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Optimisation of the Work of a Sewing Team by Using Computer Simulation

Abstract
In this publication an attempt to optimise the work of a sewing team by using the Lanner Group Witness program for computer simulation is presented. The project of organising a sewing team has been developed according to the criterion of minimising wasted time. An analysis of different team organisation variants with respect to improving the efficiency and cost consumption of garment making is performed.

Key words: *production organisation, CAD-type systems, process simulation*

Introduction

Although the clothing production process is the most important of the factors of a product making process, it is only one of those factors. It must be connected with pre- and post-production activities. Pre-production activities include, first of all, the production preparation process, while the distribution of products, their consumption and utilisation are among post-production activities. The production preparation process is associated with the development of a product-making technology and the organisation of a production process. This involves assigning tasks to individual work stations and establishing rules for their co-operation. These theoretical considerations must then be verified and corrected in practice, which affects the team's productivity. A process simulation makes it possible to investigate different team structures and to evaluate the effect of the anticipated disturbances on its functioning before the commencement of the production process.

For the simulation of a production process, the authors used the 'Witness' program developed by the Lanner Group, which is the leading manufacturer of software for the simulation of management of production plants and service shops. The 'Witness' program is one of the most popular simulation tools world-wide. It has also been used for the simulation of clothing process of garment making [2].

Assumptions

When planning the organisation of a team, the planned rhythm of a team is traditionally taken as a reference point. In industrial practice, the planned rhythm is selected on the basis of the size and labour-consumption of a production task and the number of workers available. The magnitude of this rhythm is the basis for grouping technological operations into organisational ones, performed on individual work stations.

While designing a model, a different methodology, proposed by W. Więźlak and J. Szmelter [1] in the 1960s, was used. This method consists of two stages; in the first, inseparable operations are combined into organisational ones, whereas in the second, the magnitude of the rhythm is consciously selected by optimising the time wasted in the team. The team simulation model was developed on the basis of real data (a list of technological operations and processing times) obtained in a clothing production plant.

According to the above-mentioned methodology, the smallest number of stations for N_i for performing the i-th operation is determined by the relationship:

$$N_i = INT\left(\frac{T_i - \varepsilon T_i}{T}\right) + 1$$

where:
T_i - the time of the i-th organisational operation,
T - the team rhythm,
ε - the permissible deviation from the operation time (for manual operations ε=0.15, machine-manual ε=0.10, machine ε=0.05).

The time available for performing the i-th operation is:

$$t_i = N_i T$$

The longest permissible time for making the i-th operation can be written as:

$$\tau_i = T_i + \varepsilon T_i$$

The difference between the time available for performing an operation and the longest permissible time for performing this operation determines the occurrence and length of stoppage. If $t_i \leq \tau_i$, there is no stoppage. Otherwise, there is stoppage equal to the difference of the times $t_i - \tau_i$.

The stoppage length can be written as:

$$p_i = 1/2\ [|t_i - \tau_i| + (t_i - \tau_i)]$$

The total stoppage time on all the stations in the team is

$$\sum_i p_i ,$$

while the total time assigned for performing a task can be determined as:

$$T\sum_i N_i .$$

Then, the relative time wasted by the whole team will amount to:

$$\eta = \frac{\sum_i p_i}{T\sum_i N_i},$$

while the efficiency of the i-th station will be:

$$S_i = \frac{T_i}{N_i T}.$$

Analysing the latter relationship, it should be stated that a lower efficiency of a station means its slower loading; that is, the time that the operator has at his disposal to perform a task is longer than the duration of the task.

