Evaluating Demand Driven MRP: a case based simulated study

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Abstract
This study evaluates the assumption underpinning Material Requirements Planning (MRP), buffer management and DDMRP before analysing the case company and evaluating the potential benefits, utilizing simulated data from the existing ERP system. The purpose of this research is to evaluate DDMRP in the context of improving the performance of a printing ink manufacturing company. The main issues the company is facing using a traditional MRP system include poor due-date performance, stock levels not corresponding to the actual market needs and overall system instability leading to inefficiencies. The findings indicate the potential of DDMRP to improve system stability and product availability.

Keywords: MRP, Buffer Management, Case Study

Introduction
The goal of most companies is to make money (Goldratt and Cox, 1984; Klein and Debruine, 1995) and although this concept has not changed over the last decades, the environment has. The introduction of globalisation has caused the death of the old "push and promote" style manufacturing and increased levels of volatility and variability of demand have imposed pressures on companies and their policies and procedures.

Most manufacturing companies are using enterprise resource planning (ERP) systems today for many if not most departments and functions. Whilst the environment has changed dramatically since the mid-1970s, the core component used for production planning and control has not. This material requirements planning (MRP) module has been first documented by Orlicky (1975) as only a few hundred companies were using it. Since then it has become the standard way of managing the manufacturing function. However, more and more inadequacies or misfits with a changed environment let to the development of MRP II documented in Plossl (1995). Since the developments have only achieved enhancements to the functionality (e.g. consideration of capacity), the MRP core stayed the same. This is confirmed by Ptak and Smith (2008) in their ground-breaking article that introduced the idea of actively synchronised replenishment (ASR), the later demand driven MRP (DDMRP) (Ptak and Smith, 2011). They have developed a concept that embraces the strength and validity of MRP while taking care of its weaknesses in today's environment. New components and procedures are based on various well-known methodologies including TOC and lean manufacturing.

This research is an attempt to apply DDMRP to determine its appropriateness in a specific manufacturing environment. The analysis and evaluation should provide indicators of its applicability, usefulness and appropriateness to similar environments. The research takes place in a printing ink manufacturing company, for which the synonym InkCo is used throughout the document for confidentiality reasons.

Literature review

MRP

The introduction has already supported the view that ERP systems are a common if not given feature of today's manufacturing companies (McGaughey and Gunasekaran, 2007). According to Blackstone and Cox (2005), ERP systems represent a "framework for organizing, defining and standardizing the business processes necessary to effectively plan and control an organisation so the organisation can use its internal knowledge to seek external advantage". Beside impressive advancements in scope and functionality, the MRP routines developed in the 1970s are still at the heart of current ERP's planning and control functions (Ptak and Smith, 2008). Although most ERP vendors claim that the universal approach of MRP fits all companies in all industries as so-called 'best practices' (van Groenendaal et al and van der Hoeven, 2008), issues characterised by unacceptable inventory performance, unacceptable service-level performance and high expedite-related expenses are known to practitioners well before they have been presented in a formal study (Ptak and Smith, 2011). The resulting problems taken from Ptak and Smith (2008) and Ptak and Smith (2011) are shown in the following Table 1.

Table 1 – Common MRP-related problems

Problem area	Characteristics
Forecast and MPS	All forecasts and sales plans are all wrong (Goldratt et al, 2009). MRP uses this forecast via the MPS to calculate demand and to create work and purchase orders. Market volatility and fluctuating customer demand in the short-term cause misalignment between such forecasted demand and real customer orders. The consequences are often high inventories of wrong items on one side and expediting, overtime, extra freight costs and even missed shipments on the other.
Full BOM runs	MRP pegs down the full BOM to the lowest hierarchy level independently for each stock-keeping unit (SKU) in cases when available stock is less than exploded demand. The result is many orders and a schedule that can easily change triggered by a small change at an upper level material (Wijngaard, 2007).
Manufacturing order release	MRP does not check parts availability prior to releasing work orders since only lead-time related criteria is used for making this decision. It is a basic assumption of MRP that all parts are available at the time of work order release (Smith and Ptak, 2013). Experience of reality suggests that this assumption is not often true.
Limited early-warning functionality	MRP creates work orders for items that reach the configured safety stock level. There is no visibility of items that are near this level or that might reach this level in the near future due to high customer demand (Plenert, 1999).
Lead-time ambiguity	MRP can use two different lead-time types. Using manufacturing lead-time often causes orders be released too late while using cumulative lead-time often causes orders to be released too early resulting in work in progress levels being unnecessarily high.

