Industrial process modelling with operations research method

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Abstract: The operation of a business process is not as easy as it seems for the first time. A lot of complex connections can be identified in a production process, while the performance of a machine can be either uncertain or unknown. These factors could result in inappropriate conclusions and decisions. Collecting data is an essential part of business process modelling, while operations research methods can provide a good evaluation tool for making the right decisions. The article aims at presenting a process rationalization while total process time optimization is carried out based on a minimal extra cost investment. The examined variables of the optimization were total process time and cost of human resource. The target value of total process time reduction was 10%.

Keywords: business process, network model, total process time reduction, operations research

Introduction

The aim of every company is to earn higher profit. This can be accomplished by many approaches. However, one of the most important way to achieve the optimal process time is by making process improvements. An extended network model can help to cut down the value of this indicator by selecting and scheduling the added resources. This technique can only be applied when it is possibile to reduce the total process time by investing in extra employees or machines, and when the process can perform less output than demanded by the customer. This article is organized as follows. Section 2 gives a brief introduction about operations research and network models. Section 3 presents an industrial process as a case study and the applied research methodology. Section 4 shows the original model as well as the extended network model. Finally, in the last chapter, conclusions are provided.

Theoretical Background

Operations research

The operations research is a methodology, which was invented in the middle of the 20th century when optimal solutions to military problems were searched for by applying mathematics [1]. After World War II., these mathematical models were shared and widely-used in both scientific and practical fields, such as production scheduling[2], agriculture[3], and this list could be expanded. This methodology aims at achieving the optimal solution (optimization) in the most efficient way[4]. During the calculation of an optimization, input combinations are looked for, which meet the analysts' goals the most. From the mathematicians' point of view, the most challenging task is to represent real life by mathematical models, because business processes usually have more than one variables, for example a lot of inputs and outputs[5].

A mathematical model is based on an objective, which is an n-variate *f* function, whose value must be optimized:

$$f(x_1, x_2, ...x_n).$$

There are constraints in the model, which provide a limit for the possible set of solutions. And finally, there is the set of possible solution, which is indicated by S, and this is included in Rn set [4]. In order to find an optimal solution for a production problem, network models must be applied [6].

Network models

Networks are known in many fields of use, such as routes, railways, communications, drinking and sewage networks, electrical circuits [1]. A common feature in them is that the direction of the delivery is strictly regulated. Another common characteristic is that the flow capacity of the routes in a given network is limited [4]. A general network model can the demonstrated with a G(N,A) directed graph, which consists of the following basic elements: nodes that deliver items (information, water, etc.) to the next node(s). The arcs represent logical connections between nodes, while capacity determines the limits of flow. With the application of network modelling, project management tasks can be easily solved. Especially, Critical Path Method (hereinafter CPM) and Program Evaluation and Review Technique (PERT) can be easily executed regardless of the size and complexity of the models. CPM is mostly used in the planning phase of a project production. Furthermore, this method can be useful for modeling manufacturing processes, because both the total process time and the critical path with the biggest impact on the production throughput can be determined. In addition, time slacks in the production can be analyzed, which are used for production scheduling in a very efficient way.

Methodology

Process presentation

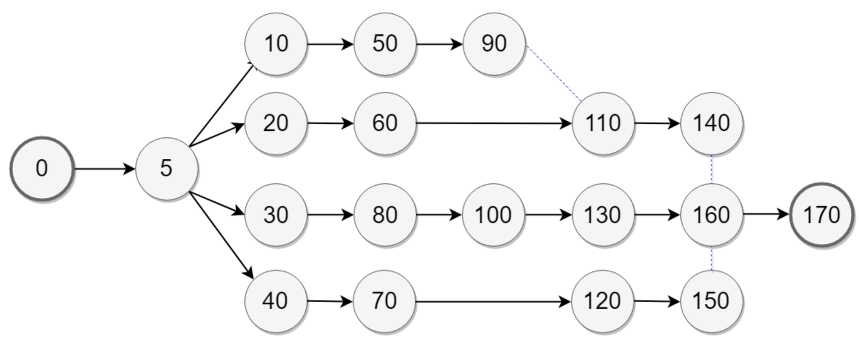
The manufacturing process produces the final product from 4 raw materials, later on indicated as Material A, B, C and D. The production process is made up of 4 different transformation process activities, plus a pre-assembly as well as an assembly stage, as can be seen in *Table 1*.

