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ORIGINAL PAPER

COMPARISON OF TIME-ORIENTED METHODS TO CHECK MANUFACTURING ACTIVITIES AND AN EXAMINATION OF THEIR EFFICIENCY

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ABSTRACT. **Background:** Warehouse Production management systems now require IT aspects which can be automated, so that processes can be easily reviewed. During our research, we analyzed four and a half years of database and machine stock of 3 food companies. We have found that companies in this industry prefer process-based production. It is important that manufacturing companies pay close attention to the proper design of automation, the purpose of which is to acquire and maintain a competitive advantage through the efficient, rapid manufacture of products. The expansion of industrial robots has increased considerably (Figure 4.), increasing the productivity, accuracy and flexibility of manufacturing processes, and has enabled a number of business processes to be re-established and new business models brought to life.

Methods: The two best time-oriented methods, the PERT and CPM analysis, were used to assess the individual stages of the production, which made estimates for the duration of the activities. When drawing the box graph, we extracted outlying data from the data set, so we obtained a more accurate statistical estimate. Using this, we made a recommendation for the expected completion of workflows, which is more accurate in determining delivery dates for sales orders. Analyzing the four-and-a-half year dataset, we determined, by using Student's t-test, that the average of the sample elements in reality is different from the estimates we made. The PERT and CPM methods have proven themselves in the past decades and continue to be of great value. The ever-changing business world and the high cost have an impact on the economy.

Results: The production times of individual companies are influenced by the use of more modern machines and well-developed manufacturing plans and schedules. Using PERT and CPM methods, we've helped to better define production time, making it easier to calculate delivery dates correctly. Automation does not stop all occupations, but only triggers certain activities and redefines jobs. There is no doubt that the technological development of manufacturing processes will change the organization of the industries concerned and affect the geographic location of each activity. There is a serious chance that the production of these products will go elsewhere to save on shipping costs.

Conclusions: During our analysis, we have found that new technologies have an impact on productivity, employment and the transformation of the geographic structure of value-added activities, that's why their role is important both for food companies and companies operating in other industries. Automation is made possible by scientific achievements and technological advances that are used to develop industry 4.0 technologies. The huge amount of data produced in the Intelligent Production Systems (Big Data) analysis and on this basis, the continuous modification of production systems, results in significant material and labor saving, efficiency gains and productivity gains, which have an impact on employment and the transformation of geographic structures. Food processing and delivery to consumers is a key factor in the security of food supply, and therefore has an essential importance in the further development of the sector.

Key words: process system manufacturing, PERT analysis, CPM method, automation, economic impact.

INTRODUCTION

As food processing and delivery to consumers is a key factor in food security, it is essential that the sector is developed as a matter of priority. It is a national interest that consumers buy high-quality, healthy and Hungarian food, boosting trade in domestic businesses.

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The development of electronic devices has enabled the design and introduction of flexible programmable machines, so today the production process has become more efficient with modern equipment, thus increasing competition among companies. One of the dominant drivers of manufacturing companies is automation, whose goal is optimizing and improving efficiency. The processes in the system are aimed at creating products that result in the company's net revenue increasing.

The production management system generates information during its operation, which should be analyzed in order to develop production processes based on the data. When testing manufacturing processes, it is advisable to use a tool that takes account of optimistic, expected, and pessimistic times. The PERT analysis calculates these times so that we can predict the feasibility of each process. Student's t-test can be used to determine if the estimated time frame for the null hypothesis is correct, i.e. whether the production processes can be completed within the desired time period, given the average of the series of data. When using the CPM method, outlying data in the model can be detected and filtered so that by calculating the average for the production records, you can get a more accurate estimate of the expected duration of the project. When processing data, determining the company's capacity and the optimum utilization of equipment is the main goal, the continuous redesign of which is one of the short and long-term goals of companies.

During our analysis, we have found that new technologies have an impact on productivity, employment and the transformation of the geographic structure of value-added activities, that's why their role is important both for food companies and companies operating in other industries.

LITERATURE REVIEW - CHARACTERISTICS OF MANUFACTURING SYSTEMS

Today's manufacturing process has become more and more comprehensive and complicated, thanks to technological advances. In order to ensure the production process is smooth, either in the food industry we are looking at, or in other industries, it is important to carry out the following elements without obstacles: procurement, warehousing, material handling, technology planning, equipment preparation, production organization for different phases, quality control, etc. [Oláh, Popp 2016].

Our new manufacturing technologies in our time produce products through cyber-physical production systems [Monostori 2015], using new technologies (such as industrial biotechnology, nanotechnology, artificial intelligence, laser technology). Beside the writings on new parameters of production processes, product-based approaches to the new era are known [Porter, Heppelmann 2014]. Accordingly, one of the key features of the new era of manufacturing is that companies are competing with products that communicate with the consumer and the manufacturer through intelligent, interconnected, e.g. cloud-based systems.

At the corporate level, users of the i40 technologies expect to achieve significant material and energy savings, increase their capacity utilization, and market their new products in line with changing demand [Burmeister et al. 2015, Ilie-Zudor et al. 2015].

The productivity impact of new technologies is influenced by company-level calculations that have shown that specific investments clearly increased investor productivity [Bughin 2016].

At national level, Graetz and Michaels [2015] study, for 17 countries, clearly demonstrates the economic and productivity gains of industrial robots. According to some opinions, new technologies promote job preservation, rapid growth in employment and industry is expected. Rapid economic growth results in significant employment growth due to technological advances [Strategic Policy Forum 2015].

The corporate survey of the World Economic Forum, as a result of industry 4.0 technologies, accounts for a global loss of 5.1 million net posts, i.e. the termination of 7.1

million jobs and the creation of two million new jobs [WEF 2016].

