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DEMAND DRIVEN MATERIAL REQUIREMENTS PLANNING. SOME METHODICAL AND PRACTICAL COMMENTS

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Abstract
Industry 4.0 will affect the complexity of supply chain networks. It will be necessary to adapt more and more to the customer and respond within a time interval that is willing to accept the product waiting. From these considerations, there is a need for a different way of managing the supply chain. The traditional concept of supply chain as a linear system, which allows optimizing individual subsystems, thus obtaining an optimized supply chain, is not enough. The article deals with the issue of supply chain management reflecting demand behaviour using the methodology Demand Driven MRP system. The aim of the publication is to extend the knowledge base in the area of demand-driven supply logistics in the context of Industry 4.0 and verify the processed theoretical knowledge in a case study.

Keywords
demand, supply chain, DDMRP, buffer, inventory.

Introduction

The aim of the article is to raise awareness of the potential of DDMRP methodology in academia and industry and to understand the new planning methodology DDMRP. Publications by Ptak C., Smith C., above, on the basis of which a case study has been developed, are known. In a survey in the WOS and Scopus databases as well as the commonly used Google search engine, a knowledge gap was found, especially in the Slovak professional publications. Therefore, there is a need to start dealing with this issue, which has resonated in foreign publications and is good aplicated in praxis for some time (aerospace, petrochemical, pharma). In connection with the transformation of enterprises with the implementation of Industry 4.0 elements, it is also necessary to deal with this aspect of the value chain, which basically ensures the effective implementation of the customized product. Current customers are already highly demanding and new techniques and methodologies will be needed to highlight demand visibility to meet their quality, cost, delivery time requirements. The present paper deals with the issue of visibility within the value chain from the perspective of a company trying to limit its production as close to demand as possible. Research methodology is shown in Fig. 1.

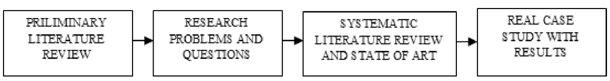


Fig. 1. Research methodology flow.

Traditional forecasting and demand planning tools are not able to flexibly synchronize supply and demand. For MRP/Material Required Planning systems, inventory management is not a priority. The output is a precise calculation of BOM/Bill of Material-based needs, which may not be realistic in terms of time, capacity, and availability of inventory. MRP systems mainly use safety stock, which is a safeguard against the uncertainty that may arise due to changes in the market [1–3].

Conversely, DDMRP/Demand Driven MRP is based on a bi-modal distribution model of inventory, Fig. 2. This is the determination of two boundary levels point of stocks i.e. point A: means a stock shortage and point B: means an excess of stock. Within the range of these two points there is an oscillation so- called "systemic nervousness", caused by the bullwhip-effect [4–7]. This variability in the value-chain leads to a reduction in system productivity [8].

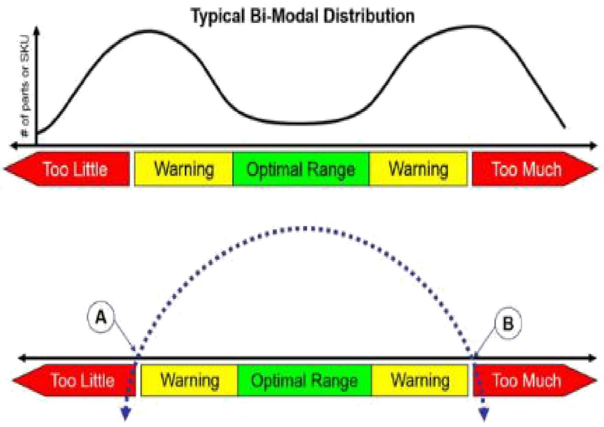


Fig. 2. Typical bi-modal Distribution with designated border points [10].

The role of DDMRP is to eliminate the influence of the bi-modal effect and to transform the supply chain from push to pull according to real demand. In publication [9] authors describe supply chains such as CAS/Complex Adaptive Systems and state that they are:

- comprehensive – a higher degree of stability is achieved through mutual interactions between entities,
- dynamic – they do not remain in any stable state for a very long time,
- nonlinear behaviour – even a small change in the initial conditions can lead to greater impulses on the other place (bullwhip effect)
- adaptable and self-regulating – i.e. they are evolving due to interaction within the system.

The key factor to achieve the correct result is systems thinking. The first thing is to understand the supply chain as CAS and accept the consequences thereof. Non-linear behaviour needs to be some way to check. According to [9, 10] effective supply chain control is possible by defining the so-called lever points (buffer bins), that represent supply chain decoupling points. This is the so-called "Demand Driven Operational Model".

The main idea of this method is to answer the question of how to secure the right stock at the right place and at the right time. Conventional MRP systems have deficiencies that damage the flow, Table 1.

Table 1
Comparison of traditional approach and pull approach DDMRP [10–14].

