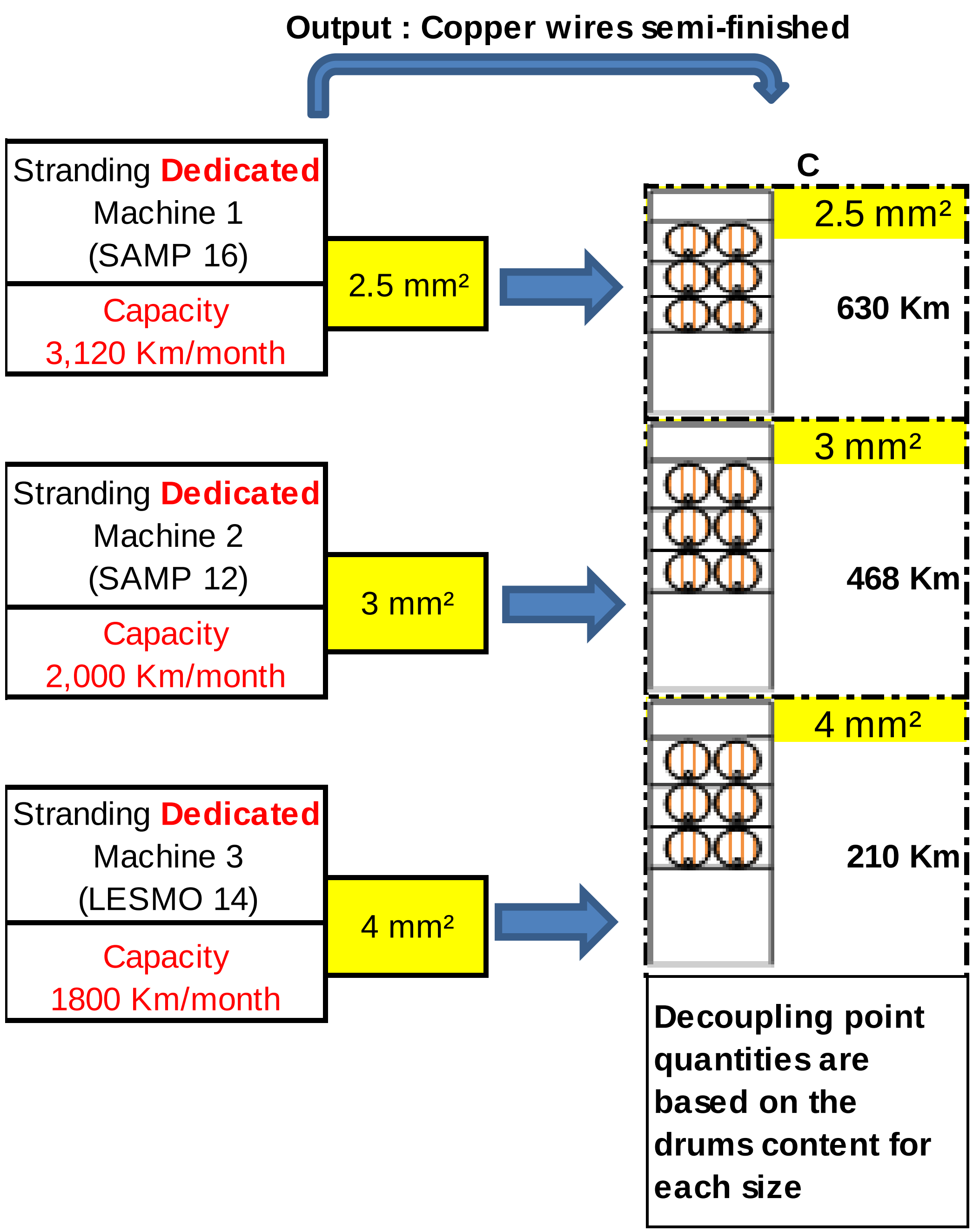
the inside the of finished good warehouse, where the Kanban item and stored and how, as well as a picture of the conveyance card in real.

