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Demand Driven Material Requirement Planning: Core concepts and analysis of its behavior on a case study

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Abstract: Demand Driven Material Requirement Planning (DDMRP) is a recent Production Planning and Control (PPC) approach. It has been mainly studied through its reported performance on specific industrial applications or through its parametrization. This article aims to analyze its main characteristics and to compare its behavior with MRP2 in an in-vitro case study. Results show that, in their basic configurations, DDMRP leads to a lower number of orders but of a larger size, and furthermore, to a slightly higher stock level (+6%) but distributed in a different way than in MRP2. Those results allow a better understanding of some strengths and weaknesses of DDMRP.

Keywords: Production planning and control systems, DDMRP, MRP2

1. INTRODUCTION

For 5 years, the economic environment faced events (COVID-19, Ukrainian war, climatic phenomena…) that led to major supply chain disruptions. This context leads industrial companies to seek new solutions to dampen the effects of those events on their performance and their ability to deliver products on time.

If we consider industrial companies as systems, then solutions can come from their different sub-systems: strategy, distribution, commercial, support activities, production… Amongst them, the production system offers different opportunities to face the new stakes. Its decision system, also referred to as the production planning and control system (PPC), is deeply involved in the performance of the production system. However, traditional approaches can fail to maintain performance in a context of high variability. This led Ptak and Smith (2011) to develop a new PPC called Demand Driven MRP (DDMRP) which is supposed to answer the new challenges.

For 10 years, different studies have leaned on specific success stories but few have truly analyzed its behavior or its core concepts. Our goal is to fill a part of this gap. In the section 2, we will provide a literature review on PPC. In the section 3, a specific focus on DDMRP will be done. Section 4 will illustrate, through an in-vitro case study realized with a simulation, the behavior of DDMRP by comparing it with that of the well-known MRP2 method.

2. PPC SYSTEMS

2.1 Definitions

PPCs are defined more by their role and scope than by a standardized definition. The objective of PPC is to enable the company to meet customer demand while maximizing resource efficiency. Thus, Olhager and Wikner (2000) and Wiendahl, Von Cieminski and Wiendahl (2005) see the PPC as a set of functions and tools that are implemented to satisfy demand. For Mcfarlane and Bussmann (2000), PPCs "represent a set of solutions to the various decision-making problems that arise in the production field". For Vollmann, Berry and Whybark (1997), a PPC "provides the information to manage material flows efficiently, use people and equipment effectively, coordinate internal activities with suppliers and communicate with customers about market expectations". The same main authors in Jacobs et al. (2011) extend the definition by integrating the notion of supply chain. They emphasize that the PPC does not make decisions, but provides the manager with the information needed to make decisions.

Concerning the scope of PPCs, not all authors propose the same approach. According to Stevenson et al. (2005), decisions are made by several functions (processes): component requirements planning, demand management, capacity management, and production order scheduling and sequencing. Jeon and Kim (2016) divide the issues to be dealt with into those relating to production planning in the broad sense (Industrial Facilities Management, Capacity Planning, Orders Planning, Process Planning, Orders Release, Scheduling, and Execution Control) and those relating to production control (Inventory Management, Production Process Design, Purchasing and Supply Management). Anil Kumar and Suresh (2008) distinguish 12 processes divided into 3 main functions pre-planning, planning, and control. This vision with 3 main functions is also the one of Kiran (2019) and is close to Jeon and Kim (2016) which is a very extensive view of PPCs functions. Some definitions (Berry and Hill, 1992; Jacobs *et al.*, 2011) see PPCs as a hierarchical process

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based on the company's strategic plan and leading to the calculation of all orders (purchasing and production), the definition of production resources at different level (strategic, tactical and operational) of decision depending of the time horizon and ending at the shop floor level with the control system of the orders. To analyze the scope of PPCs, Bayard (2023) proposes a grid divided into 3 decision levels as shown in Table 1.