Traditional approach	Demand driven approach
Planning of sales and production according to the main production plan.	Production and purchasing are demand-driven by actual customer orders.
It is based on sales forecasting when considering seasonality.	Intelligent buffers are created at critical control points of the value chain.
Application of BOM method to create material requirements and schedule purchase and production orders.	Decoupling points are created to absorb demand variability.
Once orders have been placed into the system, they become revenue's plans.	Buffer's movements are monitored on a daily basis using visual colour zones that indicate the need to take action.
Push system is applied, which causes a high level of inventory.	Buffers management improves flow of material flow and reduces inventory throughout the value chain.

Basic characteristics of DDMRP are shown in Fig. 3. The DDMRP system is based on two basic characteristics. The first one is the decoupling point that separates the dependent demand from the independent. However, it is about a strategic location definition to maximize the ROI invested in stocks at this point in the supply chain [9, 10].

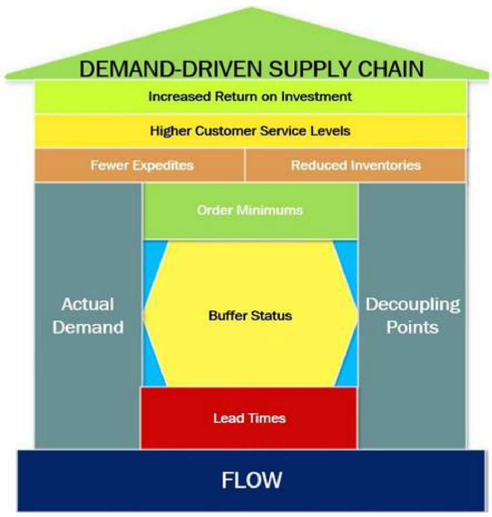


Fig. 3. Basic characteristics of DDMRP [10].

The second one is actual demand. Strategically placed buffers provide relevant information because the actual demand and changes in actual demand are monitored over the status and changes of the buffers in time [9, 10].

DDMRP is built on 6 pillars, Fig. 4 which are known and used in industrial practice such as MRP/Material Planning, DRP/Planning Distribution Requirements, Lean Manufacturing, Theory of constraints, Six Sigma, Innovation. One of the main reasons for linking these methods has been the beneficial effects of implementing these concepts individually and locally. However, none of these methods could not be implemented with reach on the overall supply chain [9–14].

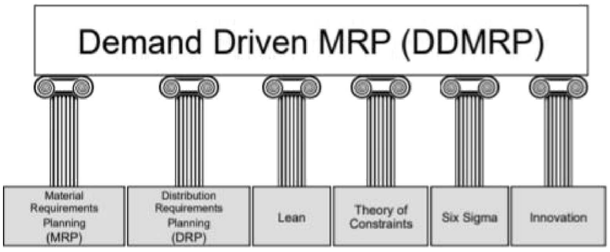


Fig. 4. Six pillars of DDMRP [10].

In the text below is processed a case study of the application of DDMRP methodology. For calculating and dimensioning of buffers was used available application from reference [15].

For further processing the data and evaluation of the results were created own tables using the program MS Excel.

Mentioned example is considered to be a simplified modification of the supply chain of a selected product. Modelling and simulating a real model would be a challenging process and from stated goal point of view, also insignificant. Input data have been modified for the case study, so that the procedure and the way of thinking, that is inherent in the DDMRP methodology are clear.

DDMRP application on the example

The goal of implementing the above-mentioned methods into a unified DDMRP concept is to maintain best practices, eliminate their weaknesses and integrate tactical replenishment based on pull. This has created one of comprehensive tool that integrates the entire supply chain, including customer and vendor integration. Implementation of DDMRP consists of five steps, Fig. 5. The first step is to determine the strategic position of the decoupling point in the logistic chain. In the second and third steps the buffers are defined. It will be based on operating parameters and reflect the dynamics of market requirements, operational changes, planned and unplanned events. The fourth step involves implementation of pull system in supplies in real-time based on actual demand. Scheduled demand management allows prioritizing and generating orders such as purchase orders, production orders, and inventorying removal. The fifth step facilitates operational control; the flow is controlled by various types of alerts and prefers orders for timely delivery to the customer [9–14].

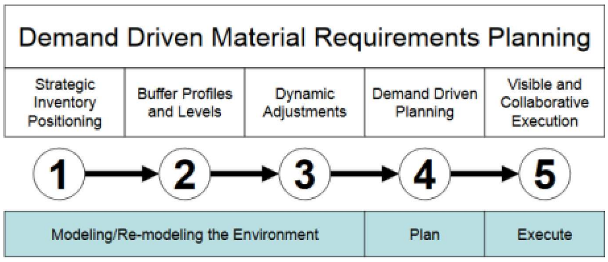


Fig. 5. Steps and components of DDMRP [10].

DDMRP uses Bill of Materials (BOM) from the MRP system. More important than determine the amount of inventory in the buffers is properly to place the buffers in supply chain. This is due to a better absorption of fluctuations in customer demand and supply variability and tends to increase overall system stability. To increase dynamics of the system, in BOMs are strategically placed buffers. These are determining decoupling point that absorb demand variability, offset the bullwhip-effect and shorten delivery times.