<u>Picture 6</u>

Cable	Description	Lot size (Pallets) 1 production card	Lot size (Km)
2.5 mm^2	DNYA 2.5B	5	137,100
	DNYA 2.5BE	6	164,520
	DNYA 2.5G	6	164,520
	DNYA 2.5J	5	137,100
	DNYA 2.5N	9	246,780
	DNYA 2.5R	7	191,940
	DNYA 2.5V	4	109,680
	DNYA 2.5VJ	9	246,780
3 mm^2	DNYA 3B	4	91,400
	DNYA 3BE	5	114,250
	DNYA 3G	5	114,250
	DNYA 3J	4	91,400
	DNYA 3N	7	159,950
	DNYA 3R	7	159,950
	DNYA 3V	4	91,400
	DNYA 3VJ	4	91,400
4 mm^2	DNYA 4B	5	114,250
	DNYA 4BE	6	137,100
	DNYA 4G	6	137,100
	DNYA 4J	5	114,250
	DNYA 4N	9	205,650
	DNYA 4R	7	159,950
	DNYA 4V	4	91,400
	DNYA 4VJ	9	205,650

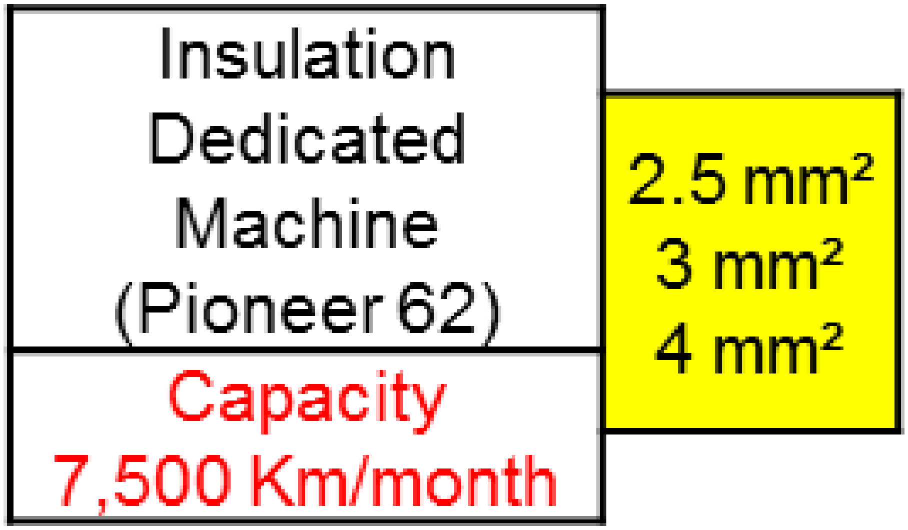
<u>**Picture 7**</u>

Stranding **Buffer Zone**

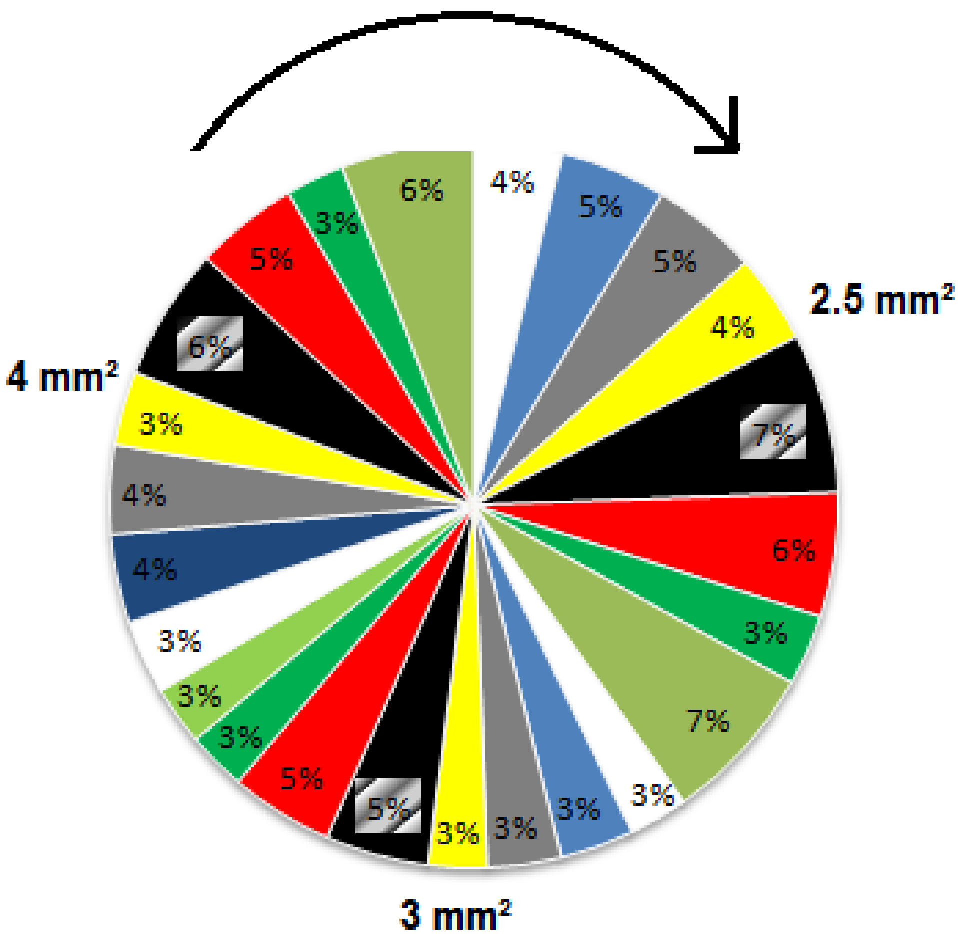


Picture 8

