INFLUENCE OF TASK ENVIRONMENT ON EFFICIENCY OF MATERIAL FLOW IN COMPANIES WITH DIFFERENT LEVEL OF INTEGRATION OF PLANNING PROCESSES

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Abstract

Efficiency of processes determines the success of companies competing in contemporary market. The efficiency of production companies are heavily dependent on the efficiency of material flow. This is mostly due to high the cost -manufacturing processes. The efficiency of material flow depends on many factors. One of key factor is the task environment of company.

The authors focused their research around the integration of planning processes in companies. They noted that companies with integrated planning processes are less dependent to changes in the task environment. Continuing with this topic, authors have developed two models: model of integration planning processes in manufacturing companies and model of material flow.

The aim of the paper is to verify the following research hypothesis: the efficiency of material flow in companies with integrated planning process is less dependent on the volatility of the task environment.

The article presents the results of simulation conducted in the software iGrafx Process for SixSigma. In the simulation experiment reflects the volatility of the task environment and planning processes at different levels of integration. The conducted experiments allowed to collect the results on the efficiency of material flow. The authors measure the efficiency of material flow in many dimensions: as operational efficiency (measured by customer service level indicator) and financial (measured by profitability indicator).

The results were statistically analysed. Authors examined the correlation between the efficiency of material flow and the volatility of the task environment in conditions of different levels of integration of planning process. The research hypothesis was verified statistically with using an ANOVA method.

Key words: planning processes integration, task environment, material flow efficiency

1. INTRODUCTION

Globalisation is related to customers' increasing requirements and this causes that it is more difficult to maintain a competitive position. The competitive position maintenance is possible due to the efficiency improvement of operational processes. Not only the mere companies but also entire supply chains compete with each other at the market. Production companies in the supply chains conduct their operational activity combined with numerous procurement and sales partners. This causes a necessity to function in the conditions of high uncertainty and changing input data. The planning processes in production companies aim at decreasing the environment change influence (task environment in particular) on the material flow efficiency.

The aim of the paper is to present an influence of integration of planning processes on efficiency of material flow in companies in conditions of volatility of the task environment. Authors of the paper use ANOVA statistical method to verify hypothesis: the efficiency of material flow in companies with integrated planning process is less dependent on the volatility of the task environment.

2. THEORETICAL BACKGROUND

2.1. Integration of planning processes

Based on the concept valid in contemporary literature references it is possible to state that the process integration makes it feasible to enhance its efficiency (Cyplik et al., 2014, p. 4468; Danese et al., 2013, p.127; Hadas et al., 2015, p.228; Pagell, 2004, p.459; Seo et al., 2014, p.740). One of the possible planning process integration tools is sales and operations planning (SOP). There are many definitions of SOP. According to Muzumdar and Fontanella SOP is a set of business and technological processes that make it possible for a company to correlate the market demand with the manufacturing and procurement potential of the company in the possibly most efficient way (Muzumdar & Fontanella, 2007, p.36). The presented definition clearly indicates the SOP relationship with the company environment. The SOP influence on the efficiency of company (and material flow as an integral element of production companies) was indicated. The most complete SOP definition is presented in the APICS dictionary (Blackstone, 2010, p.123). In this book SOP is defined as a tactical planning tool that enables connection of customers' needs with the supply chain possibilities in the medium term. Such an SOP interpretation is perceived in numerous works. In their work Tuomikangas i Kaipia (2014, p.257) describe SOP as a key business tool that makes it possible to obtain balance between the customers' orders and the supply chain possibilities. The confirmation of these observations might be found in the publication (Collin & Lorenzin, 2006, p.424), in which their authors present a solution in which integrated planning influences an increase in the supply chain elasticity O'Leary-Kelly S.W. and Flores, B.E.. (2002, p.238) performed research related to the integration level within decision-making processes by sales and production functions. According to the research results, the integration level increase influences the production enterprise efficiency improvement.

2.2. Task environment

Environment of the organization is generally defined as: all what is external to it, beyond its boundaries and what has influence on it. Due to Hatch (1994, p.54), organization's environment can be divided into two groups: general environment and task environment. In this paper only task environment will be considered. Organisation's task environment consists of the specific customers, suppliers, financiers and other entities with which it must interact to grow and survive (Castrogiovanni, 1991, p.557). The task environment may include a companies competitors, customers, suppliers, strategic partners and regulators (Scott & Lane, 2000, p.52). Task environment has a strong relations with companies and especially with its production-logistics system (Adamczak et al. 2016, p.670). The environment changeability (and task environment in particular) is largely implied by the globalisation phenomenon and economy networking (Castells, 2009, p.17).

