International Journal of Engineering Trends and Technology
ISSN: 2231 – 5381 / https://doi.org/10.14445/22315381/IJETT-V71I3P205
Volume 71 Issue 3, 33-45, March 2023

Review Article

The Demand Driven MRP Implementation in Complex Manufacturing Industries: A Systematic Literature Reviews

Daniel Benavente[1], Stephano Peralta[1], Grimaldo Quispe[1,2], Javier Moguerza[3] and Carlos Raymundo[4]

[1]*Facultad de Ingeniería Industrial, Universidad Tecnologica del Peru, Lima, Peru.*
[2]*Facultad de Ingeniería ,Universidad Nacional Autónoma Altoandina de Tarma, Tarma, Peru*
[3]*Escuela Superior de Ingeniera Informática, Universidad Rey Juan Carlos, Mostoles, Madrid, España.*
[4]*Dirección de Investigacion, Universidad Peruana de Ciencias Aplicadas, Lima, Peru.*

[4]*Corresponding Author : Carlos.raymundo@upc.edu.pe*

Received: 26 December 2022 Revised: 28 February 2023 Accepted: 17 March 2023 Published: 25 March 2023

Abstract *- Since its creation in 2011, the DDMRP planning method has been catalogued as an important tool to deal with the high variability of the environment, especially in demand, since it allows modifying inventory levels without neglecting the level of service and quality of the products. However, the volume of research available on this method is small, even more, so those considering the application in complex industries. The objective of this research was to analyze the available literature about the application of the model in complex industries, considering its application trends, buffer positioning and improvement target factors. In addition, it allowed identifying areas that other researchers should study in the future. This systematic review scrutinized different applications of the method in complex industries worldwide by analysing literature in different languages. This research identified that certain characteristics of the DDMRP require further study, especially real and simulated applications. On the one hand, more research is required in applying the last two phases of the method (planning based on demand and visible and collaborative execution), as well as the need to deepen in economic terms and the possibility of combining it with other similar or complementary methods. Thanks to this literature review, it was possible to recognize the impact of the implementation of the DDMRP in complex industries, identify the factors that influence its effectiveness and describe the need to delve into various issues that have not yet been analyzed in depth, seeking to understand the best way the studied method.*

Keywords *- Complex industry, Decoupled lead time, Demand-driven, Demand-Driven Material Requirements Planning (DDMRP), Systematic literature review.*

1. Introduction

The current context presents an important challenge for industries related to planning: the high variability of demand, resulting in increasingly inaccurate sales and availability forecasts [1]. Faced with this reality, Demand Driven MRP was born, which is presented as a flexible method, able to cope with the variations of the environment [2]. However, it has been identified that the most successful cases in the application of the method tend to be in industries with a simple Bill of Materials (BOM), presenting the possibility of deepening the application of the method in complex manufacturing industries [3]. Complex manufacturing industries are defined as those that meet some of these conditions: having a BOM greater than 3 levels, handling 15 or more references in the BOM explosion [4], or having long supply lead times that make it impossible to place emergency orders and completely stop production [5].

Given this scenario, the objective of this review is to synthesize the available results on DDMRP applications in complex manufacturing industries so that it can contribute to the research community to obtain greater visibility on the various streams of ideas, considerations and parameters that arise from its application in complex industries and pose new challenges for future research.

Based on the above, the paper attempts to answer the following questions:

- What are the recent trends complex manufacturing companies use in applying the DDMRP method?
- What are the factors that are targeted for improvement in the implementation of Demand Driven MRP in complex manufacturing industries?

- What are the main factors that influence the effectiveness of DDMRP in complex manufacturing industries?

2. Theoretical Framework

The DDMRP was created based on the analysis of 6 pillars of manufacturing industry practices; Figure 1 shows the pillars mentioned above. Together with parameters and considerations of the environment analysis, these seek to address the problems of planning, modeling, and management of the production flow in a supply chain, where certain parts of the process are protected with stock buffers called buffers [2].

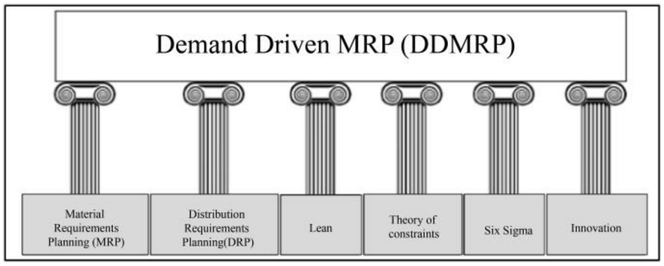

Fig. 1 DDMRP base pillars

Source: *From Ptak & Smith, 2016.*

The method has been defined under the implementation of 5 main phases. Figure 2 shows the grouping of these phases according to the role they play in the process.

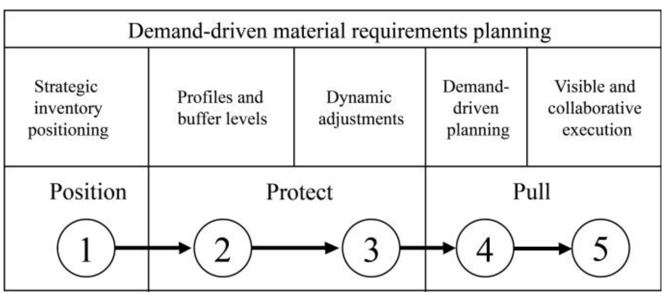

Fig. 2 DDMRP components

Source: *From Ptak & Smith, 2016.*

2.1. Strategic Positioning of Buffers

Buffers are points of decoupling in the BOM of the product that allow the reduction of the impact of the whip effect. This effect creates a distortion between what is manufactured by the organization and what is demanded, as shown in Figure 3. This is usually generated by the low effectiveness of demand forecasts [6]. In addition, the creators of the method point out that the further the process moves away from the input signal, the greater the distortion and problems generated by it. To overcome this, applying the method must effectively define the positions that require greater protection against demand variability [2].

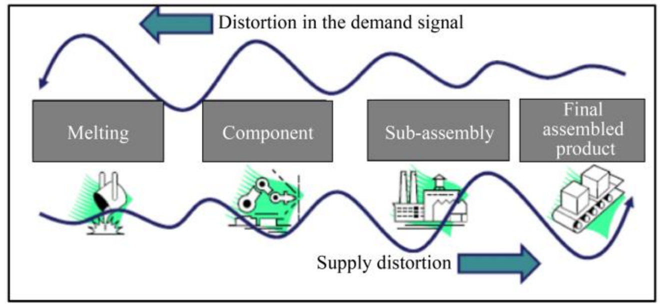

Fig. 3 Exemplification of the whip effect.

Source: From Ptak & Smith, 2016.