A dependence of the relative time wasted in a team on the magnitude of the planned rhythm has been determined

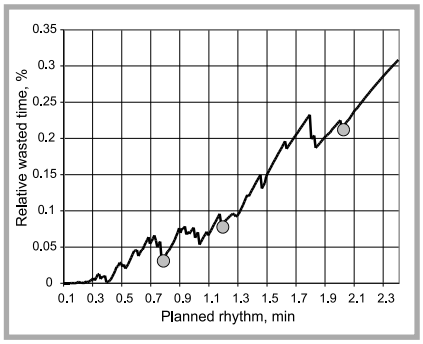

Figure 1. *Dependence of the relative time wasted in a team on the rhythm magnitude.*

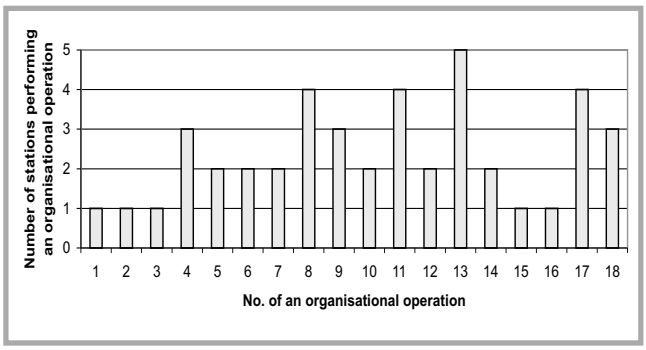

Figure 2. *Structure of a sewing rhythm for the rhythm Rp=0.77 min.*

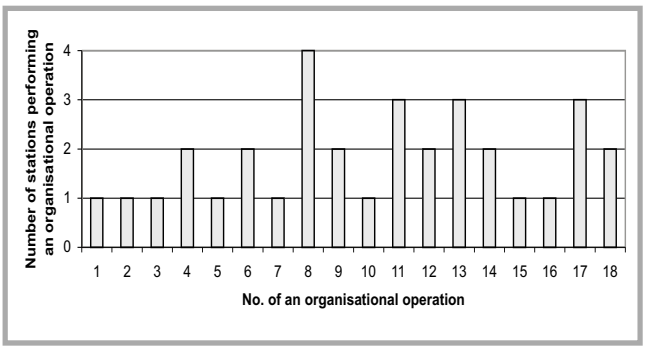

Figure 3. *Structure of a sewing team for the rhythm Rp=1.18 min.*

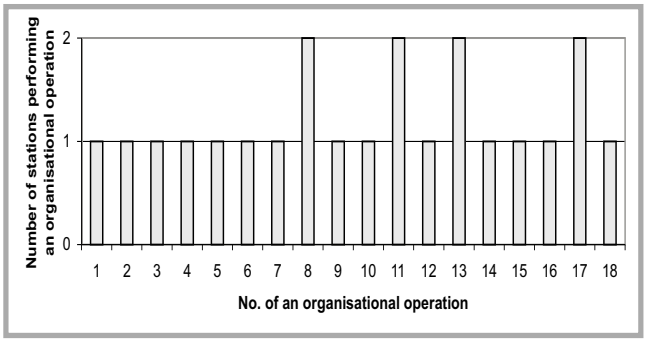

Figure 4. *Structure of a sewing team for the rhythm Rp=2.02 min.*

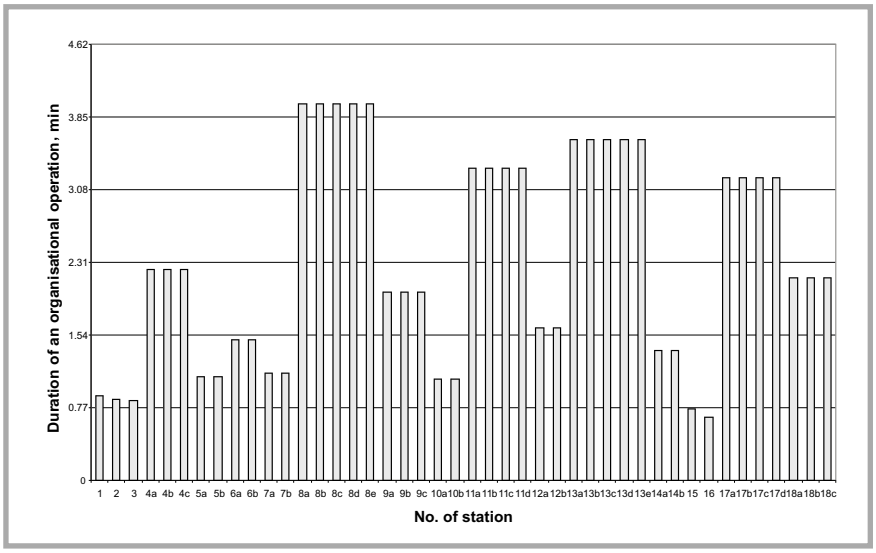

Figure 5. *Diagram of load of work stations in a team of a rhythm of 0.77 min.*

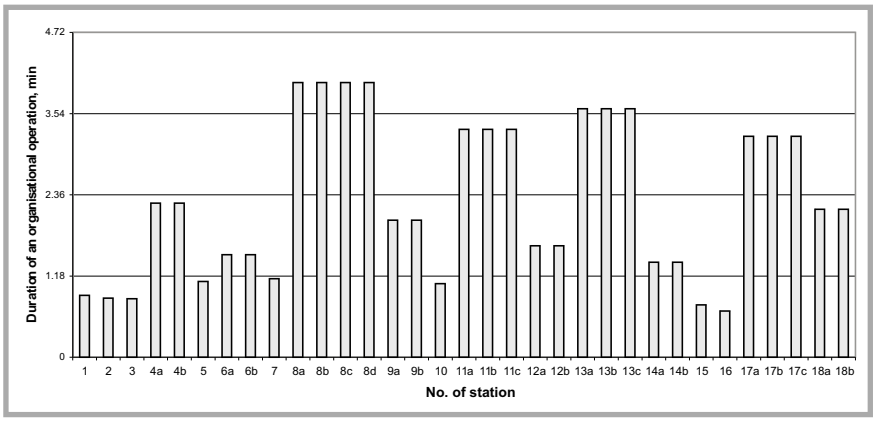

Figure 6. *Diagram of load of work stations in a team of a rhythm of 1.18 min.*

for the organisational operation durations assumed. This dependence is shown in Figure 1. Simulation models of sewing teams were developed for arbitrarily selected local minima of the functions corresponding to the rhythm values of 0.77 min, 1.18 min and 2.02 min.

The structure of the teams is shown in Figures 2, 3 and 4. The organisation of teams in the first two cases is characteristic of the flow systems. Multi-station passages performing the same technological operations can be noted here. The structure of the third team is characteristic of the belt system, in which parallel stations performing the same operation occur sporadically.

The load of the individual work stations is shown in the form of diagrams in Figures 5, 6 and 7. It has been found that - depending on the rhythm magnitude - the sizes of the teams are as follows: 44 persons for the rhythm of 0.77 min (model A), 33 persons for the rhythm of 1.18 min (model B), and 22 persons for a rhythm of 2.02 min (model C). The characteristics of the models are presented in Table 1.

These teams are characterised by an unfavourable synchronisation coefficient, which should not exceed 5%. Its high value, characteristic of the models developed, results from the assumption made that the basis for the division of labour is a technologically correct manner of combining inseparable operations into organisational ones. In a traditional approach, the division of labour is made on the basis of the planned rhythm, while the time of performance of a task should be equal to the rhythm magnitude or be its multiple.

While building a model and analysing the results, the authors made the following assumptions:

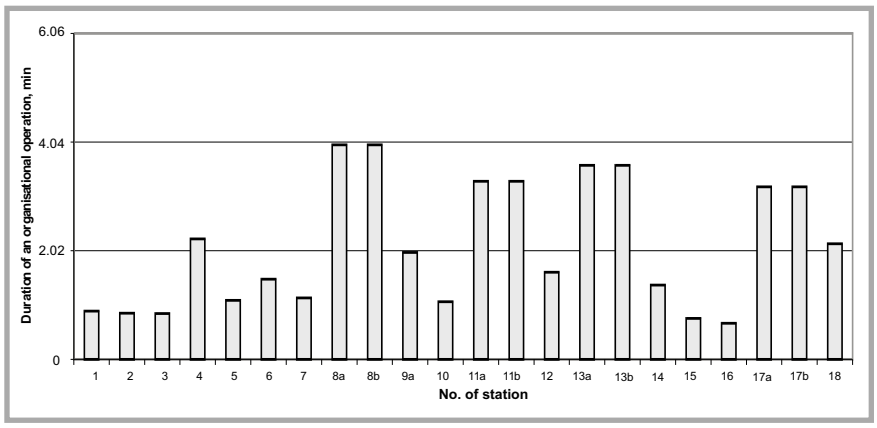

Figure 7. *Diagram of load of work stations in a team of a rhythm of 2.02 min.*

Table 1. *Characteristics of simulation models.*

Parameter	Model A	Model B	Model C
Work rhythm, min	0.77	1.18	2.02
Number of stations	44	33	22
Maximum number of parallel stations in a passage	5	4	2
Mean efficiency of a station, %	95.36	80.79	69.53
Relative time wasted in a team, %	3.08	8.10	21.60
Team synchronisation factor, %	10.20	20.84	39.58

- Providing a team with elements for processing is not limited. The first station in the team receives as many elements as it can process.
- Between the individual stations (groups of stations performing the same operation) there are containers with an inter-operational stock, into which the workers put the elements processed, and from which they take the elements for processing.
- At the beginning of a shift there is one element for processing for each worker.
- The time of performing an operation on the station is described by a normal distribution of a mean value equal to the time of the operation and the deviation depending on the operation's character (manual, machine-manual).
- The duration of a shift is 450 minutes.
- The number of elements in the containers was calculated every 8 min during the shift.
- The cost of the material per product unit is 25 zloty, the cost of the machine amortisation and energy consumption is 6 zloty per day, and the cost of the daily employment is 100 zloty per person.

Analysis of the Simulation Results

For each variant of the investigations, 10 repetitions were made. The analysis was carried out on the averaged values. Having analysed the effect of the organisation of a team on its efficiency, it was found that the efficiency of a team decreases as the work rhythm increases. This results from the fact that, on one hand, the higher rhythm of a team means a smaller number of work stations, and on the other hand, the smaller work rhythm means better synchronisation of a team's work and lower likeliness of an occurrence of 'bottlenecks' in it. The formation of congestions in the manufacturing process can be illustrated by the magnitude of the production in process. The state of inter-operational supplies in individual containers reflects the correctness of the functioning of the team. In Figure 8 the effect of the team organisation on its efficiency and the mean efficiency per individual person employed is shown, while Figure 9 shows the magnitude of production in process after finishing the work shift.

The efficiency of a team has a direct effect on the costs of the garment-making process. It is logical that the higher the work efficiency, the lower the production costs. The coefficient of correlation between these parameters is 0.967. In Figure 10, the effect of the team organisation on the cost of making a single product garment is presented.

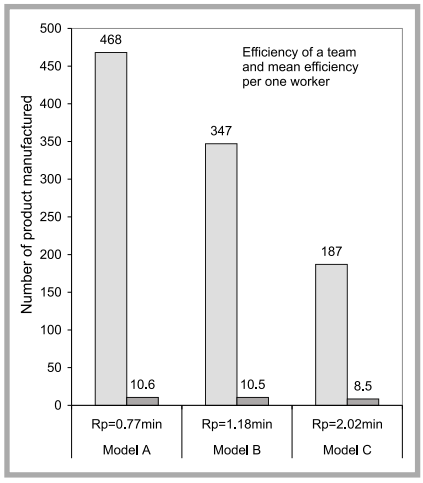

Figure 8. *Effect of the team organisation on work efficiency.*

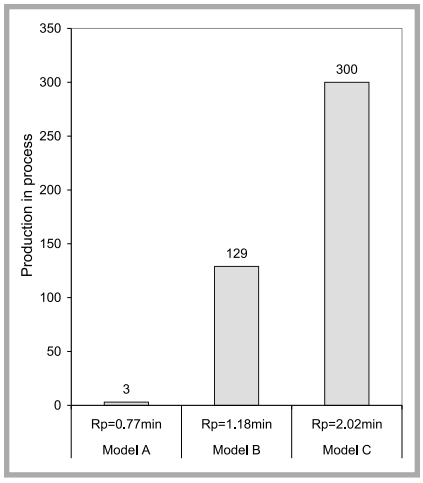

Figure 9. *Magnitude of production in process depending on the team organisation.*

