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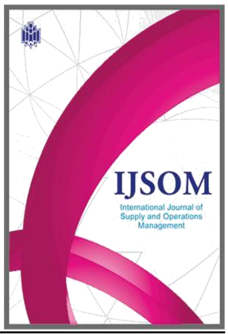

Demand Driven DRP: Assessment of a New Approach to Distribution

Yassine Erraoui *,[a], Abdelkabir Charkaoui [a] and Abdelwahed Echchatbi [a]

[a] *Laboratory Industrial Management and Innovation, Faculty of Science and Technology, Settat, Morocco*

Abstract
The distribution of goods from suppliers to customers plays an important role in the supply chain. In this paper, the approach of Demand Driven Distribution Resource Planning (DDDRP) is proposed in order to optimize the distribution flow in the supply chain. The purpose is to manage all sources of variability in "operational, management, supply and demand", while improving the traditional methods of Distribution Resource Planning (DRP). First, a review of the literature on the impact of variability upon distribution flow and the solutions proposed in this context is presented. Then, a general study of distribution industries is investigated in order to apply the DDDRP method; we show the buffers positioning in the distribution network, and the profile and levels of the buffers. After the dynamic adjustment, the Demand Driven Planning and the execution based on the net flow equation are presented. The results discuss the approach and the steps of implementing it in the distribution industry.

Keywords: Supply chain management, DRP, DDDRP, Inventory management, Bullwhip effect**.**

1. Introduction

Many researches concentrate on the optimization of the flow of merchandise through a distribution system. The pressure of the market and the cost of inventories justify the importance of this question. The most common method for managing physical flow in the distribution system is Distribution Resource Planning (DRP). In the related literature, some works focus on the inventory management as one of the keys to optimize the flow, and other works try to introduce the Just-In-Time concept in the Distribution Resource Planning (DRP) method. The recent character of the supply chain - where the complexity is growing, the customer tolerance time is short and the product life cycles are restricted - pushes towards the need for enhancing the conventional methods like DRP. Thus, this work focuses on applying the Demand Driven concept to the distribution part of the supply chain. Its originality comes from the method "Demand Driven Material Requirement Planning" (DDMRP), which is a multi-echelon demand and supply planning and execution methodology (R. Miclo & al. 2016). Therefore, the purpose of the new method, which is named "Demand Driven Distribution Resource Planning" (DDDRP) is to manage different forms of variability in “demand, operational, supply and management”, dealing with various objectives like the lead times, on time-delivery, and to reduce the cost of goods sales. The structure of this article focuses on a multitude of works accomplished in order to enhance flow in the distribution network, such as inventory management and DRP tool. Also, a part of this article aims to identify the Bullwhip effect in the distribution network, and the nature of given solutions to prevent this effect. This section finishes with a general overview of the DDMRP method.

In the last section, we introduce the concept of "Demand Driven Distribution Resource Planning", as a method for optimizing flow through the distribution network. We present a general study of the distribution industries (data not included) and take the five steps: positioning buffers in the distribution network, buffering profile and levels, dynamic adjustment, demand driven planning, and execution of open supply orders. The results of this work are related to the particularities of this approach, and the axes and steps to apply it in a distribution industry. The article ends with a conclusion and discusses further researches.

Corresponding author email address: erraoui.yassine@gmail.com

2. Review of the Literature

2.1. Inventory management in supply chain management

Supply chain management (SCM) is described by Minner (2003) as an integrative approach to planning and control of materials and information flows with suppliers and customers, as well as between different functions within a company. It is a set of approaches to integrate suppliers, manufacturers, warehouses, and stores efficiently, so that merchandise is produced and distributed at right quantities, to the right locations, and at the right time, in order to minimize system wide costs while satisfying service-level requirements (Routroy & Kodali, 2005).

Moreover, the inventory management is a major issue in SCM. Its importance in the SC requires considering the network of procurement, transformation and delivering firms. This leads to the term, "multi-echelon" network, when the product moves through more than one step before reaching the final customer.

