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An intelligent approach to automate production budget planning in the building products industry

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Abstract

Production budget planning in the building products industry is the process of committing and allocating resources to manufacture building products for 12 months ahead in order to satisfy certain criteria set by top management. It is a highly complicated and time consuming process and demands experienced production managers to handle it.

This paper discusses the development of an intelligent budget planning model in the buidling products industry as a possible alternative to traditional operation research methods. The intelligent model is a computer-based factory simulator which automates the process of budget planning using factory attributes and intelligent production rules. An industrial case study has been conducted to validate the model and the knowledge rules. The paper has concluded that the intelligent model is a practical and considerable managerial tool for exploring and testing managerial options open to production managers.

1 Introduction

Production budget planning in the building products industry is the process of committing and allocating machinery, men, space, money and time to manufacture building products for 12 months ahead in order to satisfy the certain of maintaining market share, minimise production cost and increase profit. It is a highly complicated and time consuming process and demands experienced production managers to handle it. The process of production budget planning involves the following operations:

- What and when to produce products and on which production facilities to satisfy certain criteria.
- Estimation of the quantities to be produced for each product.
- Estimation of the costs associated with shifts allocation, stock holding, plant changeovers and under-utilisation.
- Forecast of cash flow.

There are several optimisation techniques and heuristic approaches that provide near optimal results for production budget planning problems. This paper takes the view that these techniques are not widely used by management. Among the reasons put forward to explain the low utilisation of these methods, lack of credibility is most frequently cited, see Vollmann [4]. Other reasons include the cost of developing and using models and the excessive data requirement of some models. Furthermore, the optimisaton techniques apply a set of rules throughout the analysis, which cannot be adapted to unusual and unforeseen combinations of objective and constraint that arise during the process. In the search for more acceptable alternative to management, the use of the Artificial Intelligence approach is one possible alternative.

Most building products and manufacturing companies use a simple trial-and-error approach to develop their production plans, see Dawood and Neale [1] and Heizer[3]. This approach is based upon traditional planning rules and heuristics which production managers use to select feasible combinations of decision variable value for each period, and plans represented in a simplified or graphical format. Although the methods do not guarantee optimal results, its mechanics are easy to use and simple to understand. An intelligent system can incorporate the abilities of an experienced production planner who use the trial-and-error method. Thus, it can make use of an important body of knowledge related to production planning.

2 The automated production budget planning model: an intelligent approach

The model is a time-oriented dynamic factory simulator which embodies the knowledge rules and the process of allocating products to the running plant from middle management level for twelve months using the "backward scheduling technique". The objects of the model are basically entities and attributes. The entities are elements of the system being simulated and they can be individually identified and processed. Plant and products are regarded as entities of the model. Each entity possesses one or more attributes to convey extra information about it. For example certain plants can produce a set of products which others cannot. Another way of using attributes may be to control queue discipline. This priority may be used to select products for processing when there is a choice. The main attributes of the model are:

- The model is a factory simulator which automates the process of budget planning using attributes and entities of production facilities and production knowledge-base rules to administer the planning process.
- Production facilities are to be modelled as entities so that the model can access and utilise them as required.
- Production plans are to be generated and evaluated automatically without the interference of a human planner so that the manual effort will be reduced.
- Product's and plant's selection rules and allocation rules are main knowledge domain in the model.

Figure 1 shows the specification of the system which is presented by information input, process and information output.