An additional direction of technological development, which is also partially related to industry 4.0 technologies, nevertheless in the structure of value chains in the manufacturing sector, the industry has a structural change similar to the industry 4.0 technology to automate knowledge-based supportive business functions (more specifically defined cognitive tasks) in added value generation [Lacity, Willcocks 2015].

The layout of the production equipment determines the pathways of the given foodstuffs during the production process, which affects the movement of materials in production, the time and cost requirements for the various stages of production of the food, and the elasticity of the manufacturing system [Oláh, Popp 2017].

STACKABLE, STATIC STORAGE SYSTEMS

Storage operations are strongly influenced by continuously occurring major changes in production and service processes, which are mainly caused by the search for quality against volume. For a workable layout, it is necessary to calculate the requirement for storage, which can serve several purposes in the case of a large warehouse. It is important to identify the different warehouses activities that affect the planning of the warehouse layout, determine the space requirement, the ideal layout for each activity, and then match the space requirements to the individual constraints.

PROGRAM EVALUATION AND REVIEW METHOD

Time-oriented methods combine tasks so as to graphically present the entire project process. The program evaluation and review method (PERT) was developed in 1958 for the design and management of the Polaris missile project. The PERT method was developed with the help of the Gantt diagram, which is clear understandable for small projects, but for 25-30 activities the relationships become more complicated [Adetoye et al. 2017]. In the PERT method, activity times are interpreted as probability variables, so optimistic, most likely and pessimistic times are given. To fully prescribe the time planning and the network, the following 4 important steps are available:

Determine all the tasks in the project. This requires that the user of the PERT should have the necessary expertise to interpret the program. As a result of this step, we get a list of all tasks.

Determine the sequence of activities and dependency relationships. When creating a network, close attention must always be paid to the sequence of activities and events, and to identify the relationships between them [Elizaphan 2015].

Assess the optimistic, most likely and pessimistic duration of the activities as follows:

a = optimistic estimate: which is the shortest time the activity can be performed in. (The probability that the task can be achieved in a shorter time is generally 1 per cent).

m = most likely duration: this is the best approach to determining the required time. This is the most likely time.

b = pessimistic estimation: the longest time it takes to complete the given operation [Deng and Jial 2003]. (The probability that the task can be achieved in a longer time is generally 1 per cent.)

Define the expected time for each activity. For this, use the formula for the expected value of the β distribution:

$$T = \frac{a + 4m + b}{6}$$

This formula is based on the beta distribution used in statistics, where the most probable duration (m) is weighted four times more heavily than that of the optimistic estimate (a) and the pessimistic estimate (b) [Nafkha 2016].

Using the single sample t-test, we can examine whether the average of a selected probability variable in a database is significantly different from a specified m value. The test can be used if the probability variable under test is normally distributed and is measured in interval- or proportional scales [Obadovics 2016].

In the null hypothesis of the test it can be stated that the average of the examined variable is statistically the same as a predetermined m value. In the counter hypothesis, it can be stated that the average of the examined variables does not statistically correspond with (is smaller/higher than) the predefined m value.

The test statistic of the one sample t-test is:

$$t = \frac{\bar{x} - m}{s/\sqrt{n}}$$

where $\bar{x}$ is the average of the sample elements examined; s is estimated distribution of the examined sample elements; m is the predetermined value to which the average is compared; n the number elements in the sample [Hunyadi and Vita 2003].

The steps for performing this test are as follows:

- Calculate the value of the t-test statistic.
- Choose the significance level α. (This is 0.05 or 0.01 for most tests.)
- Select the t1-α value dependent on the α significance level from the table corresponding to the test. The two axes of the table are: the significance level α and the degree of freedom df (df = n-1).
- Take the null hypothesis decision [Takács 2016]:

  If $|t| \geq t_{1-\alpha}$, then the null hypothesis is rejected, i.e., the counter-hypothesis is accepted and the result is interpreted such that the mean of the examined sample elements is significantly different (at the α significance level) from the given m value.

  If $|t| < t_{1-\alpha}$, we maintain the null hypothesis, interpreting it such that the single t-test does not reveal a significant difference between the sample mean of the probability variable tested and the theoretical value (at the α significance level).

CRITICAL PATH METHOD

J.E. Kelly developed the Critical Path Method (CPM) in 1957 in order to plan maintenance breaks for chemical plants [Plotnick 2009]. The CPM method calculates and analyzes a project's timing schedule, which can be well illustrated by a graphical diagram. To fully capture the CPM net, we need to consider the following steps:

- Specify all the activities that will be performed in the project. It should be noted that while PERT analyzes handle activities and events separately, we do not differentiate them for CPM. Since they are related, in the following CPM tasks will be referred to as activities [Woolf 2012].
- The next step is to determine the sequence and relationship of the activities. Since CPM is activity-oriented, the arrows only indicate relationships. It is worth mentioning that the difference between the PERT and the CPM methods is that in the latter the nodes refer to activities, not events [Hunt, Sahimi 2017].
- Estimate the duration of each individual activity. The CPM procedure does not include any requirement for statistical estimation of these values but they can be accessed using a simple statistical model. For example, you can take the average production record for the selected period [East 2015].
- Define the critical path without reserves. To know the spare time we need to determine four values to be calculated for each event:
  - Early start (ES), this is the earliest point at which the activity can start
  - Early finish (EF), this is the early start time with the addition of the time required for the activity.

- Late start (LS), the latest start time for the activity without delaying the project
- Late finish (LF), in order not to delay the project, no activity is to be carried out after this point [Deacon and Lingen, 2015].

Define the reserve time for the activities. We can create reserve times using LS-ES or LS-EF for each event.

