CORRELATION BETWEEN THE TOOLS AND DEVELOPMENT PROCESS AND THE PRODUCTION PROCESS IN SMEs

UDK 65.017.2/.3:519.233.5 / JEL E23 / ORIGINAL SCIENTIFIC PAPER

MATEJA KARNIČAR ŠENK
DEPUTY DIRECTOR
POLYCOM ŠKOFJA LOKA D.O.O.
POLJANE NAD ŠKOFJO LOKO, SLOVENIA
mateja.senk@polycom.si

MATJAŽ ROBLEK
DOC. DR., PROFESSOR
UNIVERSITY OF MARIBOR
FACULTY OF ORGANIZATIONAL SCIENCES
KRANJ, SLOVENIA
matjaz.roblek@um.si

ABSTRACT

In the course of this study, we focused on validating assumptions on the correlation between the tools and development process and the production process in SMEs (small and medium-sized enterprises). The correlation of both processes is determined using select indicators.

On the basis of work experience in the field of quality assurance, we notice that outputs from the tools and development process often do not generate satisfactory results in the production process. This phenomenon is first observed in the production process and later in customer satisfaction feedback. The consequences of failing to achieve satisfactory results may ultimately cost an enterprise the loss of a customer and/or loss of income. During the course of this research, we have also determined that investing effort and knowledge into the tools and development process signifies valuable reimbursement for the enterprise. The correlation between both processes was determined using statistical methods.

The result of the research confirms assumptions on there being a strong correlation between both processes and provides a list of suggestions for improvements that either directly or indirectly affect the select indicators.

KEY WORDS: process, production process, tools and development process.

1. INTRODUCTION

Markets demand excellent products at an affordable price in addition to good functionality, durability and attractive design. Existing literature emphasizes the importance of introducing new products on the market for the purpose of achieving business success, contributing to company growth and impacting on profit and its role as the key factor in the development and expansion of enterprises (Booz, Allen and Hamilton, 1982; Urban and Hauser, 1993; Cooper, 2001; Ulrich and Eppinger, 2011).

For small and medium sized enterprises (SMEs), the procedure for the tools and development process is in practice poorly described, while available resources fail to provide sufficient guidance on how development processes within these companies should even be formulated. There is also limited information on how SMEs can successfully strategize and market new products. SMEs are limited in their expertise, abilities and resources (Van Zyl, 2008, Roblek, 2012). The significance of conducting research in this area is supported by Eurostat data on structural business statistics, which indicates that SMEs account for 99.8% of all companies registered in the EU, with new product development being a key process within these companies.

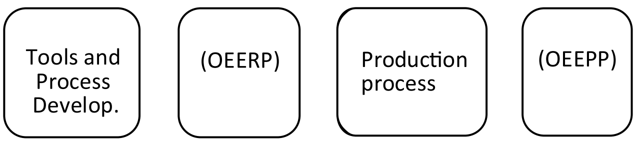
Several problems related to the evaluation of NPD projects may be identified such as there being a wide variety of theoretical methods for evaluating these types of projects (Mankin, 2007; Thamhain, 2014). In carrying out this research, we have selected a quantitative method that we were unable to detect in any previous research.

The output of the tools and development process represents direct input for the production process, or in our case, for the serial production of thermoplastics processing. Output of the tools and development process includes: developed and manufactured tools, established production, technological and control documentation and qualified personnel. In addition to these results, the tools and development process also produces other output such as: an established list of required criteria and measuring devices, a selection of appropriate material suppliers, manufactured sample pieces and machinery, preparations and devices that shape the technologically complete whole. Together, both processes form the entire course of activities which, on the basis of inputs into the tools and development process and through the thermoplastics processing production process, lead to output that has final value for the customer.

During this course of this study, we have focused on determining the correlation of both processes using indicators for the tools and development process and indicators for the thermoplastics processing production process. We have analysed the current state of operations and proposed measures for improving both processes. The indicator we selected to measure the effectiveness of process development is OEE (Overall Equipment Effectiveness) of the zero series, which is the product of three variables: utilization of facilities/equipment, utilization of time and quality of products manufactured in the zero series. This indicator determines the degree of effectiveness of the tools and development process and is hereafter referred to as OEERP . The indicators selected for the production process are the following: OEE of the serial production of thermoplastics processing.

The conceptual design of the study is schematically depicted in Figure 1. The outline is illustrated by four elements. The first element represents the procedural step – tools and process development according to APQP methodology (Advanced Product Quality Planning). The second element represents the results obtained from the development indicators – for the purpose of this study, OEERP. The third element represents the process of the production of thermoplastic injection moulding. The fourth element presents indicators of the production process of thermoplastics injection moulding. Using indicators presented in the second and fourth elements, we measured the correlation between the development process and production process indicators, or the indirect correlation of both processes. The correlation of variables specified in elements two and four were calculated.

