APPLYING THE CORRELATION THEORY IN DETERMINING THE INTERDEPENDENCE BETWEEN INSIDE TRANSPORTATION COST AND AUTOMATION LEVEL OF PRODUCTION EQUIPMENT

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Abstract: By analyzing the operation of transport system it was concluded that certain dependence exists between the inside transport and the automation level of production equipment being superintended by observed transport device. The results obtained in one our metalworking factory, in which were analyzed parameters of transport systems in dependence on automation level of production equipment were presented in the work. The obtained results show the existence of certain dependence between certain parameters of inside transport and automation level of production equipment but only in this part where automation is founded on joining of certain production operations. Applying the correlation theory defines the interdependence of the automation level of production equipment and inside transport costs.
Key words: *inside transport, automation level, production equipment, queuing theory, Correlation theory*

ОПРЕДЕЛЯНЕ НА ЗАВИСИМОСТТА МЕЖДУ РАЗХОДИТЕ ЗА ВЪТРЕШЕН ТРАНСПОРТ В ПРОИЗВОДСТВЕНО ПРЕДПРИЯТИЕ И СТЕПЕНТА НА АВТОМАТИЗАЦИЯ НА ОБОРУДВАНЕТО ЗА ПРОИЗВОДСТВО, ЧРЕЗ ТЕОРИЯ НА СЪОТВЕТСТВИЕТО.

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Резюме: Чрез анализ на дейността на заводска транспортна система, е установена зависимост между вътрешния транспорт и нивото на автоматизация на производственото оборудване. В работата са представени резултатите от направения с помощта на теорията на съответствието анализ в едно металообработващо предприятие. Получените резултати показват наличието на зависимост между определени параметри на вътрешнозаводския транспорт и степента на автоматизация на производственото оборудване. Прилагането на теорията съответствието определя взаимната зависимост на нивото на автоматизация на производственото оборудване и разходите за вътрешен транспорт.
Ключови думи: вътрешно заводски транспорт, ниво на автоматизация, производство на оборудване, корелационна теория

I. INTRODUCTION

Automation level of the production equipment and inside transport are two variable values, which are very often met in the production practice and even the economy of the production process very often depends on their correct defining. Starting from the hypothesis that between the automation level of the production equipment and inside transport exist one relation it is necessary to be determined the shape and direction of their correlation as well as the strength of their interdependence. It is of the great practical importance to be determined an analytic connection between automation level of the production equipment and inside transport so that the values of one characteristic can be evaluated on the base of another characteristic. By applying the correlation theory it is possible to determine a desired link between the automation level of production equipment and inside transport.

II. SOME PREVIOUS EXPERIENCE

Optimization of the automation level is an interesting question for everyone who is in industrial engineering, projecting of production and transportation systems, selection and optimization of production and transportation equipment or production economics. Optimization of production equipment as a function of internal transport is a narrower field. Here the problem of optimization automation level of production equipment is analyzed regarding inside transport and the path of material in the production process.

The automation level of production equipment and the influence which the level of automation of production equipment has on the production process has been reviewed in the following papers of [1], [2], [3]

Professor Groover [2] divides production equipment into ten levels:

1. Specialization of operations,

2. Combined operations,
3. Simultaneous operations,
4. Integration of operations,
5. Increase flexibility,
6. Improved material handling and storage,
7. On-line inspection,
8. Process control and optimization
9. Plant operations control,
10. Computer- integrated manufacturing.

Professor Bright [3] divides production equipment into 17 levels:

1. Hand.
2. Hand tool.
3. Powered hand tool.
4. Power tool, hand control.
5. Power tool, fixed cycle (single function).
6. Power tool, program control (functions sequence).
7. Power tool, system, remote controlled.
8. Actuated by introduction of work-piece or material.
9. Measures characteristic of work.
10. Signals preselected values of measurement (including error detection).
11. Records performance.
12. Changes speed, position, direction according to measurement signal.
13. Segregates or rejects according to measurement.
14. Identifies and selects appropriate set of actions.
15. Corrects performance after operating.
16. Corrects performance while operating.
17. Anticipates action required and adjusts to provide it.