Position

1. Strategic location of buffers – identify breakpoints to reflect variability (demand, suppliers, operational and management variability), consider customer tolerance in terms of delivery times, inventory flexibility at every point in the supply chain and operational capacity. The new decoupling points should be positioned to provide the maximum flexibility and compression of delivery times. This means that the supply chain management is divided into certain segments [9, 10].

In the context of the DDMRP it is about Active Synchronized Lead Time (ASRLT), which represents the longest branch of the BOM, i.e., the sum of delivery/production periods along its individual hierarchical levels. It should be noted that buffers creation refers only to strategic items, resp. parts, products that are strategic in terms of sales, items with long delivery, resp. production date, it is a part of the contracted product, resp. significantly affect the value of ROI/Return on Investment [9, 10].

With the strategic location of the buffers, i.e., when looking for the right answer to the Where? question, it is necessary to assess the following six key factors [9, 10]:

1) CTT/Customer Tolerance Time, resp. Demand Lead Time,
2) Market Potential Lead Time,
3) Sales Order Visibility Horizon,
4) External Variability,
5) Inventory Leverage and Flexibility,
6) Critical Operation Protection.

Protect

2. The dimensioning of the buffers can only be made after their **strategic positioning**. The amount of inventory in the buffer is calculated using a formula considers account delivery times and average daily consumption (ADU/Average Daily Usage), which will ensure that the necessary level of inventory is maintained. Buffers dimensioning is in three signalling zones – green, yellow and red [9, 10]:

- green – determines the average ordering frequency and the average order size, res. ordering cycle in days (minimum order size or average daily consumption x ordering cycle in days, yellow zone x delivery factor), items with long delivery time are allocated lower % to be refilled more frequently,
- yellow – coverage of the average daily consumption of the inventory demand (average daily consumption x delivery time - consumption over the entire delivery time),
- red – "safety stock" is divided into two parts, the first represents the specified % of the yellow zone and the determination of the red base so-called "red safety" (insurance % x red base) and the second represents the demand variability insurance policy so called red base (red base = average daily consumption × delivery time × % of red base).

3. Dynamic buffer setting is required in the context of ever-increasing volatility of customer requirements. This market dynamics impacts on the need to update individual buffer attributes as well as their strategic location. The goal is to continually optimize inventories that are positioned to maximize ROCE/Return on Capital Employed. Dynamic buffer setting is realized by mechanisms such as [9, 10]:

- calculation the average daily consumption by moving averages (depending on the delivery time);
- elimination of seasonality by means of so-called PAF/Planned Adjustment Factors, i.e., ADU'= ADU × PAF (% ADU), which changes the size of the buffer,
- PAF's use of strategic balancing to artificially change the ADU for a certain period.

Levels and buffer zones calculation

The buffers are divided into three zones: green, yellow and red. Each zone has a specific purpose; division into zones is not equipartition. Understanding the purpose and method of individual zones calculation is the key to understanding the principle of dynamic buffer setting in DDMRP compared to other inventory management techniques.

The attributes that are considered when dimensioning the buffers in the DDMRP system are shown in Fig. 6. Dynamic buffer setting is shown on a model example.

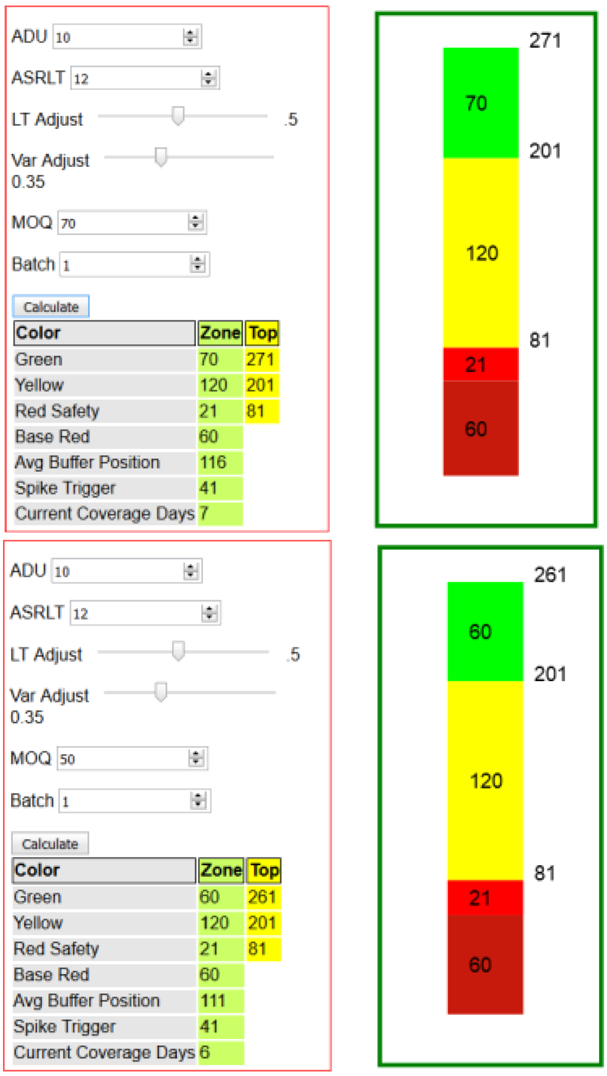


Fig. 6. Dynamic buffer setting [own processing, 15].