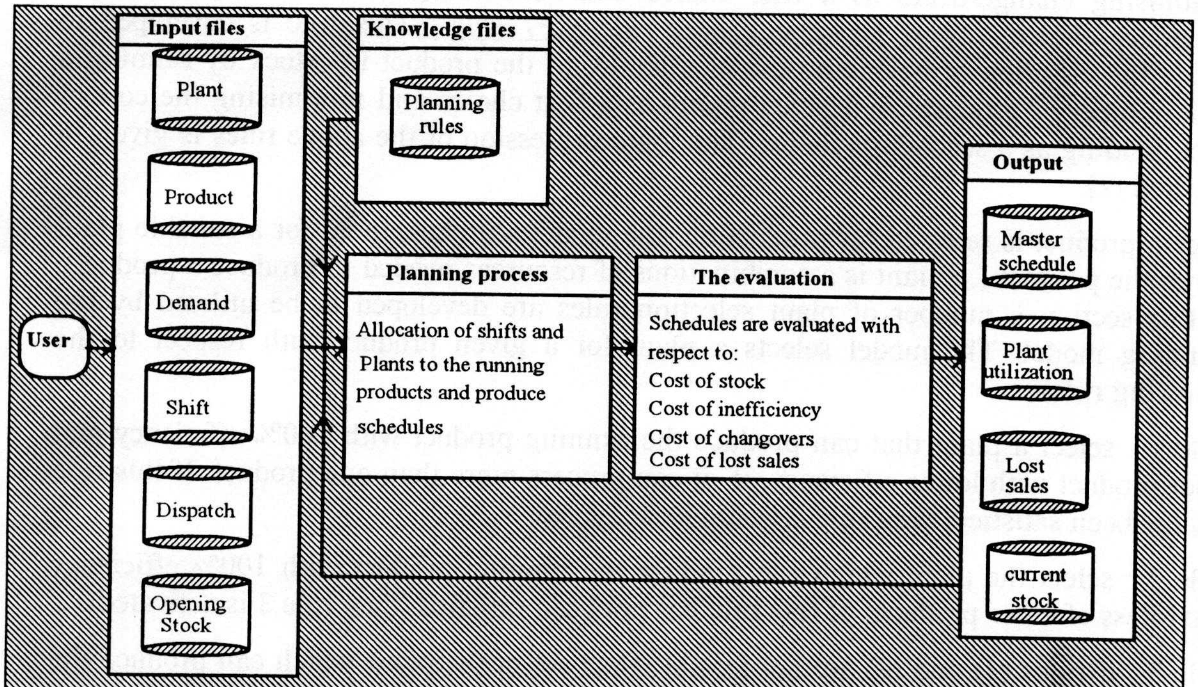

Figure 1: Specification of the model

3 Development of the planning knowledge rules.

In this stage, the knowledge rules which administer the planning process in the model were elicited and presented to be used by the model. The knowledge rules in this model are of three types: product selection rules, plant selection rules and allocation rules. Two main sources are used for knowledge elicitation, namely: production managers and published literature in the field of manufacturing systems.

In this research, the visits to the industry were conducted using the semi-structured interview. In this method the questions to be asked are of the open-ended type, in which the wording of the question is specified but the wording of the response is left to the respondent. The interviewer can seek further elaboration of a particular area, by asking further questions. The following describes briefly the knowledge rules.

Product selection rules constitute a major part of the knowledge-base in the model. These rules, as the case of the other knowledge rules, were presented in the form of IF (situation) THEN (action).

Product selection rules are used to establish the order in which products should be processed in the model. The rules follow general criteria of maintaining stock cover for products, production efficiency and minimising plant change-overs. In the model, three product selection rules are developed to model several planning strategies in the allocation process. The product selection rules which are developed in this research are: High production cost rule (HPC rule): This rule is developed to minimise, as a first choice, stock holding cost by producing expensive products 'just in time' and to minimise change-overs as a secondary choice. Long processing time rule (LPT rule):

This rule is developed to satisfy the criterion of maximising run length and ultimately minimising change-overs as a first choice and minimising stock holding cost as a secondary choice. Short processing time rule (SPT rule): This rule is developed to satisfy the criterion of balancing the availability of the product in stock by running a high number of products in a given month as a first choice and minimising the cost of stock holding as a secondary choice. The logic expression of the above rules is given in Dawood [2].