The table below presents a part of the literature, where the time span is from 1999 to 2005, addressing the multi-echelon inventory management, especially in distribution networks, from an operational research point of view. The purpose is to find the optimal policies and models for inventory management.
PS: N (in the table) denotes a number bigger than 2.

Table 1. Multi-echelon inventory management in the Supply Chain

Authors	Number of Echelons	Manufacturing site	Warehouse	Retailer	depot	stock point	distribution center	supplier	Other
Forsberg (1996)	2	-	1	N	-	-	-	-	-
Graves (1996)	2	-	1	N	-	-	-	-	-
Verrijdt & de Kok (1996)	2	-	-	-	1	N	-	-	-
Yoo & al. (1997)	2	-	-	-	-	-	1 central & N regional	-	-
Moinzadeh & Aggarwal (1997)	2	-	1	N	-	-	-	-	-
Mohebbi & Posner (1998)	1	-	-	-	-	-	-	N	-
Bollapragada & al. (1998)	2	-	N	-	1	-	-	-	-
Dekker & al. (1998)	2	-	1	N	-	-	-	-	-
Hariga (1998)	N	-	1	N	-	-	-	-	-
Korugan & Gupta (1998)	2	-	1	N	-	-	-	-	-
Ganeshan (1999)	3	-	1	N	-	-	-	N	-
Chen (1999)	3	-	-	-	-	-	-	1	stage 1 & stage 2
Van der Heijden (1999)	2	-	N	-	1	-	-	-	-
Axsater & Zhang (1999)	2	-	1	N	-	-	-	-	-
Andersson & Marklund (2000)	2	-	1	N	-	-	-	-	-
Wang & al. (2000)	2	-	-	-	1	N	-	-	-
Cachon & Fisher (2000)	2	-	-	N	-	-	-	1	-
Axsater (2000)	2	-	1	N	-	-	-	-	-
Axsater (2001a)	2	-	1	N	-	-	-	-	-
Nozick & Turnquist (2001)	2	-	1	N	-	-	-	-	-
Andersson & Melchiors (2001)	4	1	N	N	-	-	N	-	-
Chen & al. (2002)	2	-	-	N	-	-	-	1	-
Moinzadeh (2002)	2	-	-	N	-	-	-	1	-
Tee & Rossetti (2002)	2	-	1	N	-	-	-	-	-

Table 1. Continued

Authors	Number of Echelons	Manufacturing site	Warehouse	Retailer	depot	stock point	distribution center	supplier	Other
Rau & al. (2003)	3	1	-	1	-	-	-	1	-
So & Zheng -2003	2	-	-	1	-	-	-	1	-
Kalchschmidt & al. (2003)	1 and 2	-	-	-	-	-	-	-	-
Axsater (2003)	2	-	1	N	-	-	-	-	-
Minner & al. (2003)	2	-	-	-	1	N	-	-	-
Mitra & Chatterjee (2004b)	2	-	1	2	-	-	-	-	-
Chiang & Monahan (2005)	2	-	1	1	-	-	-	-	-
Jalbar & al. (2005a)	2	-	1	N	-	-	-	-	-
Jalbar & al. (2005b)	2	-	1	N	-	-	-	-	-
Routroy & Kodali (2005)	3	1	1	1	-	-	-	-	-
Kochel & Nielander (2005)	5	-	1	1	1	1	-	-	1 Branch Store

2.2. Distribution Resource Planning

DRP has become an effective method for inventory control in the multiproduct, multi-echelon physical distribution environments since 1970. The purpose is to gain full visibility of inventory levels in every node of the supply chain in order to meet the current demand.