Pull

A key when planning a demand is to definition the priority. It prefers the status of the buffer before the datum of order fulfilment.

4. Demand-based planning is characterized by generating orders in the right amount and at the right time, NFE/Net Flow Equation, also called inventory equilibrium equation [9, 10]:

NFE = inventory in stock/stock + inventory on the road – qualified demand for demand/order.

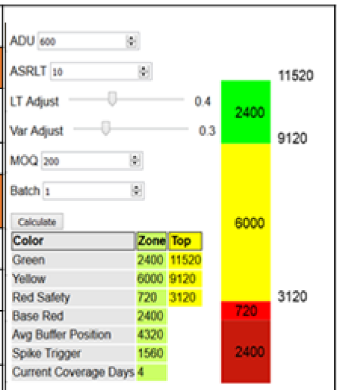
Generating an order based on a clean flow position – is calculated for each stack, where the output is so-called NFP/Net Flow Position, according to NFP order requirement is recommended, if NFP < TOY order is recommended in amount of difference TOG – NFP.

The next example will be a model example of order generation simulation over the reference period. Order Generation Simulation will be realized over the 20-day tracking period. The input data are processed in Table 2. This is part 41 with an average daily consumption ADU = 600pcs and a delivery time of 10days. Threshold was set for OST = 1560pcs and OSH = 10+1 = 11 days (i.e., demand visibility).

The inventory status of the first day of simulation is in Fig. 6. The initial inventory in stock is 6500pcs, is located in the yellow zone. One open order is on a 5000pcs, (delivery time of 10 days) delivery date in 4 weeks (choice for simulation) and a second open order of 4500pcs (delivery time of 10 days) with delivery date in 7 weeks (choice for simulation), on the way is 9500pcs. The demand corresponding to simulation day 1 is equal to 1450pcs, while in the OSH horizon = 11days, the demand for OST = 1900pcs (7th day) is considered, i.e. qualified demand will be in 3350pcs (1450 + 1900). According to the data, the NFP = 12650pcs can be determined, since TOY = 9120 (i.e. 12650 > 9120) is above TOG (109.8%), which means there is no need to initialized new order.

Table 2
Input data for part 41 [own processing, 15].

Example Part 41 Buffer Calculation			
Average Daily Usage	600	Green Zone	**2400**
Buffer Profile	P, L(.4), L(.3)		LT Factor= 2400(DLT (10)x ADU (600) x LT Factor (.4))
MOQ	200		MOQ= 200
Imposed or Desired Order Cycle (DOC)	4 dni		DOC= **2400** (4(DOC) x 600(ADU))
Decoupled Lead Time (DLT)	10 dní	Yellow Zone	**6000** (10(DLT) x 600(ADU))
OST=50% z (RB+RS)=50% z 3120= **1560 ks** OSH = 1+ 10 = **11** dní Ø target inventory status= TOR + GZ/2 = 3120+2400/2 = **4320 pc**		Red Zone	**3120** (RB(2400) + RS(720)) RB= 2400(DLT (10)x ADU (600) x LT Factor (.4)) RS= 720(RB(2400) x variabilita (.3))



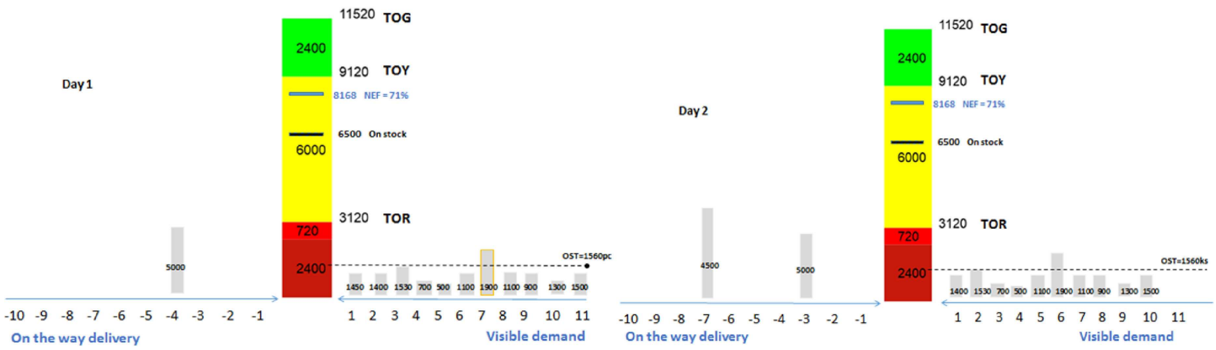


Fig. 7. Dynamic buffer setting [own processing].