Table 1 Grid for decision scope of PPC (Bayard, 2023)

Decision Level	Process
Strategic	• Master production scheduling (S1) • Global capacity (S2)
Tactical	• Detailed need per reference (T1) • Detailed need for capacity (T2)
Operational	• Release of orders (purchased and made items) (O1) • Scheduling (O2) • Sequencing (O3) • Orders monitoring (O4) • Capacity monitoring (O5)

2.2 Main PPCs overview

Different PPCs exist, we present only the main ones. One of the most well-known is probably MRP2 created in 1975 by Orlicky (1975) and enriched by Wight, Wight and Brun, (1984). According to Vollmann, Berry and Whybark (1997), its goal is *to provide the right part at the right time to meet the schedules for completed products*. For Guide and Srivastava (2000), this system should prevent from overstocks as it answers in right quantity at the right time. Orders are supposed to be linked to real demand. In reality, many companies use parameters that disconnect orders generation and real demand. Those choices can lead to overstock.

Kanban is the control system embedded in the lean manufacturing theory. It was created in the '50s in the Toyota production system and was formalized by Ohno (1988). It does not play a role of anticipated planning as orders are generated when stock is used. It is the first card-based PPC and its main target is to control stocks. For Suri (2014), it is not adapted to complex environments.

Conwip is a control system developed by Spearman, Woodruff and Hopp (1990) as an alternative to Kanban when the complexity of the production system becomes too high e.g. unpaced or with a moving bottleneck. It focuses on the work in progress (WIP) control all over the shop floor. They do not consider stock level but only the load of the floor shop represented by cards. Conwip is not able to generate orders and is necessarily coupled with another system, mainly MRP2.

Drum buffer rope (DBR) was developed by Goldratt and Cox (1993). As a part of the Theory of constraints (TOC), it focuses on the work in progress (WIP) regulation and strives to control the bottleneck flow to ensure the performance of the production system characterized by the throughput (Gupta and Snyder, 2009; Thürer, Fernandes and Stevenson, 2020). As for Conwip, it is not an order generation method but only a control system. It is not based on cards.

POLCA is the PPC of Quick Response Manufacturing (QRM) theory created by (Suri, 1998). Its main goal is to satisfy consumers by reducing lead times in a context of high variety of production (Godinho Filho and Veloso Saes, 2013). It is inspired by Kanban and Conwip as it aims to control WIP. It is a card-based system, where cards represent capacity signals.

Besides those traditional approaches, new PPCs have been created since 2000 to answer the increasing complexity of the economic context (Bagni *et al.*, 2021). Amongst them, DDMRP is one of the most studied.

2.3 DDMRP presentation

According to its creators (Ptak and Smith, 2011), DDMRP is *a formal multi-echelon planning and execution method to protect and promote the flow of relevant information and materials through the establishment and management of strategically placed decoupling point stock buffers*. DDMRP is the first layer of the method Demand Driven Adaptive Enterprise (DDAE) that is supposed to lead to a better performance than other PPCs in a *Volatile, Uncertain, Complex and Ambiguous context* (Ptak, 2018).

DDMRP is mostly studied through its performance compared to other PPCs. Some comparisons are made with a MRP2 existing in a company (Ihme and Stratton, 2015; Miclo *et al.*, 2016; Mukhlis H.F, IndraEfrialdi and Rimawan, 2019; Sinha and Ubale, 2020). Other authors compare DDMRP to other PPCs (Miclo *et al.*, 2018; Thürer, Fernandes and Stevenson, 2020). Other studies consider DDMRP parameters (Lee and Rim, 2019; Dessevre, Baptiste and Lamothe, 2020; Bayard, Grimaud and Delorme, 2021; Favaretto, Marin and Tolotti, 2021; Damand, Lahrichi and Barth, 2022; Martin, Lauras and Baptiste, 2023). More recently, some authors propose to improve DDMRP such as Duhem, Benali and Martin (2023) who use reinforcement learning or Xu et al. (2023) who integrate resource constraints.

3. ANALYSIS OF DDMRP

The official definition, proposed by Ptak and Smith (2011), shows that the focus of this method is close to Conwip and DBR because it emphasizes the role of flow. Nonetheless, it is neither a question of bottleneck nor a question of total WIP. DDMRP uses stock buffers to prevent shortages and protect the flow to ensure delivery performance.