There are numerous reports of the benefits that the companies have received from the DRP implementation (Forger 1986, Horne 1989, Krepchin 1989, Hammel and Rock 1993, Davis 1994, Frasier Sleyman 1994). Bookbinder and Heath (1988) analyzed and compared several lot-sizing policies under DRP assumptions, and Martin (1990), who was Director of Materials Management for Abbott at the time, wrote the seminal work on this subject, Distribution Resource Planning, which explained the logic and the benefits of DRP. Another work for managing DRP and optimizing inventory in the supply chain is proposed by Wang (2003). It is a Just-In-Time distribution requirements planning system under the limited supply capacity with multi-warehouse and multi-retailer scenarios. The purpose is to minimize the total cost of manufacturing and transportation by establishing an optimal distribution requirement planning. The result show that the integration of the pull SC system applied to allow the distribution of products is in time, under limited supply capacity.

André J. Martin (1997) describes "Distribution resource planning" DRP as a management process that determines the needs for inventory locations and ensures that sources of supply can meet demand. DRP is based on some input data as:

- Sales forecasts by unit of stock and by deposit
- Customer orders,
- Inventory available for sale,
- Purchasing and / or manufacturing orders initiated by product purchased and / or manufactured,
- delivery and production times,
- security stock policies,
- Minimum quantities of purchase, production and distribution.

Once all these data is integrated, DRP generates a simulation of resource requirements over time to support the logistics strategy, which includes what products will be needed, how much and when, the transport capacity requirements by vehicle type and deposit, labor, surface and equipment requirements by deposit, stock investment needs. Figure 1 shows the particularities of DRP summarized in a diagram[1].

[1] André J. Martin, (1995), « *Distribution Resource Planning* »