The method is versatile and applicable in various industries, so no specific model exists for positioning shock absorbers. It will depend on the conditions to which the company is subjected. However, the creators have defined a list of factors to consider when positioning the buffers [2]:

- Customer tolerance time.
- Lead time that allows obtaining competitive advantages.
- Sales horizon.
- Level of variability due to external factors.
- Inventory flexibility and bottlenecks.
- Critical operations.

2.2. Definition of Profilers and Buffer Levels

Once the buffers are located within the product structure, they will function as buffers against demand variability. They are an inventory that will prevent stockouts in certain parts of the line from affecting the other sections [2]. As can be seen in Figure 4, the buffer is made up of 3 sections.

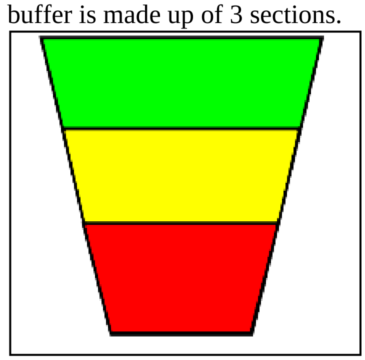

Fig. 4 Buffer composition

2.2.1. Yellow Zone

Allows to cover the regular demand at the buffer. The size of this zone is calculated based on the multiplication of the average consumption of the reference (ADU) and the lead time decoupled to that position of the BOM (DLT).

2.2.2. Green Zone

Indicates the periodicity and quantity that must be exceeded to request a replenishment order. To determine the size of this zone, the highest result among 3 factors must be selected:

- Percentage of average daily consumption: A multiplication of the ADU, the DLT and a lead time factor based on the context analysis.
- Minimum order quantity (MOQ) value.
- Minimum order cycle: The multiplication of the ADU by the frequency at which orders are placed.

2.2.3. Red Zone

Functions as safety stock and will be used in critical cases of stockouts. The size of this zone is determined by the level of variability of the environment since its main function is to buffer. It is made based on the sum of 2 parameters:

- Base red zone: A multiplication of the ADU, the DLT and a lead time factor based on the context analysis.
- Safety red zone: The base red zone is multiplied by a variability factor based on the analysis of the environment.

2.3. Dynamic Adjustments

This phase consists of the periodic review of the buffer size, which must be modified according to organizational environment changes. This means that the stock that serves as a buffer is not static as in other planning systems, such as MRP, but is adapted according to the variation in demand [2]. This is observed in the works [7,8], where they reveal better results applying methods based on DDMRP, taking into account their application in dynamic conditions.

The creators of the method indicate that these adjustments can be of 2 types:

- Planned adjustment factor: they are made based on seasonal circumstances. The planners previously identified these and sought to modify the buffer stock size based on the sector's experiences and speculations. These modifications are made in the ADU due to proximity to promotional campaigns, events of increased demand such as holidays, and in the Lead Time Factor, due to scheduled stops in the production line, maintenance, or shutdowns. They are performed on specific dates.
- Recalculated adjustments: The sensitivity of the variables for calculating the buffer levels and their evolution are analyzed to make adjustments that allow updating the buffers to the context in which the company finds itself. That is to say, the parameters ADU, Lead Time and MOQ vary with time, and the buffer levels should also vary with these variations.

2.4. Demand-based Planning

For the realization of this phase, the Net Flow Equation is defined, which is the main indicator for inventory replenishment in buffers. It is determined based on the following calculation [2]:

$$\boldsymbol{Net\ Flow\ Equation}(\boldsymbol{NFE}) = \boldsymbol{Available\ inventory} + \boldsymbol{Inventory\ on\ the\ way} - \boldsymbol{Qualified\ demand}$$

The parameters are as follows:

- Inventory on hand: This is the current stock available in the buffer.
- Inventory on the way: It is the quantity of references that have been ordered to replenish the buffer.
- Qualified demand: This is the quantity demanded, i.e., whose purchase order has been issued, with a delivery date and within the time horizon defined by the lead time or with qualified peaks. The qualified peaks are demand levels that can compromise the buffering of the buffers and are represented by 50% of the value of the red zone of the buffer [2].

When the value obtained by performing the Net Flow Equation is below the base of the green zone, replenishment orders should be placed, the amount of which should be the difference between the green zone buffer and the value obtained by the NFE [2].

2.5. Visible and Collaborative Execution

The purpose of this phase is to provide relevant information for the correct execution and planning of production. This has been defined based on a system of alerts that allows prioritizing the critical elements of the production chain that can generate buffer shortages and, consequently, stock ruptures. The alerts show the real status of the buffer and its capacity to meet the incoming demand. This supports decision-making in the organization since, at the time of issuing supply orders, it will be possible to prioritize based on the status of the buffer to avoid stockouts, i.e. an order that is requested to replenish a buffer that is in the red zone will be more important than one that is in the yellow zone since its impact will be less in cases of stock outs [2].

3. Description of the Research Protocol

To perform the analysis and answer the research question, a review of articles covering the implementation of the DDMRP method was carried out using the following protocol:

Search equation: keywords of the method were selected, allowing us to collect only articles related to the topic of study, limited to academic and confirmed applications. On the other hand, the filter is used only in the title, abstract and keywords; otherwise, sources that mention the method, but do not go into a concise application of it, could be included. Similarly, due to the recent appearance of the DDMRP and the lack of access to recent research, it was decided to include implementations of the method studied in publications of master's and doctoral theses.

The search equation used is as follows:

- (TITLE-ABS-KEY("ddmrp") OR TITLE-ABS-KEY ("demand-driven mrp") OR TITLE-ABS-KEY ("demand driven mrp")) AND PUBYEAR > 2013 AND (LIMIT-

TO (DOCTYPE, "cp") OR LIMIT-TO (DOCTYPE, "ar"))

On the other hand, Figure 5 details the research protocol followed for this review, which is based on the structure of other reviews carried out by various authors who follow a PRISMA methodology [3]. Within this structure is the review and filtering scheme for the finding of the 25 articles reviewed. These mainly include research published in English and Spanish.

