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DOES THE MRP LOGIC WORK FOR FINITE CAPACITY PLANNING AND OPERATIONS SCHEDULING ?

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ABSTRACT

During the past five years, MRP based systems have increasingly been criticized for their inability to reduce inventory levels, meet due dates and to plan at an operational level. This paper suggests that the actual reasons for these problems are some fundamental flaws in the MRP logic and its assumptions. The logic of the Optimized Production Technology (OPT) is suggested as an alternative approach that addresses the limitations of MRP based systems.

OPSOMMING

Gedurende die afgelope vyf jaar het kritiek teen MRP-gebaseerde sisteme toegeneem. Die kritiek is hoofsaaklik dat MRP-sisteme vooraadvlakke nie voldoende verminder nie; beplande datums nie haal nie en ook nie op 'n operasionele vlak beplan nie. Hierdie artikel wil voorstel dat die rede hiervoor fundamentele foute in die MRP logika en aannames is. Die logika van "Optimized Production Technology" (OPT) word as alternatief voorgestel, aangesien dit die probleemareas in die MRP-logika aanspreek.

1. INTRODUCTION

"MRP has reached its adolescence....., we're forced to admit that there are some things wrong." **Lundrigan** [20,p2]

"...yet there is a rising tide of disappointment with the MRP based methods and growing evidence that MRP may well not be 'the' way to go in manufacturing." **Kanet** [17,p57]

Why are such statements being made, and are they valid? If so, what alternative is being suggested? This article investigates the validity of the above statements by determining if literature on the subject supports such criticism (section 2) and then discusses the criticisms in detail (section 3). Finally a solution to the problem is suggested (section 4).

> The context of this article is a **job shop environment**, with **complex scheduling** requirements that cannot be done without the aid of a computer.

2. HISTORICAL OVERVIEW OF SYSTEMS USING THE MRP LOGIC

During the late 1950's and early 1960's, classical **statistical inventory control techniques** prevailed. The three main criticisms of this technique were that it assumed the past to represent the future; it did not deal with the dependent demand relationship in parent-child sub-assemblies and it did not address resource requirements [6].

With the advent of integrated circuit technology during the 1960's, dawned the era of **database management systems.** This allowed the **MRP logic** to become computerized. By 1968 several companies (e.g. Black & Decker) had already implemented **net change MRP** systems.

This period was marked by phenomenal MRP growth - APICS reported a membership of 61 000 [17]. A lucrative industry of software developers and contractors developed to meet this growth. Zais reported that in 1984 some 16 companies had sold $400 million worth of software to 17 000 clients [33]. Projections for 1987 were $1250 million. [16]

Despite the apparent success Kamenetzky points out that not many success stories are recorded [16]. During the late 1970's and early 1980's limitations experienced in MRP based systems were documented. (A MRP based system is any system that has evolved from, or is based on the traditional MRP concepts. This includes MRPII, and closed loop MRP systems.) Manufacturers therefore began to explore new horizons.

MRPII (manufacturing resource planning) evolved from traditional MRP, and established a company-wide approach to planning. In the mid 1980's however, MRPII (based on MRP logic) was also criticized ([8], [16], [17], [18], [20], [24], [25], [29]). The criticism concerned mainly its inability to reduce inventory levels; meet due dates and to plan at an operational level. Kamenetzky mentions that the rate of successful implementations were around 15% [16].

A study conducted during 1984 accused MRP as being " a $100 billion mistake", while Aggarwal mentioned in 1985 that "90% of MRP users are unhappy" [1]. The result was that manufacturers began to explore the **JIT** (Just-in-time) and **OPT** (Optimized Production Technology) philosophies as possible alternatives.

Japan had already begun exploring the JIT philosophy during the 1970's [13], but it was not until the 1980's that manufacturers in the USA and UK followed this trend. Literature on this subject ([3], [19]) reveals how some attempted to resolve the apparent "conflict" between their MRP systems and the JIT philosophy. Some authors are of the opinion that the MRP based logic is acceptable as a **material planning tool**, but that JIT complemented it in that JIT is the **execution** of these plans at an **operational** level.

Parallel to the development of JIT, **OPT** began an aggressive marketing campaign ([13], [15], [20], [23], [26], [29]), claiming to have a philosophy that overcomes MRP limitations. Having developed the OPT philosophy during the 1970's in Israel, Moshe Eliyahu Goldratt established Creative Output Inc. (COI) in the USA in 1979. By 1986 COI had "converted" about 200 companies to their philosophy. It needs to be said that these were mainly major companies such as General Electric, General Motors, Caterpillar Tractors, Xerox and Arrowhead Metal.

