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IMPACT OF DYNAMIC LOT SIZING TECHNIQUES ON COSTS OF MATERIAL REQUIREMENT PLANNING

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Abstract: Since the beginning of computerised production management, material requirement planning has been a central part of optimising company processes. The reason for this is that the precise computation and optimisation of material requirements can result in significant cost savings for the company in the short term, which can have a significant impact on the overall efficiency of the company's processes. To this end, the definition of the material requirements for production has been complemented by new optimisation methods that can be used to further improve the solution of the problem of dynamic lot sizing. In this paper, the authors investigate the effectiveness of the Wagner-Whitin and Silver-Meal algorithms through a scenario analysis. The results demonstrate that significant cost savings can be achieved by using both algorithms.

Keywords: *material requirement planning, optimization, inventory, order, cost efficiency*

1. INTRODUCTION

Today, in order to meet the dynamic growing demands of customers, manufacturing companies need to operate along inventory management and production control concepts that allow them to meet market demands with high cost efficiency, while meeting not only cost but also logistics and environmental objectives. To this end, the use of various corporate management systems is widespread, particularly in large companies. In order to achieve optimal inventory management and production control, it is essential to define the optimal material requirement, which form the basis of the process schedules. In this paper, we investigate how to improve the efficiency of this material requirement planning process by improving the results of MRP using different algorithms. In order to achieve this goal, we first describe how MRP works and how it is embedded in enterprise resource planning systems. We present the impact of two algorithms that are suitable for solving the dynamic batch sizing problem obtained by MRP, one of them being the Wagner-Whitin algorithm and the other being the Silver-Meal algorithm. A brief description of these algorithms is presented, followed by calculations and case studies to illustrate how it is possible to improve the MRP-defined process schedule. The numerical results presented demonstrate that the Wagner-Whitin and Silver-Meal algorithms are capable of improving the MRP results, thus enabling a more cost-efficient process schedule for material requirement planning.

2. MATERIAL REQUIREMENT PLANNING

Material requirement planning is a method that is very well suited to demand-driven products. It is suitable to deriving the required quantity of parts, assemblies and sub-assemblies to be incorporated at certain levels of the assembly process from the

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requirements of the higher assembly level, taking into account a number of parameters. The MRP modules of various ERP systems (SAP, ORACLE, BAAN, LIBRA4G, KYBERNOS) allow a company to meet all customer orders on time at the optimal inventory level [1].

The MRP module always examines the stock of orders within a certain time frame. Because of the defined timeframes, they can always provide the right material requirements from raw materials to finished products. If certain raw materials are not available in the warehouse in sufficient quantities to supply the production process, a procurement or production activity must be initiated for the materials without which a production or assembly activity at a higher level of the BOM cannot be initiated [2].

3. POTENTIAL APPLICATIONS OF WAGNER-WHITIN AND SILVER-MEAL ALGORITHMS

The Wagner-Whitin and Silver-Meal algorithms have applications in many areas of practical life. Their main application is in dynamic batch sizing [3,4]. Although several new methods have been developed to replace the Wagner-Whitin and Silver-Meal algorithms [5], however, the robustness of these algorithms is still the basis for their wide applicability [6,7]. These algorithms are not only applicable in deterministic environments [8], as they can be integrated with a fuzzy model to handle stochastic demands and other system parameters in the case of uncertain production environments [9]. These algorithms are well suited to be applied to conventional production batch sizing problems as well as to special domains such as natural resource management [10]. Since inventory optimization can be of particular importance in just-in-time and just-in-sequence supply processes, the application of these algorithms in these domains is also of increasing importance [11]. An interesting application area of the Wagner-Whitin algorithm is the optimization of processes that take into account warranty conditions [12]. The scope of applications often goes beyond production processes, as not only manufacturing processes can benefit from significant cost savings from an optimized lot size, but also related purchasing, distribution and inverse processes [13].

4. MRP, AS INPUT FOR WAGNER-WHITIN AND SILVER-MEAL ALGORITHM

In this chapter, an example of material requirement planning for a product consisting of several sub-assemblies and components is presented. The aim of the case study is to produce an initial set of parameters that can be used to further illustrate the efficiency of the Wagner-Whitin and Silver-Meal algorithms. The following parameters are known:

- Production master schedule: the company intends to sell 20 units of A in week 7, 30 units in week 8, 50 units in week 10 and 30 units in week 12. In addition, the company intends to sell 10 units in week 7, 15 units in week 8, 20 units in week 9, 10 units in week 10, 35 units in week 11 and 20 units of product B in week 12. In addition, the company intends to sell 120 units of component G in week 3 and 530 units in week 6.
- Inventory: 10 pieces of product A, 15 pieces of product B, 20 pieces of fitting C, 5 pieces of fitting D, 5 pieces of part E, 5-5 pieces of parts F and G.
- Safety stock: 2 of product A, 5 of product B, 10 of assembly C.
- Open order: 15-15 pieces of fittings C and D will arrive in weeks 5 and 8, 122 pieces of part G in week 5.

