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MPS OPTIMISATION MODULE FOR MRP PLANNING SYSTEM

In this paper the problem of disaggregation of a production plan on the family level into a master production schedule is described based on the example of Wavin Metalplast Buk – a leading polish plastic pipes producing factory. We propose implementation of the MPS optimisation module in Microsoft Business Solution Axapta - ERP system, being used by the factory. The module consists of a calculation part, based on a multi-objective genetic local search algorithm combined with an expert system component, and an interactive decision support part, using the extended Tchebycheff norm with penalty function.

1. INTRODUCTION

The tasks of the Manufacturing Planning and Control systems include planning and control of the manufacturing process and related resources such as materials, machines, workforce and other. Both the MPC system and the manufacturing process are designed to meet the marketplace needs and to support the overall company strategy. The MPC system provides information to efficiently manage the flow of materials and effectively utilize the workforce and other resources. It is important, that the system does not make any decisions nor manages any operations – those activities are performed by managers. The system provides only the information support for the decision makers. Typical management activities supported by the MPC system include [1]:

- Plan capacity requirements and availability to meet marketplace needs.
- Plan for materials to arrive on time in the right quantities needed for product production.
- Maintain appropriate inventories of raw materials, work in process, and finished goods – in the correct locations.
- Schedule production activities so that people and equipment are working on the correct things.
- Meet customer requirements in a dynamic environment that may be difficult to anticipate.
- Respond when things go wrong and unexpected problems arise.

In the long and short run, manufacturing must devise plans to balance the demands of the marketplace with its resources and capacity. For long-range decisions, such as building of new plants or purchase of new equipment, the plans must be made for several years. For production planning over the next few weeks, the time span will be days or weeks. This is the main idea of Hierarchical Production Planning concept which was introduced in the second half of the seventies. This approach incorporates a philosophy of matching product aggregation the to decision-making level in the organization. Each level has its own characteristics, including the length of the planning horizon, the level of detail of the required information, the scope of the planning activity etc. and decisions are made in sequence. Aggregate decisions are first made on the upper level and impose constraints on the lower level, where detailed decisions are made. The HPP system proposed by Hax and Meal [2] consists of a set of coordinated heuristics on five levels:

- capacity provision decisions and assignments of products to specific manufacturing facilities,
- aggregate production planning,
- family scheduling,
- item scheduling,
- component-part scheduling.

The process first involves specifying which products to produce in which factories and how to provide necessary capacity. The assignment of products to factories is based on minimizing the capital investment cost, the manufacturing cost and the transportation cost. In the next step an aggregate production plan for each plant is made. The aggregate plan specifies production levels, inventory levels, overtime and so on for the plant. The next step in the disaggregation calls for scheduling family groupings within the factory. Plans on the level of groups of similar products are developed. At the forth level disaggregation of each family into end the item plans is made. These plans may cover a shorter planning horizon and are constrained by the previously scheduled family groupings. In some cases we can use mathematical models to establish schedules, but in many cases we need heuristics, due to the problem complexity. At the last level detailed part and component scheduling is done with MRP logic, order launching and inventory systems or even mathematical modelling. This theoretical work can be considered a basis for MRPII – the well-known production planning concept. In this concept the family scheduling is called Sales and Operation Planning (S&OP) while the item scheduling is called Master Production Schedule (MPS). In our paper we concentrate on disaggregation of the family schedule (S&OP) into an item schedule (MPS). As an example we consider one of the ERP systems, based on MRP II logic – Microsoft Business Solution Axapta and an application of this system in Wavin Metalplast-Buk - a leading Polish plastic pipes producing company.