The authors also use some tools of MRP2 as they employ the explosion of the bill of materials and a time-phased calculation of the needs. However, the calculation of needs is very different and uses other parameters.

DDMRP also uses a visual representation that is close to Kanban with 3 zones (red, yellow, and green) that allow to evaluate the situation of a stock buffer and triggers an order when a limit is reached. It is a kind of reorderpoint where the level is calculated with an original method and with a maximum stock level. Unlike Kanban, it is not a card-based system and the quantity of an order is variable.

Ptak and Smith, (2011) claim that heritage but also argue that they bring original concepts. Indeed, they propose a new way of generating orders with specific parameters.

According to its authors, DDMRP is involved in the 3 different decision levels (strategic, tactical, and operational). The buffer placement is seen as a strategic level. However, this decision is more a question of make-to-stock vs. make-to-order if we choose between buffering final products or purchased items. Hence, this decision involves the business model and not only the PPC. If we consider the other placement options, this seems, at most, tactical because changes can be done at a short-term horizon.

Considering the processes involved, DDMRP is mostly focused on order generation and control through its priority given with the buffer status. However, it encompasses neither global load calculation nor a capacity management system. A comparison of core concepts is done in the following Table 2.

Table 2 Comparison of core concepts MRP2 vs DDMRP

	MRP2	DDMRP
Goal	*Right part at the right time*	Protect the flow
Lever	BOM explosion	Decoupling points+BOM explosion
Calculation of needs	Time Phased	Time Phased
Order Quantity	Variable	Variable
Safety stock	Possible Often fixed	Compulsory Dynamically sized
Card-based	No	No
Decision scope	S1-S2-T1-T2-O1	T1-O1-O2-O4

4. ILLUSTRATION OF DDMPR BEHAVIOR

To better understand the operating system of DDMRP, we compare it with, probably the most well-known PPC, namely MRP2. We want to understand the order generation system not evaluate if one gives better performance from a customer perspective. So will compare: order frequency, quantity, and stock levels.

4.1 The case study

In order to make the comparison, we will use a simple study case which allows a better understanding of results and phenomenons. Thus, the bill of material (BOM) of the article Final Product (FP) includes 1 SubAssembly (SA) and 2 Purchased Items (PI1 and PI2) and is as described in Figure 1. All links are set to 1 and lead times are 5 periods for each item.

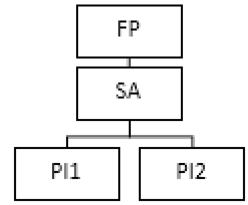

Figure 1 BOM for item FP

The demand for FP was calculated with an average of 100 units per week and a random coefficient based on a uniform law (0.8,1.2). This demand pattern is representative of industrial sectors with high levels of variability and variety such as high added value industries (e.g aerospace, luxury industry …). DDMRP is supposed to be relevant in this type of context, this is why we use this type of demand.

As we want to look at the overall behavior of the methods and not carry a fine-tuning, standard parameters will be used for both PPCs.

4.2 Parameters for MRP2

MRP2 is a time-phased PPC that will review the stock position of each article at each period. The calculation of the projected on hand for the period only needs 3 data: Gross Requirements (demand of the period and back orders), scheduled receipt, and stock position at the beginning.

The system will trigger an order if the projected on hand is below 0 or a limit set by managers. This is the first of the 2 main parameters to be settled. Often the safety stock (SS) is this limit. The second one is the lead time (LT) which represents the delay between the order release and its availability. In this example, as we compare MRP2 with DDMRP, a stock-based system, we use a safety stock calculated with one of the most adverse options:

$$SS = LT \ x \ Average \ Demand = \ 500 \ units \ (1)$$

MRP2 can be much more complex by adding other elements such as lot size, minimum quantity of order, safety lead times… As we want to analyze the behavior of the basic systems, for MRP we will only consider the 2 essential parameters LT and SS.