Insulation process

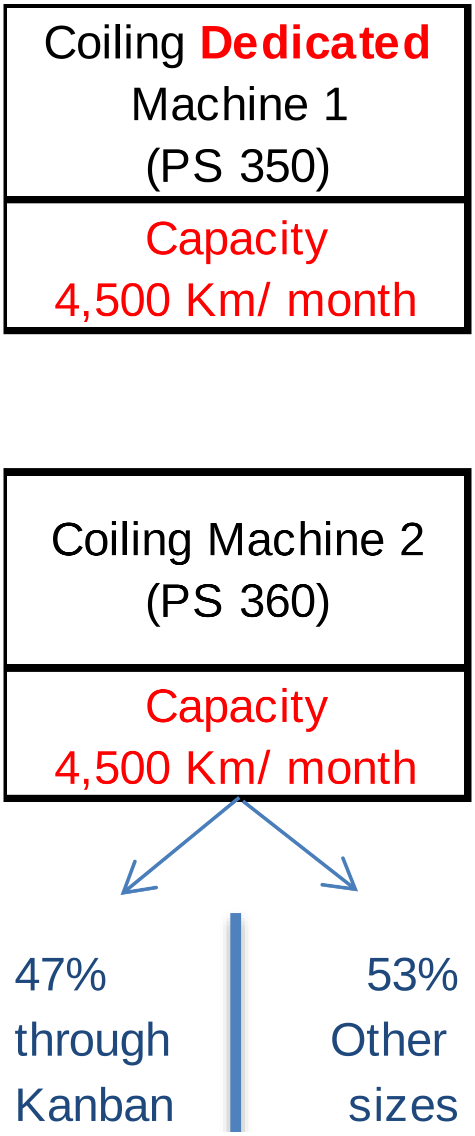


Weekly production cycle



Picture 9

Coiling Stage



Report 1

Liban Cables Finished Goods ABC Matrix in value (USD)

Supply Chain Department

Liban Cables' Finished Goods ABC Matrix ABCx (USD)

January-2014

Values (USD)	< to 2 weeks	from 2 to 4 weeks	from 4 to 6 weeks	from 6 to 8 weeks	> to 8 weeks	TOTAL
A	1,124,205	1,041,484	935,163	730,968	2,795,974	6,627,795
B	74,812	65,954	54,014	29,617	890,273	1,114,670
C	24,316	14,206	9,789	7,822	522,595	578,729
MTS	1,223,334	1,121,644	998,966	768,408	4,208,842	8,321,194
MTO	258,177	250,734	238,315	224,343	2,431,715	3,403,283
DSP	-	-	-	-	-	-
TOTAL	1,481,511	1,372,378	1,237,281	992,751	6,640,556	11,724,477