Table 1: Nodes belonging to workstages

Stages	Stage 1	Stage 2	Stage 3	Stage 4	Pre-assembly	Assembly
Nodes	10, 20, 30, 40	50, 60, 70, 80	90, 100	110, 120, 130	140, 150, 160	170

Two of the above mentioned raw materials are processed in every process stage, while the other two undergo only three transformation acitivites in their production before they reach the assembly stage. Two operators work in each workstage. The graph of the production process can be seen in *Figure 1.:*

Figure 1: Graph of the manufacturing process



In order to accomplish the process, dummy activities must be added to the production. The costs of these activities are 0. The manufacturing company produces in high batches, which means 100 pieces of product per batch. In the following parts of this article, total process time and other values are calculated according to this batch size.

Basic data

Measurements were made to determine the average activity times. The results of the normality tests carried out on each activity had a normal distribution. For the company's request, activity times were distorted and presented in time measurement unit (TMU), which are shown in *Table 2.*:

Table 2: Activity times (in tmu)

Acvitity no.	Avg. time	Acvitity no.	Avg. time	Acvitity no.	Avg. time
0-5	10	40-70	8	100-130	216
5-10	240	30-80	136	110-140	156
5-20	27	50-90	240	120-150	162
5-30	119	80-100	64	130-160	400
5-40	16	90-110 ()	0	140-160 ()	0
10-50	130	60-110	262	150-160 ()	0
20-60	30	70-120	130	160-170	146

Results

Original network model

Based on the information in the above table, the following equations were calculated in order to get the total process time of the production and to identify the critical activities:

$$-x_0 + x_5 \geq 10$$

$$\vdots$$

$$-x_{160} + x_{170} \geq 146$$

Objective:

$$-x_0 + x_{170} \rightarrow MIN!$$

Linear programming was applied to the network model. According to the results, the total process time of the manufacturing process is 1091 TMU. By evaluating the sensitivity analysis report of the model, these activities (nodes) turned out to be critical in the determination of total process time:

$$0 - 5 - 30 - 80 - 100 - 130 - 160 - 170.$$

Extended network model

The aim of the improvement was to reduce the total process time by 10%, which was equal to 982 TMU at this company. This reduction could be accomplished only by hiring new operators, because the company's financial status did not allow for investments in new machines. According to the technology and safety regulations of the production, maximum 3 additional workers can be employed at each stage. This kind of extra work could result in a 5-15% decrease in activity time depending on the workstage. In order to get realistic results, the network model must be changed and extended:

$$-x_0 + x_5 + x_{0-5} \geq 10$$

$$-x_5 + x_{10} + x_{5-10} \geq 10$$

$$\vdots$$

$$-x_0 + x_{170} \geq 982$$

Objective:

$$Cost \rightarrow MIN!$$

In this model, the total process time was a constraint, while the objective of the model was to achieve the desired total process time at the lowest possible cost.

Activity times cannot be reduced to zero by increasing the number of operators. Every workstation requires different operator skills, therefore, the cost of human resources employment differs for each activity. In the last row of *Table 3*, the amounts of time reduction per operator are indicated:

Table 3: Employee data

Stages	Stage 1	Stage 2	Stage 3	Stage 4	Pre-assembly	Assembly
Max reduction (TMU)	160	141	96	86	148	48
Costs (MMU)	125	210	150	240	130	300
Help/operator (TMU)	30	20	25	30	10	15

According to the results of the extended network model, total process time reduction can be carried out at a cost of 13 725 money measurement unit (MMU), which is the lowest possible cost taking constraints into consideration. The model's solution row provided the following recommendations for process improvement: 89 tmu extra work at the 1st process stage and 20 tmu extra work at the pre-assembly stage are necessary. 10% (109 tmu) decrease in total process time can be carried out by hiring three new employees in the 1st stage, and two operators in the pre-assembly stage. It means 5 new employees in total that equals 137.25 unit cost increase in the production. With the solution of the model, the critical path of the process did not change.

Conclusion

This article presents a case study on the optimization of a manufacturing process. If there is a possibility for reducing total process time, the cost of the reduction activities becomes an important factor, because expenses on improvement must be optimized to achieve the desired indicator at the lowest cost. In the presented case study, suggestions were proposed to achieve the 10% total process time decrease at a manufacturing company.

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