A chaos in the environment is caused by strong dependencies between entities located in various globe parts. Lorenz (1963, p.137) described the chaos behaviour mechanisms for the sake of management named it as a „butterfly effect " that relies on making large changes by seemingly trifling causes.

3. RESEARCH MODEL

One might distinguish three fundamental parts in the developed research model:
- model of the planning process integration in production enterprises,
- model of operational processes executed by production enterprises,
- model of task environment.

The most significant element of the developed research model is the model of integrating planning processes in production enterprises. The model was formed based on the results of literature research and the empirical research performed among 149 production enterprises in the territory of Poland. A detailed description of the results of the research on the planning process integration in the active production enterprises in the territory of Poland is presented in Adamczak et al. (2013, pp.12-59). Table 1 includes a qualitative description of the planning process integration levels which is developed for the sake of the research model.

Table 1. Description of planning process integration levels

Planning process integration level	Characteristics of level
D	No planning process integration, production plan developed adaptively to the sales plan, available resources at a constant level in the process duration based on standards specified in the past, no financial plan and marketing actions included in the plan.

C	Corrective procedures implemented in the area of the sales and production planning and in the area of production and procurement. The objective of the procedures is to select the most appropriate solution to executing the proposed sales plan in terms of the planned profit and return on sales by the financial plan simulation, available resources specified at a constant level in the process duration based on standards specified in the past, no marketing actions included in the plan.
B	Corrective actions as at level C with the financial plan, available resources specified based on real data about repairs and/or developing the resources as a result of the conducted investment actions, no marketing actions included in the plan.
A	All the actions conducted as at level B without the marketing plan. At integration level A the marketing plan is formed based on real data (plan promotional campaigns, extending and enlarging market areas, product portfolios, etc.). The plan is included in the planning process structures and therefore influences the material flow plan which is under construction.

Source: own study

In model of operational processes executed by production company one modelled basic material flow processes in production company. In this regard one used the SCOR supply chain referential model in version 12 (material flow was modeled with use of 5 types of processes: plan, source, make, deliver, return). The material flow processes are planned according to the procedures which were developed based on the defined planning process integration levels (table 1). The material flow performance lasts one year (material flow on every work day, planning processes once a month).

In model of task environment 3 factors were distinguished. Each of the factors is related to demand. In the planning model one specifies the demand as forecasted for each of 12 months included in the plan. The forecast for consecutive months is implied by 3 parameters: constant quantity (adopted in the model and referred to the capacity of production system) seasonality of demand and trend of demand.

The seasonality of demand was modelled in two steps. In the first step one specified a seasonality strength (Ss) was calculated according to the formula:

$$Ss = \frac{D_{S_{m_{max}}} - \overline{D}}{\overline{D}}$$

where:

$D_{S_{m_{max}}}$ – sales forecast in the month with the highest sales volume

$\overline{D}$ – average forecast for the entire year

Seasonality strength (Ss) was specified as simulation scenario parameter and underwent changes in the consecutive simulations. In the next step one modelled the seasonality phenomenon throughout the entire year according to the formula:

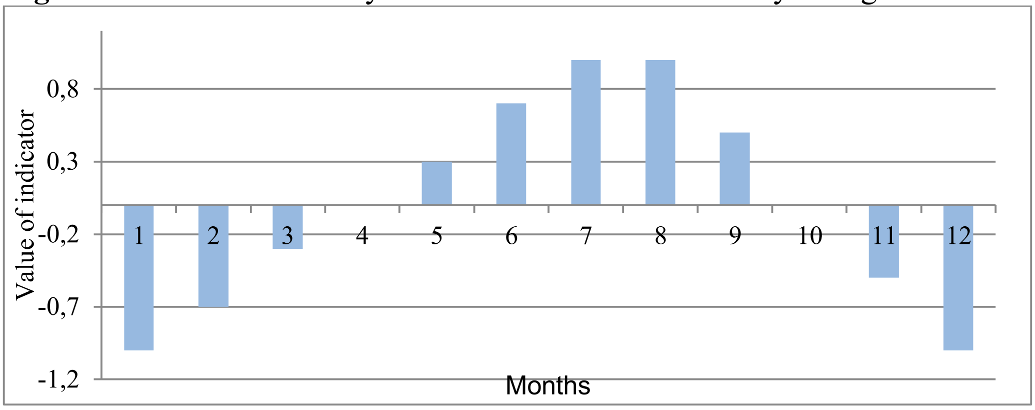
$$D_{S_m} = Ss \cdot Sc_m$$

where:

D_{S_m}- additional demand caused by seasonality of the demand
Sc_m- seasonality coefficient to m-month

The monthly coefficient values of the seasonality strength are presented in Figure 1.