- Technological lead times: 2 weeks for assembly of product A, 2 weeks for assembly B, 3 weeks for assembly C and D, 1-1 week for production and ordering of parts.
- Assembly: a product A is composed of 2 C and 3 D assemblies; an assembly B is composed of 3 C, 2 D and 1 E parts, an assembly C of 2 F parts, an assembly D of 2 G parts.
- Other specifications: the minimum quantity for assembly D and part F is 20 pieces, for part E at least 20 pieces.

The necessary tables can be generated during the MRP process (see Fig. 1).

A	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
GR							20	30		50		30
NR							12	30		50		30
INV	10	10	10	10	10	10	2	2	2	2	2	2
ORD					12	30		50		30		
B	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
GR							10	15	20	10	35	20
NR							5	15	20	10	35	20
INV	10	10	10	10	10	10	5	5	5	5	5	5
ORD					5	15	20	10	35	20		
C	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
GR					39	105	60	130	105	120		
NR					14	105	60	115	105	120		
INV	20	20	20	20	10	10	10	10	10	10	10	10
ORD		14	105	60	115	105	120					
D	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
GR					46	120	40	170	70	130		
NR					26	0	36	41	0	91		
INV	5	5	5	5	124	4	114	109	39	59	59	59
ORD		150	0	150	150	0	150					
E	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
GR					5	15	20	10	35	20		
NR					5	15	15	5	20	20		
INV	5	5	5	5	0	5	5	15	0	0	0	0
ORD												
F	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
GR		28	210	120	230	210	240					
NR		23	193	113	223	193	233					
INV	5	17	7	7	17	7	7	7	7	7	7	7
ORD	40	200	120	240	200	240						
G	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
GR		300	120	300	300	500	300					
NR		295	120	300	178	500	300					
INV	5	0	0	0	0	0	0	0	0	0	0	0
ORD	295	120	300	178	500	300						

Figure 1. MRP tables of the case study (GR=Gross Requirement, NR=Net Requirement, INV= Inventory and ORD=Order)

Once the relevant part of the process schedule for each product, assembly and component has been defined and the production batch sizes have been defined, it is possible to examine to what extent the Wagner-Whitin and Silver-Meal algorithms can improve the total cost that can be derived from the production batch sizes obtained by the MRP [14].

5. IMPACT OF SILVER-MEAL ALGORITHM ON THE COST EFFICIENCY OF MRP

In this chapter, we illustrate the cost impact of Silver-Meal algorithm in the case of part G solving a dynamic lot sizing problem. One of the low-computation-intensity methods for dynamic lot-sizing problems that provides a near-optimal solution is the heuristic suggested by Edward A. Silver and H.C. Meal in 1973. The main idea of the algorithm is that a near-optimal solution of the dynamic batch sizing problem can be determined by minimizing the average cost computed in the time windows under consideration. Since in the Silver-Meal algorithm the quantity to be procured is exactly the quantity that is in demand, the constant value of the quantities to be procured means that the variable costs associated with the procurement can be ignored, since they do not affect the solution result [14]. The weekly demand for parts to be produced is known for a six-week time window, and is in order 295, 120, 300, 178, 500 and 300 parts. The cost of starting a production is 1000 EUR, independent of the quantity to be produced. The cost of producing a part is EUR 3 per part and the cost of maintaining a part in stock is EUR 2 per week (see Table I).

Table I.

Lot sizes and their impact on costs computed by Silver-Meal algorithm

Week	*Initial cost of production [EUR]*	*Volume [pcs]*	*Production cost [EUR]*	*Stock [pcs]*	*Inventory cost [EUR]*
1	*1000*	*415*	*1245*	*120*	*240*
2	-	-	-	-	-
3	*1000*	*478*	*1434*	*178*	*356*
4	-	-	-	-	-
5	*1000*	*800*	*2400*	*300*	*600*
6	-	-	-	-	-
Total:	*3000*	*1693*	*5079*	*598*	*1196*

6. IMPACT OF WAGNER-WHITIN ALGORITHM ON THE COST-EFFICIENCY OF MRP

In this chapter, we illustrate the cost impact of solving the schedule for part G as a dynamic batch sizing problem with the Wagner-Whitin algorithm, obtained as a result of the MRP presented in the previous chapter. The input parameters of the model are the same as the scenario parameters presented for the Silver-Meal algorithm.