4.3 Parameters for DDMRP

DDMRP is harder to parametrize. First, we have to choose buffers' positions: for a simple case, the Final Product (FP) and one of the purchased item (PI2) are selected. This will allow a comparison between the 2 policies for the purchased items in the context of DDMRP. Then the buffer sizing involves choosing at least: variability and lead time factors, minimum order quantity and desired order cycle. In this experiment, we use the basic recommendations of DDMRP (Ptak and Smith, 2018). Different calculations are automatically done based on the previous parameters: Decoupled Lead Time (DLT), sizing of zones according to DDMRP principles.

With DDMRP, the system will trigger an order based on: the net flow equation (NFE), its situation inside the buffers' zones, the spike threshold, and the spike horizon. The last 2 elements have to be settled.

An originality of DDMRP is that buffers' sizing is dynamically calculated based on the average demand calculated on a defined horizon and mix of past and future data. We set it up equal to DLT as the system cannot see beyond this horizon and will only be based on forecasts as for MRP2. All parameters are summed up in Table 3.

Table 3 Summary of DDMRP parameters for buffers

	Parameters	FP	PI2
Choices for buffer sizing (*optional)	Variability factor	0.5	0.5
	Lead time factor	0.25	0.7
	Minimum Order Quantity (MOQ) *	100	100
	Desired order cycle*	1	1
Calculations for buffers' sizing	DLT	15	5
	Top of Red (TOR)	563	525
	Top of Yellow (TOY)	2063	1025
	Top of Green (TOG)	2438	1375
Choices for orders release system	Spike threshold	282	263
	Order spike horizon	15	5
	Average Daily Usage (ADU) horizon	15	15
		15 periods forward	

The experiment is led on a simulation tool executing DDMRP and MRP2 algorithms. It is run on 100 weeks with a warm-up of 10 weeks. A decision is taken for each period. In this experiment, initial stock levels have been set to cover the first 5 periods and the safety stock or the Top Of Yellow (TOY).

4.3. Results

Results can be studied at 2 different levels of the BOM: the final product and dependent items.

- *4.3.1 Final product analysis*

For the Final Product, Figure 2 shows the orders generated by the 2 PPC systems. We can see that the behaviors of MRP2 and DDMRP are dramatically different while using the basic sizing recommendations.

DDMRP generates less frequent but larger orders than MRP2. If the total quantity is the same, at the floor shop level 4 orders of 100 (MRP2) is different from 1 order of 400 (DDMRP). This could be less flexible and harder to manage in the shop floor and can cause overload but it can also protect from variability. Indeed, the Green Zone sizing method leads to larger batches less frequent than in MRP2 because it recommends choosing the largest option amongst the 3 proposed. This phenomenon underlines the major role of buffer sizing parameters (DLT and Lead time factor). It is essential to understand that this phenomenon can also happen with MRP2 when managers play with parameters e.g. batch size, safety stock, or lead time.

For the stock level of the final product, the difference is quite significant as DDMRP generates a theoretical average on hand of around 775 pieces, 1.6 times more than MRP2 with 500 pieces. This overstock will have to be compared to the customer performance, especially in a context of high variability. It could protect against uncertain customer demand.

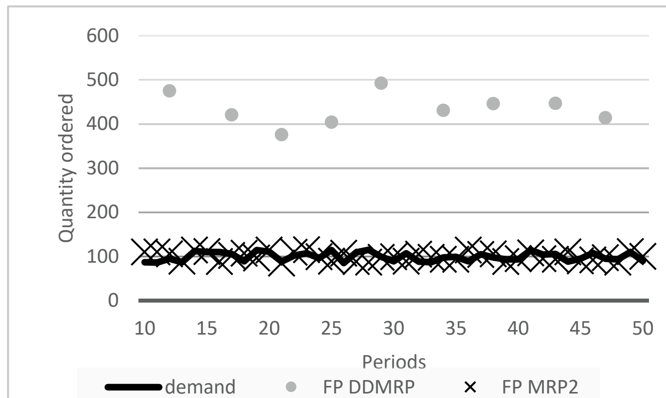

Figure 2 Comparison of order size and frequency

Beyond the size and the frequency of orders, we also notice a difference concerning the time elapsed between the order decision and its release. For MRP2, this time is equal to the Lead Time of the FP i.e. 1 one in our case. For DDMRP, it corresponds to the DLT, therefore in our case 15 weeks as there are 3 levels of BOM with 5 weeks at each level. This means that the order of week 1 for FP will be released in week 11 (1+DLT-LT = 16-5) whereas it will be released in week 6 for MRP2. With DDMRP, the demand will be served with the existing stock and the order will refill it.

