THE OPTIMIZATION OF CAPACITY UTILIZATION WITH A FUZZY DECISION SUPPORT MODEL

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Summary

The assembly of cars is a production process, whose regulation must respond to the disturbances and fluctuations that often arise in such processes. Assembly is carried out at stations connected in series, where specialized teams of workers are employed. Depending on the model variant, each model that passes an assembly area creates a different workload. The order of transport of models into the assembly area is very important for the degree of utilization of capacity at each assembly station. The problem is to fix the order in such a way that the utilization of capacity is as constant as possible and as near to 100 % as possible, in order to guarantee low-cost assembly for the given long-term production plans. This paper presents an industrial application of a fuzzy decision support model for the supervision of capacity optimization in the car assembly process.

Keywords: fuzzy decision making, relationships between goals, capacity utilization, production planning.

1 INTRODUCTION

The assembly of cars is a production process, whose regulation must respond to the disturbances and fluctuations that often arise in such processes. The blocking and release of different models and special equipment require flexible reactions by the staff supervising the control system, in order to guarantee that utilization of the assembling capacity is as regular as possible. To achieve this, the supervisor often adjusts the production process manually by modifying the order of introduction of the car bodies into the assembly area and the mixture of special equipment required. Due to the complexity of the effects of different mixes of equipment on the utilization of capacity, adequate manual supervision of the assembly process is very difficult. If all restrictions are to be incorporated into the supervisor's decision, an automated decision system is required.

2 THE OPTIMIZATION PROBLEM

The complexity of the optimization problem to be solved can be described as follows. The production of the vehicles is performed in various successive steps. First, the car bodies are preformed. Then, these preformed car bodies are painted and stored in the so-called high store.

According to the production program, the painted car bodies are transported into the assembly area, where modules such as undercarriage or motor, or special equipment such as electric window lifters, sunroofs or air-conditioning systems, depending on the model variant, are assembled.

The assembly is carried out at various assembly stations connected in series, where specialized teams of workers are employed. Depending on the model variant, each model that passes the assembly area creates a different workload at the individual assembly stations.

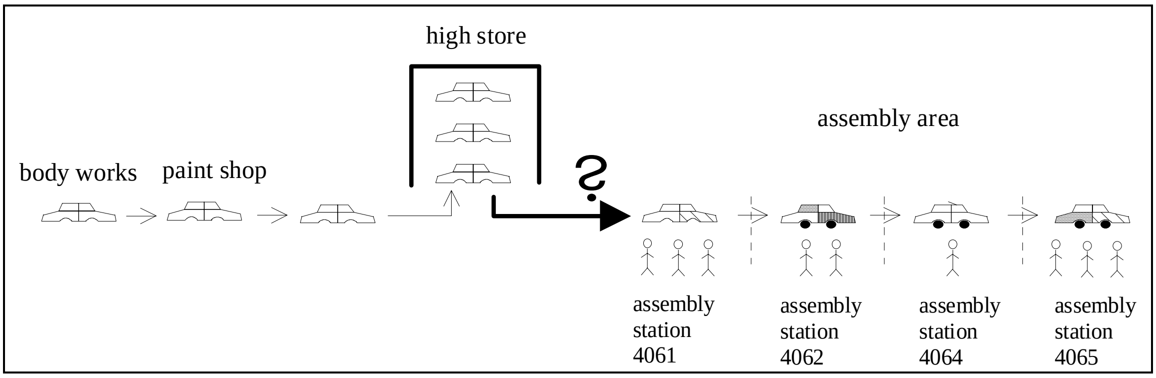

Figure 1: Assembly process of cars

The order of transport of the models into the assembly area is very important for the degree of utilization of capacity at the assembly stations. The problem is to fix the order in such a way that the utilization of capacity is as constant as possible and as near to 100 % as possible, in order to guarantee low-cost assembly with the given long-term production plans. Figure 1 gives an overview of the structure of the assembly process. Figure 2 shows a practical capacity utilization diagram for a set of different assembly stations.

Factors such as the blocking or release of model variants, special equipment, colours, etc., in the areas of preforming and painting alter the number of car bodies to be optimized in the high store. That is why it is necessary for these factors to influence the optimization parameters,

in order to determine the sequence in which the vehicles are to be taken out of the high store. The optimization parameters indicate how many items of every model variant and of special equipment (for example model No. 3 without sunroof) are to be assembled, expressed in number of pieces for the relevant day.

The complexity of the effects of blocking on the number of pieces of model variants and special equipment available renders manual supervision nearly impossible, if all restrictions concerning the assembly and the utilization of capacity are to be met.