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Table 3
Simulation of generating orders by DDMRP [own processing].

Actual date (10-august)

part 41	Planning priority	On stock	On the way	Qualified demand	NFP	Recommended order size	Required input-simulation day	TOR	TOY	TOG	DLT
1	109.81%	6500	9500	3350	12650	0		3120	9120	11520	10
2	97.66%	5050	9500	3300	11250	0		3120	9120	11520	10
3	84.38%	3650	9500	3430	9720	0		3120	9120	11520	10
4	78.30%	7120	4500	2600	9020	2500	11.	3120	9120	11520	10
5	95.66%	6420	7000	2400	11020	0		3120	9120	11520	10
6	86.11%	5920	7000	3000	9920	0		3120	9120	11520	10
7	86.11%	4820	7000	1900	9920	0		3120	9120	11520	10
8	76.56%	7420	2500	1100	8820	2700	18.	3120	9120	11520	10
9	92.19%	6320	5200	900	10620	0		3120	9120	11520	10
10	80.90%	5420	5200	1300	9320	0		3120	9120	11520	10
11	67.88%	4120	5200	1500	7820	3700	21.	3120	9120	11520	10
12	91.75%	2620	8900	950	10570	0		3120	9120	11520	10
13	83.07%	1670	8900	1000	9570	0		3120	9120	11520	10
14	73.52%	3170	6400	1100	8470	3050	24.	3120	9120	11520	10
15	93.49%	2070	9450	750	10770	0		3120	9120	11520	10
16	88.72%	1320	9450	550	10220	0		3120	9120	11520	10
17	84.38%	770	9450	500	9720	0		3120	9120	11520	10
18	77.43%	2970	6750	800	8920	2600	28.	3120	9120	11520	10
19	93.49%	2170	9350	750	10770	0		3120	9120	11520	10
20	85.68%	1420	9350	900	9870	0		3120	9120	11520	10
	Average inventory	**4047**	7505	1604	9948	727,5					

Table 4
Size of the demand for simulation [own processing].

simulation day	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
demand in pc	1450	1400	1530	700	500	1100	1900	1100	900	1300	1500	950	1000	1100	750	550	500	800	750	900

The second day of simulation is in Fig. 7. Inventory in stock is at the level of 5050pcs (6500–1450pc request in day 1). Open orders of 5000pcs and 4500pcs have moved on the timeline by one day to the right, i.e. supply on the way remained in amount 9500pcs. Visible demand on the 2nd day of simulation will be at 3300pcs (1400+ 1900). According to the data, NFP = 11250pcs, (i.e. 11250 > 9120) can be determined in TOG (97.6%), i.e., there is no need to initialized new order.

Other simulation days were processed by MS Excel in Table 3. Demand size for each simulation days was choices, Table 4.

Presentation selected indicators for simulation is shown in Fig. 8 (NFP, stock and qualified demand during the simulation period of 20 days). From the course of NFP (influenced, among other parameters, by qualified queries), it is clear that when the TOY level drops, the order is generated at the recommended level equal to the TOG and NFP differences. This will ensure an increase in open orders. This order will appear on the day the order is sent to the supplier and will increase the inventory on the day the order is delivered to the stock, and will be deducted from the open orders. It is a key element of DDMRP that ensures that the buffers are kept at the right height.

It is also possible to monitor changes in the size of the monitored parameters during the simulation and compare them to each other, Fig. 9.

5. Visibility and execution in DDMRP means application of different types of alerts with respect to the existence of dependent and independent decoupling points in the BOM. Their job is to prioritize already-generated (open) orders (at different levels of the supply chain – orders for purchased items, orders for produced items or transport requirements, i.e. output from the planning stage, i.e. after approval of the order recommendation) into two categories: inventory status and synchronization, i.e. monitoring inventory exhaustion at each strategic location and highlighting potential problems. Buffer status alerts reflect the actual and scheduled decoupling point status (independent points). Buffer status alerts do not use the NFP = Inventory in buffer + Inventory on the way – Qualified order requirements, but use on-site information, i.e., stock status, separating order generation activities from open order management activities. This is the definition of dependence and independent points in the BOM splitting according to authors Ptak and Smith, Fig. 10.