Once a product is selected for production, the model searches, then, for a suitable plant to run the product (a plant is a combinations of resources needed to produce a product). In this section a number of plant selection rules are developed to be utilised by the planning model. The model selects a plant for a given product with respect to the following rules:

Rule 1 : select a plant that can produce the running product with 100% efficiency and other product with lower efficiency, if it can process more than one product. If this rule has not been satisfied, then rule 2 would be activated.

Rule 2 : select the plant which can produce the running product with 100% efficiency regardless of other products. If this rule has not been satisfied, then rule 3 is activated.

Rule 3: if rules (1) and (2) are not feasible then select the plant which can produce the running product with the best efficiency level.

Finally,The allocation rules are developed to direct the process of planning in a logical and sensible way. The rules represent the current practices of the allocation process. These rules can be grouped as:

- Checking the availability of shifts, plant and demands.
- Updating time and information after each event in the process.

4 Evaluation of production plans

The model keeps records of plant utilisation and changeovers, and units produced in each month and stores this information in text files (see figure 1).

Having achieved the planning process, the plans would be evaluated in terms of cost of stock, under-utilisation and changeovers using three spreadsheet models. These are: The stock model. This model calculates the monthly level and cost of stock for each product in the planning process. The utilisation model. This model calculates the cost associated with using inefficient plant. The changeover model. This model calculates the cost of changeovers for plant in the model. A plant's change-over occurs when a product is allocated to a plant which must be set up before it can be run.The mathematical equations of the above three models are given in Dawood [2].

5 Validation of the model: The case study

The main object of the case study is to validate the model by comparing its outputs by the one of a human scheduler. This is the most efficient way of validating the model and exposing its potential. One of the leading precast companies was approached for a case study. The company responded positively to our invitation and sent a complete set of information about one of their factories (the MID factory), in the form requested by the author, and a production plan for 1994 budget year. The MID factory information was used to run the model and a set of plans were produced and compared with the company plan. The following shows the factory information used in the case study.

- One production plant (A). Table 1 shows the attributes for the plant.
- Shift pattern is shown in table 2.
- Curing time is four weeks for all products.
- Cost of capital (interest rate) is 5% per month.
- Demand period is 12 months and demand forecast is given in table 3. Dispatches (actual sales)are assumed to be equal to demand.

The following discusses and evaluates the strategy of the human planner (company plan).

Table 1. Plant's attributes used to test the model

Attributes of plant (A), Current set up: PR1

Products that can run	Production units/shift	Efficiency %	Changeover cost (Ł)
PR1	171	100	400
PR2	137	100	400
PR3	211	100	400
PR4	154	100	400

Table 2. Shifts available for plantA

Month	Shift available for plant A
January 1994	34
February 1994	36
March 1994	44
April 1994	34
May 1994	34
June 1994	36
July 1994	27
August 1994	27
September 1994	43
October 1994	27
November 1994	36
December 1994	32

Table 3. MID demand pattern

Prod Code	PR1	PR2	PR3	PR4
Cost/unit	Ł15	Ł19	Ł15	Ł18
Open Stoc	4234	3041	2649	1416
Dec 93	1757	735	992	252
Jan 94	2331	976	1316	224
Feb 94	2677	1109	1494	380
Mar 94	3016	1248	1682	428
Apr 94	3262	1350	1828	462
May 94	2955	1223	1648	419
Jun 94	3077	1273	1717	437
Jul 94	3139	1299	1752	445
Aug 94	2493	1031	1390	354
Sept 94	2554	1057	1425	363
Oct 94	2401	994	1340	340
Nov 94	1476	611	824	209
Dec 94	6441	3835	3817	1151

6 The company plan

Based on the MID factory information given above, the company has produced a production plan based on their own system. The plan is presented in a shift report format as shown below in table (4) and this is the only format that their system can keep.