Against the background to the evolution of the MRP based systems as discussed above, some explanation of the criticisms against the MRP logic and its assumptions now follows.

3. CRITICISMS OF THE MRP LOGIC BASED APPROACH

Software developers and management consultants have often blamed the failure of MRP based systems on ([8]):

1. Inaccurate input data.
2. Unrealistic master production schedules (MPS).
3. Lack of top management support.
4. Lack of end user education.

Kanet [17] and Kamenetzky [16] both argue that while there is some truth in these objections, the real reason is some fundamental flaws in the MRP logic. According to them the objections are merely symptoms, and not the root cause.

Several authors ([8], [16], [17], [18], [20], [24], [29]) have identified the fundamental flaws in MRP based systems as:

1. Independent parameters (such as lot sizes, lead times (including queue times) and safety stocks) are actually **dependent** on the work schedule. Hence these should not be predefined, but

calculated by the system according to the scheduled work and resource availability. For example, because queue times have to be predetermined, the time used is usually average queue times. The result of using average queue times is late deliveries when the workload is high and unnecessary WIP when the workload is low [17].

2. **Batch splitting** and **"pass-ahead-batches"** (i.e. overlapping) is not optimized by the system but must be predetermined by the user. Batch splitting and overlapping is what actually happens on the shop floor, and hence the planned schedule is bound to differ from reality. This substantiates the accusation that MRP systems perform poorly at an operational level.

3. The system ignores **constraints** (machine, manpower, tooling) at an operational level. If a software system allows the user to have machine loads in excess of 100%, it assumes **infinite loading**. This often results in schedules that are not possible, an unfeasible MPS and poor due date performances.

4. Some MRPII systems have modules that do true finite capacity planning. The problem with many of these is that they "optimize" for individual workstations - the problem of **sub-optimization** [16]. This suboptimum often conflicts with the global optimum. This can result in poor due date performance (either too early or too late).

5. Material and resource planning is done **sequentially** instead of **simultaneously**. Time phased material requirements should be calculated simultaneously with the finite loading of resources on an operational level. Materials and operations are functionally related and planning should not be done on separate levels. Many planners solve this problem by giving unrealistically large lead times to ensure that materials are available on time, and this again leads to unnecessary WIP.

6. It lacks **true vision.** MRP based systems often do not indicate the true bottlenecks (2 & 3 above), but rather indicate over-utilized capacity. (Over-utilized capacity in a specific time bucket is often the result of poor scheduling, and not that of a true physical constraint to material flow through the factory)

7. Because true vision is limited, MRP based systems struggle to deal with **the effects of disturbances.** These effects are dealt with by keeping inventory buffers (as opposed to time buffers). The problem with this is that the system provides enough material in plenty of time, just in case everything goes wrong! This can again lead to predetermined lead times having to be increased and a "Catch 22" situation - the input data becomes more and more unrealistic, WIP increases, lead times are increased, and so forth.

This aspect (lack of forward vision to deal with effects of disturbances) is also a criticism of the JIT philosophy. With JIT, buffers (using methods such as the "kanban") are built to overcome disturbances. However the question that remains is how big the buffer should be made to ensure that a smooth flow is maintained? Some form of computerized planning tool is still required for complex scheduling environments.

8. The above-mentioned aspects clearly indicate that MRP based systems have limited **decision support** capabilities. The user would usually have to modify the MPS by means of trial and error until a feasible (operationally executable) plan exists.

This article has the view that it is these fundamental flaws in the MRP logic and assumptions that have led to MRP's failure to continually reduce inventory levels, meet due dates and to plan at an operational level. More detailed explanations of how these flaws have led to MRP's failure can be found in the following references: [8], [16], [17], [18], [20], [24], [29].

Kamenetzky [16] captures a great deal of the discussion above in the following principle: For any **operation**, three conditions are required - available material, available tooling and available resources (workcentre and manpower). He states that "because MRPII evolved from MRP systems, it still emphasizes the first condition (material availability) at the expense of the other two."

MRP based systems (this includes MRPII systems) should be seen for their original intentions - to plan material flows and not for detailed operational planning! While the authors do not wish to undermine the many benefits of MRP based systems (it formalized production planning, encouraged an integrated database, and company-wide approach to planning), we need to understand and accept its limitations. MRPII has come a long way to overcome some of these limitations, but the result was systems that are expensive and complex to operate. The question remains whether there is another way to plan at an operational level, as well as ensure smooth material flows?