By leaving extreme data out of the database, we can get more accurate statistics. The box-plot serves as storage for the outlying data, the essence of which is to increase or decrease the upper and lower limits of the interquartile range [Vad et al. 2017]. The box diagram is a graphical representation of variables along the quartiles. The distances between the individual parts of the boxes indicate data skewness, dispersion and outlying values [Thirumalai et al. 2017].

Using the box diagram we can graphically illustrate the scope and location of the values of the variables. In addition, it shows whether the dataset has outlying points, and information on symmetry and skew data can be obtained [Verde 2014].

The upper corner of the box is the third quartile, i.e. 75% of the data, the lower corner is the first quartile, i.e. 25% of the data, and the center of the box contains 50% of the data. So the size of the sample is the difference between the third quartile and the first quartile, i.e. the middle 50% interval. The line in the box indicates the median. If the median line is not evenly spaced from the lower and upper corners, the data is asymmetric. The ends of the lines starting from the box indicate maximum and minimum values [Rietz and Stannarius 2017].

The box illustrates two types of outlying data:

- slightly outlying values: these values are outside the inner boundary point but are located within the outer boundary point and are marked with circle symbol. These values are outside the interquartile range at * 1,5 distance.
- extreme outlying values: these values are located outside the outer boundary point, marked by a star symbol [Lem et al. 2017].

MATERIALS AND METHOD

During my research I examined 3 companies that deal with food production and have the most modern production lines in the domestic food industry. Along with an annual production capacity of above ten thousand tons, they focus on innovative, forward-looking product development and optimal value for money. They consider food safety important and do not forget the importance of environmental awareness.

Table 1. The most important data of the companies surveyed

Indicators	**Company "A"**	**Company "B"**	**Company "C"**
Beginning of the examined period	2013. 02. 01.	2013. 02. 01.	2013. 02. 01.
End of the examined period	2017. 10. 01.	2017. 10. 01.	2017. 10. 01.
Production records number (items)	15 855	16 187	14 898
Examined production volume (kg)	1 000	1 000	1 000
Low Quarterly Record (minutes)	56,48	57,11	57,19
High Quarterly Record (minutes)	58,49	59,10	59,10
Interquartile *1,5 (minutes)	3,01	2,99	3,02
Optimum production interval (minutes)	53,47 – 61,50	54,12 – 62,09	54,17 – 62,12
Number of outlying data (items)	103	122	102
Optimized production time (minutes)	56,2	57,4	58,1
Estimated production time (minutes)	56,7	58,1	58,6
Production Pessimistic Duration (Minutes)	57,8	58,8	59,1

Source: Author's own research, 2017

Innovative machines are capable of mixing, shaping, filling, coating, baking, freezing, measuring and packing products in a large quantity, without any human intervention. The manufacturing process is directed and controlled by trained professionals. The factories also have their own laboratory and a specialist office in order to check the quality of the products.

Thanks to the new methods, productivity can change internationally, as well as geographical rearrangements, new jobs can emerge.

For the purposes of analysis, the most important information about the companies is given in Table 1.

The 3 companies were analyzed for four and a half years of data, which analyzed the acceptability of the length of time taken to manufacture a product. The main aim was to examine the production times in a deeper way, which allowed me to draw conclusions that resulted in the optimization of production time, i.e. a reduction in production time. The calculations serve customer requirements better, as well as making it possible to plan capacity utilization, which can have a significant impact on the economy.

During my research, I applied the PERT and CPM analysis to show these results. Using these methods, I determined the time required for the production of the quantities on the machines, so I made estimates for the future for the time periods. It is important to mention that outlying data in the data set was taken out of the model, so I obtained a more accurate estimate of the average calculation from the production records.

I used a one-tier Student t-test for the dataset to find out whether the mean of the sample elements was significantly different (with a 5% significance level) from the estimated value of the given PERT analysis.

We have examined the effects of the new technologies used in manufacturing on the economy. We have found that not only employment has a significant impact on automation, using robots, but also productivity and geographic rearrangement.

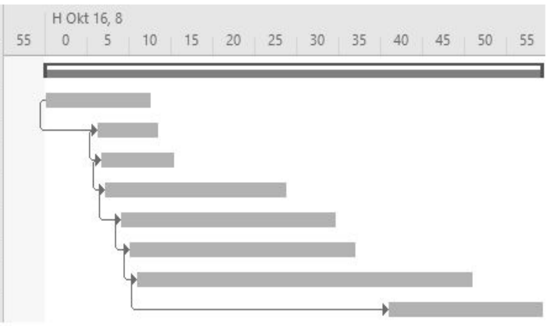
RESULTS - SEQUENCE OF THE MANUFACTURING PROCESS

Based on the experience gained in the food industry, it can be said that for companies specializing in this industry, given the importance of having a ready, working system, process-based production is a common solution, as the growth of material pathways is a significant time loss for companies.

The material supply process of production depends on orders and suppliers, who can be penalized for late delivery. The goal is to keep companies in contact with reliable suppliers and to have good resources, tools and human resources at their disposal.

The main production process of one of the three companies is illustrated in Figure 1 in Microsoft Project. The indicated timescales apply to the preparation of 1 ton of finished product.