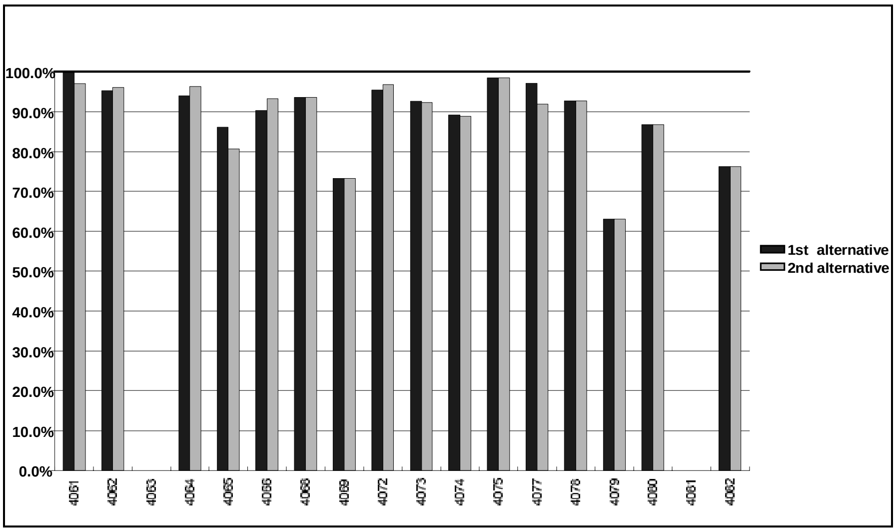

Figure 2: Capacity utilization of assembly stations 4061 - 4082

The problem of optimal capacity utilization of the assembly stations described above can be understood as a multicriterial optimization problem in the following way. Every assembly station's degree of utilization is viewed as an optimization goal. This means that if we have, for instance, n assembly stations a_i with the corresponding indices $i = 1,..., n$, then there is a vector of goals ($g_{a1}, ... , g_{an}$) to be maximized. The goal function g_{ai} has values belonging to the interval [0,1] where 0 stands for 0 % utilization of capacity of the assembly station g_{ai} and 1 stands for 100 % utilization of that station. For simplicity, we write g_i instead of g_{ai}. The domain of each goal function is a vector of quantities of equipment (e_{j1}, ... , e_{jm}) to be assembled into the car bodies in the planning period, and m is the number of types of equipment. Each e_{jk} means the quantity of equipment items of the type j. For simplicity again, we write e_j instead of e_{jk}. Every vector (e_1, ... ,e_n) is a possible decision alternative. The goal function g_i expressing the capacity utilization of the assembly station a_i can be understood as

$$g_i : (e_1, \ldots ,e_n) \longrightarrow [0,1] , \; i \in \{1, \ldots , n\} . \qquad (1)$$

For each decision alternative, for example, the vector (e_1, ... ,e_n) its impact on the capacity utilization of a_i determines the corresponding value of g_i. However, since the impacts cannot be described in an analytical way, an estimate has to be calculated for each vector (e_1,....., e_m). The estimates are calculated by an analysis algorithm based on statistical data that reflect the distribution of degrees of different capacity utilization corresponding to different equipment vectors. The statistical distribution was used to estimate the desired impacts and thus to derive an estimation algorithm providing for the calculation of values of every possible (e_1, ... ,e_n)[1].

In conclusion, the optimization problem to be treated can be defined as

$$\mathbf{Max}\ (g_1, \ldots ,g_n) \qquad (2)$$

Note that every g_i is a fuzzy goal function over the space of the decision alternatives (e_1, ... ,e_n).

There are two more important aspects to consider.

1. The assembly stations represented as capacity utilization functions are not always independent of each other. Moreover, they may affect each other in the sense that a better capacity utilization of a particular assembly station affected by an e_k may cause a worse utilization of another station and, vice versa, the goal functions g_i , $i \in \{1, \ldots , n\}$ interact. This means that an adequate decision model for the solution of the capacity utilization problem should be able to deal adequately with interacting goals. Relationships between goals such as co-operation and competition must be recognized and taken into account.

2. Since different assembly stations may cause more or less significant costs, it should be possible to attach varying priorities to the different goals g_i.

[1]Because of the limited number of pages the estimation algorithm is not disscused in this paper.

3 INDUSTRIAL APPLICATION

The optimization problem described in Section 2 has been solved using the software tool FuzzyDecisionDesk [2], which is based on the decision model discussed in [1]. The System works at BMW, Factory Regensburg on an IBM compatible PC with an Intel 486 DX2/66 MHZ processor and a graphical user interface under Microsoft Windows.

4 CONCLUSIONS

The application presented in this paper is based on the concept of fuzzy relationships between goals. It shows that the decision model helped to solve a complex optimization problem in the field of capacity utilization in the assembly process of an automotive company. Because of the relatively high problem- independence of the decision model, there is strong evidence that the decision model can be applied in a variety of fields.

5 REFERENCES

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