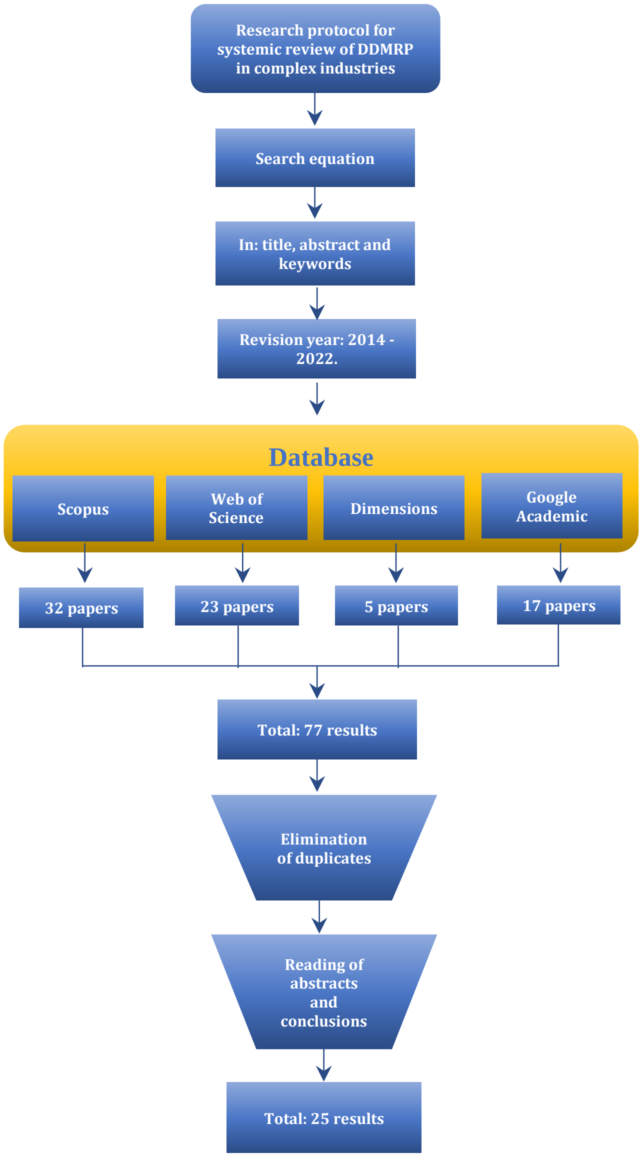

Fig. 5 Research protocol for the systematic review of DDMRP

In addition, the following criteria were considered for the eligibility of the studies:

- The research must be an application of the method in a year after 2013. This is to review updated and mature information from the creation of the method to the variations applicable to each specific case.
- The selected article must indicate having been applied in a company with a BOM of more than 3 levels, have more than 15 references per product in the BOM explosion, or specify that the supply lead time is not less than 30 days because these are the predefined characteristics that identify a complete industry [4,5].
- The study must have been published in a scientific journal or found in a repository of master's or doctoral theses. This condition was chosen to ensure the reliability of the data collected by the research [9].
- The application should be performed using the DDMRP method for production planning as the main one in order not to confuse it with a similar variation such as the Demand Driven Distribution Resource Planning (DDDRP).

4. Methodological Analysis

For the analysis of the documents found on the application of DDMRP in complex manufacturing industries selected to answer the proposed questions, the first thing done is a categorization by continent, which can be seen in Figure 6.

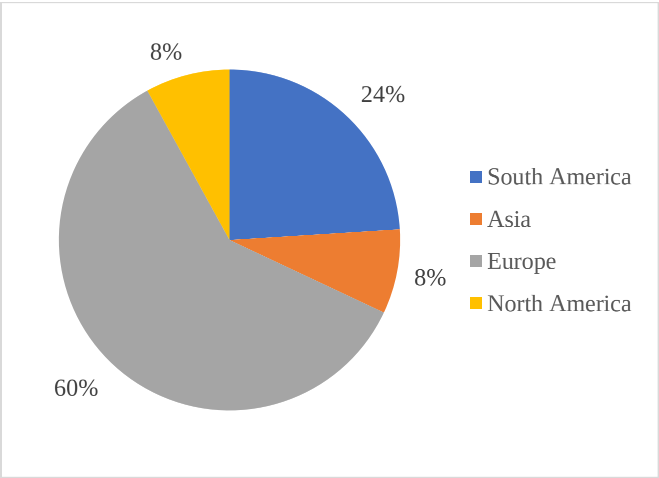

Fig. 6 DDMRP applications in complex manufacturing industries by continent

As can be seen from the graph shown, most of the applications of the DDMRP method to complex industries have been carried out in Europe, followed by South America, which is important to highlight since this method was born in North America, where few publications have been found that meet the characteristics required for this research. In the search for answers to the questions posed, parameters were defined to be analyzed in the literature review.

4.1. Component 1: Application Trends

The first component is directly related to the integral application of the method. The theoretical application of the DDMRP is presented in the development of five phases, which are weighted at the same level; however, a previous systematic review noted that the method was only partially applied [3]. Based on this, the review seeks to identify whether this has changed by reviewing the phases described by the researchers during its application. These phases are:

- Strategic inventory positioning.
- Profiling and buffer levels.
- Dynamic adjustments.
- Demand driven planning.
- Visible and collaborative execution.

4.2. Component 2: Factors Targeted for Improvement in the Applications of the Method

The second component relates to the results that have been obtained in DDMRP applications in complementary industries. Any method implementation seeks improvements in different aspects of an organization, which also applies to Demand Driven MRP. This element will recognize the impact, both positive and negative, that the application of this method has generated in complex manufacturing industries, specifically in the following factors:

- Service level: Fulfilment of purchase orders and quality of the final product.
- Storage space: Physical space used for product storage.
- OHS: Parts availability.
- Lead time of delivery: Time of delivery to the final customer without reducing the quality of the delivered product.
- Planning capacity: Visibility of the supply chain.
- WIP inventory: Quantity of in-process products stored, availability of in-process products.
- Working capital: Economic impact of the model on the company.

4.3. Component 3: Factors Influencing the Effectiveness of the Method

The creators of the method did not define a definitive way for all cases regarding the positioning of buffers along the supply chain. However, the evolution of the method's application worldwide has generated an approach of applicable policies for resolving this issue [10]. As mentioned, these depend on the criteria used in the organization. This third component refers to the recognition of the buffer positioning policies chosen for the application of DDMRP in complex industries, which can be:

- Purchased products (P)
- Manufactured products (M)
- Final products (F)
- Purchased and manufactured products (PM)
- Purchased and final products (PF)
- Manufactured and final products (MF)
- Purchased, manufactured and final products (PMF)
- Experience - trial and error

5. Results and Discussion

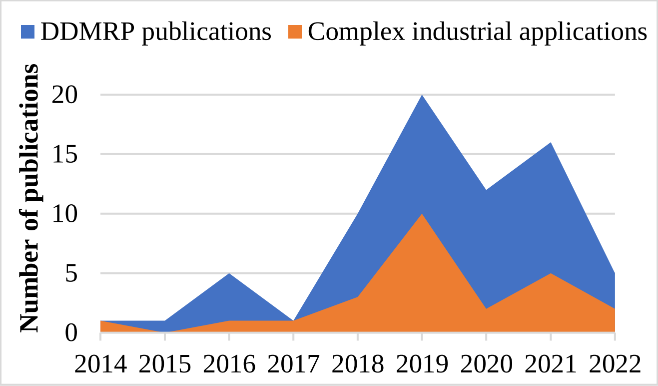

Fig. 7 Research protocol for the systematic review of DDMRP

In Figure 7, the orange area represents the publications made on DDMRP according to their year of publication. In contrast, the gray area shows the applications in complex industries, which are the ones used for this research. It is recognized that the first papers on this method are from 2014, i.e., 3 years after the birth of the method, which agrees with what was found by a previous systematic review [3], which also found that the first publications on the method were until at least a couple of years after its publication. On the other hand, it is also recognized that the number of publications per year has been increasing, reaching its highest point in 2019, until in 2020, the number of annual publications decreased. This was caused by the Covid-19 pandemic, which generated the availability of access to companies, and their data is lower. In 2021, the number of publications will increase again, a trend likely to be replicated in 2022, a year still in progress. It can also be inferred from the graph that, to date, there is not a significant number of articles on the subject, let alone applications in complex industries.