Professor Bright commented upon the validity of his mechanization levels in the following way:

"These levels cannot be defended too vigorously. Examples can be cited that would somehow confound this classification. Whether one level is truly mechanically "higher" than another is, perhaps, open to argument. Obviously, the moves from one level to the next are not equally important, useful, technically difficult, or economically valuable. Their importance varies from plant to plant, and industry too industry. Doubtless, additional subdivisions could be defined, and one might argue for levels.

Some of these levels are occasionally entangled with much lower levels. The recording of performance, for instance, often can be found on Level 3. Frequently, machines on Level 5 or 6 employ higher levels for part of their operation. So this system of levels should not be considered as a completely rigorous classification. However, it does explain degrees of mechanical maturity. It attempts to lend order and understanding to the increasing refinement in the performance of more highly automatic machinery." [3]

When the objectives in matters of system productivity are achieved, the next objective is of financial nature. That is primarily achieved through replacement of equipment with cheaper equipment. That leads to a compromise between price and production performance without decrease in demanded productivity of equipment [4]. Costs as the criteria for selection of CNC machines of different levels, is also reviewed in [5].

III. AUTOMATIZATION LEVEL OF THE PRODUCTION EQUIPMENT

Automation of the production equipment i.e. of production system has the task:

- to reduce physical effort of a man,
- to increase productivity,
- to increase product quality,
- to increase economical efficiency.

As a measure of automation for production equipment-machine, production process i.e. production system most frequently is used one measure named: level of automation. The automation level represents the relation of the number of automated functions to total number of functions and can be determined by means of the formula [6], [7], [8], [9]:

$$A^0 = A_f / A_u \quad (1)$$

where:

A° - automation level,

A^f - number of automated functions,

A_u - total number of functions.

Since nowadays is present a great number of different production equipment having available quite considerable variety of construction and technological characteristics it is therefore very difficult to make comparisons between them. In order to determine the number of automated functions and their comparing the sorting of their single characteristics can be done in different ways. One of them, neither the only one nor the final, is as the following [10], [11]:

1. Type of the equipment drive: manual, mechanical.
2. Method of managing the machine cycle: manual, manual-mechanical, automated, numerical controlled, adaptive control, computer aided.
3. Way of workpiece changing: manual, manual-mechanical, automated, without human assistance.
4. Way of clamping for workpiece: manual, manual-mechanical, automated, without human assistance.
5. Number of working axes: one, two, three, four ($4x90^o$), four ($360x1^o$), more than four.
6. Way of checking for machine piece: manual, manual-mechanical, automated, without human assistance.
7. Way of cutting tool change: manual, automated.
8. Way of adjustment and correction for tool in relation to machine: manual, by pattern, automatic adjustment and correction.
9. Sawdust removal: manual, manual-mechanical, automated.
10. Number of working spindles: one spindle, two spindles, more than two spindles.
11. Transport of workpiece from machine to machine: manual, manual-mechanical, automated, without human assistance.

By using of listed eleven criterions with forty one parameter it can be estimated the level of automation for production equipment. The automation level of one machining system, which means automation level of the production equipment, is determined by the following function: [9]

$A^0 = f(K_1 - K_{11}; P_1 - P_{42})$ (2)

The minimal automation level refers to the production equipment with manual machining and the maximum automation level to the computer integrated production equipment with automatic designing of product, technology and planning (CIM).

Based on such classified characteristics of the production equipment it can be made the evaluation of the automation of their functions and, at extreme case, it can be determined even the automation level of the production equipment. [12], [13]

The automation level is one relative measure of the automation which shows the development phase of managing information to which all changes are automated. For example: the automation level would be as follows: for a radial drill 0,12 for a radial drill with a circular table 0,15, for a horizontal drilling and milling machine 0,17, for a machining centre 0,48.

IV. INTERNAL TRANSPORT

When planning and projecting internal transport a care must be taken to an influence which transport has on designing of production/technological process and their interdependence. It is impossible to be projected any system of internal transport without simultaneous project of the production technological process or vice versa, it is impossible to be projected one technological process and made a choice for some technological equipment, determined the optimal level of its automation without simultaneous project of the internal transport. [14]

When selecting production and transportation equipment there should be saved as much time and money as possible, the same tame decrease the amortization period, increase profit and productivity, and decrease maintenance and exploitation cost. Factors that affect working costs of production or transportation equipment are numerous. To make the right choice, it is necessary to make detailed analysis of all the relevant factors, which build the exploitation price of the selected production and transportation equipment.