2. PLANNING PROCESS IN AXAPTA

Microsoft Business Solution Axapta is a customisable, scalable and global Enterprise Resource Planning (ERP) solution. The system comes from late 90's and is based on another ERP system – Concorde XAL, which has over 10 thousend installations worldwide. Axapta consists of several modules and offers support in financial managament, analytics, human resource managament, project managament, customer relationship managament, supply chain managament, e-commerce, manufacturing and retail managament. One of the most powerful modules of the Axapta system is the planning module. It covers the planning process from forecasting, through master planning to short term production and materials planning. Using this functionalities one can implement the MRP II concept. In this paper we consider the process of disaggregation of the S&OP into MPS, so let us start with a brief introduction on how it could be done in Axapta. In order to input the sales forecast into Axapta one needs to create the forecast models first. They can be created as models and sub models, therefore simulation of different scenarios of the demand pattern is allowed. Every forecast model can contain unlimited number of forecasted lines. Every forecasted line contains quantity optionally with values and other fields important for financial simulations. The most important feature from the planning point of view is that one can input the forecasted line on the level of items, but also on the level of item groups (families). Axapta enables planning by families by introducing the, so called, item allocation key concept. The user can define as many item allocation keys as necessary and forecasting can be done using these item allocation keys. The concept of item allocation key is very simple – the user has to define the percentage division of the key into finished items. This division is one dimensional and steady in time. Then during the process of forecasting the planning forecast of the item keys is changed to the forecast of finished items, according to the defined ratios. Then the next step of the planning process is based on the forecasted quantities of the finished items. The forecasted quantities are then one of the inputs to the master scheduling process which proposes as an output production (or purchase) of necessary items. The current stock level and all the future receipts and issues, coming from the planned production orders, purchase orders, sales orders and so on constitute the input data to the master scheduling process. Axapta tries to minimize the stock levels and doesn't offer support to build stock levels ahead of time to cover higher demand in lower seasons. Then, item by item, the system calculates the net requirements and on this base proposes receipts to the cover requirement. Then the user can make decision which proposals of the system should be accepted and changed to real production (purchase) orders. After the creation of the production order it can be planned in details.

3. PROBLEM STATEMENT

3.1. Description of the factory

Wavin Metalplast-Buk is a leading polish supplier of plastic pipe systems. It is a part of a European concern Wavin, present in 24 countries. Wavin produces pipes and fittings made of PVC, PE or PP, infiltration systems, inspection chambers, manholes, plumbing systems, water management systems, underfloor heating systems and much more. Wavin Metalplast-Buk employes more than 400 people and is noted between 500 biggest polish factories (according to profit).

Main features of the considered factory from the planning point of view include:

- the machines in the extrusion department make finished products in one operation and the machines in the injection department are organised in specialized lines which also can be treated, from the planning point of view, as single specialized parallel machines,
- the production is realized in batches (discrete production),
- the production cycle is short (several minutes),
- production batches are small to middle,
- there are many finished products, which are divided into groups from the point of view of the demand and raw materials used,
- production is mainly planed for stock with some products produced for orders,

- setup times are often sequence-dependent,
- finished items can have multiple routes having different efficiency,
- most finished items have one-level bill of materials,
- finished items are divided into three classes A, B and C; class C items are produced only for order, class A items have to be always on stock, and class B items are produced mainly for order but small stock level is also acceptable.

3.2. Planning process in Wavin Metalplast-Buk

Currently the planning process in the factory consists of three levels:

- budgeting – planning on the level of item groups, done once a year with one year horizon;
- sales & operation planning – planning on the level of item groups with monthly time buckets, done every month with 3 months planning horizon; during the sales & operation planning process (including S&OP meetings) dedicated software is used; basic data for S&OP planning process, that is information about stock levels projected for the beginning of the planning period, monthly sales forecast for the next 3 months, available resources and so on, are taken from MBS Axapta;
- master production scheduling – planning on the level of finished items, done every week with 2 weeks planning horizon; input information for MPS includes:

  sales forecast – it is prepared by sales and marketing departments on the level of item groups and then disaggregated into sales forecast for finished items according to item allocation keys – as an input for MPS only sales forecast for class A items is taken into account,

  sales orders – from sales orders registered in Axapta requirement for class B and class C items is taken,

  current stock levels,

  production orders,

  master data for the finished items (f.e. safety stock, bill of materials, routes),

  production plan from the S&OP planning process, on the level of item groups,

  available resources.

As the result of the master planning process we obtain detail production schedule for the next two weeks. During the creation of MPS the planner has to satisfy strong constraints to obtain an executable schedule and at the same time he tries to optimise multiple criteria.