The results have been subdivided into 3 components according to the research questions of this review, and the results obtained are detailed below:

5.1. Results of component 1: Applications Trends

Table 1 will be used to explain the results, showing relevant information on the documents reviewed for the analysis. The table shows the number assigned to each research for recognition in the following lines. The authors, type of document, country and year are mentioned.

The table is divided into 2 sections: Case study and application of the method.

Table 1. Analysis of the application of DDMRP in complex industries

No.	Authors	Type	Country	Year	Case Study					Application of the method				
					Type of application		Reason for complexity			Phases developed				
					Simulation	Real Application	BOM	Number of references	Lead time supply	Strategic positioning	Profiles and buffer levels	Dynamic adjustments	Demand-based planning	Visible and Collaborative execution
1	Hietikko	Article	Finland	2014	X		X			X	X	X		
2	Borda	Thesis	Ecuador	2016		X		X		X	X	X	X	
3	Shofa & Widyarto	Article	Switzerland	2017	X				X	X	X	X		
4	Kortabarria et al.	Article	Spain	2018		X	X		X	X	X	X	X	X
5	Miclo et. Al	Article	France	2018	X		X			X	X	X		
6	Pérez	Thesis	Ecuador	2018	X				X	X	X			
7	Zachariah	Thesis	Italy	2018	X		X		X	X	X	X	X	X
8	Builes	Thesis	Columbia	2019	X				X	X	X	X		
9	Pekarcikova et.al	Article	Slovakia	2019	X				X	X	X	X		
10	Cajamarca	Thesis	Ecuador	2019	X				X	X	X	X		
11	Solorzano	Thesis	Ecuador	2019	X				X	X	X			
12	Navarrete	Thesis	Ecuador	2019		X	X			X	X	X		
13	Ducrot & Ahmed	Thesis	EE. UU	2019	X			X		X	X	X		
14	Mira	Thesis	Portugal	2019	X		X			X	X	X		
15	Provenzano	Thesis	Italy	2019	X		X			X	X	X	X	
16	Zuliani	Thesis	Italy	2019	X		X			X	X	X		
17	Velascon et al.	Article	Canada	2020	X		X			X	X	X		X
18	Almeida	Thesis	Portugal	2019	X					X	X	X	X	
19	De Rosa	Thesis	Italy	2020	X		X			X	X	X		
20	Bayard et.al	Article	Austria	2021	X		X			X				
21	Hasbulah & Santos	Article	Indonesia	2021	X			X		X	X	X		
22	Blanco	Thesis	Spain	2021	X			X		X	X	X	X	X
23	Costa	Thesis	Portugal	2021	X		X				X	X		
24	Buccomino	Thesis	Italy	2021	X		X			X	X	X		
25	Thurer et.al	Article	China	2022	X		X			X	X			
% of total					0.88	0.12	0.56	0.16	0.32	0.96	0.96	0.84	0.24	0.16

With respect to the case study heading, this is subdivided into 2 sections:

On the one hand, it shows the information on the type of application, since it can be a simulation or a real application to a company, it also shows the reason why it is identified that it is a complex industry, either because the BOM has 4 or more levels because on average the products have more than 15 references or because the supply lead time is greater than or equal to 30 days.

The second heading, on the application of the method, refers to the 5 phases that make up DDMRP, recognizing which phases were explained and applied in each of the research collected.

5.2. Results of Component 2: Objective Factors for Improvement in the Application of the Method

Table 2 subdivided into two headings. The first shows the authors' general appreciation of the application they developed, explaining whether they recognize that it was a total or partial improvement. The second heading shows the information on the factors in which they recognize the variation in the application of DDMRP in a complex company, which are service level, storage space, OHS, lead time, planning capacity, WIP inventory and working capital.

Table 2. Target factors analyzed in the implementation of DDMRP.

N°	Authors	Type	Country	Year	Results								
					General Appreciation		Factors analyzed						
					Partial improvement	Integral improvement	Level of service	Storage space	On Hands Stock (OHS)	Delivery lead time	Planning capacity	WIP inventory	Working capital
1	Hietikko	Article	Finland	2014		X			X			X	
2	Borda	Thesis	Ecuador	2016		X	X		X			X	X
3	Shofa & Widyarto	Article	Switzerland	2017		X				X			
4	Kortabarria et al.	Article	Spain	2018		X	X		X		X		
5	Miclo et. Al	Article	France	2018		X	X					X	
6	Pérez	Thesis	Ecuador	2018		X	X		X				
7	Zachariah	Thesis	Italy	2018		X	X		X				
8	Builes	Thesis	Columbia	2019		X	X	X					
9	Pekarcikova et.al	Article	Slovakia	2019		X					X		
10	Cajamarca	Thesis	Ecuador	2019		X		X					X
11	Solorzano	Thesis	Ecuador	2019		X			X				
12	Navarrete	Thesis	Ecuador	2019		X			X			X	X
13	Ducrot & Ahmed	Thesis	EE. UU	2019	X		X		X	X	X	X	
14	Mira	Thesis	Portugal	2019	X		X		X				
15	Provenzano	Thesis	Italy	2019	X				X			X	X
16	Zuliani	Thesis	Italy	2019		X	X		X				
17	Velascon et al.	Article	Canada	2020		X	X		X	X	X		
18	Almeida	Thesis	Portugal	2019		X	X		X				X
19	De Rosa	Thesis	Italy	2020	X		X		X			X	
20	Bayard et.al	Article	Austria	2021	X		X						X
21	Hasbulah & Santos	Article	Indonesia	2021		X			X			X	
22	Blanco	Thesis	Spain	2021		X	X		X	X	X	X	
23	Costa	Thesis	Portugal	2021	X					X	X		X
24	Buccomino	Thesis	Italy	2021	X		X		X			X	
25	Thurer et.al	Article	China	2022	X		X		X			X	X
% of Total					0.32	0.68	0.64	0.08	0.72	0.24	0.04	0.44	0.32

5.3. Results of component 3: Objective factors for Improvement in the Application of the Method

This section analyzes the factors that influence the effectiveness of the application of the method. As evidenced in Table 1, 96% of the research provide scopes on the execution of the phases of positioning and definition of buffers, being these the most popular and applied. This makes the "Strategic buffer positioning" phase key to the application's success in the selected company. Figure 8 shows which positioning policies were adopted in the applications within complex manufacturing industries related to the target improvement factor in the application. That is, what the companies sought to improve by applying the method. These factors are those indicated in Table 3 and their respective combinations: inventory level and costs (IL+C), inventory level and service level (IL+SL), service level and costs (SL+C) and the top 3 factors (SL+C+IL). In addition, the applications have been classified by type of industry using color coding, as shown in Table 3. In addition, Figure 8 uses the numerical order in which the authors were presented in Table 1 to refer to their research.