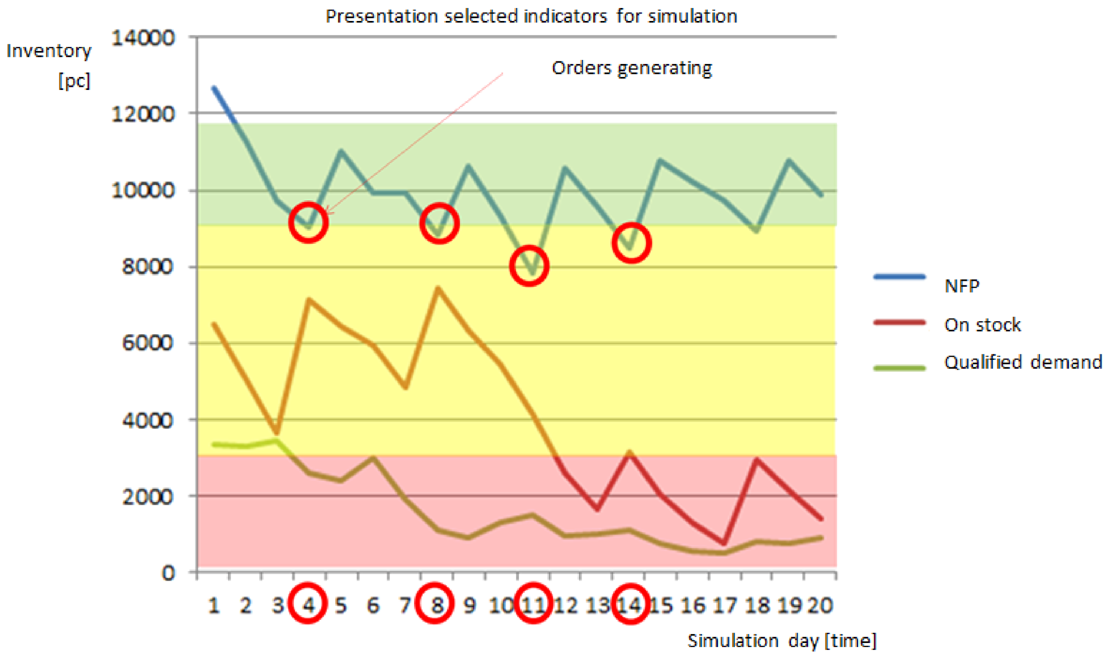

Fig. 8. Presentation selected indicators for simulation [own processing].

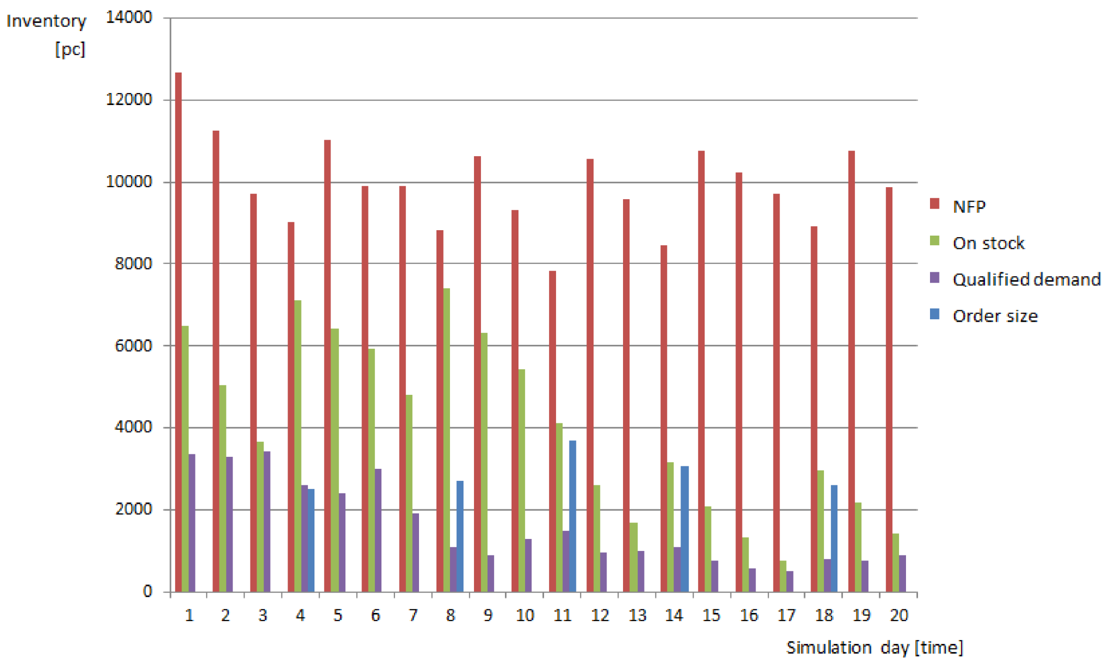

Fig. 9. Level of selected indicators after simulation [own processing].

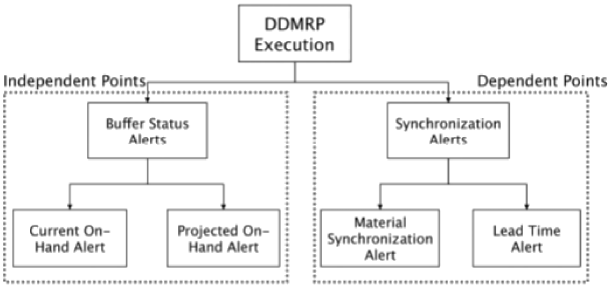

Figure II-XXI: DDMRP alert types (Ptak and Smith, 2016)

Fig. 10. Alert types in DDMRP [own processing].