Unresponsive demand determination	MRP allows you to consider forecasted demand in the MPS in full or not at all. Full consideration requires the calculation of safety stock levels once per planning period. Demand volatility could cause stock misalignment with market needs due to the fixed character of configuration. Non-consideration turns the company into a make to order configuration. Since this is not possible for all companies (Fisher, 1997), a lethal cost spiral and permanent expediting might be the result.
Lacking priority consideration	MRP considers work orders for stock replenishment, regular customer demand and past due demand as equal. This results in the need to continually observe and analyse work orders and production schedules, resulting in manual priority changes (Ptak and Smith, 2008).

It now becomes obvious that standard MRP does not really deliver what organisations in our current environment need. Companies basically have two options: to live with the issues and suboptimal results standard MRP delivers or to invest in SCM software to circumvent them. On the basis of the findings made, it can be concluded that MRP is not the standard instrument shaping "the way of life in the future" (Orlicky, 1975) anymore. Ptak and Smith (2008) support this claim by arguing that "the world that existed when MRP was developed no longer exists".

DDMRP

DDMRP is designed to be a framework for production planning and control that incorporates MRP functionality while explicitly addressing its known weaknesses (Ptak and Smith, 2011) by incorporating ideas from TOC such as strategic buffering, replenishment and buffer management (Smith and Ptak, 2010). Ptak and Smith (2011) have defined five major components as the building blocks of DDMRP. They are designed to be introduced and applied jointly as "ignoring any of these components will reduce the value of the solution dramatically in most environments" (Ptak and Smith, 2011). The following Table 2 explains their characteristics.

Table 2 – Five components of DDMRP

Component	Characteristics
Strategic inventory positioning	Ptak and Smith (2008) found that the question of how much inventory one should hold needs to change to asking where inventory should be positioned. It is necessary to protect the supply chain from fluctuating customer demand and supply variability. Inventory of raw and intermediate items can also help to compress cumulative lead-times and improve overall stability.
Buffer profiles and levels	Buffers are calculated for manufactured, purchased and distributed items. The calculation is based on the average daily usage (ADU), variability and lead-time. Furthermore, minimum order quantities are considered if needed. Ptak and Smith (2011) define three distinct buffer zones (green, yellow and red).Green stands for nothing to do, yellow indicates the rebuild or replenishment zone and red means special attention required.
Dynamic adjustments	DDMRP considers recalculated adjustments, planned adjustments and manual adjustments within the model triggered by external events changing ADUs.
Demand-driven planning	DDMRP separates parts into five distinct categories (replenished, replenished override, min-max, non-buffered and lead-time managed) and parts are allocated to one of the five categories according to their needs.

Highly visible and collaborative execution	DDMRP contains a sophisticated alerting system that circumvents the priority-by-due-date issue of classic MRP by establishing alerts based on buffer states while still considering due dates as a second source of information. Alerts are created based on the buffer state of the part in focus. Collaboration is needed to establish clear rules for decision-making based on these buffer states.

The description has shown that DDMRP seems to to address major weaknesses of standard MRP in a consequent way. It uses well-established elements of TOC and other continuous improvement methodologies to form a unique framework for production planning and control. Although existing literature evaluating DDMRP performance is rare, it can be concluded that it is well placed on the shoulders of its predecessors or roots.

Research methods

Steenhuis and Bruijn (2006) said as a contribution to the methodology debate, that "[…] different approaches should not be seen as more or less valuable but rather as a portfolio of techniques that together can help to create insight into the problems of and solutions for the field of operations management." In line with this, this research involves both case analysis to determine the underlying reasons for the current performance and a simulation study designed to compare the impact of adopting DDMRP planning and control over traditional MRP. The case research was designed to uncover the issues underlying the current performance (Yin, 2009) to determine the applicability of DDMRP from a theoretical point of view to the case company. Using theory in this way by putting them in a real world scenario is, according to Bertrand and Fransoo (2002), an adequate approach of problem solving intended by this study.