Table 4. Company plan in a form of shifts report

Time	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Shift Avai	34	36	44	34	34	35	27	27	43	27	36	32
PR1	16	18	31	7	16	17	9	13	27	9	18	14
PR2	9	9	4	9	9	10	9	5	9	9	9	9
PR3	9	6	6	15	6	6	7	6	6	6	6	9
PR4	0	3	3	3	3	3	2	3	1	3	3	0

Figure 2 shows stock movement per month for each product in the stockyard. The figure shows only the dispatchable stock at the end of each month (after sales have occurred) and not stock under curing. The same format is used for the plans generated by the model.

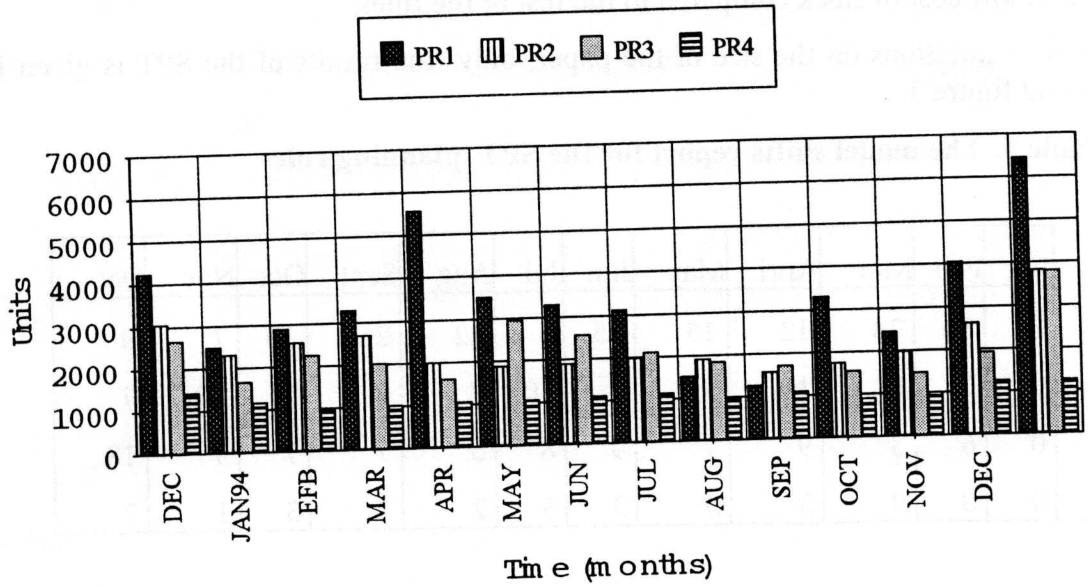

Figure 2: Stock movement of the MID factory, Human scheduler

7 The output of the model

In this section, the output of the model is evaluated and compared with the Company plan. Table 5 gives the results of evaluating the company plan and the three rules at the end of the planning period.

Table 5. Comparison between the model and company plans

	HPC	LPT	SPT	Company
Cost of stock	Ł126444	Ł118618	Ł113891	Ł117616
Cost of changeovers	Ł10400	Ł6800	Ł12400	Ł14000
Total	Ł136844	Ł125418	Ł126291	Ł131616

From the table, it can be seen that the SPT rule has produced minimum cost of stock compared to the rest of the rules and it is 3% better than the company plan. The HPC has produced a higher cost of stock compared with the rest of the rules and it is 7% worse than the company plan. The LPT has produced approximately similar cost of stock to the company plan.

The SPT rule has produced low volume products as late as possible (very close to the delivery date) and left high volume products (product 1) to be stocked, see figures 3. As can be seen in the figures, Product 1 has dominated the stock yard while other products were made just in time and stock level for such a product is very minimum. Product 1 is cheap to produce and consequently cheap to stock and this explains why this rule has resulted in low cost of stock compared to the rest of the rules.

Due to the limitations on the size of the paper, only the results of the SPT is given in table 6 and figure 3.