When aligning a supplier's plan with actual customer requirements, there is a problem with the prioritization of order processing when the priority is determined by the due date. If order processing is executed in order of their acceptance, the fulfilment date may not always be met. In addition to the parameters mentioned above, the Current On-Hand Alert is used in the DDMRP, which signals the priority of the orders according to the current state of the buffer. This approach is different from that of DDMRP planning. The target inventory status (case study) is defined as TOR + GZ/2, thus defining the interface where the inventory should be in stock. If the level of stock in the store is above the TOR, it is a sufficient level of inventory, a visually green colour. If this level is below the TOR, it is important in which zone it is located. If it is in RS zone, which balances demand variability, i.e. the signalling in the system will be displayed in the yellow zone, if the stock level is below this level, i.e. intervene the RB, in the system will be doing change from yellow to red, which means the urgency to deal with this situation.

Priority visualization is in red, yellow and green colour with % status indication. Most often, the On-hand Alert level is set at 50% of the TOR. This is a level of inventory in which priority increases from yellow to red. To determine the priority level should be calculated % = On-hand/TOR * 100 (lower % – higher priority). For colour definition is determinative comparison of On-hand and TOR. In the case of On-hand>The TOR is assigned a green colour, if the On-hand <TOR is assigned a yellow colour, and if the On-hand ≤ On-hand Alert is assigned a red colour. Status of the priorities is processed in Table 5.

As shown in Table 5 is apparent, e.g. from a planning point of view on Day 4, the zone is marked with a yellow colour, but it is green in terms of its real status. It is important to separate the view in the planning part from the execution. Viewing the actual status of the priorities provides relevant information for order management that has already been created (notice to speed up the open delivery or to modify the priority of the production orders).

Table 5
Determination of the signal level Current On-hand Alert [own processing].

		Actual date (10-august)											
Current On hand Alert	Signal level	part 41	Planning priority	On stock	On the way	Qualified demand	NFP	Recommended order size	Required input-simulation day	TOR	TOY	TOG	DLT
208.3%	1560	1	109.81%	6500	9500	3350	12650	0		3120	9120	11520	10
161.9%	1560	2	97.66%	5050	9500	3300	11250	0		3120	9120	11520	10
117.0%	1560	3	84.38%	3650	9500	3430	9720	0		3120	9120	11520	10
228.2%	1560	4	78.30%	7120	4500	2600	9020	2500	11.	3120	9120	11520	10
205.8%	1560	5	95.66%	6420	7000	2400	11020	0		3120	9120	11520	10
189.7%	1560	6	86.11%	5920	7000	3000	9920	0		3120	9120	11520	10
154.5%	1560	7	86.11%	4820	7000	1900	9920	0		3120	9120	11520	10
237.8%	1560	8	76.56%	7420	2500	1100	8820	2700	18.	3120	9120	11520	10
202.6%	1560	9	92.19%	6320	5200	900	10620	0		3120	9120	11520	10
173.7%	1560	10	80.90%	5420	5200	1300	9320	0		3120	9120	11520	10
132.1%	1560	11	67.88%	4120	5200	1500	7820	3700	21.	3120	9120	11520	10
84.0%	1560	12	91.75%	2620	8900	950	10570	0		3120	9120	11520	10
53.5%	1560	13	83.07%	1670	8900	1000	9570	0		3120	9120	11520	10
101.6%	1560	14	73.52%	3170	6400	1100	8470	3050	24.	3120	9120	11520	10
66.3%	1560	15	93.49%	2070	9450	750	10770	0		3120	9120	11520	10
42.3%	1560	16	88.72%	1320	9450	550	10220	0		3120	9120	11520	10
24.7%	1560	17	84.38%	770	9450	500	9720	0		3120	9120	11520	10
95.2%	1560	18	77.43%	2970	6750	800	8920	2600	28.	3120	9120	11520	10
69.6%	1560	19	93.49%	2170	9350	750	10770	0		3120	9120	11520	10
45.5%	1560	20	85.68%	1420	9350	900	9870	0		3120	9120	11520	10
		Average inventory		**4047**	7505	1604	9948	727.5					

In the DDMRP, it is also another way of alerting the so called Projected On-Hand Alert. It calculates the red zone for a short time horizon to highlight potential supply chain supply problems. It is based on data like NFE but with the difference, that it does not recommend new orders, but points to buffer, whose supply is secured through open orders but needs to be urged.

Conclusions

The main objective of the article was to highlight the potential that can be achieved by implementing the DDMRP in the supply chain. Since DDMRP is introduced into the company as a software module (eg SAP component or module from other companies), it is not possible to make study on a complex model. Although a simple example is given. It is possible to draw some conclusions from the realized case study. These are some differences in character-based inventory management systems, commonly introduced in companies such as MRP and Kanban. In general, it is mainly about the level of visibility and the rate of acceptance of dynamics in individual systems, which results in the definition of a specific size of orders in cooperation with several factors mentioned in the article (delivery time, market dynamics, consumption dynamics, etc.). In the case study, a way to implement a product across multiple BOMs (which indicate grades in the supply chain) and to determine the optimal size of the buffer via DDMRP is in progress.

