Effective production planning for purchased part under long lead time and uncertain demand: MRP Vs demand-driven MRP

M J Shofa¹*, A O Moeis² and N Restiana³
¹Department of Industrial Engineering, University of Serang Raya, Indonesia
²Department of Industrial Engineering, University of Indonesia, Indonesia
³PT Krakatau Steel Tbk, Indonesia

* m.j.shofa@gmail.com

Abstract. MRP as a production planning system is appropriate for the deterministic environment. Unfortunately, most production systems such as customer demands are stochastic, so that MRP is inappropriate at the time. Demand-Driven MRP (DDMRP) is new approach for production planning system dealing with demand uncertainty. The objective of this paper is to compare the MRP and DDMRP for purchased part under long lead time and uncertain demand in terms of average inventory levels. The evaluation is conducted through a discrete event simulation with the long lead time and uncertain demand scenarios. The next step is evaluating the performance of DDMRP by comparing the inventory level of DDMRP with MRP. As result, DDMRP is more effective production planning than MRP in terms of average inventory levels.

Keywords: Demand-driven MRP, long lead time, MRP, uncertain demand

1. Introduction
Nowadays the business environment is in the stochastic system with fluctuating demand, long lead time, inaccurate forecast, huge variety of product, and complex network impact on production planning and inventory control [1], meanwhile MRP as production control system is appropriate for the deterministic environment [2]. Therefore, MRP has many deficiencies to face current business environment.

In stochastic condition, some researches proposed modified MRP to anticipate uncertain demand and lead time to get good service level goals [3][4][6][7]. DDMRP method is workable under long lead time and uncertainties environment with variability of demand and supply. Nevertheless, there are few of researches elaborate the benefit of DDMRP. It is indicated that there is opportunity to compare MRP and DDMRP. This study fills this gap by means of evaluating the performance of DDMRP and MRP for purchased part under long lead time and uncertain demand in terms of average inventory level in the industrial world.

2. Literature review
MRP was first popularized by Joe Orlicky's in 1975, in figure 1 depicts the history of MRP from time to time, begin with MRP, closed-loop MRP, manufacturing resources planning (MRP II), advanced planning and scheduling systems (APS), and the enterprise resources planning (ERP). There are 5 inputs in MRP: Master Production Schedule (MPS), Bill of Material (BOM), item master, orders, requirements a lot of items that are needed and MRP combine them [7][8].
MRP is appropriate under deterministic environment. Poorly, most production systems are stochastic. Therefore, the deterministic assumptions of MRP are often too restrictive. So that, under demand uncertainty MRP combined with lot sizing [9], safety stock and safety lead time [10], while under lead time uncertainty, MRP’s approached with markov process and newboys model [11], brunch and cut algorithm [12], and periodic order quantity [13]. Under Inaccurate forecast, MRP combined with properly forecasting models [14] and under long lead time MRP cominde with lot size and and planned lead time setting [15].

Finally, traditional MRP is not relevant with the current environment. Wherein companies that have experienced in MRP got chronic problems and the risk of high variation, overstock, and shortage in supply planning and customer demand. Such conditions, impact on three main factors, inventory performance, service level performance, high expedite related expenses and waste Error! Reference source not found..
Strategic inventory positioning is the first step in DDMRP. It considers where inventory should be placed. The six positioning factors are used to determine the initial positioning strategy such as customer tolerance time, market potential lead time, demand variability, supply variability, inventory leverage and flexibility, and the critical operation protection. In strategic positioning is introduced a realistic lead time called actively synchronized replenishment lead time (ASR lead time) - the core concept behind DDMRP. It is defined by the longest unprotected or unbuffered sequence in the BOM for a particular parent.

In DDMRP, buffer profiles and levels provide the appropriate buffer position and strategic replenishment to reduce variability from both demand and supply. It revised from the conventional inventory management in terms of the seasonal level inventory into three color-coded zones that comprise the total buffer. These zones are green, yellow, and red zone. Green represents an inventory position that requires no action, yellow represents a part has entered its rebuild or replenishment. Red represents a part that is in jeopardy requiring special attention [1].

Figure 4a shows the zone stratification in buffer stock is segmented in green (G), yellow (Y) and red (R) zone, and figure 4b shows the inventory effective-Ineffective curve with overlaid color-coded zones and displays the meaning of each colored zone. This color coding system will be used in both planning and execution priority management.

To calculate each buffer profiles (G, Y, and R), the average daily usage / ADU over the percentage of lead time is taken. It is calculated follow some formulations, wherein:

\[
\text{Green Zone} = \text{ADU (Average daily usage)} \times \text{Lead time} \times \text{GZ Lead time} \quad (1)
\]
\[
\text{Yellow Zone} = \text{ADU} \times \text{Lead} \quad (2)
\]
\[
\text{Red Zone base} = \text{ADU} \times \text{Lead time} \times \text{RZ Lead} \quad (3)
\]
\[
\text{Red Zone safety} = \text{Variability factor} \times \text{Red zone base} \quad (4)
\]

and, buffer zone is calculated:

\[
\text{Top of Red} = \text{Red Zone} \quad (5)
\]
\[
\text{Top of Yellow} = \text{Top Of Red} + \text{Yellow Zone} \quad (6)
\]
\[
\text{Top of green (TOG)} = \text{red zone base} + \text{red zone safety} + \text{yellow green} + \text{green zone} \quad (7)
\]

Dynamic adjustment is buffer profile adjust. Adjusting buffer profile is used to adapt company production planning to a dynamic environment. There are three types of adjustment: recalculated adjustment, planned adjustment, and manual adjustment.