Figure 1. Research Concept



On the basis of the problem observed in a real environment and upon reviewing the findings of previous studies, we formulated the following research question:

How strong is the correlation between the selected indicators of the development process and the selected indicators of the production process in small and medium-sized enterprises?

Indicators of the production process were monitored on the basis of internal monitoring using the production information system.

2. METHODOLOGY

The following statistical methods were used in the course of this study:

The normalcy of data distribution was verified using the Kolmogorov-Smirnov test. On the basis of the normalcy of data distribution, the Pearson and Spearman coefficient correlations were calculated. We also provided the coefficients and constants of the regression equation.

In the first step, we identified the research problem and hypothesis, or formulated the research question. This was followed by a study of domestic and foreign literature related to the field in question. We then studied appropriate methods to either confirm or reject the hypothesis of research question. On the basis of the selected methodology, we prepared the research plan and collected and prepared data for carrying out statistical analyses. This was followed by processing and evaluating data and finally, by an analysis of results, inference and explaining phenomena and a study of correlations. We then provided an evaluation on whether the research question, or hypothesis, may be confirmed. Finally, an attempt was made to provide explanations as well as a summary of the research with recommendations for further study.

3. RESULTS

154 completed projects that had already been transferred to regular serial production were examined in the course of this study. This analysis was carried out using statistical tool SPSS 20. The range of the selected indicators is listed in the following table.

Table 1. Range of the selected indicators of the population

Indicator	Type of Variable	Range
OEERP	Independent	0-50%; poor project 50-80%; moderately good project 80-200% very good project
OEEPP	Dependent	0-50%; poor project 50-80%; moderatley good project 80-200% very good project
Availability	Dependent	0-50%; poor project 50-80%; moderately good project 80-200% very good project
Quality	Dependent	0-50%; poor project 50-80%; moderately good project 80-200% very good project
Productivity	Dependent	0-50%; poor project 50-80%; moderately good project 80-200% very good project

Projects whose data deviated by over 200% from the mean were then excluded from the total population of 154 completed projects.

The projects were divided into four groups. These groups differ from one another by a different "degree of success" of individual projects.

Group 1 includes projects that differ least by range (up to 50%) between the overall efficiency of the development and production phases. Of a group of 71 completed projects, 15 fit this criteria, so that approximately 21% of the projects are of this type. Statistical data is provided in the table below:

Table 2. Statistical data of selected sample Group 1

		OEERP	OEEPP
Total size	Valid	15	15
	Missing	0	0
Mean value		99.3333	121.1453
Std. deviation		35.10325	39.45340
Minimum		17.00	22.42
Maximum		142.00	172.00

From the table, it is evident that results reached an average of 99.33% in OEERP and an average of 121.15% in OEEPP. An analysis of the correlation was then carried out.

Table 3. Spearman's correlation coefficient for selected sample Group 1

			OEERP	OEEPP
Spearman's rho	OEERP	Correlation coefficient	1.000	.786**
		Sig. (2-tailed)	.	.001
		N	15	15
	OEEPP	Correlation coefficient	.786**	1.000
		Sig. (2-tailed)	.001	.
		N	15	15

Because this sample included only 15 projects, the Spearman correlation coefficient was used to verify the correlation. The results indicate that there is a statistically significant ($p < 0.05$) high positive correlation between the OEERP and OEEPP variables. This means that by increasing the overall efficiency of the development processes using OEERP, the overall efficiency of the OEEPP regular series production process rises.

Group 2 consisted of 29 cases. The difference between OEERP and OEEPP ranged between 50-100%. These projects represent the greatest number of cases. It is typical of these projects to have achieved poorer results in the development phase, so that overall efficiency is lower than that of Group 1 but overall efficiency in the production phase is higher. Statistical data is provided in the table below.

Table 4. Statistical data of selected sample Group 2

		OEERP	OEEPP
Total size	Valid	29	29
	Missing	0	0
Mean value			145.6324
Std. deviation			18.98529
Minimum			91.00
Maximum			183.34

From the table, it is evident that values reached an average of 68.97% in OEERP and an average of 145.63% in OEEPP.

Table 5. Spearman's correlation coefficient for selected sample Group 2

			OEERP	OEEPP
Spearman's rho	OEERP	Correlation coefficient	1.000	.718**
		Sig. (2-tailed)	.	.000
		N	29	29
	OEEPP	Correlation coefficient	.718**	1.000
		Sig. (2-tailed)	.000	.
		N	29	29

Because only 29 projects were included in this sample, the Spearman correlation coefficient was used to verify the correlation. Results indicate that there is a statistically significant ($p < 0.05$) high positive correlation between the OEERP and OEEPP variables. This means that increasing the efficiency of development processes through OEERP raises the efficiency of the OEEPP regular serial production process.