Name of activity	Time	Start	Finish	Prevention
Production timings	0,99 h	H 17.10.16.	H 17.10.16.	
Raw materials	12,5 min	H 17.10.16.	H 17.10.16.	
Shaping machine	7,2 min	H 17.10.16.	H 17.10.16.	2KK+6,2 perc
Coating	8,6 min	H 17.10.16.	H 17.10.16.	3KK+0,5 perc
Baking	21,5 min	H 17.10.16.	H 17.10.16.	4KK+0,5 perc
Softening	25,7 min	H 17.10.16.	H 17.10.16.	5KK+0,5 perc
Quality control	27 min	H 17.10.16.	H 17.10.16.	6KK+1 perc
Freezing	40 min	H 17.10.16.	H 17.10.16.	7KK+1 perc
Packing	18,4 min	H 17.10.16.	H 17.10.16.	8KK+30 perc



Source: Author's own editing, 2017

Fig. 1. Food manufacturing process

The processing begins with unpacking the raw materials and placing them in the cutting machine, where Company B dices and liquefies 1 ton of the finished product in 12,5 minutes. Each workstation has a control unit that can be set to determine the speed and length of time the machine process the raw materials and semi-finished products. After this, the raw material is given a regular shape in a total of 7,5 minutes by a molding machine, which is the starting point of a conveyor belt process, then the products are coated, seasoned, then the products on the belt are fried in oil and softened with steam, resulting in finished products. Quality control, which takes up to 27 minutes of the production process, is the most important stage in production, as it is the last control point before the customer at which faults can be detected. At this point, several characteristics of the products (taste, color, form) are examined. When problems arise, the finished product is automatically rejected. After the quality check, the finished products are frozen. The temperature of the freezer is determined depending on the state of the finished product, and may be up to -70°C. In the case of the companies under examination, a finished product usually spends 30-40 minutes in the freezer before being wrapped. The products to be packed – whose weight can only vary by a maximum of 10 grams from requirements - are placed in the packing machine compartments. If the weight does not meet the specifications, its contents are placed in the reject box. The packaging machine wraps the finished product with one cut and glue application. This workflow at Company B for 1 ton (about 2200 packages) takes 18,4 minutes. Packages are placed in the boxes and taken to a frozen store where the finished product will be sold within 1-1,5 weeks.

USE OF THE PERT METHOD

After reviewing the processes, I used the PERT method for estimating the expected duration of the activities for each company. Following the optimistic, expected, and pessimistic timing of scheduled activities, I calculated the estimated duration of the activities using Microsoft Project. To calculate the estimate, I took the β distribution as the most probable time and gave it a weighting four times higher than the optimistic and pessimistic estimates. The probability variable applies to continuous and finite intervals. For company A, the probability of the occurrence of each process and the result of the β distribution are shown in Figure 2.

It can be stated that the estimated duration of the processes approaches the expected duration quite closely (the difference is only in the hundredths of a second range). Subsequently, a β-estimate was prepared for each company for 1 ton of finished product. The work duration of companies A, B and C is estimated at 56,814 minutes, 58,175 minutes and 58,647 minutes.

The estimates describe the expected completion date for a project, showing that company A will be able to prepare the same amount of product 1,261 minutes faster than company B. The result is due to the optimum utilization of the production equipment.

The results of the β estimates revealed that the companies can produce 1 ton of product in about 58,1 minutes. During my research, my main goal was to determine how much the 58,1 minutes calculated differs from the manufacturing time accumulated over four and a half years of the companies' operations. For this I used the Student's t-test.

The null hypothesis was that the average duration of manufacture was less than or equal to 58,1 minutes, and the counter-hypothesis states that companies have an average production time for 1 ton of production greater than 58,1 minutes. The t-test was performed at a 5% significance level, i.e. a decision to accept the null hypothesis would occur at 95% probability. It follows from the choice of null hypothesis and counter-hypothesis that I work with one-sided critical values.

The results of the t-test applied to the database of the 3 companies are shown in Figure 2.

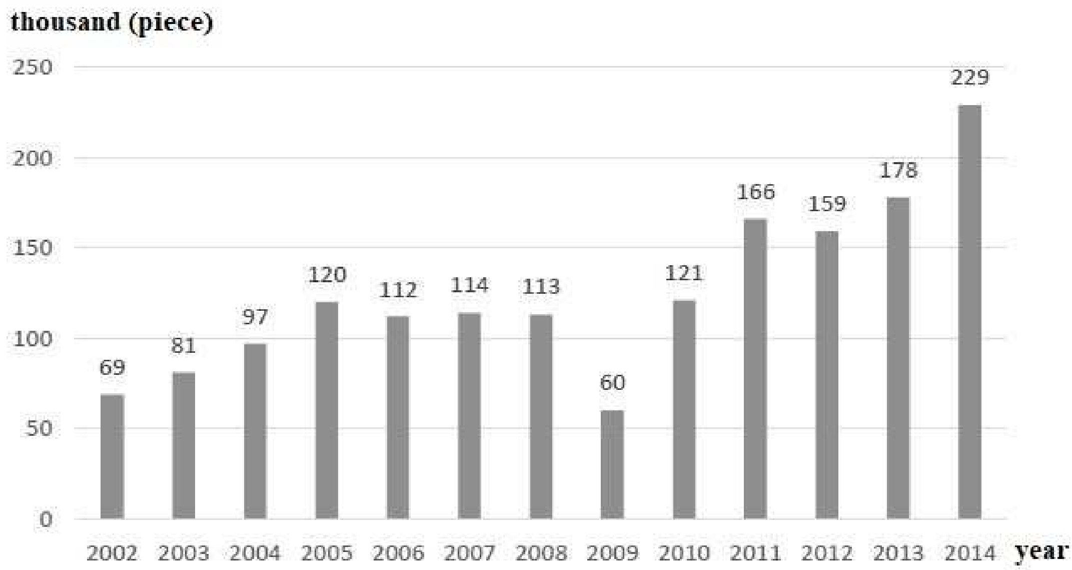
Since the T-test at companies "A" and "B" shows the expected result is less than 1,645, I therefore accept the null hypothesis that the production of 1 ton of finished product can be carried out within 58,1 minutes. (Note: the software used cannot work on a one-sided critical value, so the value of the Sig. (2-tailed) column for Company A is low.) From company A's 15854 production period it can be seen that it takes much less time to produce the required quantities compared to the other two companies, due to the precise design of the production plan and the optimization of the machines. For company B, we can state with 95% confidence that it can deliver the expected result, but it will have to spend a lot more time in precisely organizing process-oriented activities so that in the future the expected duration approaches the optimistic duration. Company C should focus on purchasing another machine as it is behind the two companies in terms of production speed. The increasing use of robots has a significant effect on the production of products, with these tools the problems can be better managed and improved as if they were examining human failure.