Table 5. The model shifts report for the SPT planning rules

	Jan	Feb	Mar	Apri	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
PR1	34	30	28	12	15	15	6	12	26	10	7	0
PR2	0	0	8	10	9	9	10	7	8	7	25	7
PR3	0	6	8	9	7	9	8	6	7	7	3	18
PR4	0	0	0	3	3	3	3	2	2	3	1	7

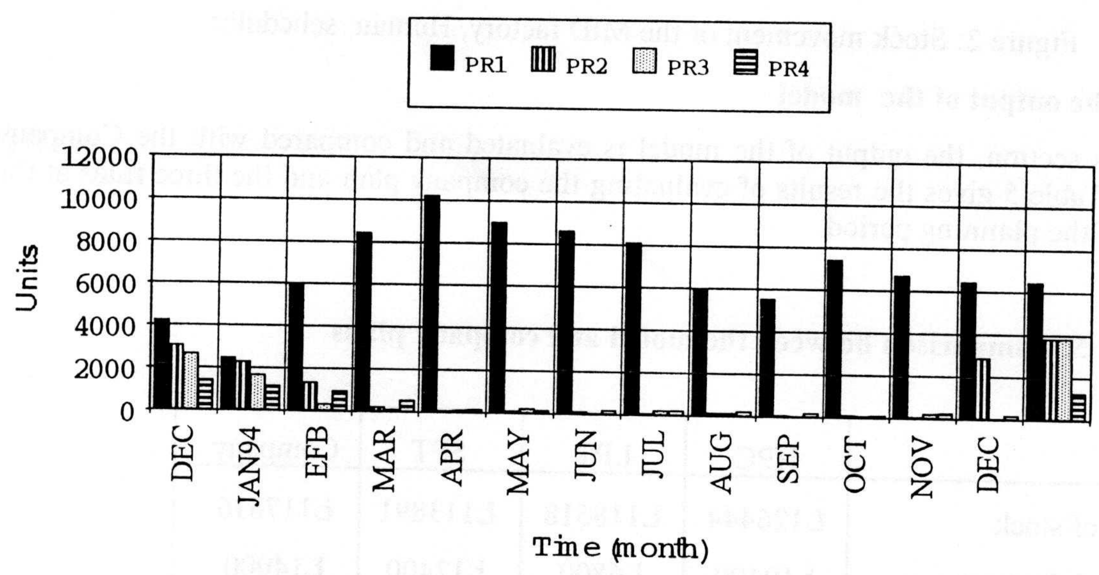

Figure 3: Stock movement of MID factory, SPT rule

The following points summarise the advantages and disadvantages of the model:

- The model has produced sensible and executable plans without the intervention of a human scheduler and can be regarded as the way forward for automating the process of planning in the industry.
- The model (in the case of the HPC and LPT rules) has produced rather risky plans as there was no contingency or buffer to counter fluctuation in demand for certain products.

- The model provides a good test bench to test planning rules and examine the relationship between variables in the production process.

  It can be anticipated that under different factory and demand attributes, the rules would produce different behavior compared to this case study. In this case the results produced in this paper cannot be generalised in any way.

8 Summary and conclusions

The objective of the paper was to introduce and discuss the development of an intelligent production planning system for the application in the building products industry. Previous research has concluded that the optimisation techniques are not widely used by practitioner. Among the reasons put forward to explain the low utilisation of these methods, lack of credibility is most frequently cited.

It is concluded in this research that the artificial intelligence approach is one of the acceptable alternatives to management. This is mainly due to the rule-driven nature of this approach and its ability to mimic the decision making of a human planner. The intelligent production planning model is a computer-based factory simulator which automates the process of planning using factory attributes and intelligent production rules. In order to validate the model, an industrial case study was conducted. The results of the case study suggested that the model can produce faster and cheaper production plans compared to the company plans.

The paper has concluded that the model is a practical and considerable managerial tool for exploring and testing managerial options open to production managers. The model is suitable for companies which produce a variety of concrete products on several plant. The authors welcome any collaboration with the industry to further the knowledge and application of the model.

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