The basic structure of costs of production and transportation equipment (invested equipment) is as follows:

1. Working equipment costs,
   1.1 cost of amortization,
   1.2 maintenance costs,
   1.3 cost of tools and accessories,

2. Energy costs,
   2.1 costs of fuel and energy used,
   2.2 cost of lubricants etc,
3. Costs of foreign services,
4. Costs of interest rates and assurance,
5. Cost of labourers,
6. Cost of working space.

Analyzing a transport system which attends all requests connected to the production equipment appeared during the time and according to the FIFO principle (the first request for attendance first arrived and attended at first). Any machine tool (production equipment) can send a request for attendance at any time *t* and the number of requests which can be released will be endless. Let us assume that the intensity of an attendance request is λ and the intensity of attendance is μ. When an attendance request is sent by some production equipment one transport device (there are S transport devices) will proceed, if free, to the attendance [15], [16], [17].

Analyzing the exploitation costs for particular types of transportation equipment, which is a function of the intensity of demand for manipulating lambda and the length of the transport way L = 200 m we get results which are shown in Figs 1-4.

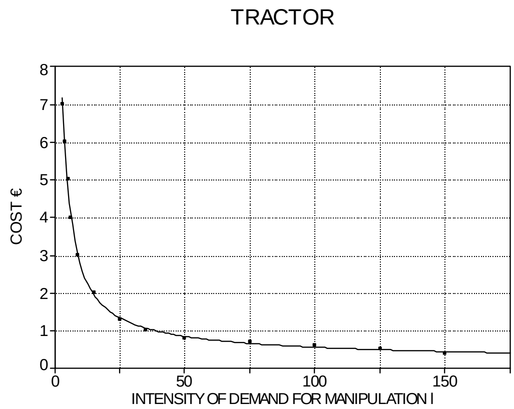

Fig. 1: Exploitation cost of a tractor as a function of intensity of demand for manipulation

The relation between the transportation costs of a tractor and the intensity of demand for manipulation λ can be approximated by the following equation:

$T = a + b L + cL^2 \ln L + d \ln L + f / L^2$ (3)

where:

$a = 5.7646$; $b = 0.03577$; $c = -2.03398e^{-05}$; $d = -1.7$; $f = 56.7978$

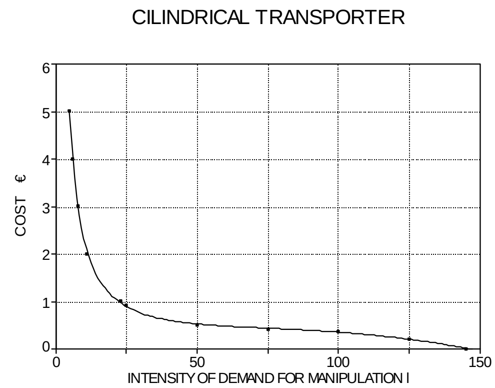

Fig. 2: Exploitation cost of a cylindrical transporter as a function of intensity of demand for manipulation

The relation between the transportation costs of a cylindrical transporter and the intensity of demand for manipulation λ can be approximated by the following equation:

$T = a + b L + cL^3 + d / L^{0.5} + f \ln L / L$ (4)

where:

$a = -3.1945$; $b = 0.01777$; $c = -4.07775e^{-07}$; $d = 29.3766$; $f = -17.21088$

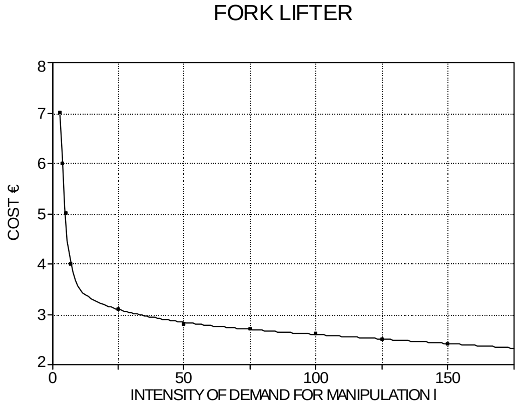

Fig. 3: Exploitation cost of a fork lifter as a function of intensity of demand for manipulation