3.3. Criteria

The main criteria, considered for the factory are the following:

- deviation between the S&OP plan at the family group level and the sum of the MPS for finished items from the given family – this criterion should be minimised, because the S&OP plan is a result of a top level management decision, with influence on purchasing, cash flow, work labour and so on,

- unrealised profits, that is profit which will not be realised because there will be shortages in the stock level – because Axapta will propose receipts for all items being required by the customers or being forecasted in the sales forecast, so we could state this criterion as minimising the number of the proposals with due dates before end of the planning horizon, which are not approved,
- efficiency of the chosen routes – it will be calculated as a relation between the best (in the terms of time) route and the chosen one, in the future we could consider marking routes with a preference factor,
- utilization of machines – this criterion will be usually maximised, but the decision maker should have the possibility to change the direction of the criterion, for example during the peak season when the stock levels are low, even small changes in the demand could create problems and the capacity buffer is very desirable,
- setup time – the criterion should be minimised, because for many finished items the setup times are sequence-dependent so a proper items mix could reduce the setup times significantly.

4. MPS OPTIMISATION MODULE

One of the reasons for the implementation of MBS Axapta in the considered factory was the need for the support of the master production scheduling process. Unfortunatelly, MBS Axapta, as the other ERP systems, doesn't support any optimisation of the MPS from the multiple criteria point of view. The forecast on the family level is disaggregated, in a very simple way, into a forecast at the finished item level and then the system simply proposes production in quantities necessary to fulfill the demand and minimum stock level, corrected by the defined sizes of the production batches. Axapta does it item by item without considering any relationships between products. In fact, the system takes into account only the criterion of non-realised profit, that is proposes production of everything what is required by customers, without taking into account other criteria. However, the considered factory can not produce on the base of the demand only because of the seasonality of the demand, the capacity lower than the demand in the peak months, and optimal sizes of production batches,. Goods are produced mainly to stock with building a stock level, which should suffice for the peak months. Thus most of the time the stock levels are so high that the system does not propose any production for the nearest period and the user has to create the production plan manually or choose proposals for the next periods. To overcome this problem we could use another feature of the system that is the seasonal minimum stock levels and using this functionality we require that the stock level should raise during the lower demand months. But this way we can only implement that stock level should raise for all the finished items by the same factor through the year and Axapta will propose production of the finished items smoothly without taking into account sequence-dependent setup times, what causes additional costs and decreases the production capacity of the factory.

Such kind of behaviour is not sufficient for the factory so the need for mechanism supporting the disaggregation of the S&OP into a master production schedule with a kind of optimisation arises. The problem could be also expressed as follows:

- choose from all Axapta proposals (resulting from sales forecast, sales orders and minimum stock levels) those which should be approved for the nearest period (planning horizon) – we choose items and quantities to produce;

- choose the route, to be used when producing finished items – every item could have many production routes and the best choice depends on the production mix of the items approved for the planning horizon;

- schedule the production (as a planning horizon we assume two weeks period, but it is not a strict requirement and can be changed).