Figure 1. Values of monthly coefficients for the seasonality strength



Source: own study

In order to keep the conditions (equal demand sum) unchanged in the case of all experiments independent of the seasonality strength the sum of the values of the coefficients for the entire year equals 0.

The trend of demand and the seasonality of demand were modelled at 2 stages. At the first stage one specified the trend strength (Ts) was calculated according to the formula:

$$Ts = \frac{D_{T_{ml}} - \bar{D}}{\bar{D}}$$

where:
$D_{T_{ml}}$ – last-month sales forecast (in the planning horizon)
$\bar{D}$ – average forecast for the entire year

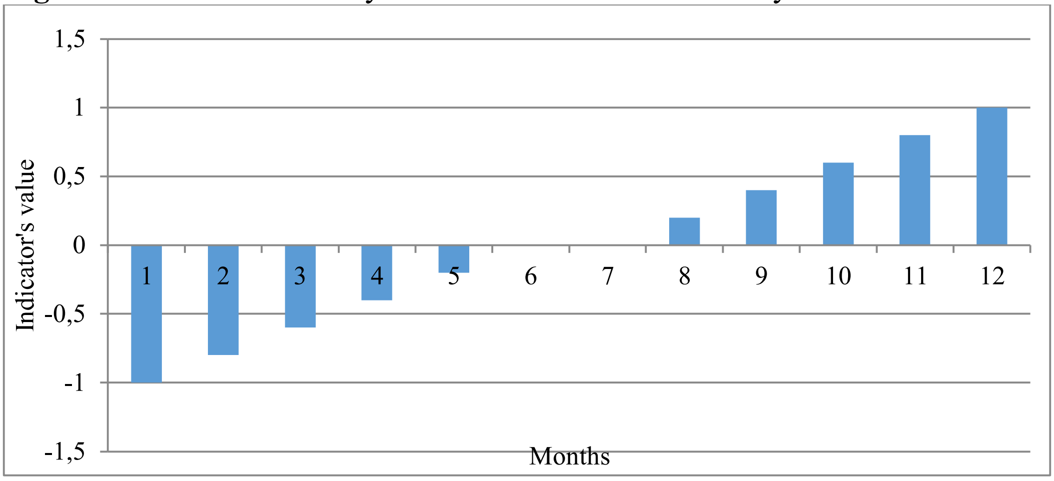
Trend strength (Ts) was specified as a simulation scenario parameter and underwent changes in the consecutive simulations. At the next stage one modelled the demand trend phenomenon throughout the entire year according to the formula:

$$D_{T_m} = Ts \cdot Tc_m$$

where:
D_{T_m}- additional demand caused by trend of the demand
Tc_m- trend coefficient to m-month

The monthly coefficient values of the seasonality strength are presented in Figure 2.

Figure 2. Values of monthly coefficients for the seasonality trend



Source: own study

In order to keep the conditions (equal demand sum) unchanged in the case of all experiments independent of the trend strength the sum of the values of the coefficients for the entire year equals 0.

The real demand, which will appear this month, is implied by the forecasted demand (calculated based on the parameters as described above) and the forecasting error. The real monthly demand (laid out to consecutive work days of the month) is specified by means of normal distribution (authors assume that simulation was conducted in the terms of MTS model - to fast rotation items). The distribution parameters are: monthly (average) forecast, monthly forecast multiplied by the demand fluctuations (standard deviation) parameter. The demand fluctuations were specified as a simulation scenario parameter and underwent changes in the consecutive simulations. It is required by the drawing in accordance with the normal distribution to perform simulations in numerous iterations.