The relation between the transportation costs of a fork lifter and the intensity of demand for manipulation λ can be approximated by the following equation:

$$T = a + b\,L + cL/\ln L + d/L^{0,5} + f\,e^{-L} \quad (5)$$

where:

a = 1.1563; b = -0.02647; c = 0.1563;
d = 6.66103; f = 146.215

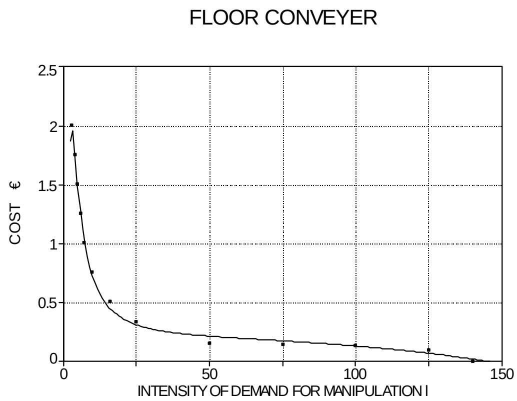

Fig. 4: Exploitation cost of a floor conveyer as a function of intensity of demand for manipulation

The relation between the transportation costs of a floor conveyer and the intensity of demand for manipulation λ can be approximated by the following equation:

$$T = a + b\,L + cL^{2,5} + dL^{0,5}\ln L + f/L^{1,5}, \quad (6)$$

where:

a = 0.8529; b = 0.05376; c = -6.0348e-06;
d = -0.1193; f = 7.4646

V. THE INSIDE TRANSPORT COST AS A FUNCTION AUTOMATIZATION LEVEL OF PRODUCTION EQUIPMENT

We have conducted an analysis of 41 technologies, divided into 5 groups (group technology). Reviewed were the inside transport cost (electric fork lifter) as a function of the automation level of production equipment which this transport is supplying. The cost is shown by working time; the results are shown in table 1.

Table 1: Average value of inside transportation cost as a function of automation level of production equipment

No. of technologies	Automation level of production equipment			
	0,12	0,15	0,17	0,48
1	2,436	0,812	0,609	0,609
8	0,609	0,203	0.150	0.150
9	1,218	0,406	0,3045	0,304
10	0,815	0,27	0,203	0,203
13	1,05	0,35	0,260	0,260
Σ 41	1,017	0.3386	0,2529	0,252
Average value of inside transportation cost as a function of automation level of production equipment is calculated with the following formula: $T_{SR} = \Sigma\, T_i\, n_i \,/\, \Sigma\, n_i$ (€ / part)				

The diagram in Fig. 5 shows the relation between the automation level and the inside transportation costs.

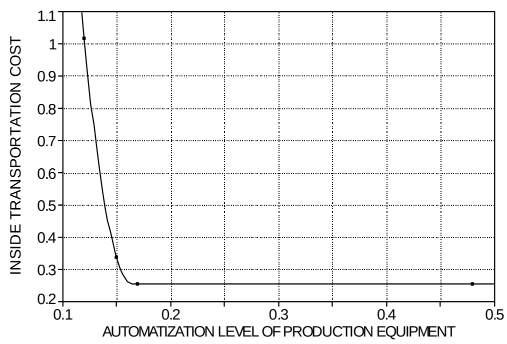

Fig. 5: Diagram of the relation between the automation level and the inside transportation costs.