June-2014

Values (USD)	< to 2 weeks	from 2 to 4 weeks	from 4 to 8 weeks	from 8 to 16 weeks	> to 16 weeks	TOTAL
A	931,634	703,597	613,864	275,309	537,010	3,061,414
B	79,856	38,350	64,907	71,742	66,351	321,207
C	233,966	206,895	316,576	396,706	1,387,148	2,541,291
MTS	1,245,456	948,843	995,347	743,757	1,990,509	5,923,912
MTO	77,880	60,115	83,016	64,719	1,096,129	1,381,859
DSP	64,118	52,910	54,356	48,152	23,044	242,580
TOTAL	1,387,454	1,061,867	1,132,719	856,628	3,109,682	7,548,350

December-2014

Values (USD)	< to 2 weeks	from 2 to 4 weeks	from 4 to 8 weeks	from 8 to 16 weeks	> to 16 weeks	TOTAL
A	869,587	803,324	1,267,516	861,748	323,981	4,126,156
B	105,256	101,145	110,354	121,216	84,818	522,789
C	160,479	152,195	251,645	298,037	1,097,079	1,959,435
MTS	1,135,321	1,056,664	1,629,516	1,281,000	1,505,878	6,608,379
MTO	57,778	53,413	95,105	131,324	780,191	1,117,810
DSP	77,436	77,056	104,720	100,503	42,063	401,778
TOTAL	1,270,535	1,187,132	1,829,341	1,512,827	2,328,131	8,127,967

June-2015

Values (USD)	< to 2 weeks	from 2 to 4 weeks	from 4 to 8 weeks	from 8 to 32 weeks	> to 32 weeks	TOTAL
A	927,335	825,673	1,176,821	731,225	83,554	3,744,609
B	100,876	63,617	89,174	192,745	283,441	729,853
C	34,667	27,817	35,257	63,531	118,787	280,059
MTS	1,062,877	917,108	1,301,252	987,502	485,782	4,754,521
MTO	39,440	26,765	51,098	135,971	292,884	546,158
DSP	43,042	41,833	59,598	113,225	10,518	268,215

Report 2

Liban Cables Evolution of MTS families

Supply Chain Department

DOMESTIC

	Stock (T)	SALES (T)	Coverage (weeks)	Quality (%)
Dec-14	512	158	9.4	43
Jan-15	470	224	8.3	40
Feb-15	460	219	8.1	23
Mar-15	454	211	8	37
Apr-15	381	243	6.8	55
May-15	429	192	7.8	39
Jun-15	419	159	7.6	46
Jul-15	370	190	6.7	42
Aug-15	300	223	6.1	71
Sep-15	304	269	5.9	77
Oct-15	315	202	6	70
Nov-15	325	220	6.2	78
Dec-15	237	203	4.4	67
Jan-16	244	187	4.8	72
Feb-16	308	202	6.2	71
Mar-16	240	248	4.8	60
Apr-16	286	207	5.9	73
May-16	299	242	5.8	77
Jun-16	322	212	6.2	82
Jul-16	333	184	6.6	77
Aug-16	277	237	5.5	74
Sep-16	250	253	4.9	76
Oct-16	231	222	4.3	65
Nov-16	275	192	5.4	60
Dec-16	270	180	5.3	83
Jan-17	265	172	5.6	56
Feb-17	268	147	5.5	62
Mar-17	272	265	5.5	40
Apr-17	304	185	6.1	67
May-17	312	234	5.8	63
Jun-17	364	221	7.2	77
Jul-17	326	259	5.9	92
Aug-17	331	225	6	81
Sep-17	345	200	6.8	84
Oct-17	334	205	7.1	72
Nov-17	267	175	6.3	75
Dec-17	277	154	5.9	81