Table 3. Color coding by industry

Type of industry	Inquiries (N°)	Color used
Electrical appliances	21 y 25	
Food industry	2, 6, 10, 11, 13	
Automotive industry	1, 3, 5, 12, 15	
Locksmith industry	4, 7	
Utensils industry	8	
Pharmaceutical industry	22, 24	
Wood industry	16	
Plastic industry	14, 18	
Unspecified	9, 17, 19, 20, 23	

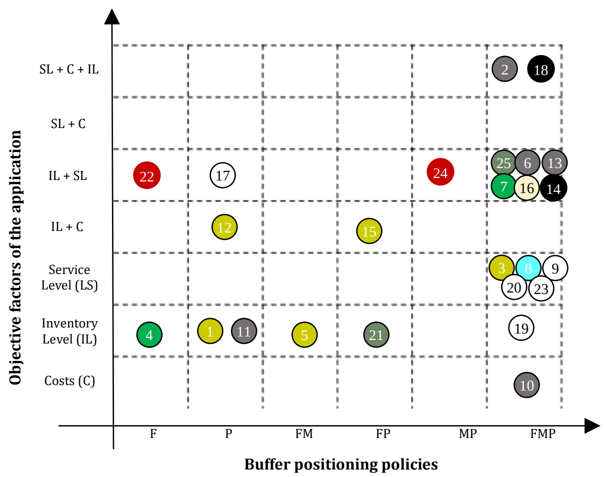

Fig. 8 Relationship between the positioning policy adopted and the target factor to be improved by the application.

5.4. Discussion of component 1: Application Trends

Regarding the application of DDMRP methodology, research affirms that for the realization of each phase of the method, a large amount of information is required, so this is complicated to implement and could not be applied to any company because it requires much experience for the definition of subjective parameters [11,12].

Regarding the first phase's application, research usually focuses only on implementing the strategic positioning of buffers. Moreover, the placement of these buffers is usually not documented since it is a highly complicated phase where rules must be defined, and experts must agree on them [10]. On the other hand, studies are identified that omit the explanation of the first phase during their investigation. However, its execution developed in the simulation is understood since it is necessary for the execution of the following two phases [18].

Regarding the second phase, on profile definition and buffer levels, the importance of buffer positioning is pointed out; not placing buffers correctly can lead to a significant reduction in the service level, up to 50% [14]. This would explain why most research considers this point in their application.

The third phase, the dynamic adjustments, is a turning point in the method since the calculation of the parameters for the variation of the dampers is performed. The variation in the parameters makes the model quite sensitive [15]. In turn, this phase can generate an increase in the inventory level in certain parts of the chain [15,16]. However, it is proposed that the choice of the model should not be based on the one with the lowest inventory but on the one that allows the best response times [17].

With respect to the last two phases, as seen in Table 1, few detailed studies exist. Phases four and five do not require a large amount of data, as the previous three phases do, since they only depend on the buffer levels calculated previously, the expected demand for the following days, the available inventory, and the buffer variation at the beginning of the implementation [18]. However, some studies point out the importance of these phases [19], assuring that this is the heart of the methodology since it is here where the alerts for buffer replenishment are established, depending on the variations in demand and daily consumption, allowing the optimization of the purchase lots, thus avoiding unnecessarily large batch orders, and allowing a significant cost reduction in purchase orders and physical storage space.

Conclusion of component 1, the analysis of sources showed that most of the applications in complex industries carried out by researchers are based especially on the first three phases of DDMRP since there is a tendency to recognize that the use of buffers is what really makes the difference compared to other planning methods, so most of these applications are based on the first three phases of the method. However, the few studies that also apply the last two phases recognize that they are as or more important than the previous ones since it is in these that the replenishment of the buffers is ensured, allowing great improvements in the organization. It is recognized that the study of these last phases has not been deepened, even though there are successful cases in which the integral application of DDMRP has been applied, since they tend to benefit aspects that are not normally studied by researchers, such as the relationship with suppliers, reduction in purchase orders and avoidance of stock ruptures. Phases 4 and 5 should be studied during the application of this method for future research, recognizing its relevance and allowing the expansion of the knowledge about the studied methodology since its application in the reviewed research confirms its usefulness and positive impact on the organization.

5.5. Discussion of component 2: Objective factors for Improvement in the Application of the Method

The purpose of this component is to analyze the main factors that are the target of improvement in the studies carried out on applying the method in complex industries. Although DDMRP is indeed presented as a method capable of contributing to the improvement of several indicators in industries, such as delivery lead times, inventory level, working capital, availability, collaborative visibility, and service level, among others [2], studies were found that questioned the results proposed by the creators of the method for being too promising, indicating that these could be due to particular conditions of the application and pointing out that these should be corroborated in different contexts to ensure its effectiveness [17,20,21]. Due to resource limitations and the modular approach that can be given to the Demand Driven methodology; explained in its different fields of application, manufacturing, logistics, sales, and operations; the reviewed studies concentrate their efforts on improving specific factors. These have been identified and classified in Table 1, in the field "Results", where it is distinguished, in the first place, the general appreciation of the study towards the benefits provided by the method, differentiating the studies that mention that its application is a complete or integral improvement (68%) and those who indicate that the execution of DDMRP generates improvements in some aspects of the organization, but has a cost in factors, so companies must be prepared to make the necessary commitments (32%). Secondly, the main objective factors mentioned as a priority in the applications were ranked. The results according to the concentration of the factor are as follows.