The diagram shows that the resulting characteristic, the points on the diagram are approximately exponential and can be approximated with the following equation:

$$y = ab^x \quad (7)$$

it is necessary to determine the coefficients a and b so that the sum of quadratic deviations stays on a minimum. If we write down the previous equation in the following form:

$$\log y = \log a + x \log b \quad (8)$$

and introduce the following replacements:

$$a_0 = \frac{(\Sigma y_i)(\Sigma x_i^2) - (\Sigma x_i)(\Sigma x_i y_i)}{n x_i^2 - (\Sigma x_i)^2},$$

$\log y = Y$; $\log a = a_0$;
$\log b = a_1$; $x = X$

we get a linear equation as follows:

$$Y = a_0 + a_1 X \quad (9)$$

coefficient a_0 is:

$$a_0 = \frac{(-1.6047)(0.2928) - (0.92)(-0.44609)}{4(0.2928) - (0.92)^2}$$

$a_0 = - 0.183$ (10)

coefficient a_1 is:

$$a_1 = \frac{n(\sum x_i y_i) - (\sum x_i)(\sum y_i)}{n \sum x_i^2 - (\sum x_i)^2},$$

$$a_1 = \frac{4(-0.44609) - (0.92)(-1.6047)}{4(0.2928) - (0.92)^2},$$

$a_1 = - 0.948$ (11)

we get a linear relation:

$Y = - 0.183 – 0.948 X$ (12)

Because it is:

$a_0 = - 0.183 = \log a$

it implies that
$a = 10^{-0.183} = 0.656$
$a_1 = - 0.948 = \log b$

it implies that
$b = 10^{-0.948} = 0.113$

Therefore the form of relation between automation level of production equipment and the cost of inside transportation can be described as follows:

$Y = 0.656 \cdot 0.113^X$ (13)

To determine the correlation level of the automation level of production equipment and the inside transportation cost, it is necessary to determine the correlation coefficient.

So we get the following result for the correlation coefficient:

$$r = \sqrt{\frac{(\sum(x_i - x^s)(y_i - y^s))^2}{\sum(x_i - x^s)^2 \sum(y_i - y^s)^2}} = \frac{\sum X_i Y_i}{\sqrt{(\sum X_i^2)(\sum Y_i^2)}}$$

$$r = \frac{-0.0909}{\sqrt{(0.0846)(0.4106)}}$$

$r = - 0.487$ (14)

The resulting correlation between automation level of production equipment and inside transportation costs is a result of a calculation for the combine factory "Zmaj«, and it verifies the hypothesis that there is a relation between automation level of production equipment and inside transportation.

If we test the correlation level, to determine how sure we can be when saying that the correlation level between automation level of production equipment and inside transportation cost is a function of the correlation coefficient.

If we make a basic hypothesis:

N_0 ($\varphi_0 = 0.58$),

that the inside transportation cost is a function of the automation level of production equipment and an alternative hypothesis:

N_1 ($\varphi > 0.58$)

When we use the hypothesis ($\varphi = \varphi_0 \neq 0$) for $n^3 \geq 30$ specimens, we can use the Fisher transformation:

$z = 0.5 \ln [(1+r) / (1-r)]$ (15)

this has approximately a normal distribution:

$N (0.5 \ln [(1+\varphi_0)/ (1-\varphi_0)] ; 1/ (n-3)^{1/2})$ (16)

If we change from natural to common logarithm ($1/2 \ln a = 1.1513 \log a$) the z has a normal distribution:

$N (1.1513 \log [(1+\varphi_0)/ (1-\varphi_0)]$ (17)

and we get that:
$z = 1.1513 \log [(1+r)/ (1-r)]$
$z = 1.1513 \log [(1+0.437)/ (1-0.437)]$
$z = 0.3567$ (18)

$\mu_z = 1.1513 \log [(1+\varphi)/ (1- \varphi)]$
$\mu_z = 1.1513 \log [(1+0.58)/ (1-0.58)]$
$\mu_z = 0.6625$ (19)

$\sigma_z = 1/ (n-3)^{1/2} = 1/ (41-3)^{1/2} = 0.162$ (20)

because:
$|t| < t_{0.05}$ (21)

and
$1.88745 < t_{0.05} = 1.96$ (22)

so we can accept with a 95 % probability the basic hypothesis.
For $\varphi = 0.59$ we get:
$z = 0.3567$,
$\mu_z = 0.6777$,
$\sigma_z = 0.162$,
$t = -1.9816$
and:
$1.9816 > t_{0.05} = 1.96$ (23)

We can be 95 % sure that there exists some relation between inside transportation cost and automation level of production equipment.