The expansion of industrial robots has increased considerably (Figure 3.), increasing the productivity, accuracy and flexibility of manufacturing processes, and has enabled a number of business processes to be re-established and new business models brought to life.

	Test Value = 58.1					
					95% Confidence Interval of the Difference	
	t	df	Sig. (2-tailed)	Mean Difference	Lower	Upper
A_Company	-52,930	15854	,000	-,62229	-,6453	-,5992
B_Company	-,422	16186	,673	-,00493	-,0278	,0180
C_Company	7,928	14897	,000	,09723	,0732	,1213

Source: Author's own editing, 2017

Fig. 2. Student's t-test for the production of the three companies



Source: International Federation of Robotics [IFR 2013]

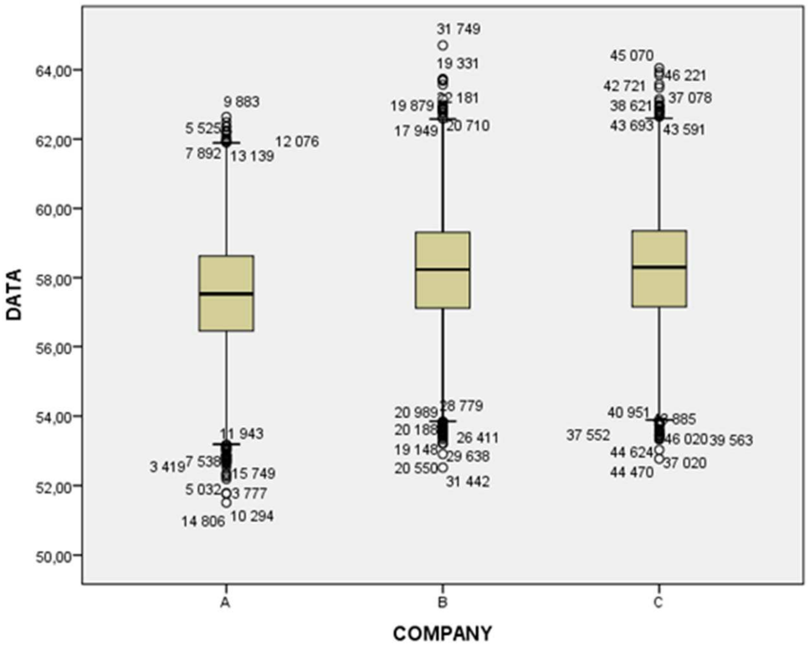
Fig. 3. Number of industrial robots sold internationally

During the analysis, let us not forget that the main goal of companies is not only to meet customers' needs faster, but also to provide consumers with good quality food at an affordable price.

RESULTS OF THE CPM METHOD

For companies it has become increasingly important to perform comprehensive, complex logical and chronological activities as quickly and as efficiently as possible. Thus, the ultimate goal of the CPM method is - after appropriately considering the processes - to calculate the duration of each activity and the expected completion of the project.

If we include the extreme data contained in the production records, this results in a somewhat inaccurate result, so leaving them out gives more reliable statistics. The box graph is the appropriate place to show this outlying data. By analyzing the manufacturing records of each company, the box graph can be used to determine interquartile coverage, which covers the middle 50% of the data (Figure 4).



Source: Author's own editing, 2017

Fig. 4. Box charts of companies ("A", "B", "C")

The box chart shows that the optimal production interval for company "A" is between 53,47 and 61,50 minutes, so that records outside this interval have been removed from the data set. After calculating quartiles, 1,5 times the interquartile range is extracted from the lower quartile, and the lower value of the optimal interval is obtained.

Company "B"'s database contains most outlying data, 122 items in total. The results show that the 3 companies have a similarly large quantity of outlying data, which could be due to defects in production.

In the box graphs of all three companies, the median line is approximately equidistant from the bottom and the top, indicating the symmetry of the distribution of the data. I used trimming to remove the outlying values of the companies, with the aim of using the box graph data to leave out the elements outside the optimum interval of the production time.

By filtering, we can get a more accurate estimate of the duration of the expected project completion. Descriptive statistics obtained with databases containing and not containing outlying data are shown in Figure 5 below.

From the filtered and unfiltered data for the three companies, it can be stated that the removal of outlying data significantly influenced the outcome of the estimate. For company C, for example, the maximum value of two databases differs by 1,29 minutes, which alters the average by more than 0,5 minutes. This discrepancy may have been due to the workstation stopping due to a failure, so it is important to review the company's processes and reduce machine errors.

	N	Minimum	Maximum	Mean	Std. Deviation
A_unfiltered	15855	51,20	62,82	57,7903	1,81210
A_filtered	15752	51,51	62,64	57,4781	1,47971
B_unfiltered	16187	52,12	65,80	58,4974	1,85761
B_filtered	16065	52,52	64,71	58,0948	1,48725
C_unfiltered	14898	51,65	65,34	58,7339	2,01706
C_filtered	14796	52,77	64,05	58,1971	1,49597

Source: Author's own research, 2017

Fig. 5. Key data of companies surveyed

It is important not to apply a weighted average calculation to the data set because we will then take some values into account with a greater weight, which can significantly modify the estimated production time, so we get a distorted estimate that is not as close to the expected production time.