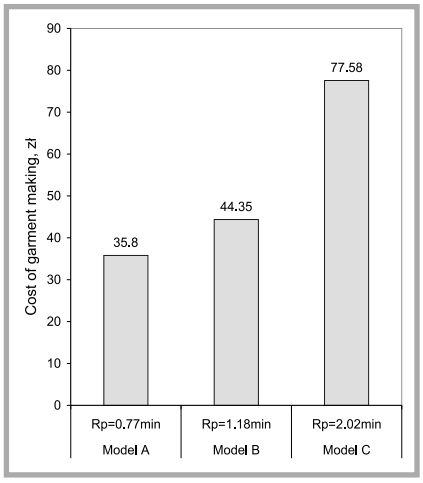

Figure 10. *Effect of the team organisation on the cost of garment making of a product item.*

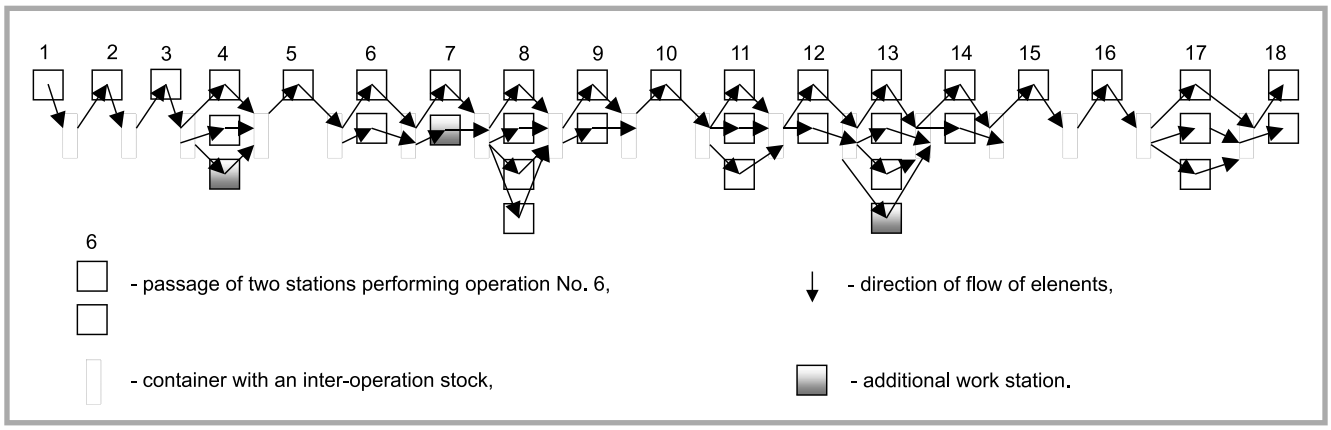

Figure 11. *Arrangement of stations in a team of a rhythm of 1.18 min (model B).*

On the basis of the preliminary simulation studies, it has been found that the team organisation in a belt system (Model C, with a work rhythm of 2.02 min) is the least effective. The very large production in process, the low team efficiency and the high cost of garment making, along with the low technological parameters of the team (the efficiency of stations, the time wasted in the team and the very high synchronisation coefficient (Table 1)) caused this team to be excluded from further considerations. The other extreme variant was Model A, which was characterised by the most favourable features. This model was not considered either, since its modifications would have a very limited range. Thus, further investigations were restricted to Model B, whose modifications could lead to interesting observations. The organisational diagram of this team is shown in Figure 11.