From the available literature, it seems as if OPT is one way of doing this planning. Swann suggests that because OPT dynamically determines lot sizing (to maximize throughput) by operation, and does so considering conditions as they actually exist, "There is simply no way to emulate this feature with MRP." [29]

4. THE "OPT" PHILOSOPHY - A SOLUTION ?

What is OPT? Lundrigan provides the answer in a nutshell: "...suppose there were a way to take the best of MRPII - a computerized database system - and the best of JIT - improvements of flow and elimination of waste - and put them together in a kind of westernized just-in-time? That's exactly what optimized production technology (OPT) purports to do." [20]

What does OPT do? Swann mentions that OPT attempts to do what any intelligent scheduler would do: avoid idle time on a bottleneck; assign production away from overloaded resources to those with available capacity; alter lot sizes, combine setups, send ahead partial lots and determine priorities at operations, thus calculating "real" queue times and not average estimates [29].

OPT is more than a software package - it is a manufacturing operating **philosophy**, though this article will only focus on the OPT philosophy and not its software. COI regards this philosophy as so important that they do not sell their software to a company that will not implement the OPT philosophy.

Haylett mentions four foundations of the OPT philosophy to be [13]:

a) The Goal : The real goal of manufacturing is to make money in the present as well as in the future [11, p18]. ("Throughput" is defined as the **rate** at which the system generates **money**). There are three ways to determine if this goal is being attained: Net profit (absolute measure); return on investment (relative measure) and cash flow (present survival). (Goldratt explains these concepts further in "The Race" [11, p20]).

OPT strives for this goal by **simultaneously** increasing throughput, reducing inventory and cutting operating expenses. How doing these achieves the goal is explained in two of Goldratt's books - "The Race" ([11, pp30]) and "The Goal" ([9]).

b) Balance : There is no such thing as a balanced factory. The factory resources must be categorized into bottlenecks and nonbottlenecks (A bottleneck is anything that limits the system from achieving higher performance in terms of making more money).

c) Cost accounting : Traditional methods cause this to be the enemy of achieving the goal. The reader is requested to refer to [11, pp20], as this issue is beyond the scope of this article.

d) The nine rules : These rules are explained in greater detail in the following references: [13], [15], [20], [23].

1. **Balance flow, not capacity.** A balanced (capacity) shop cannot operate efficiently (in terms of achieving the goal). The Japanese rule is: "If you don't need it, don't make it".

2. **The level of utilization of a nonbottleneck is not determined by its own potential but by some other constraint in the system.** Only bottlenecks should work at 100% capacity - and they should pace production. The workload of nonbottlenecks can only be increased by running work not immediately required, or by processing work that bottlenecks cannot absorb: neither is conducive to achieving the goal.

3. **Activation and utilization of a resource are not synonymous.** Many planners have incorrectly aimed at 100% activation rather than 100% utilization. **Utilization** is the level at which a resource should be used to achieve the goal. **Activation** is the level at which we could use a resource [9, p210]. For example: If a nonbottleneck has 5 hours scheduled work during a 8 hour shift, but only works for 4 hours:

Utilization= 4/5 =80%   Activation= 4/8 =50%

4. **An hour lost at a bottleneck is an hour lost for the total system.** This is the central OPT focus - to plan the bottlenecks "optimally", as it is the bottleneck that determines throughput in a factory.

5. **An hour saved at a nonbottleneck is just a mirage.** Excess capacity will always exist. To activate nonbottlenecks when bottlenecks do not require this, is not conducive to achieving the goal. It actually costs money, rather than saves money as traditional cost accounting would imply.

6. **Bottlenecks govern both throughput and inventories in the system.** In accordance with JIT principles, OPT plans on a "hand to mouth" basis. There should be no queues in front of

nonbottlenecks, and **only a time buffer** "queue" in front of the bottleneck.

7. **The transfer batch may not and often should not be equal to the process batch.** As many expediters know, the concepts of transfer batch sizes, overlapping and lot splitting are fundamental to the efficient planning of operations.

8. **The process batch should be variable and not fixed.** Batch sizes are a function of the planned schedule and vary by operation and over time. Bottlenecks therefore will have large batch sizes (to decrease setup losses), while nonbottlenecks will have smaller batch sizes, as setup losses don't "cost" anything (they have excess capacity).