PERT AND CPM METHODS DIFFERENT BEHAVIOR

The CPM network differs significantly from the PERT network, even though the activities and the critical path are the same. Generally, the CPM method uses fewer virtual events because it assigns activity not to the arrows linking events, but only to the node. However, a fundamental difference is that the PERT method treats the probability of times explicitly, while CPM does not. This difference stems from the fact that while the CPM method was designed for routine business tasks, PERT was used for new developments.

The results of analyses of data sets are summarized in Table 2. It can be stated that by using the CPM method, we can get a more accurate end time thanks to the outlying data being removed from the models. For the PERT method, the activity times follow a beta distribution where the sum of the variance of the critical path activities corresponds to the assumed variance of the project. Determining the three "valid" time estimates and putting them into PERT formulas often causes problems in practice: it is often difficult to estimate the time of an activity, particularly in three different ways, and this is not helped by the subjective definition of a and b. How optimistic or pessimistic should one be? Another problem within the PERT is over- or underestimating the duration of the activities, and their costs. Underestimation often leads to delays in the project and hurries resource allocation. Overestimation results in inaction, resulting in management's attention being diverted to less successful areas, resulting in planning expenditure being lost.

Table 2. The result of the PERT and CPM methods for the companies under examination

Characteristics	**Company A**	**Company B**	**Company C**
PERT method (minutes)	56,814	58,175	58,647
CPM method (minutes)	57,53	58,19	58,25

Source: Author's own research, 2017

For PERT, the three estimates are becoming less common in practice, and the single "best estimate" is preferred. This amendment also simplifies some of the theoretical questions already raised and reduces the complexity of PERT. However, this simplification results in the loss of essential features of PERT, which can improve statistical accuracy, although it is not necessarily perfect.

In both methods, project activities can be individually identified, meaning that all activities have a clear start and end time, but projects change over time, so the network created at the beginning of the project may become inaccurate later. It is a fact that the formalization of the network and the specification of activities hamper the flexibility needed to manage the changing situations arising during a project's progress.

Links between project activities cannot always be predicted in terms of their sequence, and it is not necessarily true that the end time of the project is determined by the longest time taken by summing the values of the expected duration of the activities. In some projects the order of certain activities depends on the outcome of the previous activity. As the project progresses, it often happens that some activities are so delayed that this delay lengthens the entire project time. Therefore, it is suggested that the critical path concept should be replaced by the critical activity principle with regard to the focus of management attention.

The critical path approach also raises some practical issues, alongside theoretical problems. In the case of the PERT method, the lack of understanding of the staff performing the operations is usually a problem in the statistical foundation of the model. Sources of misunderstandings can include using the three estimate values, the beta distribution of the activity time, the normal distribution, and the sum of the variance of the activities in calculating the probability of completion of the project. These misunderstandings create mistrust and opposition. Thus, executives need to handle PERT in such a way as to ensure those who are entrusted with supervising and monitoring the conduct of activities understand the essence of critical path planning and PERT's statistical features.

The costs associated with critical path methods are sometimes criticized, although the cost increase will generally be fully offset by the project's time savings and higher-level design savings.

The PERT and CPM methods have proven themselves in the past decades and continue to be of great value. In a sudden and constantly changing business world with its accompanying high costs, management must be able to design and effectively direct the company's activities. It is a fact that managers have a tool to build projects transparently, identify those responsible for each area, anticipate the possible causes of the delay, and save time in costly projects. It also seems likely that different techniques which include cost factors will be used more and more frequently in the future, which have an impact on the economy. These technologies play an indispensable role in both food manufacturing companies and companies operating in other industries.

ECONOMIC IMPACT OF NEW TECHNOLOGIES

Contradicting the effects of new technologies on the productivity, employment and the transformation of the geographic structure of value-added activities, it can be expected to result in job losses, but this is possibly can compensated by new jobs.

New technologies enable outsourced production activities to return to developed countries.

The transformation of the geographic structure of value-added activities is the most relevant issue from the Hungarian point of view, as it affects the most strongly performance of the economy, employment and the perspectives of the development of economic operators.

The huge amount of data produced in the Intelligent Production Systems (Big Data) analysis and on this basis, the continuous modification of production systems, results in significant material and labor saving, efficiency gains and productivity gains. The reliability and transparency of production processes and product quality are growing.

From the point of view of the product, through product-based data collection, feedback, and vendor-based solutions, companies are more familiar with customer requirements and usage habits, so they can expand their service palette (or perhaps switch to a service-based business model) increase their competitive advantage.

One of the most extreme debates emerged about the impact of new technologies on employment. Automation does not stop all occupations, but only triggers certain activities and redefines jobs.

There is no doubt that the technological development of manufacturing processes will change the organization of the industries concerned and affect the geographic location of each activity. The geographic rearrangement of activities is made possible by the peculiarities of new technologies. There is a serious chance that the production of these products will go elsewhere to save on shipping costs.

Optimization of production planning and scheduling and production information systems increase efficiency, and on the other hand, these systems take on engineering and management tasks previously carried out by local specialists.

Automation is made possible by scientific achievements and technological advances that are used to develop industry 4.0 technologies. Business functions become mechanized, such as bookkeeping, payroll, marketing, workforce selection, data collection, processing and other administration. Within the organization of multinational corporations, these activities are currently performed mostly in shared service centers.

CONCLUSIONS AND RECOMMENDATIONS

To achieve the smooth running of the manufacturing process the smooth operation of the following elements is essential: procurement, warehousing, material handling, technology planning, equipment preparation, manufacturing organization, final product preparation and quality control.