Each of the 3 scenario parameters, which determined the task environment changeability, occurred in the simulation experiment in 3 states: 1-L – low changeability, 2-M – medium changeability, 3-H – high changeability. In table 2 there are numerical values of the parameters that correspond to each of the defined states:

Table 2. Values of changeability parameters in the case of selected factors of task environment

State of task environment factor	Demand fluctuation	Trend of demand	Seasonality of demand
1-L	0.10	0.00	0.00
2-M	0.20	0.15	0.15
3-H	0.30	0.30	0.30

Source: own study

Efficiency of a material flow in manufacturing company will in this article be interpreted as a sum of two factors (Clermont, 2016, p.1358; Frankowska & Jedliński, 2011, p.78):

- effectiveness of action – ability to achieve set goals;
- efficiency of action – an optimal use of owned resources (may be related to the rationality of management, economy or profitability).

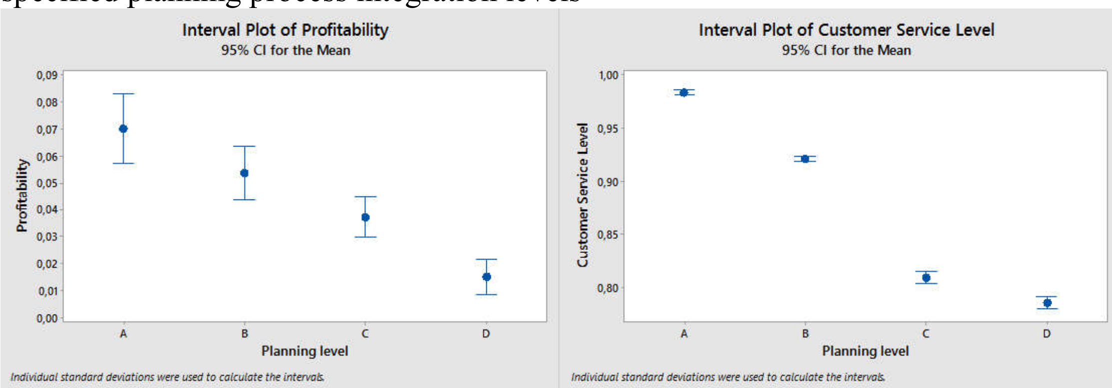
Two factors presented above could be treated as a special economic efficiency cases. The economic efficiency might be specified as a result of a business entity's activity. It is a result of the relation between the obtained effects and the borne costs (Farrell, 1957, p.268). The most frequently used economic efficiency measures are: logistic cost level, general cost level, profit and sales profitability. The measures might be found in the work by Hahn and Kuhn (2011, p.518). The operational efficiency is most frequently expressed by means of such measures as customer service level, delivery time, prognosis accuracy, inventory level. These measures were applied by Kolinski and Śliwczynski (2015a, p.215), Kolinski and Śliwczynski (2015b, p.178); Koliński el al. (2016, p.135) and Sodhi and Tang (2011, p.529).

4. ANALYSIS OF RESULTS

4 factors are considered in the simulation experiment. According to the presented model the factors could occur in 3 states (3 factors reflecting the task environment changeability) and 4 states (factor reflecting the planning process integration level). The simulation was performed in 10 iterations due to the necessity to eliminate the random factor influence within the simulation results. Thereby, 1080 ($3^3 \cdot 4 \cdot 10$) simulations were performed in the experiment. According to the adopted efficiency interpretation (chapter 3) the following measure values were analysed: profitability and customer service level. More details about simulation model are described in one of the previous paper of the authors (Adamczak et al. 2014).

In the first place it was checked whether the model reflected the adopted solution: the higher planning process integration level causes an increase in the material flow efficiency. The indicator values in the case of particular planning process integration levels are presented in Figure 3.

Figure 3. Profitability and customer service level indicator values in the case of the specified planning process integration levels



Source: own study

The planning process integration has a positive impact on the material flow efficiency indicator values. As implied by the charts presented in Figure 3, the profitability and customer service level indicator values are higher in the case of higher planning process integration levels (value of indicators: profitability and customer service level is the highest in conditions of A level of integration of planning processes). Once the model assumptions were confirmed by the result analysis the authors moved on to the stage of verifying the research hypothesis: the efficiency of material flow in companies with integrated planning process is less dependent on the volatility of the task environment This hypothesis verification was performed by means of 2 methods: the quotient and regression one.

In the quotient method the obtained results were divided into 4 subsets that reflected each of the planning process integration levels. As to each subset and each parameter reflecting the task environment changeability, one calculated a ratio of the indicator values in 2 consecutive parameter states. The ratio calculation formula is as follows:

$$quot. = \frac{value_{ls} - value_{hs}}{|value_{ls}|}$$

where

$value_{ls}$ -indicator value with the lower state of the parameter reflecting the task environment changeability

$value_{hs}$ -indicator value with the higher state of the parameter reflecting the task environment changeability

The values of ratios at each planning integration level are presented in tables 3-6.