- Service level: This is the second most reviewed factor in the studies (64%). To maintain the competitive advantage and prestige of the organization, it is essential to maintain a high level of service; therefore, it is possible to place buffers on products whose unavailability means that customer orders cannot be filled [5]. The method is also applied to face the instability of demand and the low accuracy of forecasts that generate noncompliance and delays in the delivery of its products; therefore, traditional systems, such as DDMRP [14,18] and SES-EOQ-ROP [6], can be replaced by one that reviews changes in demand with a greater periodicity [34]. On the other hand, the application of DDMRP does not necessarily imply a substantial improvement in the level of service. However, it does provide greater stability and improvement in other aspects of the production system [34]. In contrast, the planning method should not be based solely on demand forecasts and forecasts but also on the relationship and availability of suppliers, with emphasis on reinforcing the flow of information in the supply chain [19].
- On the other hand, the application of the method based on customer satisfaction, explained in terms of order fulfilment, delivery times and product quality, is also proposed. A comparison can also be made between inventory positioning policies, levels of variability and operational capacity, focused on improving the level of service and reducing inventories. However, increasing the level of service requires an increase in the level of inventories [10]. In this same sense, the results of DDMRP are also compared against the execution of other methods, such as MRP, Kanban and ConWIP, under different contexts of variability and availability, finding that the service level reaches values similar to those of a Kanban application, but with a lower inventory level, so their combination allows optimizing their impact [23].
- Storage space: This factor is little mentioned in the literature (8%), possibly because it can be considered part of reducing the level of invention. At the beginning of the execution of the method, the storage space tends to increase due to the inclusion of buffers, but as the months go by, the space consumption is considerably reduced [15]. On the other hand, DDMRP contributes to the improvement in inventory turnover, which results in a reduction of storage space consumption [24]. This factor can be considered a consequence of the inventory level reduction, and therefore, it would not be much mentioned in the literature.
- On Hand Stock (OHS): It is the most mentioned in the literature (72%), which can be explained because it is one of the main objectives in the approach of a change of the production planning system. The inventory level can increase in certain seasons, but it is necessary to face demand variations [31]. In addition, this is a fundamental factor to consider in industries that operate with perishable products since studies focus on the decrease of the inventory level as a consequence of the increase of product turnover, which, if kept in stock, would be completely lost [22]. A system of replenishment alerts can also be incorporated to support inventory turnover and optimize ordering with suppliers [19]. On the other hand, applying the method is likely to increase inventory levels, but this is not necessarily negative since the overall balance between the benefits and costs of maintaining buffer inventory is positive in relation to the implementation of DDMRP [23].
- WIP inventory: This factor, which refers to the availability of work in process, is usually approached as a complement to the OHS inventory level [13, 27,28]. However, both terms do not necessarily refer to the same thing since comparing DDMRP with the Kanban system. Both obtained results similar to those of Kanban regarding OHS inventory reduction. However, the WIP inventory level is lower for the first method, being more optimized in this aspect, but with the deficiency of not being able to reach the service level of Kanban [23]. The DDMRP method is highly capable of increasing the availability of products in process, streamlining the production line, and generating benefits in terms of service level and profitability [17].
- Lead times of delivery: Although this is an important factor with high participation in the results that the implementation of DDMRP can have, not much research has been found that focuses on the method's impact on these (24%). Including buffers significantly reduces delivery times, despite not achieving a 100% service level. [34]. A strategic replenishment method for purchased products has also been proposed to reduce the impact of the supply lead time, improving the delivery lead time [29].
- Planning capacity: This factor is addressed in a single research, which highlights the importance of considering it, as it allows the interrelation of the supply chain at different levels: suppliers, distributors, and customers, similar to a Vendor Managed Inventory (VMI) system. This has allowed them to optimize planning and reduce setbacks and costs [5]. The lack of depth in this factor may be due to the fact that it is related to the execution of the last phase of DDMRP, and, as can be seen in Table 2, only 16% of the studies delve into this aspect.
- Working Capital: Although not explicitly mentioned by most of the studies (32%), this factor can be inferred to be

a consequence of the improvement of the abovementioned factors. The method has been proposed as a means for cost reduction in terms of inventory due to the references of the results proposed by the creators of DDMRP. This method can stabilize the level of inventory within the bimodal distribution in such a way that there is sufficient inventory to not resort to cost overruns due to rush orders or loss of sales due to stock breakage, using buffers to decouple the chains most sensitive to variability in the BOM, which reduces the impact on the distortion of the planned and the reality [17]. Inventory turnover is fundamental for the reduction of shrinkage, which has an impact on the reduction of working capital invested; to this end, buffers are positioned at process bottlenecks and on purchased products so that product obsolescence is greatly reduced [28]. The working capital can increase during the first phases of DDMRP execution due to the increase in the inventory level, according to the industry. In order to avoid this becoming a loss for the organization, an ABC categorization system is applied, where the method is applied only to products A and B so that the level of working capital invested is controlled [32]. On the other hand, the level of working capital will be related to the level of service that the companies want to achieve; that is, if only the DDMRP method is used, the organizations must commit themselves to one of these 2 factors; but this commitment does not reach levels of unfeasibility in the application of the method [36]. In view of this, there is a proposal to combine DDMRP with other methods, such as Kanban and ConWIP, but this has yet to show good results in practice [23].

Conclusion of component 2, the literature found focuses on evaluating 3 factors: service level, OHS and WIP inventory level. These factors could be related to the causes of the remaining 4 factors. However, this may not always be the scenario since the increase in service level tends to be explained with an inverse relationship to the reduction of working capital, i.e., the more the organization's service quality increases, the higher the costs invested in its implementation. In view of this, it is pertinent to look more deeply into the implementation of the method in terms of economic balance, costs, and revenues. This has not been found in the current literature review. This is important because it will allow organizations to have a clearer vision of which factor to prioritize when applying a DDMRP: inventory level or working capital. On the other hand, more research on the combination of DDMRP with other methods such as Kanban, ConWIP and TOC would help to solve the dilemma between the choice of service level, inventory level and working capital, as some authors mention that it would allow achieving a balance between these factors. However, no articles that apply these combinations to complex manufacturing industries have been found.

5.6. Discussion of component 3: Factors influencing the effectiveness of the method

Since the conception of the method, its creators have indicated that parameters very specific to each industry and even to each company must be analyzed and applied based on the planner's criteria [21]. This has been present in most of the research reviewed. However, there are also those who propose an analysis based on a categorization of the chosen policies [10].

Buffers can be placed only on finished products, arguing that stockouts of final products generate large economic losses and losses in the level of service offered to the customer [19]. Complementing this policy, buffers can also be placed at the levels with manufactured or in-process products, indicating that in the automotive industry, products are usually sold in process, so stockouts should be reduced; furthermore, in this industry, there is no slack in the customer's tolerance [21]. This justification is related to what other authors indicate, sharing a positioning criterion based on the prioritization of the availability of parts and finished products to reduce the economic impact of stockouts; before which it is recognized that the location of buffers in purchased and final products allows achieving optimal results in terms of inventory level and costs [16]. This contrasts with other planning methods applied in the companies where the studies were carried out; MRP and SES-EOQ-ROP, respectively.

On the other hand, in studies in industries with perishable products, buffers were positioned only in purchased products, understanding that stock breakage in these industries is usually initiated by the lack of availability of raw materials, which generates low stock turnover, resulting in economic losses [35]. In this sense, including buffers in sensitive references is a great way to deal with supply variability, which may be due to supplier availability or long delivery times [13,27]. Another researcher also shares this policy but with a different approach, pointing out that trial-and-error experience can be used to determine the positioning criteria [10].