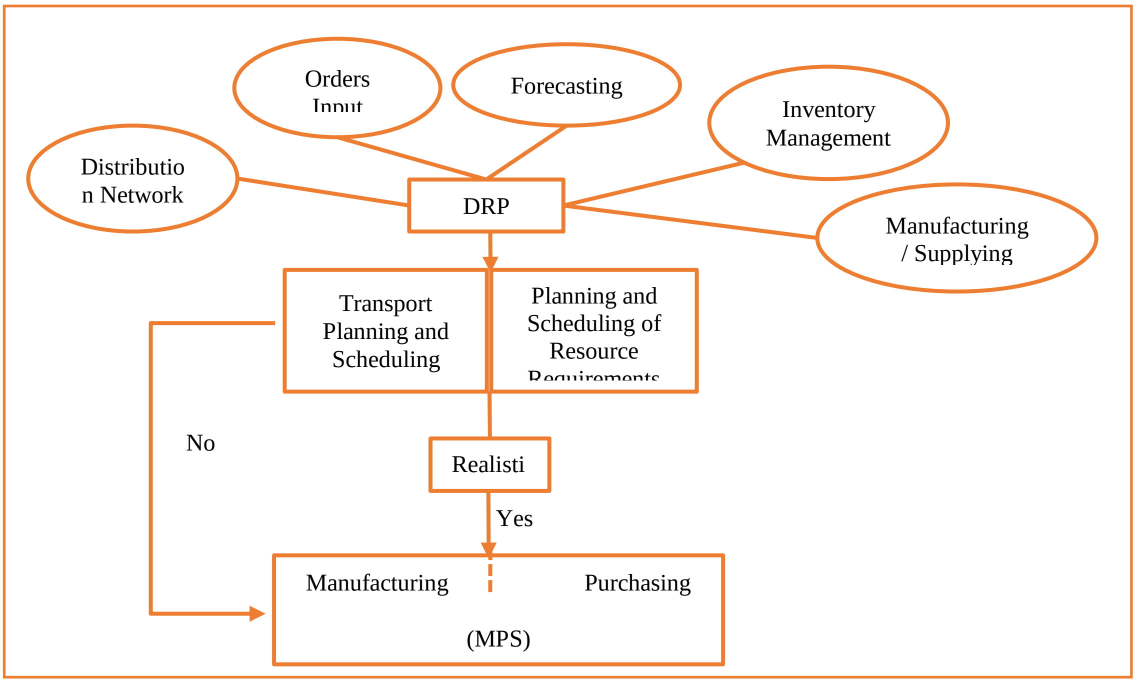

Figure 1. DRP Process Diagram

2.3. Bull-Whip effect and variability in distribution

In the management of supply chain, scientists and industrials notice the fact of Bullwhip effect. It means that the variability process increases as we move from a level to another in the supply chain (Figure 2). Some researches discuss this phenomenon, e.g. Bagnha and Cohen (1995), Kahn (1987) and Metter (1996), focusing on analyzing the causes of the Bullwhip effect, and the solutions to reduce its impact. In particular, Lee & al. (1997a, b) identify five main causes of the Bullwhip effect including the use of demand forecasting, supply shortages, lead times, batch ordering, and price variations. Then they offer some suggestions to reduce the impact of this effect, such as the centralization of the demand information. Frank Chen (2000) also try to quantify the bullwhip effect along with determining its impact of the demand forecasting.

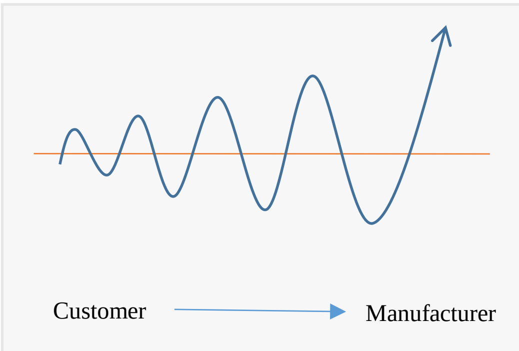

Figure 2. The bullwhip effect

Thus, the bullwhip effect is manifested in the amplification of variability, which leads to the systematic distortion in demand information. Figure 3 – evoked by Lee (2016) - shows a retail store's sales of a product, alongside the retail's orders issued to the manufacturer which indicates the distortion in demand information.

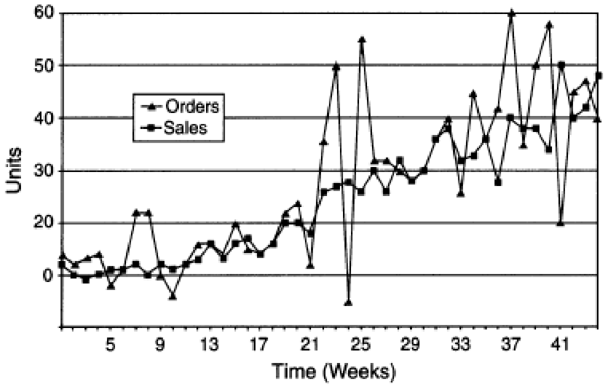

Figure 3. Comparison between orders and sales

Hau L. Lee & al. (1994) affirm that the bullwhip effect refers to the phenomenon where orders to the supplier tend to have larger variance than sales to the buyer (i.e., demand distortion), and this distortion propagates upstream in an amplified form (i.e., variance amplification). This phenomenon has been recognized in many markets such as Procter & Gamble (Lee & al. 1994). The distortion of demand information implies a number of consequences in the supply chain, leading to serious cost implications. For example, the unplanned purchases of supplies cause excess raw materials, then expensive excess capacity due to the need for more inventory space. Consequently, this brings additional transportation costs due to inefficient scheduling and premium shipping rates. By a measure published in Fuller (1993), the inefficiencies bear part in responsibility for the $75 billion to $100 billion worth of inventory caught between various members of the $300 billion (annual) grocery industry. Moreover, trade estimations suggest that these activities can result in excess costs in the range of 12.5% to 25% (Kurt Salmon Associates, 1993).

Lee (2016) focuses on the consequence related to the inventory status. He proposes that the keys to improving the channel coordination and dampening the bullwhip effect are primordially based on information about inventory status and Sell-through data. In an experimental context for inventory management, Sterman (1989) made in evidence the bullwhip effect in the "Beer Distribution Game", in which the supply chains contain four players who make independent inventory decisions without consultation with other chain members, relying only on orders from the neighboring player as the sole source of communications. The experiment shows that as far as on moves up in the supply chain, the variances of orders amplify, which increase the bullwhip effect. Economists like Holt (1960), Blinder (1982), and Blanchard (1983) have concluded that the main role of inventory is like a buffer to smooth production in response to demand fluctuations. Table 1 summarizes the contributing factors to the causes of the bullwhip effect in the literature, as well as the counter-measures and practices in various industries, mentioned in Hau L. Lee (2016).