The evidence was gathered via an internal survey, semi-structured interviews, observation and an analysis of the existing Enterprise Resource Planning (ERP) system. Senior and middle managers, together with employees were involved in the semi-structured interviews. Altogether, 4 questionnaires have been distributed internally 15 functional involved colleagues with a response rate of 80%, 4 in-depth interviews have been conducted facilitated by aide-mémoires, 41 deliberate observation activities have been undertaken and various reports and SQL statements have been used in order to produce the case study.

The simulation model was created using SQL and Excel and designed to compare DDMRP and MRP performance using representative parts data from the ERP system (Feng et al., 2012). These simulated results were then compared with the actual company performance and the case evidence was utilized in explaining the results and predicting the potential impact of adopting DDMRP. For simplicity and capacity reasons, a representative set of 28 products out of the full product line of the case company has been selected.

Analysis

The case

The company (InkCo) has its headquarters in Germany for more than 150 years and offers high quality inks for screen, pad and digital printing applications as well as liquid coatings to customers in about 80 countries all over the world. InkCo's track record of innovation stretches back over more than 60 years, featuring many industry-first solutions for both industrial applications and graphic design.

The case analysis of all relevant functions along the supply chain initially identified eleven undesirable effects (UDEs) that characterised the the ongoing situation. However, they have been found to be interrelated and also overlapping to an extent, which made it necessary to condense them down to a more manageable number of six. The following Table 3 lists the UDEs together with explanations derived from the case data to allow for recognition of the related features.

Table 4 – Six case UDEs

Component	Characteristics
There are frequent shortages of finished goods (**UDE #1**)	• Annual budget is treated as the only truth, which it is obviously not. The resulting self-constructed MPS is often misleading. • Forecasting is seen as an universal solution to demand determination and production planning • Reality shows that budgets and forecasts do not fulfil their anticipated accurateness
There is excessive levels of expediting (**UDE #2**)	• Stock levels do not correspond to actual demand • Self-constructed MPS is not able to deliver stable figures • Sales performance is measured partly on order intake, which often does not consider available capacity
There are frequent shortages of raw materials (**UDE #3**)	• Demand for intermediate products is calculated manually based on the released production orders • Established min/max-style configurations for standard materials are not dynamically adjusted • Since production order fulfilment is weak in presence of permanent changes, their accuracy is questionable • Resulting demand for raw and packaging materials is often made on guesses or experience
Production plans have a very limited life (**UDE #4**)	• Fluctuating and not foreseeable demand for finished goods requires expediting • Availability of intermediates and raw materials frequently demands for improvisation and immediate changes of original plans
Production lead-times are too long (**UDE #5**)	• Performance measurement favours local efficiencies over demand-orientated behaviour • Expediting interrupts production orders by the need to fit in small batches related to urgent customer orders • Inadequate stock buffers (too high or too low) require many small batches to be produced. Resulting cleaning and setup occupies existing machinery longer than needed. • The result is lead-times of some weeks that almost eliminate any flexibility.
There is chaos (**UDE #6**)	• Demand is often not foreseen • Priorities are unclear with the exception that customer orders should be shipped whatever it might cost • Current tools (e.g. MRP and individual solutions) do not address the requirements • Performance measurement is inadequate • Expediting has become the standard mode of operation • Complaints from sales, logistics and higher management address symptoms only

Combining the generic issue categories of standard MRP implementations shown in the literature review with the aforementioned UDEs, one sees clearly that InkCo is suffering quite significantly from MRP shortcomings as the next Table 4 shows.

Table 5 – Generic MRP issues connected to case UDEs

Issue	UDEs
Unacceptable inventory performance	UDE1, UDE2, UDE3, UDE5, UDE6
Unacceptable service-level performance	UDE1, UDE4, UDE6
High expedite-related expenses	UDE2, UDE3, UDE4, UDE6

The strong presence of the case UDEs under the MRP issues shows that the introduction of DDMRP methodology might be helpful, since the creators of DDMRP explicitly strive to address these issues.