In my view, the food path adopted depends on the location of the production equipment, which affects the flexibility of the manufacturing system, material handling, time and cost requirements and lead times in the different stages of food production. Companies in the food industry prefer process-based production, as the production line solution reduces the lead times between each step, thus increasing the volume of production within a given time interval. It is important that manufacturing companies pay close attention to the proper design of automation, the purpose of which is to acquire and maintain a competitive advantage through the efficient, rapid manufacture of products.

During our analysis, we found that automation has increased the productivity, accuracy and flexibility of production processes, influenced the employment and the geographical location of the manufacturing companies.

It is in the interests of companies not only to manufacture the production volume that is needed within the deadline but also to provide consumers with high quality food.

During the operation of the production management system, information is produced, so the quality of semi-finished and finished products can be continuously monitored during work processes. In the case of foods, quality checks must be carried out on all finished products. The more accurate the test, the higher the cost.

During our research we made estimates for the duration of the activities using the PERT method. Based on various calculations, the estimated completion time of the project is

58,1 minutes, which generally states that a food producing company can produce 1 ton of a product within 58,1 minutes. With the help of the CPM method and the box diagram, we filtered outlying data from the production records so we obtained more accurate data when calculating the average. This finding and the accompanying calculations help to better define production time, making it easier to calculate delivery dates well.

The production times of individual companies are influenced by the use of more modern machines and well-developed manufacturing plans and schedules.

Companies (in this case company "C") have to reconsider the organization of processes, as even 1-2 minutes can result in the loss of huge production volumes. A more precise organization of process-oriented activities is the main objective, so that the average duration of production can be reduced later.

Every company wants to maintain and develop the quality of the products they produce, which can be achieved when production is carried out correctly.

Due to decision support systems, management information is growing, and some strategic decisions become more solid. Using built-in business analytics, companies can open new business directions and offer value to their customers in a different way. The supply will be more customized than before, and product-related services will continue to grow.

Food processing and delivery to consumers is a key factor in the security of food supply, and therefore has an essential importance in the further development of the sector.

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PORÓWNANIE METOD PLANOWANIA PROJEKTÓW WERYFIKUJĄCYCH DZIAŁALNOŚĆ PRODUKCYJNĄ I ICH EFEKTYWNOŚĆ

STRESZCZENIE. **Wstęp:** Zarządzanie magazynem produkcyjnym wymaga nowego podejścia od strony system IT, który może być zautomatyzowany i dzięki temu możliwe jest uzyskanie większej przejrzystości procesów. W czasie badań, przeprowadzono analizę w oparciu o dane z okresu czterech i pół roku dla trzech firm z branży spożywczej. Stwierdzono, ż firmy z tej branży preferują produkcję procesową. Istotne jest, że przedsiębiorstwa produkcyjne zwracają istotną uwagę na właściwe zaprojektowanie automatyzacji, której celem jest utrzymanie przewagi konkurencyjnej poprzez szybka i efektywną produkcję wyrobów. Wzrost zastosowania robotów przemysłowych jest istotny, zwiększając przy tym produktywność, dokładność oraz elastyczność procesów produkcyjnych. Doprowadziło to stworzenie i wdrożenia nowego modelu biznesowego w życie.

Metody: Dwie najlepsze metody planowania projektowego, analizy PERT i CPM, zostały zastosowane dla stworzenie poszczególnych etapów procesu produkcji, które były oceniane w trakcie ich trwania. W trakcie tworzenie wykresu pudełkowego, usunięte zostały dane, mocno odbiegające od większości wyników, uzyskując dzięki temu bardziej dokładne dane statystyczne. Poprzez zastosowanie takiej metody analizy danych, uzyskano większą dokładność w określeniu dat dostawy dla zleceń sprzedaży. Analizując dane z okresu czterech i pół roku przy użyciu testu t-Studenta, stwierdzono, że średnia badanych elementów jest inna od poczynionych estymacji. Metody PERT i CPM są metodami sprawdzonymi i przydatnymi. Zmieniający się model biznesowy i wysoki poziom kosztów mają wpływ na ekonomię.

Wyniki: Czasy produkcyjne poszczególnych przedsiębiorstw są uzależnione od nowoczesnych maszyn oraz dobrze wdrożonego planu produkcyjnego i harmonogramów produkcyjnych. Stosując metody PERT i CPM, możliwe jest lepsze zdefiniowanie czasów produkcji a co jest z tym związane, ułatwia obliczanie wymaganych czasów dostaw. Automatyzacja nie powoduje zaprzestania tych czynności, narzuca jedynie ich przedefiniowanie. Nie ma wątpliwości, że rozwój technologiczny procesów produkcyjnych zmieni organizację przemysłu jak również geograficzną lokalizację poszczególnych czynności. Istnieje duże prawdopodobieństwo, że produkcja tych wyrobów zostanie przesunięta w inną lokalizację w celu obniżki kosztów transportu.

Wnioski: W wyniku przeprowadzonej analizy, stwierdzono, że nowe technologie mają wpływ na produkcyjność, zasoby ludzkie oraz transformację struktury geograficznej aktywności zwiększających wartość dodaną. Ich rola jest istotna zarówno dla przedsiębiorstw z branży spożywczej jak i przedsiębiorstw prowadzących działalność w obrębie innych dziedzin. Automatyzacja jest możliwa dzięki postępowi naukowemu i nowych rozwiązaniom technologicznych, których wdrożenie jest częścią rozwoju technologii Industry 4.0. Duża ilość danych wytwarzanych w inteligentnych systemach produkcyjnych (Big Data) i w oparciu o nie, ciągła modyfikacja procesów produkcyjnych, umożliwia osiągnięcie istotnych oszczędności surowcowych oraz w poziomie zatrudnienia, zwiększeniu efektywności i produktywności, co ma wpływ na poziom zatrudnienia i transformację struktur geograficznych. Produkcja żywności jak i dystrybucja do klientów mają kluczowe znaczenie dla bezpieczeństwa zaopatrzenia w żywność i dlatego istotny jest dalszy rozwój tego sektora.