The table below summarize the principal causes of the bullwhip effect from the literature:

Table 2. Causes of the Bullwhip effect

References	***Causes***	***References***	***Causes***
Lee HL & al. (1997)	Demand forecasting	Geary S & al. (2006)	multiplier effect
Lee HL & al. (1997)	order batching	Erkan B & al. (2008)	lack of synchronization
Lee HL & al. (1997)	price fluctuation	Moyaux T & al. (2007)	misperception of feedback
Lee HL & al. (1997)	rationing and shortage gaming	Moyaux T & al. (2007)	local optimization without global vision
Heydari Jafar & al. (2009)	lead time	Moyaux T & al. (2007)	company processes
Chandra C & al. (2005)	inventory policy	Alony I & al. (2007)	capacity limits
Jakšič M & al. (2008)	replenishment policy	Lee HL & al. (1997)	the strategic interaction of two rational SC members
Geary S & al. (2006)	improper control system	Croson R & al. (2009)	neglecting time delays in making ordering decisions
Lee HL & al. (1997)	lack of transparency	Skiadas CH (1986)	lack of learning and/or training
Alony I & al. (2007)	number of echelons	Croson R & al. (2009)	Fear of empty stock

Table 3. Causes, factors and measures to prevent Bullwhip effect in distribution

Contributing factors	***Causes***	***Counter-measures***	***State of practice***
• Multiple forecast • Long lead time • High order costs	Order batching	• Single control of replenishment • Lead time reduction • EDI & CAO	• VMI (P&G and WalMart) • Quik Response mfg strategy • McKesson, Nabisco
• Proportional rational scheme • Ignorance of supply conditions • Unrestricted orders & free return policy	Shortage game	• Allocation based on past sales • Shared capacity & supply information • Flexibility limited over time, capacity reservation	• Saturn, HP • Scheduling sharing (HP, motorola) • HP, Sun, Seagate
• No visibility of end demand	Demand signaling	• Access sell-thru or POS data	• HP, Apple, IBM

2.4. Demand Driven Concept for inventory management in manufacturing

Regarding the inventory situation, Ptak & Smith (2016) make in evidence in "Demand Driven Material Requirements Planning (DDMRP)" book, two universal points of inventory (the red parts): one is "too little", where there are miss sales and lack of components, and the other is the extreme right point ("too much") where there are more space committed and excess cash (Figure 4a). The flow breaks down at those points. The purpose is protecting the flow by making the inventory in an optimal range (the green part). In reality, companies exhibit what is known, the "bimodal effect", which shows sorts of oscillations, shifting from one extreme to another (Figure 4b). The yellow part corresponds to the warning state of inventory

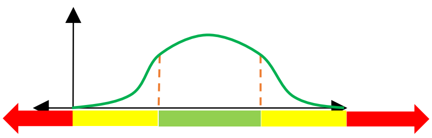

Figure 4a. Optimal range in inventory

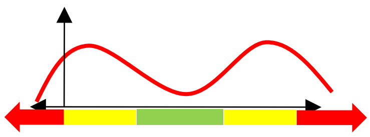

Figure 4b. bimodal aspect

The main DDMRP promises are promoting the flow by reducing variability and detecting demand variations. DDMRP reveals the weak links of other push or pull flow methods with references to MRP II and Lean Management. It was created by Ptak and Smith at the beginning of the 21st century and was presented in the 3rd edition of Orlicky's Material Requirements Planning in 2011. DDMRP uses known concepts taken from MRP (Material Requirements Planning), DRP (Distribution Requirements Planning), Lean, Six-Sigma, and TOC (Theory of Constraints) and innovations (Ptak and Smith, 2011).