Simulation
A set of products that cover the variety of the whole product range in terms of including all product types and also the different sales profiles from fast moving over average until slow moving products was defined. To this sample the DDMRP methodology was applied by first determining buffer profiles and sizes. Data used to perform this task was extracted from the ERP system of InkCo to be as realistic as possible. After having determined the buffers, 2013 data was used to run a simulation that basis production related decision-making solely on buffer status. The results for the 28 products being part of this simulation include 43% less high-inventory alerts, 45% less low-inventory alerts and 95% less stock outs. Furthermore, 39% of the products show a reduced inventory while overall inventory could be reduced by 2%. One might claim that this simulation is not fully representative because the future sales were known to the researcher. However, in order to address this possible weakness, sales visibility of only two weeks in the future was strictly maintained, which is a common feature of InkCo's real life situation.

To better illustrate the simulation activities undertaken, one product example is discussed in more detail. ADSP2 1l is a black all-purpose screen printing ink. It is well established in the market and therefore sold on a regular basis. InkCo has it categorized as a standard product being part of the A category of fast moving SKUs. Its lead-time falls into the long category of more than one month, because raw material in form of pigments has a significant lead-time from placing the order until goods receipt. Table 6 summarizes the facts of 2013 and of the simulation.

Table 6 – ADSP2 1l simulation results

Source	#High-inv. alerts	#Low-inv. Alerts	#Stock outs	Avg. stock level
Reality	58	19	5	2,354
Simulation	32	59	0	1,691

The DDMRP buffer determination resulted in an overall buffer size of 3,688 litre divided into 3,034 litre TOY, 851 litre TOR and 196 litre red safety. Figure 1 shows the application of the buffer zones to the real stock levels of 2013. One sees that unnecessary high stock levels did occur as well as stock outs towards the end of the year. Furthermore, production and batch size decisions do not seem to follow a specific scheme.

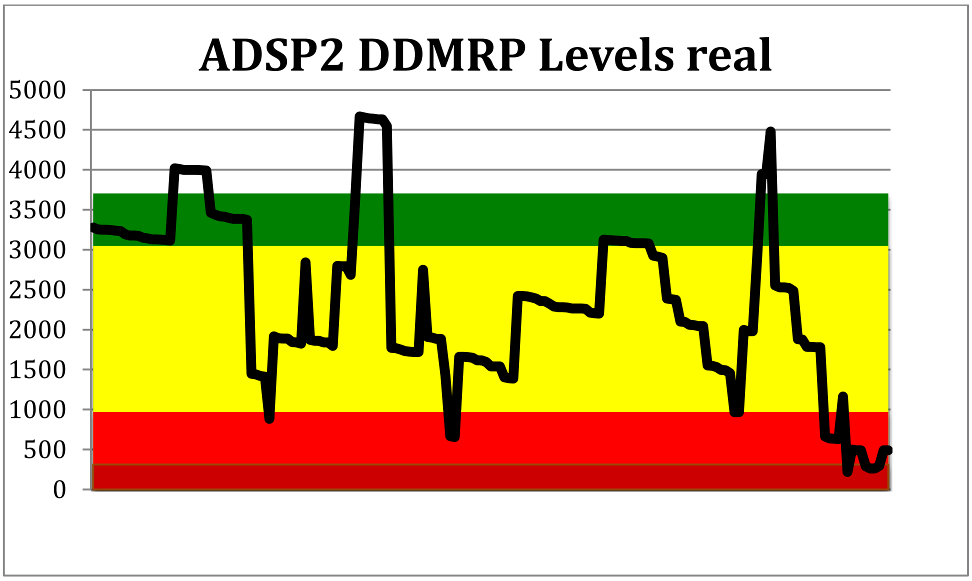

Figure 1 – ADSP2 1l stock levels and DDMRP buffers 2013

The simulation was based on some rules of thumb including production decisions in the middle of the red base buffer, batch sizes to reach the green buffer or better to reach its middle and demand visibility of roughly ten days. The resulting stock levels shown in the next Figure 2 provide a different picture than the real stock levels shown in the previous figure. The decision-making rules bring standardisation into production decisions that are solely based on buffer status and upcoming demand in form of customer orders. It was always possible to follow the DDMRP systematic during the simulation.