Słowa kluczowe: tworzenie procesów systemowych, analiza PERT, metoda CPM, automatyzacja, wpływ ekonomiczny

VERGLEICH VON METHODEN FÜR DIE PLANUNG DER PROJEKTE, DIE DEN PRODUKTIONSBETRIEB UND DESSEN EFFEKTIVITÄT VERFIZIEREN

ZUSAMMENFASSUNG. Einleitung: Die Verwaltung eines Produktionslagers erfordert ein neues Herangehen an das IT-System im vollautomatisierten Lager, wodurch eine höhere Transparenz von Prozessen erzielt werden kann. Im Rahmen der betreffenden Forschungen wurde eine Analyse anhand der im Zeitraum von viereinhalb Jahren in drei Firmen der Lebensmittelbranche gewonnenen Daten durchgeführt. Es wurde dabei festgestellt, dass die Firmen aus dieser Branche eine prozessmäßige Produktion bevorzugen. Es sei auch hervorzuheben, dass die Produktionsfirmen einer richtigen Projektierung von Automatisierungsansätzen eine große Achtung schenken. Dessen Ziel ist es, Wettbewerbsvorteile durch eine schnelle und effektive Herstellung von Produkten aufrechtzuerhalten. Es wird ein steigender Einsatz von Industrierobotern beobachtet, wodurch die Produktivität, Präzision und Flexibilität von Produktionsprozessen erhöht werden. Das hatte eine Ausarbeitung und die daraus resultierende Implementierung eines neuen Business-Modells zufolge.

Methoden: Die zwei besten, projektmäßigen Planungsmethoden, dh. die PERT-Analyse und die CPM-Analyse, wurden zur Etablierung der einzelnen Etappen eines Produktionsprozesses, welche dann während der Vorgänge beurteilt wurden, in Anspruch genommen. Während der Bildung einer Kastengrafik (eines Box-Plots) wurden einige, von den meisten Ergebnissen stark abweichenden Daten entfernt, dank dessen mehr genaue statistische Daten ermittelt werden konnten. Dank der Inanspruchnahme einer solchen Methode für die Datenanalyse erzielte man eine bessere Genauigkeit bei Festlegung von Lieferdaten für die Verkaufsaufträge. Bei der Analyse der innerhalb von viereinhalb Jahren anhand des t-Student-Testes gewonnenen Daten stellte man fest, dass der Durchschnittswert der analysierten Elemente anders ist als die betätigten Ästimationen. Die PERT- und CPM-Methoden gelten dabei als zuverlässige und brauchbare Methoden. Das sich verändernde Business-Modell und das hohe Kostenniveau üben einen Einfluss auf die Wirtschaftlichkeit aus.
Ergebnisse: Produktions-Zeitintervalle in den einzelnen Produktionsbetrieben hängen von modernen Maschinen und einem korrekt eingeführten Produktionsplan sowie von einzelnen Zeitplänen innerhalb der Produktion ab. Durch die Anwendung der PERT- und CPM-Methoden ist eine bessere Definierung der Produktions-Zeitintervalle möglich, und was damit zusammenhängt, erleichtern die genannten Methoden die Festlegung der erforderlichen Lieferzeiten. Die Automatisierung verursacht kein Abschaffen dieser Tätigkeiten, sie zwingt lediglich deren Neudefinition auf. Es besteht kein Zweifel darüber, dass die technologische Entwicklung innerhalb der Produktionsprozesse eine Neuorganisation der Industrie und eine neue geografische Verortung der einzelnen Aktivitäten mit sich bringen wird. Es ist daher höchstwahrscheinlich, dass die Herstellung gewisser Produkte zwecks einer Kostenminimalisierung woanders hin verlegt werden wird.
Fazit: Infolge der durchgeführten Analyse wurde festgestellt, dass neue Technologien die Produktivität, Personalressourcen und die Transformation der geografischen Verortung von Aktivitäten, die die Wertschöpfung zu erhöhen vermögen, positiv beeinflussen. Deren Rolle scheint nicht nur für die Unternehmen von der Lebensmittelbranche, sondern auch für die auf anderen Gebieten tätigen Firmen relevant zu sein. Die Automatisierung ist dank des wissenschaftlichen Fortschritts und neuer technologischer Lösungen, deren Einführung ein Teil der Entwicklung der Technologie Industry 4.0 ist, möglich. Eine Vielzahl der innerhalb von intelligenten Produktionssystemen (Big Data) generierten Daten und die ständige Modifizierung von Produktionsprozessen ermöglichen die Erzielung wesentlicher Einsparungen von Rohstoffen und Personalressourcen, sowie die Erhöhung der Effizienz und der Produktivität, was auch das Beschäftigungsniveau und die Transformation von geografischen Strukturen mit beeinflusst. Die Herstellung von Lebensmitteln und deren Verteilung unter die Marktkunden spielen eine schlüsselhafte Rolle bei der zuverlässigen Lebensmittelversorgung. Daher scheint die weitere Entwicklung dieses Sektors für die soziale Sicherheit äußerst wichtig zu sein..

Codewörter: Generierung von Systemprozessen, PERT-Analyse, CPM-Methode, Automatisierung, wirtschaftlicher Einfluss

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