As one can see we decide to solve the problems of deciding about items and quantities to produce and scheduling in one step. This is unusual for MRP II processes, when we have these two processes separated. But the reason for separating these decisions is mainly the complexity of the problem, in our case routes and bill of materials are flat and simple so the problem seems manageable. The advantage of such connection is that already during the MPS process we can take into account the scheduling criteria depending on the schedule, that is utilisation of machines and setup costs.
Because we should take into account multiple criteria and exact preferences of decision maker are not clear and could change in time, we decide to implement interactive procedure for solution generation. In the first phase a set of potentially Pareto-optimal solutions is generated and then the system supports the decision maker in choosing the final solution. The purpose of the first phase is to generate good approximation of the nondominated set according to the given criteria. Because of the complexity of the problem we can't use the exact solution so we decide to use one of the heuristics - we use a multi-objective genetic local search algorithm proposed in [3]. The algorithm uses the feature that finding the whole nondominated set is equivalent to finding the optima of all weighted Tchebycheff and all weighted linear scalarizing functions. Of course it is not computationally effective to find all of them for the real problem we consider. But good approximation of the nondominated set could be found by simultaneous optimisation weighted Tchebycheff, weighted linear or composite scalarizing functions with normalized weight vectors by a random choice of the scalarizing function in each iteration. Below we present the general scheme of the algorithm used.

```
Generate the initial set of solutions
repeat
        Draw at random a weight vector defining the current scalarizing function
        Select from the set of previously generated solutions two solutions being
        good on the current scalarizing function
        Recombine the two solutions
        Apply a local heuristic to the offspring
until the stopping criterion is met
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Fig. 1. The general scheme of the multi-objective genetic local search algorithm [3]

The details of our implementation of the multi-objective genetic local search algorithm for a similar problem are presented in [4]. In our system we will also implement expert system with following tasks:

- reduction of the search space explored by the multicriteria genetic algorithm by using expert knowledge about the problem domain; as we showed in [5] the reduction of the search space explored could reduce computational time of the algorithm, while giving comparable results;
- model weak preferences of the decision maker, which are difficult to express as direct criteria; this way we can express for example rules about preferences in using routes ("when requirement for resources is low choose only most prefered routes", "when demand for a group Alfa_1 item is lower than 10000 Pcs choose for items from this group only routes on machine Mach_1" and so on);

The expert system will be activated before the multi-objective genetic local search algorithm and will prepare input data to this algorithm.

As the result of the first phase we obtain a set of solutions, potentially very huge one, so we can not present all of the solutions to the decision maker. Thus a kind of support is necessary. In the second phase the solutions are presented to the decision maker and he is supported in choosing one final MPS.

At the beginning of the process of choosing the final solution the decision maker can switch on and off the optimisation criteria, which should be taken into account. Then the solutions generated by the multiple objective genetic local search algorithm are ranked based on the aggregated value according to the chosen criteria.

As a multicriteria objective function the distance from the "ideal" point in the sense of extended Tchebycheff function is used.

The best solution according to the current objective function is then presented to the user. The user interface will provide the following functions:

- presentation of the solution found on a Gantt chart,
- displaying the value of the aggregated objective function for the current solution,
- displaying the value of all criteria with the possibility of displaying the value on different levels of aggregation (for example, the value of the deviation between S&OP and MPS for every group separately),
- comparison of the current solution with any other solution: the user can compare two solutions on every criterion and on every level of aggregation. It will be possibile to see only differences between solutions.

If the decision maker is not satisfied with the solution found, the dialog module will enable the interaction with the system through modification of the preference structure, the solution space or the MPS. Decision maker should have the possibility to force the system to search for better solutions according to a chosen criterion at the cost of others, less important at the moment. To that end the objective function can be modified by the decision maker by choosing which criteria should be taken into account. Decision maker can also declare how much he is ready to waste on a given criterion, to profit on others.

This "relaxation" of criteria will be implemented as a penalty function in the objective function. Details on the extended Tchebycheff norm with the penalty function can be found in [6]. If the user is not satisfied with the solution found and he changes the objective function the new best solution according to a new objective function is found in the potentially Pareto-optimal set and the interactive procedure is repeated until the decision is made. Then the chosen MPS is changed to the real production orders.

5. SUMMARY

In our paper we have described the problem of disaggregation of a production plan on family level, coming from the S&OP process, into a master production schedule for Wavin Metalplast Buk – a leading polish plastic factory.

We propose an implementation of MPS optimisation module for Microsoft Business Solution Axapta ERP system used in factory. The concept of the module based on earlier work of the authors is described. The module consists of calculation part, based on the multi-objective genetic local search algorithm combined with an expert knowledge component, and interactive decision support part, using the extended Tchebycheff norm with the penalty function. The proposed system is planned to be implemented in Wavin.

LITERATURE

1. Vollman T. E., Berry W. L., Whybark D. C., Manufacturing Planning and Control Systems, McGraw Hill, New York 1997.
2. Hax A. C., Meal H. C., Hierarchical integration of production planning and scheduling, in M. A. Geisler, ed., Studies in Management Sciences, vol. 1. Logistics, New York, Elsevier, 1975.
3. Jaszkiewicz A., Multiple objective metaheuristic algorithms for combinatorial optimisation, Wydawnictwo Politechniki Poznańskiej, Poznań 2001.
4. Józefowska J., Zimniak A., Zastosowanie wielokryterialnego algorytmu genetycznego w systemie wspomagania planowania krótkoterminowego Komputerowo Zintegrowane Zarządzanie, Tom.I. WNT Warszawa 2002.
5. Józefowska J., Zimniak A., Algorytm genetyczny z ograniczonym obszarem przeszukiwań dla wielokryterialnego problemu plecakowego. Polioptymalizacja i Komputerowe Wspomaganie Projektowania Mielno 2002, Wydawnictwo Uczelniane Politechniki Koszalińskiej, Koszalin 2002.
6. Słowiński R., Soniewicki B., Węglarz J., DSS for Multiobjective Project Scheduling, European Journal of Operational Research, Vol.79, Nr 2, 1994.