As a first step, we can define that if there is no stock of the required part in the sixth week, then this required quantity must be produced in the sixth week. We can then examine the possible production variants in week five. There are two possibilities in week five if there is no stock of the required parts

- only the fifth week's quantity is produced,
- the fifth and sixth weeks' quantities are produced.

The advantage of batch production is the single start-up cost, the disadvantage is the cost of holding the stock for the sixth week. For this reason, the choice between the two options is the one with the lower resulting cost.

As shown in Fig. 2 and 3, the inclusion of an additional week of production not only increases the total cost but also changes its composition, for example, if both the fifth and sixth week of demand are produced in the fifth week, the inventory holding cost will appear, but it will result in a better sub-solution than if only the fifth week of demand is produced in the fifth week. This is possible because the start-up cost savings from pre-producing the sixth week are greater than the cost of holding the excess part in stock.

We can then look at the production variants possible in the fourth week. There are three options in the fourth week if there is no stock of the required parts:

- produce the fourth week's quantity,
- produce the fourth and fifth weeks' quantities,
- the fourth, fifth and sixth week's requested quantities are also produced.

As shown in Fig. 2 and 3, the inclusion of the additional week of production again increases the total cost, but in the fourth week, only the fourth week's parts requirement is produced, as the cost of holding stock from the additional production in both cases exceeds the savings on the start-up cost.

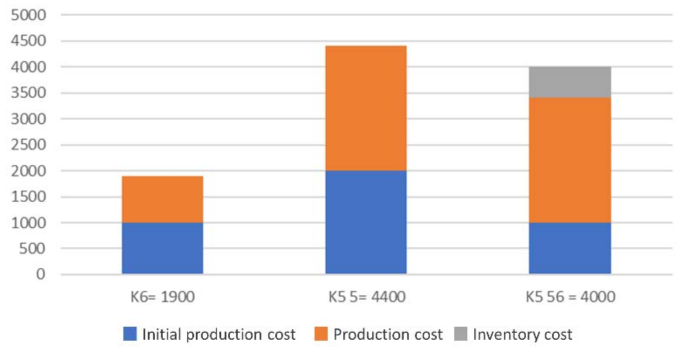

Figure 2. Cost structure of part-solutions of part G for production week 4 to 6

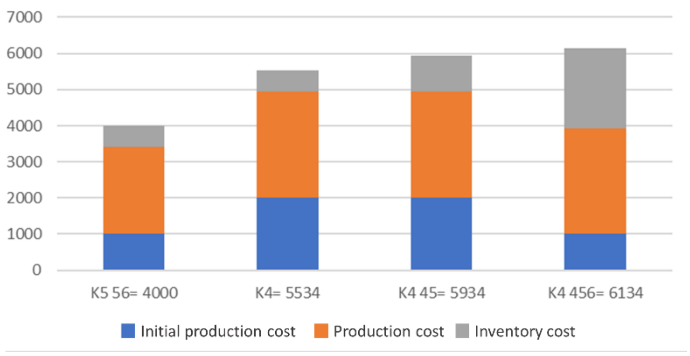

Figure 3. Cost structure of part-solutions of part G for production week 4 to 6

Similar to the above reasoning, the optimal production quantity can be defined as the minimum of the possible production variations in the third week. As shown in Fig. 4 and 5, the total cost increased further with the start of the third week of production. In the costs of the third week sub-solutions, it can be observed that the optimal solution was obtained when neither the start-up cost nor the inventory holding cost is a minimum value. The graph shows that the more weekly production is started in the third week, the higher the inventory holding cost becomes, while the start-up cost shows a decreasing trend. In order to determine the optimal level of production to be started in the second week, five cases have to be considered.

As shown in Fig. 5, for the second week of the optimal production plan, it is not sufficient to produce only the quantity of parts needed for the second week, because if the second, third and fourth weeks are produced in the second week, a more favourable solution is obtained by keeping the start-up cost and the inventory holding cost lower. As a last step in the calculation, the six cases for the first week are examined.