DDMRP is divided into 3 steps and 5 components (Figure 5). The first step, ʺpositionʺ, consists in determining the position of the decoupling points in the Supply Chain which acts as a variability absorber. Then the flow is protected with buffers that are sized and dynamically adjusted according to a number of parameters. Finally, the flow is pulled firstly with demand driven planning which enables the supply orders to be generated. It is then possible to move to the execution phase which is a daily visual and collaborative management step.

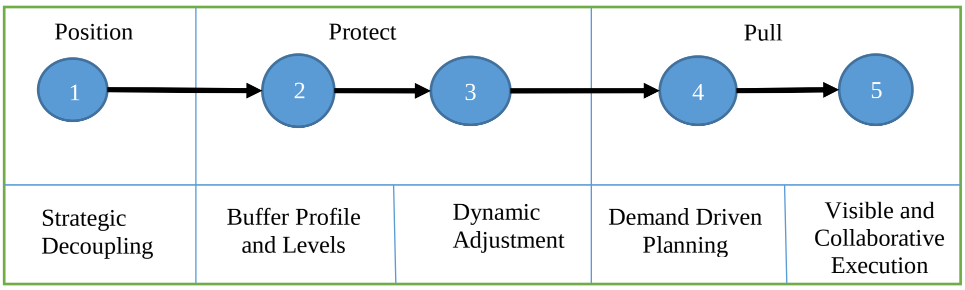

Figure 5. Steps of DDMRP

In the first step, that is, strategic decoupling (or positioning buffer), DDMRP places decoupling buffers in the supply chain, to stop transference and amplification of variability as long as one passes in the supply chain. The other benefits are shortening planning horizons and compressing lead times.
The second step involves sizing the buffer profile to construct the level of absorption in every decoupling point. The buffer contains three zones: the red, yellow and the green one. Each zone has specific methods to calculate it, referring to the part demand information based in historical and/or forecast and the DDMRP part setting, which allows for creating values for each zone. The dynamic buffer adjustment concerns the update of buffer levels, which flex up and down as the average daily usage is changed. This concept replaces the static safety stock used in MRP.

After the dynamic adjustment, the forth component of DDMRP is in order. The Demand Driven Planning, based on the qualified sales and not on the forecast is the process of generating supply orders. Using the net flow equation:

$$OH+OS-QS=net\ flow\ position$$

OH: On Hand Quantity
OS: Open Supply Quantity
QS: Qualified Sales Order Demand

Figure 6. Net Flow Position

This produces the net flow position used to decide the planning way (Figure 6). If it is below the top of the yellow zone, a supply order is issued to reach the top of the green zone. The final step – visible and collaborative execution - deals with the management of open supply orders. It interprets signals on open supply priorities against the on-hand buffer status. The lower the on hand level, the higher the priority to maintain the flow and the execution priority. So, the priority is assigned by the buffer status and not by the due date.

3. DDDRP in distribution industries: A general study

3.1. Presentation and parameters of the study

The Demand Driven Distribution Resource planning can be explained as a multi-echelon inventory planning and execution solution. The method is based on six main axes; MRP, DRP, Lean, Six-Sigma, Theory of Constraints and innovation. It can help with executing, in an optimal range of inventory, for a warehouse, the materials prioritized to be purchased, from his supplier, which can be another warehouse or the manufacturing company.
The method DDDRP is implemented in 5 main steps.