9. **Schedules should be determined by looking at all of the constraints simultaneously - lead times are a result of the schedule and cannot be predetermined.** Simultaneity is an important concept of OPT. Because OPT does not predetermine planning parameters, it does not create the problem of sub-optimization. By not predetermining planning parameters, OPT can plan these simultaneously - to achieve a global near optimum. (OPT does this by plotting a nine dimensional graph [13] - but further information remains proprietary of its developers)

The OPT philosophy is based on points a), b), c) and the 9 rules as mentioned above. In some of the references given, the authors' suggestions for improvements to detailed operational scheduling of MRP based systems, are in fact the foundations of OPT, although they do not always realize this.

It is important to notice that the following strong points of OPT address the fundamental flaws in MRP based systems (as outlined in section 3):

1. OPT recognizes that **production parameters** are a function of the work schedule and are therefore not predetermined.

2. OPT calculates the process sizes, and uses **overlapping** to achieve maximum material velocity (or minimum cycle times). Hancock provides some insight into the effects of lot splitting [12]. OPT aims to balance flow, and not machine loads.

3. OPT focuses its planning on the effective management of constraints. OPT separates the bottlenecks from the non-bottleneck - the vital few from the trivial many. **Finite loading** is a cornerstone in OPT. The result is a MPS that is feasible without excessive expediting.

4. As bottlenecks determine the throughput of a system, and OPT "optimizes" for bottlenecks, OPT achieves a near **global** optimum. According to Goldratt there are usually less than six true bottlenecks in a factory, and so the method of optimization is made simpler and faster (since less conflicts exist).

5. Based on real time schedules, OPT plans materials and operations (including tooling and manpower) **simultaneously.**

6. Because OPT plans operations as they realistically occur on the shop floor, it has reliable **"forward vision"** in terms of true machine constraints, manpower shortages, tooling requirements, and material shortages.

7. OPT deals with the effects of disturbances by keeping **time buffers** (not inventory buffers) in front of critical resources. (A time buffer does not require additional inventory, but only that preceding operations are completed a little earlier than the bottleneck requires). With OPT's reliable "forward vision", the size of these time buffers are relatively easy to determine. The idea is similar to the "kanban" size concept.

8. OPT can provide valuable information to support the planner in decision making as OPT simulates reality well, and does so relatively easily and quickly. (The planner does not have to juggle the MPS and capacities by means of trial and error to achieve a "good" schedule).

From the discussions above, the **benefits** of OPT should be apparent. The following references further outline these benefits: [7], [20], [23], [26], [29], [30], [31], [32].

The main **problem** with the OPT philosophy is that it requires a high level of discipline on the shop floor. The schedule is determined realistically, and must be adhered to. Failure to do this can cause severe throughput disruptions.

This section has merely described the philosophical aspects of OPT. How the OPT software applies these principles has not been dealt with. The following references outline the logic of the OPT software: [4], [15], [20], [22], [23], [31], & [32].

For readers familiar with MRPII based systems and terminology, Vollmann explains the principles and logistics of OPT, within the traditional MRP framework and terms. (Refer to [31] & [32])

Today there are few critics who dispute the value of the OPT philosophy for a complex job shop environment. The question that needs to be asked is whether these principles can be formalized and programmed at a feasible cost.

The original OPT software was expensive, and its "secret algorithm" remains proprietary of its developers. However, the authors have developed a heuristic algorithm firmly based on OPT principles. To prove the feasibility of this algorithm the authors are developing a prototype in a modern database language.

With such software developed, will it work in the "real world"? From examples in the references given, there appears to be little evidence for doubting OPT's ability to work in the real world. However, this remains to be proven in the South African context.

5. CONCLUSION

Literature has revealed that there are indeed limitations in MRP based systems, mainly in their inability to force down inventory levels on a continual basis, meet due dates and plan at an operational level. These limitations are mostly the result of fundamental flaws in the MRP logic and assumptions. The OPT philosophy appears to provide solutions exactly where MRP based systems have been criticized. It does not help to continually "patch-up" existing systems if they have fundamental flaws. OPT attacks the root causes of these flaws, and provides a key to the process of ongoing improvements.

The sunken costs (financially and emotionally) of MRP based systems is considerable, with much vested interest on the part of managers, consultants, programmers and academics. However, if the situation is one where MRP based systems have indicated limitations, and complex scheduling is needed, is it not time for change?

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