FLEXIBLE

	Stock (T)	SALES (T)	Coverage (weeks)	Quality (%)
Feb-15	361	149	7.9	24
Mar-15	373	132	8.9	37
Apr-15	374	143	9.3	27
May-15	348	164	8.9	22
Jun-15	339	172	8.4	29
Jul-15	295	178	7.7	54
Aug-15	217	197	6	30
Sep-15	205	189	5.6	65
Oct-15	259	178	7	58
Nov-15	254	169	6.7	52
Dec-15	241	148	6.3	49
Jan-16	255	167	6.7	66
Feb-16	283	151	7.6	37
Mar-16	310	152	8.6	33
Apr-16	295	168	7.6	47
May-16	274	176	7	55
Jun-16	298	170	7.8	41
Jul-16	294	169	7.4	42
Aug-16	301	207	7.2	46
Sep-16	284	183	7.1	48
Oct-16	288	162	7	36
Nov-16	287	155	7.6	38
Dec-16	259	167	6.8	57
Jan-17	237	165	6.5	33
Feb-17	286	110	7.7	33
Mar-17	354	148	9.2	25
Apr-17	338	132	8.8	22
May-17	358	156	8.9	29
Jun-17	347	175	8.6	24
Jul-17	255	223	6.4	67
Aug-17	227	193	4.6	39
Sep-17	241	153	5.9	46
Oct-17	277	149	7.8	32
Nov-17	266	133	7.5	48
Dec-17	224	137	6.5	49

Report 3

Liban Cables Finished Goods ABC Matrix (% of total inventory)

Nexans | Liban Cables

Supply Chain Department

Liban Cables' Finished Goods ABC Matrix (% of total inventory)

January-2014

Values	< to 2 weeks	from 2 to 4 weeks	from 4 to 6 weeks	from 6 to 8 weeks	> to 8 weeks	TOTAL
A	9.6%	8.9%	8.0%	6.2%	23.8%	56.5%
B	0.6%	0.6%	0.5%	0.3%	7.6%	9.5%
C	0.2%	0.1%	0.1%	0.1%	4.5%	4.9%
MTS	10.4%	9.6%	8.5%	6.6%	35.9%	71.0%
MTO	2.2%	2.1%	2.0%	1.9%	20.7%	29.0%
DSP	-	-	-	-	-	-
TOTAL	12.6%	11.7%	10.6%	8.5%	56.6%	100.0%

June-2014

Values	< to 2 weeks	from 2 to 4 weeks	from 4 to 8 weeks	from 8 to 16 weeks	> to 16 weeks	TOTAL
A	12.3%	9.3%	8.1%	3.6%	7.1%	40.6%
B	1.1%	0.5%	0.9%	1.0%	0.9%	4.3%
C	3.1%	2.7%	4.2%	5.3%	18.4%	33.7%
MTS	16.5%	12.6%	13.2%	9.9%	26.4%	78.5%
MTO	1.0%	0.8%	1.1%	0.9%	14.5%	18.3%
DSP	0.8%	0.7%	0.7%	0.6%	0.3%	3.2%
TOTAL	18.4%	14.1%	15.0%	11.3%	41.2%	100.0%

December-2014

Values	< to 2 weeks	from 2 to 4 weeks	from 4 to 8 weeks	from 8 to 16 weeks	> to 16 weeks	TOTAL
A	10.7%	9.9%	15.6%	10.6%	4.0%	50.8%
B	1.3%	1.2%	1.4%	1.5%	1.0%	6.4%
C	2.0%	1.9%	3.1%	3.7%	13.5%	24.1%
MTS	14.0%	13.0%	20.0%	15.8%	18.5%	81.3%
MTO	0.7%	0.7%	1.2%	1.6%	9.6%	13.8%
DSP	1.0%	0.9%	1.3%	1.2%	0.5%	4.9%
TOTAL	15.6%	14.6%	22.5%	18.6%	28.6%	100.0%