Group 3 includes projects where the difference among them is even greater than among those in the first two groups. These types of development projects are even less successful in the development phase but demonstrate good results in the regular serial production phase. The table below depicts the following statistical data:

Table 6. Spearman's correlation coefficient for selected sample Group 3

			OEERP	OEEPP
Spearman's rho	OEERP	Correlation coefficient	1.000	.276
		Sig. (2-tailed)	.	.226
		N	21	21
	OEEPP	Correlation coefficient	.276	1.000
		Sig. (2-tailed)	.226	.
		N	21	21

From the table, it is evident that projects reached an average of 33.10% in OEERP and an average of 153.00% in OEEPP.

The results of the correlation analysis are as follows:

Table 7. Spearman's correlation coefficient for selected sample Group 3

			OEERP	OEEPP
Spearman's rho	OEERP	Correlation coefficient	1.000	.276
		Sig. (2-tailed)	.	.226
		N	21	21
	OEEPP	Correlation coefficient	.276	1.000
		Sig. (2-tailed)	.226	.
		N	21	21

Because this sample included only 21 projects, the Spearman correlation coefficient was used to verify the correlation. The results indicate that there is a statistically insignificant ($p > 0.05$) medium-high positive correlation between the OEERP and OEEPP variables. This means that increasing the efficiency of OEERP raises the efficiency of OEEPP but because the correlation is not statistically significant, it is not necessarily true that the same correlation would be observed in another group. These projects represent the worst possible types of projects because they indicate that the process has been developed very poorly and that it was optimized only during the serial production phase.

Runs that achieve a value of less than 50% OEERP in the development phase require many upgrades and development measures in the production phase in order to achieve an adequate level of development.

Group 4 includes projects that demonstrated the best results in the development phase but achieved worse results in serial production. These projects are fewest in number.

Table 8. Statistical data for selected sample Group 4

		OEERP	OEEPP
Total size	Valid	6	6
	Missing	0	0
Mean value		114.8333	104.1667
Std. deviation		37.08054	33.25908
Minimum		60.00	59.00
Maximum		159.00	137.00

From the table, it is evident that projects reached an average of 114.83 in OEERP and an average of 104.17 in OEEPP.

Table 9. Spearman correlation coefficient for selected sample Group 4

			OEERP	OEEPP
Spearman's rho	OEERP	Correlation coefficient	1.000	.928**
		Sig. (2-tailed)	.	.008
		N	6	6
	OEEPP	Correlation coefficient	.928**	1.000
		Sig. (2-tailed)	.008	.
		N	6	6

Because the sample included only 6 projects, the Spearman correlation coefficient was used to verify the correlation. The results indicate that there is a statistically significant ($p < 0.05$) high positive correlation between the OEERP and OEEPP variables.

Comparative Study

The purpose of the comparative study was to determine the correlation between the select indicators of the Phase RP development process and the indicators of the Phase PP production process. According to our estimates, the development process should significantly affect the efficiency of the regular serial production process.

The development process in this case comprises measuring the shape of the workpiece, analysing optimal utilization and associated calculations and preparing the method of processing.

The production phase comprises preparation, sawing logs into various assortments of wood, stacking and packaging.

According to empirical estimates, the development process should significantly affect the efficiency of the entire regular series production and should, in particular, increase yield and reduce the amount of waste. To perform the analysis, we selected an accuracy rating on a scale of up to 100% for the development process. The proportion of the accuracy of the estimates of the listed activities in the development phase is considered as an independent variable.

For the production process, we selected the yield of a cubic metre of a certain type of wood assortment. Yield means the amount of the product as depending on the entire volume of the work piece.

Efficiency (yield) is measured in percentage. 152 completed projects were analysed. These represent the entire population. The analysis was carried out using statistical tool SPSS 20. The range of the selected indicators are listed in the table below.

Table 10. Range of selected indicators of the comparative study

Indicator	Type of Variable	Range
Phase RP	Independent	100-50% poor grade 51-80% moderate 81-100% excellent
Phase PP	Dependent	1-50% poor efficiency 51-80% moderate efficiency 81-100% excellent efficiency

A representative sample was prepared on the basis of assessing actual efficiency and computational efficiency. From the population we thus selected 32 projects. Following is some statistical data of the selected sample.

Table 11. Statistical data of the comparative research study sampling

	N	Minimum	Maximum	Middle range	Std.deviation
PhaseRP	32	72.00	83.00	77.5000	3.81846
PhasePP	32	78.00	83.00	80.6875	1.71215
N	32				

We then carried out verification of the normalcy of the data distribution. On the basis of the obtained results, it may be concluded that the distribution of both variables is normal. The table below lists statistical data on verification of the normalcy of the distribution.