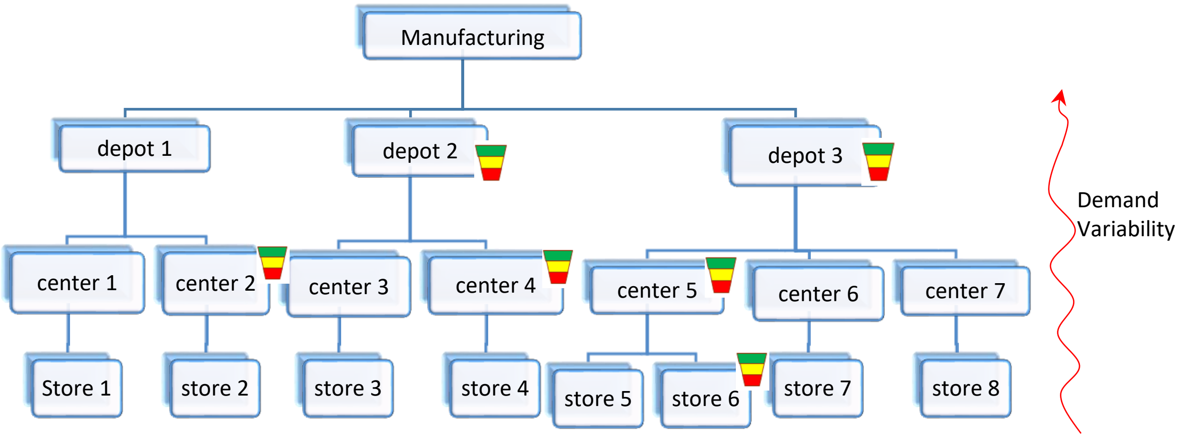

Figure 7. Buffer positionning in the distribution network

The first step is "strategic inventory positioning". It consists of positioning a buffer on a warehouse, concerning an article that belongs to the distribution flow, in order to control the amplification of demand variability. Figure 7 shows the positioning of the buffer in the distribution network. The DDDRP issue is to pull replenishments between strategic buffers, and push planning orders for non-buffered articles. The positioning is done from a financial point of view.

The second step is to define profile and levels; it serves to the absorption level of variability in the decoupling points. The buffer contains three zones including red, yellow and green, using some specific methods for calculation, referring to the part demand information based in historical and/or forecast and other part settings related to DDDRP, which allows for creating values for each zone (Figure 8).

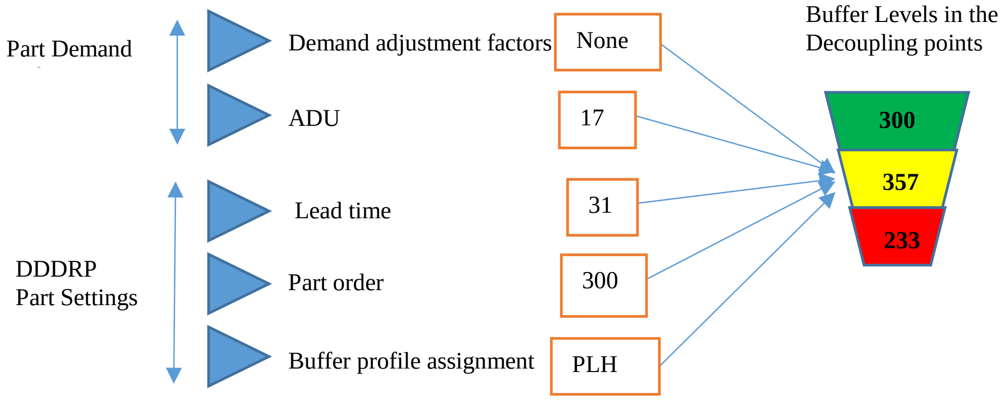

Figure 8. Buffer Level in the Decoupling Point

The information needed for buffer level construction concerns multitude of parameters; the lead time of distribution from a warehouse (supplier) to another warehouse (receiver), this one is the sum of four phases, which constitutes the time needed for distribution. It contains the launch and preparation time of the order, the loading, transiting, unloading and stocking. The result is the decoupling lead time (DLT) for each reference between two consecutive warehouses. In the distribution context, it is defined as the longest cumulative coupled lead time chain in a distribution item's product structure. Moreover, for each reference available for the distribution, the average daily usage (ADU), the initial state of inventory, and the selling price are primordial parameters to calculate the buffer levels.