The literature review and empirical research helped in providing answers to the major differences between the two methodologies MRP and DDMRP.

The main difference between MRP and DDMRP is that the DDMRP focuses on pull from customer's i.e. control is based on demand signals that are determined on the basis of qualified daily sales, not on potential contracts. The request is in the DDMRP system generated after the order was placed to eliminate the impact of supply oscillations in the supply chain - the bullwhip-effect (i.e., overhead or lack of inventory in the system). The key in demand planning is prioritizing, which favours the status of buffer before the date of fulfilment the order. This increases the efficiency of inventory management over the conventional MRP system.

Complexity and variability of the present business environments and especially of the supply chains require being adaptive to tackle increasing variability. In view of the above and the case study carried out, it can be stated that:

- DDMRP methodology is suitable to apply on the entire product portfolio of the company, but it could be applicable also for a part of the product portfolio.
- DMRP cannot be applied to all the identified buffers – for example by the purchase of raw materials, it is problem with too high lead time and with it related no actual demand for such a long period.
- If suppliers are managed by contract and due to the high price volatility is defined as the quantity of supply – by the low price company will buy more than the actual needs to save the purchasing cost.
- In the long term, DDMRP implementation will affect the embedded culture and working habits of the company, but the transition will probably become essential and possibly provide a sustainable competitive advantage.

The vision of the future is self-regulation in enterprises, which will be based on the autonomous functioning and mutual communication of machines of predominantly robots and products according to information in real time. Sensors will monitor the whole production process, system integration will allow customers to interact with the design and production process. Increase in machine and equipment utilization, shorter production cycle times, faster response to customer requirements due to self-regulation of incoming transactions (without human interaction) is also expected [16, 17].

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References

[1] Ahmad K., Zabri S. M., *The deployment of performance measurement system under the supply chain management environment: The case of Malaysian manufacturing companies*, Management and Production Engineering Review, 2018, vol. 9, no. 1, pp. 3-12.

[2] Klos S., Ptalas-Maliszewska J., *The impact of ERP on maintenance management*, Management and Production Engineering Review, 4, 3, 15–25, 2013.

[3] Trebuňa P., Fiľo M., Pekarčíková M., *Supply and distribution logistics*, Ostrava: Amos, 2013.

[4] Mendes Jr. P., *Demand Driven Supply Chain: A Structured and Practical Roadmap to Increase Profitability,* Springer, Berlin, Germany, 2011.

[5] Nielsen P., Michna Z., *The impact of stochastic lead times on the bullwhip effect – an empirical insight*,

Management and Production Engineering Review, 9, 1, 65–70, 2018.

[6] Rosová A., *The system of indicators of distribution logistics, transport logistics and material flow as a tool of controlling in logistics enterpise*, Acta Montanistica Slovaca, 15, 1, 67–72, 2010.

[7] Straka M., Malindzak, D., *Algorithms of capacity balancing of printing machineries for Alfa Foils, a.s. planning system*, Acta Montanistica Slovaca, 14, 1, 98–102, 2009.

[8] Wicher P., Staš D., Karkula M., Lenort R., Besta P., *A computer simulation-based analysis of supply chains resilience in industrial environment*, Metalurgija, 54, 4, 2015.

[9] Smith D., Smith Ch., *Demand Driven Performance: Using smart metrics*, McGraw-Hill Education, USA, 2013.

[10] Ptak C., Smith C., *Demand Driven Material Requirements Planning (DDMRP)*, Industrial Press, Inc., 2016.

[11] https://www.demanddriveninstitute.com/the-method?lipi=urn%3Ali%3Apage%3Ad_flagship3_pulse_read%3B%2B%2BRViU76TZufZi9CcGkRLg%3D%3D

[12] Wilkner J., *On decoupling points and decoupling zones*, Production & Manufacturing Research, 2, 1, 2014.

[13] http://www.beyondmrp.com/demand-driven-mrp-portal/demand-driven-mrp-5-elements/demand driven-mrp-strategic-inventory-positioning/

[14] http://36mfjx1a0yt01ki78v3bb46n15gp.wpengine.netdna-cdn.com/wp-content/uploads/2016/04/Exec-DDMRP-IntroductionJBWV1.6.pdf

[15] http://leanontoc.com/BufferCalc.html

[16] Edl M., Kudrna J., *Methods of industrial engineering*, Plzeň: Smart Motion, 2013.

[17] Poor P., Basl J., *Czech Republic and Processes of Industry 4.0 Implementation*, Proceedings of the 29th DAAAM International Symposium, DAAAM International, Vienna, Austria, pp. 454–459, 2018.