Table 12. Verification of the normalcy of the distribution of the selected sample

	Kolmogorov-Smirnova			Shapiro-Wilk		
		df	Sig.		df	Sig.
PhaseRP	.181	32	.009	.891	32	.004
PhasePP	.157	32	.045	.888	32	.003

The correlation analysis was carried out using the Pearson correlation coefficient. The results indicate that the correlation between the estimates derived in the development phase and the final efficiency is very strong.

The results are listed in the table below.

Table 13. Pearson correlation coefficient of the comparative study

		Phase RP	Phase PP
Phase RP	Pearson corr. coeff.	1	.893**
	Sig. (2-tailed)		.000
	N	32	32
Phase PP	Pearson corr. coeff.	.893**	1
	Sig. (2-tailed)	.000	
	N	32	32

The regression model is good. The regression relationship explains 79.8% of the variance in the production process (the coefficient of determination is therefore 0.798).

Table 14. Regression model of the comparative study

Model	R	R squared	Adj. R squared	Standard deviation
1	.893a	.798	.791	.78305

If noting the regression line equation:

Phase PP = 49.653 + 0.400·Phase RP

From the data, we evaluate that if the assessment of efficiency in the development process, therefore, the indicator Phase RP, increases by 1, then the overall efficiency of the production process increases by 0.400.

Table 15. Coefficients and constant regression model of the comparative study

Model		Unstd. Coefficient		Std. coefficient	t	Sig.
		B	Std. error	Beta		
1	(Constant)	49.653	2.858		17.375	.000
	PhaseRP	.400	.037	.893	10.872	.000

On the basis of the obtained results, we have confirmed the hypothesis that the quality of execution of the development phase impacts on the output of the production process.

4. DISCUSSION

Using statistical analysis, we have determined that there is a statistically high positive correlation between the OEERP and OEEPP variables within the select group of projects. The partial correlation among variables was statistically insignificant only in the group that displays very poor results in the development phase but even this correlation was medium-high positive. The results therefore indicate that an effective development process expressed through OEERP raises the selected indicator OEEPP of the regular serial production process. We performed a comparative analysis of companies that are in no way associated with branch 22.290 and determined that the results are similar, so it may be concluded that there is a strong statistical correlation of success between the development and production phases.

We are determining that there are currently no studies available which examine the direct impact of the tools and development process on the production process using an indicator such as OEE. Most frequently used are financial methods that are popular when project evaluation requires economic justification. By generating numeric measurements, their results are easily comparable and thus enable the ranking of projects (Thamhain, 2014). However, this is not the only method of measurement. Akhilesh (2014) groups a number of general factors for evaluating research project proposals into seven categories: (1) technical factors, (2) research direction and balance, (3) marketability factors, (4) production factors; (5) financial factors; (6) timing of research and (7) other factors.

Further studies could extend this research to a greater number of enterprises. We anticipate that there are limitations in the types and methods of measuring the success of an individual process. Given that enterprises determine different criteria, it is not feasible to anticipate a singular method of measurement. Research could also be expanded to encompass different activities. It is also possible to study what types of indicators enterprises use in order to measure the effectiveness of a particular process and how they measure the impact between processes. We also recommend conducting research on the ways in which such assessments and measurements are carried out in large enterprises.

REFERENCES

1. Booz, Allen, & Hamilton (1982). New product management for the 1980's. New York: Booz, Allen & Hamilton, Inc
2. Cooper, R. (2001).Winning at New Products. Massechussets.
3. Mankin, E., 2007. Measuring Innovation Performance. Research-Technology Management, 50(6), pp. 5-7.
4. ROBLEK, Matjaž, KERN, Tomaž, ZAJEC, Maja. Knowledge management of the new product development process with process-knowledge allocation model. V: The 6th IEEE International Conference on Management of Innovation and Technology, 11-13 June 2012, Sanur Bali, Indonesia. *ICMIT 2012 : proceedings of*. [S. l.: s. n.], cop. 2012, pp. 214-219.
5. Urban, G. L. and J. R. Hauser (1993). *Design and Marketing of New Products*, Prentice-Hall.
6. Ulrich, K.T. and S.D. Eppinger (2011). *Product design and development*. Boston: McGraw-Hill Higher Education
7. Van Zyl, W. (2008) The new product development process : small firm success by studying larger firms. University of Stellenbosch
8. Thamhain, H. J., 2014. Assessing the Effectiveness of Quantitative and Qualitative Methods for R&D Project Proposal Evaluations. Engineering Management Journal, 26(3), pp. 3-12.
9. Thamhain, H. J., 2005. Management of Technology. Hoboken, New Jersey: John Wiley & Sons Inc. .