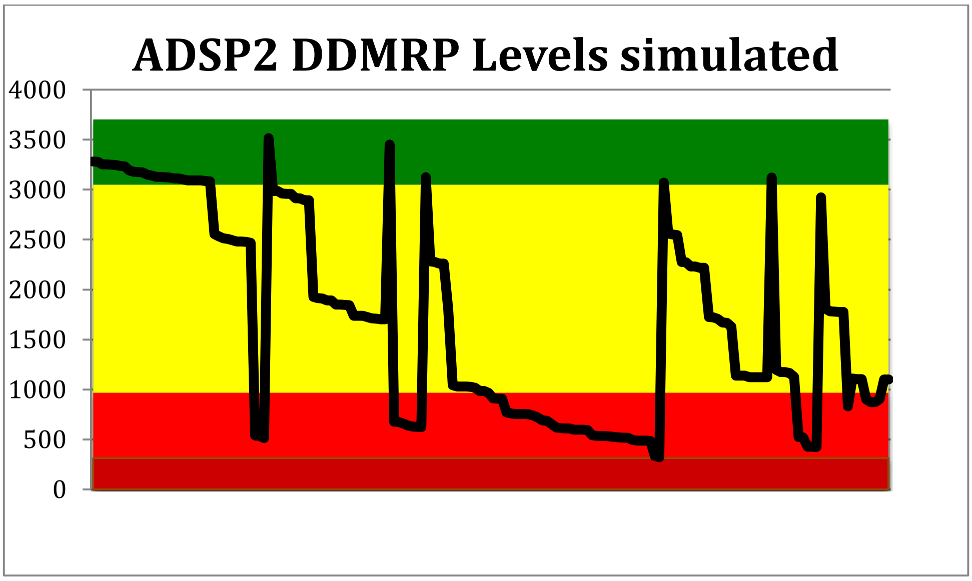

Figure 2 – ADSP2 1l stock levels and DDMRP buffers simulated

In an attempt of assessing the results, one can clearly identify the reduced amount of high inventory alerts, which are expected to have a financial benefit to InkCo in form of reduced capital invested in the warehouse. Furthermore, the simulation was able to avoid the stock outs towards the end of the year by triggering production decision earlier than in reality. However, the number of low inventory alerts has risen to about three times the amount than in reality. A reason for this is the rule of letting inventory levels fall down to the middle of base red before scheduling a production. Especially the long red period during summer time has caused many of such alerts. Finally, the average stock level could be lowered by impressing 28% while having availability significantly improved. This means that DDMRP has helped to improve availability while being able to lower costs in parallel.

The overall results of the simulation activity are now presented briefly under the categories of availability, stock and structure together with some ideas about its limitations. DDMRP techniques have the potential to improve product availability dramatically by first providing the decision makers with a clear and simple set of rules to be applied to the products in focus. All examples showed an increasing fit of the actual stock levels with the specific demand patterns of the products. This increased availability has effects on the level of stock. The determined buffer zones indicate optimal stock levels and trigger production orders being released and completed in order to build up stock. In these cases an increased stock level would be the consequence. The other classic examples of too much stock could also be found among the examples. Here, DDMRP buffers are effective in reducing stock that might have been built up due to performance criteria requiring the exploitation of local efficiencies or due to the lack of demand visibility. It becomes clear that DDMRP establishes a certain structure that determines distinct rules for planning and execution behaviour. First, demand becomes visible by showing it in conjunction with the resulting buffer states. Decision-making became detached from past experience and sales forecasts in favour of consequent consideration of on hand stock and actual demand. Second, justification for decisions being made can be easily derived from DDMRP buffers, whereas the traditional ways of working often demand for complicated and sophisticated argumentation.

It needs to be identified that the relatively small amount of SKUs used in this simulation might reduce the generalizability of the findings made. While looking at the results from the reality of 2013, one might ask whether this was the maximum the current system can be produce. Moreover, one needs to question the replicability of the simulation results in the real environment of 5,200 SKUs. The aforementioned conflicts and competition for resources might have a limiting effect.