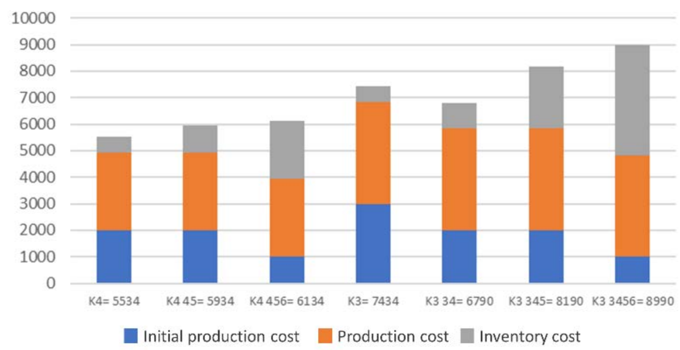

Figure 4. Cost structure of part-solutions of part G for production week 2 to 4

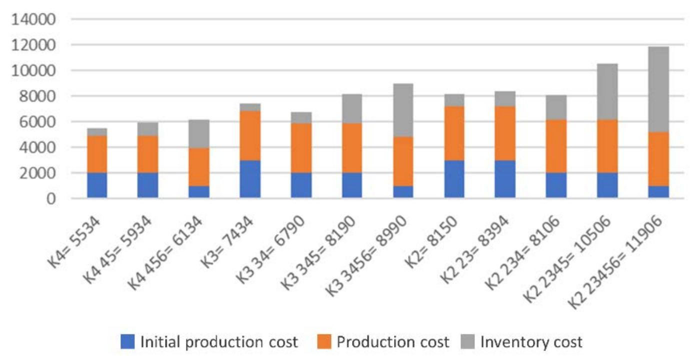

Figure 5. Cost structure of part-solutions of part G for production week 2 to 4

Once the above calculations are done, the optimal production plan can be determined according to the following sequence:

- At the beginning of the first week, there is no stock of the required parts to be produced, so in the first week, the quantity of parts required for the first and second week, 295 and 120 pieces, are produced.

- At the beginning of the second week, the parts required for the second week are available, since they were produced in the first week, and therefore no production is carried out in the second week.
- Since there is no stock of the required parts in the third week, the quantity of parts required for the third and fourth week, 300 and 178 pieces, will be produced in the third week.
- As in the previous point, at the beginning of the fourth week, the fourth week's parts requirement is available, since the quantity of parts required was produced in the third week, so no production takes place in the fourth week.
- At the beginning of the fifth week, no stock of the required parts is available, so the quantity of parts required for the fifth and sixth weeks, 500 and 300 pieces, respectively, is produced in the fifth week.
- Since the required quantity of parts is available at the beginning of week six, no production will take place this week.
- The optimal cost for the total production of parts will be EUR 9275.

A comparison of the costs obtained by Wagner-Whitin and MRP is shown in Figure 6.

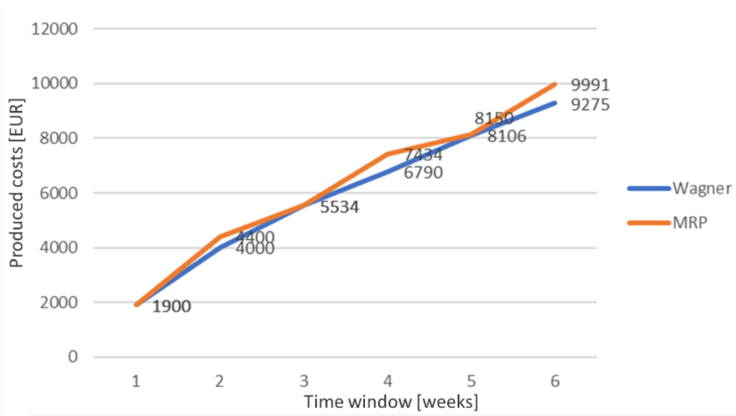

Figure 6. Comparison of costs resulted by MRP and Wagner-Whitin algorithm

7. SUMMARY

As shown in Figure 6, the cost of the production process is significant between the costs calculated using the MRP method and the Wagner-Whitin algorithm. The optimal values associated with each week in a six-week long time window can be seen in the breakdown of each week.

During the first week, the optimal results of both calculations coincide, so there will be no percentage change. During the second week, the Wagner-Whitin algorithm shows a significant change compared to the MRP. From the data of the two values, the reduction can be calculated, resulting in a total cost saving of 9.09%. In the third week, there is also a coincidence, showing that the production batch sizes under both methods have the same efficiency. The total cost savings for the fourth week of production is shown in the data to result in a reduction of 8.66% in favour of the Wagner-Whitin algorithm. The total cost savings for the fifth week of production are very minimal, with a reduction of only 0.54%

compared to the MRP method. The last week of production also results in a total cost reduction, so the percentage change is 7.16%.

Overall, the two methods show that the WWA production plan per time window gives better results than the MRP production batch sizes. This is confirmed by the overall cost reduction of approximately 25.5 % for the production as a whole.

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