Report 4

Liban Cables Supply Chain Dashboard for 2017

Supply chain Dashboard Lebanon

	unit	Jan-17	Feb-17	Mar-17	Apr-17	May-17	Jun-17	Jul-17	Aug-17	Sep-17	Oct-17	Nov-17	Dec-17	Total YTD	Average per Month	Objectif / Budget	Delta Avg 2016 vs Budget	delta Avg 2017 vs Avg 2016	Average 2016
Activity																			
Total tonnage received from Supplier	Ton	2,566	1,976	2,946	2,206	2,515	2,928	2,542	2,999	1,572	1,909	2,302	1,071	27,532	2,294			4.57%	2,194
Total Gross weight received from production	Ton	2,012	2,065	2,458	2,215	2,290	2,423	2,372	2,317	2,178	2,253	1,674	1,287	25,542	2,129			8.31%	1,965
Total Gross weight delivered to customers	Ton	1,904	2,510	2,516	2,159	2,064	2,323	2,724	2,353	2,020	2,120	1,457	1,997	26,145	2,179			4.96%	2,076
Nbr of shipment to customer	Nbr	593	684	718	617	713	649	762	734	530	600	519	448	7,567	631			-3.83%	656
Nbr of line shipped	Nbr	5,457	4,739	6,849	5,052	6,571	6,601	7,206	6,716	5,005	5,647	5,003	4,842	69,688	5,807			-9.59%	6,423
Nbr of drum cutting (requested)	Nbr	79	90	69	129	110	94	97	111	77	109	84	74	1,123	94			7.57%	87
COGS (Sales) (SDC)	K$	4,972	5,915	6,163	5,421	6,286	5,491	6,655	6,088	5,031	5,984	4,437	4,309	66,752	5,563			9.62%	5,074
Order intake (Cu+3*Al)	ton	2,373	1,831	2,294	1,927	3,906	1,912	1,907	1,075	1,249	1,746	1,094	849	22,163	1,847			11.40%	1,658
Order deliveries (Cu+3*Al)	ton	1,831	2,095	2,284	1,750	1,798	2,151	2,882	2,216	2,144	2,195	1,375	1,484	24,205	2,017			2.85%	1,961
Quality																			
Shortages Raw Material	Nbr	2	3	2	1	1	1	3	1	1	2	0	1	18	2	5	-70%	-18.18%	2
Shortages Finished Goods (Coils)	Nbr	55	123	48	7	20	22	5	29	16	51	23	27	426	36	200	-82%	-30.88%	51
Nbr of reference where sales were out of stocks	Nbr	11	17	8	6	4	5	3	8	3	8	4	6	83	7			-41.92%	12
Customer service																			
OTIF-PCA	%	74.0	78.7	85.5	82.5	91.0	91.7	77	90	69	83	87	91	-	83	90	-7%	1.87%	82
customer claims (supply chain)	Nbr	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	-100%	-100.00%	0
Stocks (standard costs)																			
FG Inventories	K$	5,921	5,152	5,091	5,388	5,955	6,261	5,813	5,827	6,567	6,388	6,760	6,357	-	5,957			-6.80%	6,391
WIP Inventories	K$	2,257	1,927	2,444	2,142	2,449	2,340	2,225	2,282	1,913	1,917	1,869	1,963	-	2,144			23.94%	1,730
RM Inventories	K$	6,764	5,582	6,184	5,868	5,623	5,595	5,468	6,231	6,617	5,414	6,238	4,980	-	5,880			-3.23%	6,077
Total Inventories	K$	14,943	12,660	13,719	13,398	14,027	14,196	13,506	14,341	15,097	13,719	14,867	13,300	-	13,981			-1.52%	14,197
Coverage in weeks																			
coverage FG	weeks	5.0	4.3	3.9	4.0	4.3	4.7	4.1	4.2	4.8	4.9	5.7	5.6	-	4.6	5	-7.60%	-15.30%	5.5
coverage WIP	weeks	1.9	1.6	1.9	1.6	1.8	1.8	1.6	1.6	1.4	1.5	1.6	1.7	-	1.7	2	-17.05%	14.48%	1.4
coverage RM	weeks	5.7	4.6	4.7	4.4	4.1	4.2	3.9	4.4	4.8	4.1	5.3	4.4	-	4.6	6	-24.10%	-11.56%	5.1
total coverage*	weeks	12.6	10.5	10.5	10.0	10.2	10.7	9.5	10.2	11.0	10.4	12.5	11.7	-	10.8	13	-16.67%	-10.13%	12.1

*Total coverage excluding Technicas sales from Nexans Korea.