The simulation studies of this team have shown that there are 'bottlenecks' caused by differences in the individual stations. They appear in the co-operation of those stations between which the differences in efficiency are greatest. They refer to passages 3 and 4 (the differences in the efficiency of the stations reach 23%), passages 6 and 7 (the differences in the efficiency of the stations reach 34%) and passages 12 and 13 (also 34%). At the end of the work shift, the inter-operational supplies between these passages are 100, 8 and 20, respectively; thus, the elements in the three containers constitute practically the whole inter-operational stock in the team. The very high level of the stock in the container between passages 3 and 4 results from the unlimited access of the first station to the elements intended for processing, as well as the relatively low efficiency of stations 1, 2 and 3 (these stations are capable of processing a greater number of elements than planned).

In order to increase the efficiency of the passages generating a stock, additional three stations were introduced into passages 4, 7 and 13, one into each passage.

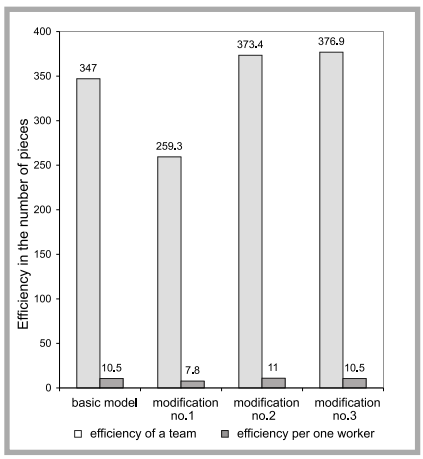

Figure 12. *Effect of the model modification on the team efficiency.*

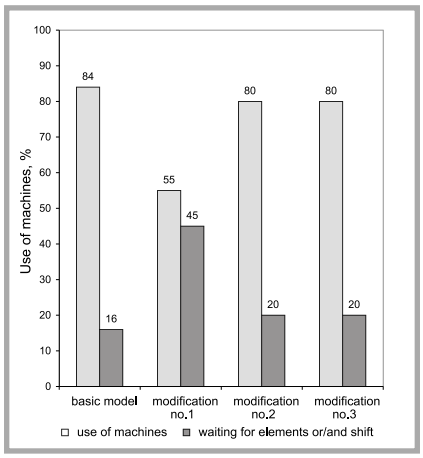

Figure 13. *Average degree of machine utility during a work shift.*

Then, three organisational variants were considered:

- When expanding a team by three stations, the employment was not increased, since the operators of unloaded stations were assigned the operation of additional machines. The operator in passage 1 was thus instructed to operate an additional machine from passage 4, the operator from passage 6 to operate a machine from passage 7, and the operator from passage 12 to operate a machine from passage 13. First, the worker operated his own machine, and while he was free he operated the additional machine.
- One operator was employed to operate these three additional stations (an increase in employment of 3%); the worker works on a given machine until a greater number of elements are accumulated in the container at one of the remaining ones. When this happens, this operator goes to the machine at which the greatest quantity of elements has been accumulated.
- A worker was employed for each additional machine (an increase in employment by 9%).

The effect of these decisions on the efficiency of the work, the use of the machine park and the production costs was assessed. The model modification results are presented in Figures 12-15.

The introduction of three additional stations aiding the loaded operations, and assigning their operation to three unloaded workers performing the preceding operations, caused a decrease in the team efficiency by approx. 25% (a decrease per person employed by 26%). This mainly resulted from the fact that loading station 1 supplied the whole team.