The aforementioned policies have certain points in common and share the objective of improving terms inventory levels. However, there is also research with a unique position within the literature found, where the positioning was performed only on manufactured and purchased products, considering that generally, availability problems are usually generated by delays in the main activities and bottlenecks of the production line. In addition, in certain industries, it may be feasible to implement an FMP policy. However, the high costs of the pharmaceutical industry make adopting this criterion ineffective. This is the only case identified where it is applied only to manufactured and purchased products. However, it can be inferred that this is a secondary criterion used by companies where it is impossible to implement, possibly due to economic factors. This FMP policy is the most widely applied [11].

The positioning of buffers in all components of the BOM is the most commonly applied method in the studies reviewed, but the reasons for this choice are usually varied. On the one hand, some studies share considerations of other policies, such as reducing the impact of noncompliance with lead times agreed with the supplier that generates stockouts [24,29,30]; and the criticality of the components to be protected with the buffer [30]. While other studies, not having a defined standard for positioning, decide to apply the FMP policy to evaluate the results and take action. However, these studies decide to add buffers in the final products since their objective is to guarantee the level of service [30,31]. Although this policy indeed makes it possible to achieve high service level percentages, it tends to increase inventory levels to achieve it; therefore, companies must consider the trade-off they are willing to make before adopting it [14]. Despite this, there are industries where this trade-off benefits the company since the extra costs generated by unavailability are greater than those of including buffers [15]. Another researcher shares this idea and adds that, according to his experience, having a low inventory level is not synonymous with a greater capacity to respond to demand. Companies should seek to achieve an adequate inventory level that allows them to cope with variations in demand. This indicates that the method's success in adopting this policy may be directly related to the type of industry in which it will be applied [17]. As a solution to this dilemma, a combination of planning methods, such as Kanban-DDMRP or ConWIP-DDMRP, is proposed, depending on the variability of demand and the costs associated with unavailability [23]. In this sense, using MP inventory policies in low-variability contexts and FMP in high-variability contexts can also be recommended [15].

Conclusion of component 3, most of the applications are performed under the FMP positioning policy, as it is the one that best allows obtaining high percentages in the service level factor. This decision may not be the one that best optimizes the process in terms of inventory and costs (without having low results as with the use of MRP or forecasting algorithms). However, these can be supported by an improvement in the overall profitability of the production process since the difference between inventory holding costs and stock breakage costs is substantial. In the search for continuous improvement, some authors mention as an alternative solution the combination of other methods with DDMRP. However, these studies are still very few, and it is considered necessary to further investigate them in different contexts and industries to verify their effectiveness.

6. Conclusion

This systematic literature review on DDMRP applications in complex industries has allowed us to recognize the characteristics most reviewed by researchers and the topics that need further addressing for future research.

Firstly, there has been an increase in the number of studies on this method, which was affected by the restrictions on access to the industries due to the Covid-19 pandemic. The method has spread from North America to other continents over time, with a greater number of studies in Europe, but also having an impact in South America and Asia, which is beneficial for the evaluation and testing of the effectiveness of DDMRP in different contexts, under the circumstances unique to each region.

Secondly, the last two phases of the method have not been sufficiently addressed by research, despite the fact that there are studies, especially in Europe, that demonstrate their effectiveness. Therefore the importance of including them in the execution of the method, also considering that in its applications, little input information is always required, which does not represent a barrier to its implementation. However, the small amount of research in this regard prevents sustaining this idea. On the other hand, there are cases of success in integrating suppliers and customers in the company's information flow that applies the method. This situation especially benefits the last phase of DDMRP. However, there are not enough studies to support this idea, so it is recommended the realization of applications of this method, including the last two phases, taking advantage of the interconnection between the organization and its suppliers and customers.

Similarly, the dilemma of choosing the method's approach to the inventory level or service level objective factor requires further study because, in the literature reviewed, DDMRP is performed with an improvement approach by choosing one of these factors, which directly influences the levels of the other. Future research should study how to obtain an equilibrium point for the approach of these factors, on which the method can be developed without negatively impacting the stability of the production system. On the other hand, the combination of production planning and execution methods such as ConWip-DDMRP and Kanban-DDMRP require further research so that they can be applied according to the variability and seasonality of the context, which has been raised in the literature reviewed as an alternative for the optimization of the objective factors when applying the method. Likewise, the economic impact of the implementation of the method requires further analysis, which should evaluate and analyze the costs and expenses required for the execution of the DDMRP and the economic balance that it would generate.

Finally, more research on combinations of inventory positioning policies that do not require maintaining buffers on all product types within the BOM is needed since most studies prioritize in this phase of DDMRP the achievement of a high level of service at the cost of increasing the inventory level. On the other hand, few studies consider cost optimization within the objective factors to be achieved in relation to the chosen buffer positioning policy since the phase tends to have as its main objective the reduction of the inventory level and the protection of the production line. However, this type of policy can generate additional costs for the industry, so more studies should be conducted on using inventory positioning policies for cost optimization. On the other hand, more studies are needed to analyze the adoption of buffer positioning policies based on the variability of the environment and the organisation's context.

References

[1] Cássia Taisy Alencar de Andrade, Ana Paula Henriques de Gusmão, and Wladson Silva, "World Class Manufacturing Performance Measurement Using a Maturity Model and the Flowsort Method," *International Journal of Production Research*, vol. 59, no. 24, pp. 7374–7389, 2021. [CrossRef] [GoogleScholar] [Publisher link]

[2] Ptak, C., and Smith, C, *Demand Driven Material Require-Ments Planning (DDMRP)*, Industrial Press, Incorporated, 2016.

[3] Ahlam Azzamouri et al, "Demand Driven Material Requirements Planning (DDMRP): A Systematic Review and Classification," *Journal of Industrial Engineering and Management*, vol. 14, no. 3, p. 439, 2021. [CrossRef] [GoogleScholar] [Publisher link]

[4] Angela Patricia Velasco Acosta, Christian Mascle, and Pierre Baptiste "Applicability of Demand-Driven MRP in a Complex Manufacturing Environment," *International Journal of Production Research*, vol. 58, no. 14, pp. 4233–4245, 2020. [CrossRef] [GoogleScholar] [Publisher link]

[5] Alaitz Kortabarria et al., "Material Management Without Forecasting: From MRP to Demand Driven MRP," *Journal of Industrial Engineering and Management*, vol. 11, no. 4, p. 632, 2018. [CrossRef] [GoogleScholar] [Publisher link]

[6] Hasbullah Hasbullah, and Yadi Santoso, "Overstock Improvement By Combining Forecasting, EOQ, and ROP," *Journal PASTI*, vol. 14, no. 3, p. 230, 202. [CrossRef] [GoogleScholar] [Publisher link]