Table 3. Coefficient value quotients in the case of neighbouring task environment parameter states at planning process integration level A

Parameter state	Seasonality of demand		Trend of demand		Demand fluctuations	
	Prof.	CSL	Prof.	CSL	Prof.	CSL
L-M	1.7668	0.0000	0.8480	0.0098	-0.3122	-0.0020
M-H	2.5551	0.0000	1.6819	0.0277	-0.2249	0.0036
Average	2.1609	0.0000	1.2650	0.0187	-0.2686	0.0008

Source: own study

Table 4. Coefficient value quotients in the case of neighbouring task environment parameter states at planning process integration level B

Parameter state	Seasonality of demand		Trend of demand		Demand fluctuations	
	Prof.	CSL	Prof.	CSL	Prof.	CSL
L-M	0.9973	0.0000	0.7571	0.0077	0.1620	0.0015
M-H	2.6319	0.0001	2.3463	0.0145	0.2474	0.0098
Average	1.8146	0.0001	1.5517	0.0111	0.2047	0.0056

Source: own study

Table 5. Coefficient value quotients in the case of neighbouring task environment parameter states at planning process integration level C

Parameter state	Seasonality of demand		Trend of demand		Demand fluctuations	
	Prof.	CSL	Prof.	CSL	Prof.	CSL
L-M	0.0035	0.0000	1.4305	0.0649	-0.0930	0.0138
M-H	49.7739	0.0004	2.7560	0.0670	-0.2997	0.0087
Average	24.8887	0.0002	2.0932	0.0660	-0.1964	0.0113

Source: own study

Table 6. Coefficient value quotients in the case of neighbouring task environment parameter states at planning process integration level D

Parameter state	Seasonality of demand		Trend of demand		Demand fluctuations	
	Prof.	CSL	Prof.	CSL	Prof.	CSL
L-M	0.0046	0.0000	3.0078	0.0568	0.8191	0.0186
M-H	4.3232	0.0402	1.4352	0.0583	3.1727	0.0290
Average	2.1639	0.0201	2.2215	0.0575	1.9959	0.0238

Source: own study

In order to simplify the presentation one calculated average quotient values in the case of particular process integration levels. The analysis results are presented in table 7.

Table 7. Average values of the indicator value quotients in the case of neighbouring task environment parameter states at all planning process integration levels

Planning level	Profitability	Customer service level
A	1.0524	0.0065
B	1.1903	0.0056
C	8.9285	0.0258
D	2.1271	0.0338

Source: own study

The average values of the quotients presented in table 7 tend to be increasing. This is accompanied by the decrease in the planning process integration level. There are two exceptions from this rule: quotients of the profitability indicator at planning process integration level C and the customer service level indicator at planning process integration level B. The quotient values show the task environment changeability influence on the material flow efficiency in production companies. The smaller the difference between the values of the efficiency indicators, the smaller the task environment changeability influence on the material flow efficiency. To make a conclusion based on the results in table 7 it might be (although ambiguously) stated that the efficiency of material flow in companies with integrated planning process is less dependent on the volatility of the task environment – therefore, the formulated hypothesis is positively verified.

The second research hypothesis verification method is based on specifying regression equations in the case of sets of task environment parameter values and indicator values at particular planning process integration levels. To simplify the interpretation, the research was confined to linear regression equations. In the case of such an assumption the task environment changeability influence will be specified by the value of the regression line slope. Before one began the regression analysis it had been checked by means of the ANOVA method whether the indicator values in the case of various task environment changeability states were statistically significantly different from each other. In the ANOVA method one formulated a pair of statistical equation hypotheses in the case of each indicator and each task environment factor:

H_0: The indicator values in the case of all the task environment factors are not different from each other.

H_1: The indicator values in the case of all the task environment factors are different from each other.

The analysis was performed on the assumption that significance level $\alpha=0.01$ The p-value in the case of the consecutive ANOVA-verified pairs of hypotheses were presented in table 8.