VI. CONCLUSION

From the described research, in using modern methods in projecting production and transportation systems we can see that there exists a certain degree of relation between inside transportation and automation level of production equipment and that this correlation is not a strong one. The correlation shows in the part where the automation level is based on the aggregation of single production operations. Where the automation level is a result of the automation of control operations this correlation is very weak. By defining this correlation we make possible a more economical choice of technological operations and the choice of an optimum automation level of production equipment.

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LIST OF USED SIGNS:

A°	- automation level,
A^{f}	- number of automated functions,
A_{u}	- total number of functions,
λ	- arrival rate,
μ	- service rate,
ρ	- offered load by server,
r	- correlation coefficient,
φ	- linear correlation coefficient,
μ_z ; σ_z	- normal distribution,
z	- Fisher transformation,
n	- size specimen

Recommended for publication of Editorial board

ГОДИШНИК на Минно-геоложкия университет "Св. Иван Рилски", Том 54, Св.III, Механизация, електрификация и автоматизация на мините, 2011
ANNUAL of the University of Mining and Geology "St. Ivan Rilski", Vol. 54, Part III, Mechanization, electrification and automation in mines, 2011

МНОГОЦЕЛЕВА ОПТИМИЗАЦИЯ НА ПРОЦЕСА СМИЛАНЕ В БАРАБАННА ТОПКОВА МЕЛНИЦА ПО ОБОБЩЕНА ФУНКЦИЯ НА ПОЛЕЗНОСТ

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РЕЗЮМЕ. Работата представя продължение на изследването на барабанни топкови мелници. На базата на проведен пасивен факторен експеримент в обогатителна фабрика за медни руди и на получени три целеви функции е избрана обобщена функция на полезност. Резултатите от експеримента са подложени на статистически анализ посредством програмата Statgraphics. Получен е адекватен модел на обобщената функция на полезност. Намерени са оптималните стойности на управляващите фактори, действащи на процеса смилане и графично е показано тяхното влиянието върху стойностите на обобщената функция на полезност.

MULTIPURPOSE OPTIMIZATION OF THE PROCESS OF GRINDING IN A DRUM BALL MILL SUMMARIZED IN THE UTILITY FUNCTION

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ABSTRACT. The work presents prolongation of drum ball mills examination. A summary function of utility is selected on the base of conducted passive factor experiment in a concentration plant, processing copper ore, and the three obtained functions. The results of the experiment are subjected to statistical analysis using the program Statgraphics. An adequate model of the summary function of utility is received. Optimal values of the governing factors are found and their influence on the summary function of the utility is graphically shown. The most important practical conclusions are systematized.

1. **Теоретична постановка**

Качеството на функциониране на един обект или система е комплексен показател, съставен от множество целеви параметри /1/. Всеки от тях има определено значение, но не е достатъчен за оптимално управление на обекта. Оптималните стойности на различните целеви параметри обикновено се получават при различни стойности на множество управляващи параметри, а оптимизацията само по един критерий не винаги е най-доброто решение. В действителност реалните технологични оптимизационни задачи винаги са многоцелеви.

Някои от многоцелевите задачи могат да се сведат до един основен параметър, а останалите да играят ролята на областни ограничения. Такова разделяне обаче не винаги е възможно.

Множеството целеви параметри

$$Q(x) = [Q_1(x), Q_2(x).....Q_m(x)] \quad (1.1)$$

носи названието векторен критерий. Оптимизационната задача при векторен критерий изисква намирането на x^*, при който множеството целеви параметри $Q_j(x), j = 1, 2,....m$ ще удовлетвори комплекс от компромисни изисквания.

Съществуват различни концепции за решаване на оптимизационните задачи с няколко критерия за оптималност.

Предложените методи могат да се разделят главно на две групи:

1.Методи за намиране на множеството Парето-оптимални решения (множество на неподобряващи се точки).

2.Методи на скаларизацията и компромисните решения.

В задачите за векторна оптимизация се е наложила концепцията за Парето-оптималност съгласно принципа, предложен от Парето /1/. Парето-оптималното управление е такова, че всяко отклонение от него води до влошаване