Demand driven planning is supply generation. It is based on what the available stock equation place the part. Open order is needed when a part stocked are available in yellow zone (rebuild zone), wherein:
Available stock = on hand + on order – demand (past due, due today, qualified spike) \hspace{1cm} (8)

To be able to define threat of spike to the inventory, order quantity spike threshold (OST) should be defined, OST is measured from the percentage of red zone, for this percentage Ptak and Chad provides guidance with 50 percent of the red zone and OST is used for all stocked items [1]. As for the time horizon becomes the criterion of order spike is time where the environment can react rationally to changes that occur. Horizon spike order is usually defined in the lead time of the relevant part. And finally, visible and collaborative execution. It is challenge priority by due date. Priority by due date gives the real day-to-day inventory and materials priorities.

3. Research Metodology
3.1 Flow of The Research
Figure 5 displays flow of the research. In order to compare the effectiveness of MRP and DDMRP, simulation run for 180 days. The indicator that will see is in term of average inventory level. A case study is conducted on manufacturing company in Indonesia. This study focused on Piston-1 with 45 days of lead time. Input data is taken in the period January-December 2015.

3.2 Input Parameters
This research investigated on purchased part Piston-1 with lead time is 45 days (table 1) and demand forecasts for one year is on table 2.

### Table 1. Lead time and part type.
| Lead time (day) | Type   |
|----------------|--------|
| 45             | Purchsed |

### Table 2. Annual Demand Forecast.

| Month | Demand Forecast |
|-------|-----------------|
| 1     | 4700            |
| 2     | 51480           |
| 3     | 49500           |
| 4     | 43200           |
| 5     | 36360           |
| 6     | 44040           |
| 7     | 37020           |
| 8     | 38880           |
| 9     | 39840           |
| 10    | 41040           |
| 11    | 37020           |
| 12    | 6564            |

Scenarios were given as shown in table 3 with the actual demand is generated based on random factor number to make stochastic environment, simulation run on two systems: MRP and DDMRP for 180 days.

### Table 3. Demand variability (daily).

| Week | Demand (daily) |
|------|----------------|
| 1    | 0 5505 1992 0 1992 5505 0 |
| 2    | 0 2283 0 0 0 5440 0 |
| 3    | 2817 1878 5505 0 5505 0 0 |
| 4    | 1992 5780 2817 5505 0 240 5700 |
| 5    | 5452 0 2817 0 2067 2067 0 |
| 6    | 2817 5440 2067 5440 0 0 0 |
| 7    | 240 2817 5505 0 2058 240 2283 |
| 8    | 0 2283 1905 0 1905 1905 1905 |
| 9    | 0 240 1992 2283 0 0 5452 |
| 10   | 0 2067 0 2817 240 2058 0 |
| 11   | 0 2817 0 5440 3900 2067 2817 |
| 12   | 0 0 2817 0 0 5505 |
| 13   | 2283 3900 0 0 0 2283 0 |
| 14   | 0 0 5505 3900 0 1878 0 |
4. Result and discussion

4.1 Production planning using MRP

From the input parameter: demand forecasts, lead time data, and demand variability, MRP and DDMRP is generated. In MRP implementation find that the inventory level is ranged 31,541-162-195 pcs/day and the average level inventory is 106852 pcs/day, as shown in figure 6. The inventory conditions is on instable condition in the end, if any spike conditions the inventory will be stockout.

![MRP Implementation for Piston-1](image)

Figure 6. Demand and inventory condition of piston-1 using MRP method.

4.2 Production planning using DDMRP

DDMRP method is simulated. Firstly, remodelling with strategic inventory positioning, buffer profiles and levels and dynamic adjustment before generating the production planning system. Using strategic replenish position the lead time for part Piston-1 is decoupled from the supplier lead time.

Table 3a shows DDMRP Parameter based on remodelling of DDMRP method. ADU is calculated from the forecasts and Green Zone (GZ) lead time and Red Zone (RZ) lead time is stated based on data converted in percentage. Variability factor and initial state inventory is based on actual data. From the ADU and ASR lead time, buffer profiles can now be investigated as displayed table 3b.

Then, simulation using DDMRP is run. In this simulation find the inventory level is ranged 80,304-120,000 pcs/day and the average inventory level is 95,284 pcs/day. Figure 7 shows the inventory level is on stable condition, it can be preventive for spike in demand.

![Table 3](image)

Table 3. a) DDMRP parameter and b) Buffer profile and levels of piston-1.
5. Conclusion

Base on the purpose of this study is to evaluate the performance of DDMRP and MRP in terms of average inventory level, DDMRP improve the inventory level from 106,852 pcs/day to 95,284 pcs/day (11% reduced) and make inventory on the stable condition, so that DDMRP is more effective production planning than MRP.

This research is just a prototyping of how to realize the production planning with DDMRP and MRP. Further research can compare DDMRP with other production planning method.

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