[7] Daeli Franco-Quispe et al., "Production Planning and Control Model to Increase on-Time Deliveries Through Demand-Driven MRP and PDCA in A Make-to-Order Environment of Non-Primary Manufacturing Industry," *Human Interaction, Emerging Technologies and Future Systems V*, vol. 319, pp. 1209–1217, 2022. [CrossRef] [GoogleScholar] [Publisher link]

[8] Lucy Casallo et al., "Application of Mixed Methodologies in the Production Planning of Screw Conveyors for the Flour and Pasta Food Industry," *International Journal of Engineering Trends and Technology*, vol. 70, no. 8, pp. 435-446, 2022. [CrossRef] [Publisher link]

[9] J. D. Velásquez, "A Short Guide to Writing Systematic Literature Reviews Part 3," *DYNA*, vol. 82, no. 189, pp. 9–12, 2015. [CrossRef] [GoogleScholar] [Publisher link]

[10] Stephanie Bayard, Frederic Grimaud, and Xavier Delorme, "Study of Buffer Placement Impacts on Demand Driven MRP Performance," *IFAC-Papersonline*, vol. 54, no. 1, pp. 1005–1010, 2021. [CrossRef] [GoogleScholar] [Publisher link]

[11] Frances Buccomino, "*Manufacturing Planning and Control System: The Ddmrp Applied to a Business Case*," Politecnico Di Torino, 2021. [Publisher link]

[12] Tavares, and Ana Carina Mira, "*Demand Driven Material Requirements Planning (DDMRP): Exploratory Study*," Universidade Nova De Lisboa, 2019. [Publisher link]

[13] Hulas Raj Tonday et al., "Study of Implementation of Agile Supply Chain for Efficient Delivery of Essentials During Covid-19," *SSRG International Journal of Mechanical Engineering*, vol. 8, no. 8, pp. 1-5, 2021. [CrossRef] [GoogleScholar] [Publisher link]

[14] Pedro Miguel Pimenta Almeida, "*Leveling Stocks of Raw Materials and Components in an Automotive Industry*," General Study UC Scientific Repository, 2020. [Publisher link]

[15] Builes, J. "*Framework for DDMRP Implementation At Non-Stick GSA Plant*," Universidad EAFIT. Repository, 2019.

[16] Fabio Provenzano, "Modelli Innovativi Di Gestione Delle Scorte Nella Filiera Logistica: Applicazione Del Metodo DDMRP Nel Setto-Re Automotive," *Politécnico Di Torino*, 2019. [Publisher link]

[17] Borda, L. "Demand Driven Methodology for Service Improvement and Cost Reduction," *Universidad EAFIT*, Medellin, Colombia, Repository, 2016. [CrossRef] [GoogleScholar] [Publisher link]

[18] Joana Costa Portela, "*Development of a DDMRP Methodology Simulation Model*," Scientific Repository of the Polytechnic Institute of Porto, 2021. [Publisher link]

[19] Blanco, A, "*Analysis of the Demand Driven Material Requirements Planning (Ddmrp) Methodology and Its Implementation in the Pharmaceutical Plant of Servier S.L*," Universi-Dad Pontificia Comillas, 2021.

[20] Pradeep Verma, "Effective Execution of Mergers and Acquisitions for IT Supply Chain," *International Journal of Computer Trends and Technology*, vol. 70, no. 7, pp. 8-10, 2022. [CrossRef] [Publisher link]

[21] Romain Miclo et al., "Demand Driven MRP: Assessment of a New Approach to Materials Management," *International Journal of Production Research*, vol. 57, no. 1, pp. 166–181, 2019. [CrossRef] [GoogleScholar] [Publisher link]

[22] Solorzano, I. "Design of a Demand Driven Management Model for the Corporate Purchasing Process of A Business Group in the Food Sector Based on the Collaborative Planning Methodology," *Escuela Supe-Rior Politécnica Del Litoral*, 2019.

[23] Matthias Thürer et al., "Production Planning and Control in Multi-Stage Assembly Systems: An Assessment of Kanban, MRP, OPT (DBR) and DDMRP by Simulation," *International Journal of Production Research*, vol. 60, no. 3, pp. 1036–1050, 2022. [CrossRef] [GoogleScholar] [Publisher link]

[24] Cajamarca, F, "Design and Implementation Proposal of a Demand Driven Management - MRP Model for the Supply and Inventory Management Processes of a Company That Processes and Markets Animal Nutrition Products. (Tesis De Maestría)," *Escuela Superior Politécnica Del Litoral*.

[25] Pérez, M., "Design of a Demand Dri-Ven Management Model - MRP, for the Raw Material Purchasing Process of a Food Supply Company," *Escuela Superior Politécnica Del Litoral*, 2018.

[26] Dhruva Joshi, and Dr. Nagendra Sohani, "Study of 3rd Party Logistics in Automotive Manufacturer Company," *SSRG International Journal of Industrial Engineering*, vol. 2, no. 2, pp. 19-21, 2015. [CrossRef] [Publisher link]

[27] Hietikko, J, "*Supply Chain Integration With Demand Driven Material Requirements Planning System - Case: Wärtsilä 4-Stroke*," University of Vaasa, 2014.

[28] Navarrete, J. "Design of a Demand Driven Management Model - Mrp, for the Supply of Air Oils and Lubricants for A Supersonic Aircraft Fleet," *Escuela Superior Politécnica Del Litoral*, 2019.

[29] Mohamad Jihan Shofa, and Wahyu Oktri Widyarto, "Effective Production Control in an Automotive Industry: MRP Vs. Demand-Driven MRP," *AIP Conference Proceedings*, vol. 1855, no. 1, p. 020004, 2017. [CrossRef] [GoogleScholar] [Publisher link]

[30] Miriam Pekarcıkova et al., "Demand Driven Material Requirements Planning. Some Methodical and Practical Comments," *Management and Production Engineering Review*, vol. 10, no. 2, 2019. [CrossRef] [GoogleScholar] [Publisher link]

[31] Zachariah, A. *Demand Driven Materials Requirement Planning (DDMRP). A New Method for Production and Planning Management*," Politecnico Di Milano, 2018.

[32] Juan Gallegos Mardones, "Working Capital Management and Business Performance: Evidence From Latin American Companies," *Economic Research-Ekonomska Istraživanja*, vol. 35, no. 1, pp. 3189–3205, 2022. [CrossRef] [GoogleScholar] [Publisher link]

[33] Haftu Hailu, and Tewedros Hailu, "Reduction of Long Delivery Time By Implementing Advanced Kaizen (Problem Solving Approach)," *SSRG International Journal of Industrial Engineering*, vol. 4, no. 3, pp. 26-48, 2017. [CrossRef] [Publisher link]

[34] Léo Ducrot, and Ehtesham Ahmed, "Investigation of Potential Added Value of DDMRP in Planning Under Uncertainty at Finite Capacit," *Massachusetts Institute of Technology*, 2019. [Publisher link]