Table 8. p-value values obtained in the ANOVA method

Task environment factor	Profitability	Customer service level
Demand fluctuation	0.984	0.039
Trend of demand	<0.001	<0.001
Seasonality of demand	<0.001	0.412

Source: own study

According to the adopted assumption related to the significance level values there is no need to withdraw the null hypothesis in the cases. The null hypothesis is about no differences between the efficiency indicator values (the p-value value in those cases is higher than the adopted significance level). This means that the profitability indicator value will not get statistically significantly changed if the demand fluctuation parameter values are changed. As regards to the customer service level indicator, the profitability value will not get changed if the factors of demand fluctuation and seasonality of demand are changed. Due to the above these cases will be excluded from further regression analysis. As regards to the remaining 3 cases, one performed the regression analysis. It was supposed to specify the linear regression equations for the relationship between the efficiency indicator value and the task environment changeability parameter value in the case of each of the planning process integration levels. The regression function formulas are presented in tables 9 and 10.

Table 9. Regression function formulas in the case of the profitability indicator

Planning level	Regresion line	R^2
Trend of demand		
A	0.1185 – 0.3218 Trend of demand	13.6%
B	0.09212 – 0.2562 Trend of demand	13.9%
C	0.09648 – 0.3932 Trend of demand	59.9%
D	0.06829 – 0.3539 Trend of demand	64.0%
Seasonality of demand		
A	0.1853 – 0.7670 Seasonality of demand	77.0%
B	0.1418 – 0.5877 Seasonality of demand	73.0%
C	0.06654 – 0.1936 Seasonality of demand	14.5%
D	0.03269 – 0.1166 Seasonality of demand	6.9%

Source: own study

Table 10. Regression function formulas in the case of the customer service level indicator

Planning level	Regresion line	R^2
Trend of demand		
A	1.002 – 0.1211 Trend of demand	48.9%
B	0.9317 – 0.06782 Trend of demand	19.7%
C	0.8617 – 0.3445 Trend of demand	82.0%
D	0.8298 – 0.2929 Trend of demand	63.2%

Source: own study

It was assumed in the analysis that the smaller the slope value means a smaller influence of a given factor on the efficiency indicator value. Thereby, one should expect smaller values (absolute values) of the slope in the conditions of higher planning process integration levels. As implied by the regression function formulas in tables 9 and 10 such an unambiguous situation exists in no case. The situation relies on reflecting the proposed trend of changes in the case of all the planning process integration levels. However, one might find certain regularities. The profitability indicator level is less dependent on the trend of demand parameter values at higher integration levels (A and B) than at the lower ones (C and D). Similarly, the customer service level indicator value is less dependent on the trend of demand with the higher planning process integration levels than with the lower ones. The dependency of the profitability indicator value on the seasonality of demand is exact the opposite. The value of the both indicators is higher in the case of higher planning process integration levels. The divergent values of the coefficient of determination make it more difficult to interpret the results. If this indicator value goes under 0.6, the interpretation might be significantly flawed. In the authors' view it is therefore impossible to verify the research hypothesis as it depends on the above presented results.

5. CONCLUSION

One of the key tasks of planning processes in production companies is to make the material flow efficiency independent of the task environment changeability. In the article the authors searched for an answer to the question about whether the above objective is possible to be achieved by means by the authors' own planning process integration model (with respect to both the contents – integrated plans and process– integrated plan development). The formulated research hypothesis: the efficiency of material flow in companies with integrated planning process is less dependent on the volatility of the task environment was verified by means of 2 methods: quotient and regression.

In the quotient method one analysed the differences in the efficiency indicator values between the consecutive parameter states. They reflected the task environment changeability in the conditions that corresponded to various planning process integration levels. One averaged the results from various environment-changing factors. The focus was merely put on average values of the measure quotient values of efficiency indicators in the case of particular planning process integration levels. The analysis conducted by this method made it possible to positively verify the forumlated research hypothesis.

In the regression method the focus was put on analysing the dependencies between the efficiency indicator values on the changeability of the task environment parameter values (separately in the case of each task environment changebaility parameter). The analysis conducted by this method did not make it possible to unambigously verify the forumlated research hypothesis.

To conclude the above considerations one should notice that the planning process integration in accordance with the presented model makes it feasible to make the material flow efficiency independent of the task environment changeability. However, it is impossible to indicate what integration influence is on the material flow independence on particular task environment changeability aspects (demand fluctuation trend of demand, seasonality of demand). The conducted experimental research does not make it feasible to prove the relationships of particular factors of the changing task environment. While defining the next research objectives, one should increase the number of factors that would describe the task environment changeability and extend the number of states in which the factors might occur. Such an action would enable obtainment of an even larger result database. As a consequence, the results would be more profoundly analysed.

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