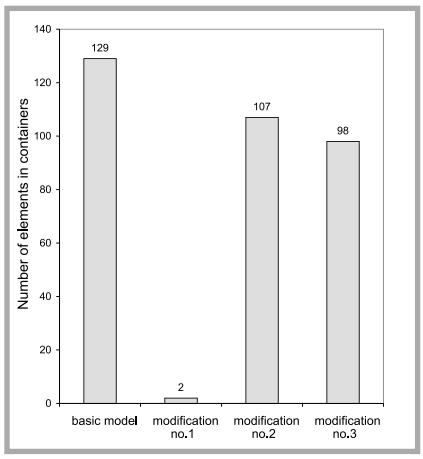

Figure 14. *Magnitude of the production in process at the end of the work shift.*

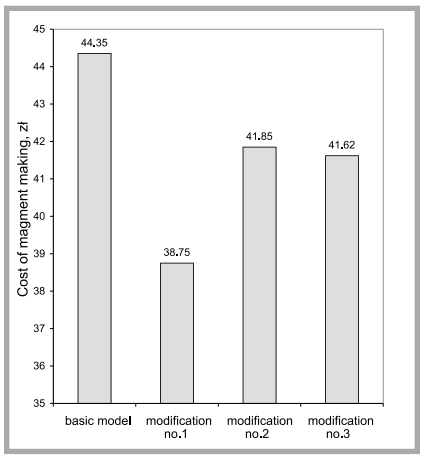

Figure 15. *Cost of garment making per product unit.*

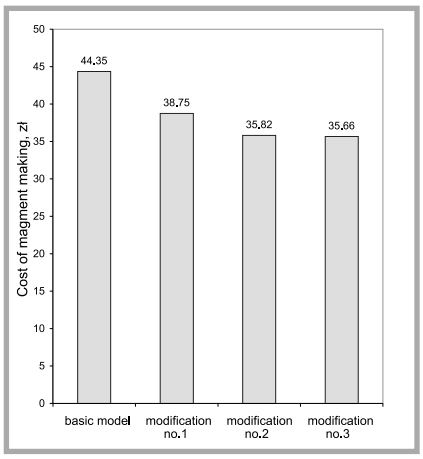

Figure 16. *Cost of garment making per product unit.*

The degree of the machine utility on this station decreased from 100% for the basic model, to 65% after modification. This retarded the work rate of the whole team, which on the one hand resulted in a decrease in the efficiency of use of the machine park in the team by about 34%, while on the other practically ran down the inter-operational stock. The unit cost of garment making was reduced by 12%, but this was caused by the lower costs of materials (as fewer products were produced).

The employment of an additional worker, a so-called 'jumper' who aided the work in the places where 'bottlenecks' occurred, resulted in an increase in the team efficiency of about 8% (an increase per worker of 5%) and a decrease in the unit cost of garment making of about 6%. However, it should be pointed out that the first station, dismissed from an additional task, will again be responsible for generating a high level of inter-operational stock. The retardation of this station (loading the operator with an additional task) by 18% will cause a reduction of an inter-operational stock to 17 elements at the end of the work shift with the unchanged efficiency of the team. This will result in a reduction of the unit cost of a product of a further 13%. The employment of two more persons did not have any significant effect on the team's work efficiency.

In Figure 16 the unit costs of product garment making with the retardation of work of the first station in the team (in the second and third modification of the model) are presented. An explanation should be given for the fact of the unchanged efficiency of the use of the machine park for the second and third modification of the basic model. This is so, because in the case of the operation of three additional machines by one operator, these stations are waiting both for elements for processing and the operator. In the case of the employment of three workers for the additional three machines, on the other hand, the efficiency in the modified passages improved and, consequently, these stations waited longer for the elements for processing.

Conclusions

- The magnitude of the planned rhythm has a significant effect on the team efficiency. An increase in the rhythm causes a decrease in the team efficiency, which results from a smaller number of members in the team and the worse synchronisation of work (as the magnitude of the production in process increases). This also causes a decrease in efficiency per person employed. A greater rhythm also has a substantial effect on the growth of costs of garment-making per product unit.
- It is essential that the organisational design of the garment making process should ensure that the first stations in a processing team are not unloaded, since they might generate an inter-operational stock. This will not improve the team efficiency, but it may increase the costs related to the production in process.
- The simulation carried out has shown that the theoretically developed, correct organisation of a team requires correcting in the process of affecting the production. This can have a significant effect on the efficiency of the team work. Thus, many possibilities appear for using simulation models, which are capable of considering many variants of solutions before the commencement of a production process.

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