- *4.3.2 Dependent items*

The second comparison is about the consequences on the dependent items. For MRP2, the orders are generated every week, so with the time offset, dependent items have a demand every week. The quantity is variable but the average is around 100 pieces per week.

As seen in Figure 3, with DDMRP, the demand signal arrives once every 4 weeks because of the orders of the FP transmitted to SA which triggers the demand for PI1 and PI2. There is a difference between the 2 purchased items as they are managed under different policies respectively MRP2 and DDMRP. The number of orders is the same for both items. However, the buffered item (PI2) has globally less regular but larger orders over 100 periods than PI1, with an average quantity of 483 vs 427.

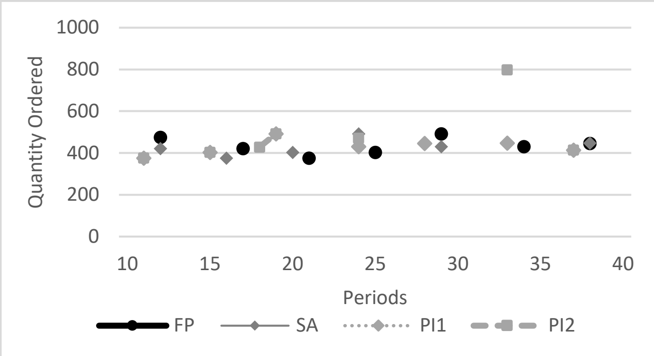

Figure 3 DDMRP orders summary

The time elapsed between 2 orders is not as regular as for the PI1 managed under MRP2. Further studies should be led before any conclusion, especially on a higher bill of materials.

Finally, concerning stock levels, Table 4 shows that DDMRP leads to a slightly upper total stock (+6%) but not distributed in the same way.

The cost of each item should be studied before making any conclusion. According to the authors, DDMRP allows to place stock where it is needed and should lead to a better performance.

Table 4 Average stock level in pieces

STOCK IN PIECES	DDMRP	MRP2
FP	775	500
SA	0	500
PI1	0	500
PI2	1 352	500
TOTAL	2 127	2 000

5. CONCLUSIONS AND PERSPECTIVES

Conceptually, DDMRP is a PPC mostly centered on the operational level and it embeds its own orders trigger method. It is a time-phased system, with a reorder point and a variable quantity. DDMRP has different common points with other PPCs but it includes an original way to calculate the safety stock through different parameters. It also proposes a priority management of the orders at the floor shop level. Nonetheless, it doesn't manage neither the total load nor the capacity calculation. Other components of DDAE are supposed to manage those issues.

In the illustrative case, we studied the behavior of the DDMRP calculator and highlighted that the orders were less frequent but larger than in a standard version of MRP2. This can lead to some challenges in the shop floor. Further studies have to be led to find out whether those phenomena are typical or not of DDMRP, and to evaluate their impact on its performance. The method also requires more parameters than a classic MRP2 and the role of each one of them is not clearly defined.

Considering the PPCs analysis, it is clear that there is a need for a more structured comparison of PPCs. The goal would be to find out the main characteristics of PPCs and their field of performance as many authors recommend adapting the PPC to the industrial and organizational situation.

Finally, in the case study, DDMRP led to a total stock above MRP2 but this conclusion cannot be extended yet. The performance of DDMRP has to be evaluated with a discrete event simulator. It will allow to include more stochastic phenomena (failures, reject rate, lead times…) and more detailed rules of PPCs to estimate the interest of this increased stock.

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