Discussion

The case study has provided an in-depth analysis of the case company. During this analysis, a set of UDEs describing the performance limiting issues at InkCo could have been identified. A certain degree of fit between issues and DDMRP focus could be justified, which made replacing current procedures and policies by DDMRP components a valid and also promising idea. The following simulation activity has enhanced this finding by providing a clear understanding of the current situation as of 2013 and possible improvements resulting from DDMRP methodology. However, one need to be cautious while interpreting the results since the simulation had to accept past performance as a given fact. Although one cannot identify to what degree past performance could have been improved by better using or applying current ERP functionality, at least some doubts remain.

Nevertheless, DDMRP seems to be of beneficial character to the case company, which is shown by contrasting the current situation represented by the identified UDEs with possible improvements resulting from the DDMRP methodology. The following Table 7 shows the results.

Table 7 – UDEs and DDMRP improvement potential

UDEs	Findings	Literature support
There are frequent shortages of finished goods (**UDE #1**)	Adequate buffer levels consider demand, variability and lead-time	Schragenheim et al (2009), Ptak and Smith (2011)
There is excessive levels of expediting (**UDE #2**)	Highly visible and replicable execution, dynamic buffers adjust to varying demand, clear rules for priorities	Ptak and Smith (2011)
There are frequent shortages of raw materials (**UDE #3**)	Demand-driven planning, MRP connects demand for finished goods to demand for raw materials, strategic inventory positioning	Schragenheim et al (2009), Ptak and Smith (2011), Plossl (1995)
Production plans have a very limited life (**UDE #4**)	Adequate buffer levels, highly visible and replicable execution	Schragenheim et al (2009), Ptak and Smith (2011)
Production lead-times are too long (**UDE #5**)	Often smaller lot sizes, strategic inventory positioning reduces exposure to stock-outs	Goldratt and Cox (1984), Srikanth (2010), Ptak and Smith (2011)
There is chaos (**UDE #6**)	Clear rules for decision-making, interconnectedness of all relevant functions, reliable and supporting levels of stock absorb variability	Ptak and Schragenheim (2004), Srikanth (2010), Ptak and Smith (2011)

The application of DDMRP is therefore seen to be able to turn the UDEs in to desirable effects. The introduction of DDMRP has been found to be capable of delivering the improvements of availability and stability of the system sought. As another appreciable effect, the reduction of lead-times supported by various elements of DDMRP (e.g. strategic inventory positioning or smaller lot sizes) needs to be mentioned

Conclusion

DDMRP was shown to strategically locate aggregated inventory buffers within the MRP based dependent demand planning process. These buffers provide pull signals and are adjusted using a form of dynamic buffer management (Cox and Schleier, 2010), effectively integrating the key features of MRP and TOC. The case research evidence demonstrates how the current lack of buffer control encouraged instability explaining the mix of both high inventory and shortages with no formal signalling system to support prioritization, timely expediting and escalation when the system becomes unstable. These findings were largely consistent with the literature associated with the limitations of MRP (Ptak and Smith, 2008). The case study enabled the location of the aggregated buffers to be identified and buffer management target stock levels to be determined in advance of the simulation study. The simulation results across 28 sample products showed how the aggregation and formalized signalling system reduced high and low inventory alerts by 45% and stock outs by 95%. Surprisingly, the results did not include a significant reduction of stocks as well-known researchers of the field including (Ptak and Smith, 2011; Umble and Umble, 2001; Balderstone and Mabin, 1998) have identified. Furthermore, it needs to be acknowledged that the improved simulated performance was not fully attributable to the adoption of DDMRP concepts. Reasons for this include the poor practice in terms of procedures and data accuracy. Further, analysis is being directed at establishing the degree to which this has influenced the results and to what extent the DDMRP system would also be sensitive to poor implementation practice. However, applicability is seen to be generally given but resulting value depends on the specific and unique situation of the adopting company. Further research needs to uncover more aspects of DDMRP in terms of its value to manufacturing organisations.

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