The buffer level and profiles are constructed using the parameters above, exploiting the following DDMRP expressions:

$$Red\ Base\ =\ ADU\ *\ DLT\ *\ lead\ time\ factor$$
$$Red\ Safety\ =\ Red\ base\ *\ variability\ factor$$
$$Total\ red\ zone\ =\ Red\ Base\ +\ Red\ Safety$$
$$Yellow\ Zone\ =\ ADU\ *\ DLT$$
$$Green\ Zone\ =\ ADU\ *\ DLT\ *\ Lead\ Time\ factor$$

The buffer sizing leads to the calculation of the average inventory (cost). The issue is to compare and decide between the different ways of positioning buffers.

The level of protection flexes up and down based on operating parameters, market changes and planned or known future events. This is defined by the dynamic adjustment of the buffer. The traditional DRP uses the Safety Stock concept, which is adopted from a static point of view. However, the dynamic character of the supply chain is manifested in a variation of the decisive parameters of the buffer levels and profile, especially the average daily usage. Thus, the continuous changes of the parameters push for updating the buffer situation daily. Figure 9 is an example of the lead time compression taken from "Demand Driven Material Requirements Planning (DDMRP)" book (Ptak and Smith, 2016).

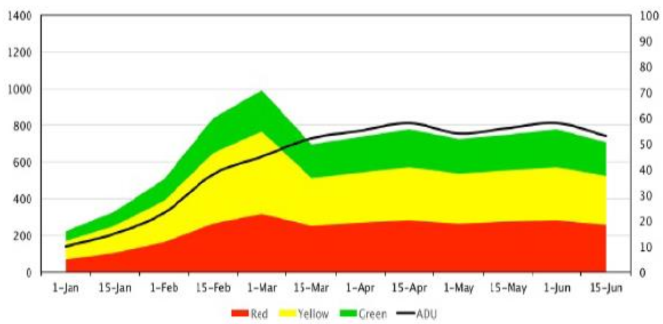

Figure 9. Lead Time Compression

The demand driven planning is based on the Qualified Sales, without taking forecasts as priority. It is the step of generating supply orders. This generation is done via the equation determining the position of the net flow position. This information is crucial for deciding to issue a supply order (Figure 6).
The net flow equation is defined as:

$$OH + OS - QS = net\ flow\ position$$

OH = On Hand Quantity, indicating the quantity of stock physically available
OS = Open Supply Quantity, indicating the quantity of stock that has been ordered but not received.
QS= Qualified Sales Order Demand. It is the sum of sales orders past due, sales orders due today, and qualified spikes.
After the planning, the Demand Driven Execution uses the On-Hand Buffer Status to execute and manage open supply orders. The lower the On Hand level, the higher the priority to maintain the flow and the execution priority. The DRP systems used to assign the priority by date, which is rejected by this step, where the priority is assigned by the buffer Status.

4. Conclusion and perspectives

The present paper discusses the Demand Driven approach in the distribution part for the supply chain. The issue is to remediate the supply chain variability partially manifested in the demand distortion through warehouses. As one moves away in the distribution network, from the source directly related to the customer, the amplification of variability is noticed in forming the bullwhip effect. This study pauses the first keys and steps to adopt the demand driven concept. Advantages of using this approach are related to shortening the lead times and absorbing variability in buffer positions. Yet, there is a need for focusing in research on various points evoked by this work: From the variability point of view, the sources of variability are numerous. Studies must take into consideration the other forms like the management, the supply and operational variability. We focused on one side of these types, due to the importance of demand variability as a factor in customer satisfaction. The buffer positioning is a point of future work. The purpose is to find the optimal way to implement buffers in the distribution network. Therefore, the subject may use operational research for a number of references, to optimize the objective function related to the average inventory cost. Another study may trait the different factors (variability, lead time …) because of the lack of studies in affecting values to these factors. Finally, this study should be implemented in a real case study, with all the data and parameters needed to compare it with the traditional ways of managing inventory as DRP.

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