

INVESTIGATION OF IMPLEMENTATION OF "SIX SIGMA" METHODOLOGY IN SMALL PRODUCTION ORGANIZATIONS AND PREDICTION OF ITS WIDER APPLICATION IN CROATIAN COMPANIES

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Professional paper

This paper deals with the results of investigating implementation of six sigma methodology in small production organizations in the Republic of Croatia and with experiences from some European countries (Great Britain and Finland). At the end, the authors performed the DELPHI method to predict the time of wider application of this methodology in small Croatian organizations.

Key words: Six Sigma Methodology, small Croatian organizations, prediction, business excellence, quality

Istraživanje primjene metodologije "šest sigma" u malim proizvodnim organizacijama te prognoza njezine masovnije primjene u hrvatskim poduzećima

Strukovni članak

Članak obrađuje rezultate istraživanja u primjeni metodologije 6σ u malim proizvodnim organizacijama u RH i iskustva u primjeni 6σ-programa u malim organizacijama nekih zemalja u Europi (Velike Britanije i Finske). Na kraju, autori su proveli "Delphi" metodu s ciljem prognoziranja vremena početka masovnije primjene navedene metodologije u malim hrvatskim poduzećima.

Ključne riječi: metodologija 6σ, mala hrvatska poduzeća, prognoza, poslovna izvrsnost, kvaliteta

1

Uvod

Introduction

Considering the issue of quality, the *western* term that has been most frequently used is the "Six Sigma" (6σ). Professional journals and web sites of well-known consulting companies abound in training ads relating to implementation of such methodology. Meetings of companies that have already introduced the "Six Sigma" methodology into their business processes take place. Enormous revenues have been reported to result from the application of the "Six Sigma" methodology, etc.

The "Six Sigma" methodology is a quality management program used by Motorola in mid 1980s to fight the continuous losses against market competition that managed to produce higher quality products at lower costs. The takeover of the Motorola TV production company in the USA by the Japanese has been considered the crucial event, as under the new management the company started producing TV sets with 20 times less faults than before under the Motorola management. Worth emphasizing is that the entire success was achieved by using the same work force, technology and means of production. At the time, their belief that "if the Japanese can do it, we can do it, too" represented the main driving force to the Motorola management.

In 1988, the "Six Sigma", i.e. the Motorola quality improvement program, was fully appreciated after the financial results had been published. Motorola received the "Malcolm Baldrige", a prestigious American annual quality award, and in accordance with the obligations of the prize winner, Motorola shared the secret of the company success with other American organizations.

The "Six sigma" methodology includes a set of tools and methods based on the SPC – statistical process control, which may help companies to improve their products' quality, decrease operational costs and increase their clients' satisfaction.

Experience worldwide shows that the "Six Sigma" methodology has been successfully implemented into

improvement processes of large business systems it had initiated from. All findings indicating successful application of this methodology mostly relate to large world corporations and companies [15-19]. There are only few scientific and professional papers on the application of this methodology in small production organizations. It is largely due to this fact that the research [12] was started and the model formed to implement the "Six Sigma" in small production organizations which are the base of economy in our country.

In analysing the available Croatian references in the area of management, quality management and business excellence, no research had been found on the implementation of the "Six Sigma" methodology in small Croatian organizations. The gap was filled with the research [12, 14] conducted in Croatian companies that had already set up a quality management system in compliance with the international standards creating a solid base to use the 6σ-program and continue towards business excellence.

In other words, the paper presents the findings of research conducted on the implementation of the "Six Sigma" methodology in small production organizations in Croatia and several countries in Europe. As the results relating to a more serious implementation of the stated methodology are poor, a research on the time necessary to introduce mass implementation of the "Six Sigma" in Croatian companies has also been conducted. The results are presented in the second part of the paper.

2

Selection and description of the investigated sample Izbor i opis uzorka za istraživanje

The researched population included about 1 700 organizations that, according to the data provided by the Croatian Society for Quality in end 2007, had a quality management system complied with the ISO 9001 standards. Determining the size of the sample is of utmost importance because if the sample is not suitable, it is highly probable that the objectives of the research will not be reached in full.

The sample comprised 98 organizations, i.e. 5,76 % of

the researched population. As per form and characteristics it can be classified as quota type, which means that the author has chosen respondents based on indicators of the population. The sample is "non-statistical", based on the researcher's assessment. It comprises respondents available during the research and who, according to the decision made by the researcher, were competent as regards the required answers. One of the criteria to selecting the sample was knowledge of the business activity with particular emphasis being given to mechanical and similar production. Business activities of the respondents (the organization) are different and have been classified according to international classification (European Accreditation Classification), as shown in Figure 1.

The Table 1 shows that most of the organizations are engaged in the metal industry (Metal Products EAC 17, Machines and Equipment EAC 18, Non-metal Products EAC 15, Other products EAC 23), i.e. 81 % of total investigated organizations. In addition to these organizations, the research included 19 organizations dealing with products made of plastics, wood, electrical and optical products.

Table 1 shows the organizations included into research by size or number of employees at the time the research was conducted (Table 2). It is clear that most of the organizations (96 %) fall into the category of small and medium sized

organizations (SMEs) (Table 3 - as per the Accounting Act of the Republic of Croatia, Official Journal 146/2005).

According to the data provided by the Ministry of Economy, Labour and Entrepreneurship for 2005, the SMEs include:

- 99 % registered business entities
- 55 % total employees in the Republic of Croatia
- 44 % total GDP
- 60 % export of the Republic of Croatia.

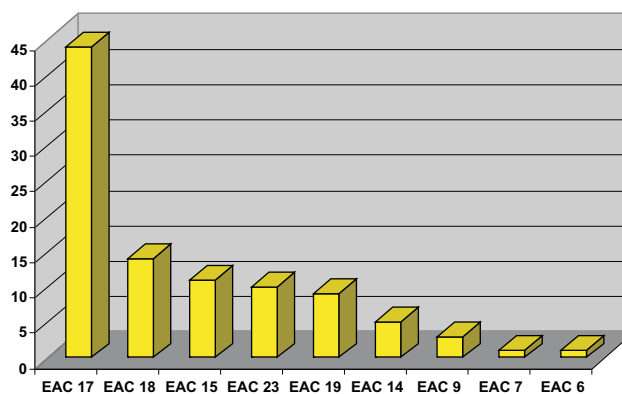


Figure 1 Structure of monitored organizations related to EAC classification

Slika 1. Struktura promatranih organizacija u uzorku prema EAC klasifikaciji

Table 1 Investigated organizations according to EAC classification
Tablica 1. Pregled organizacija obuhvaćenih istraživanjem prema EAC klasifikaciji djelatnosti

Item	EAC scope of activity	No. of organizations	Item	EAC scope of activity	No. of organizations
1.	Agriculture, fishing	-	21.	Aviation industry	-
2.	Mining	-	22.	Transport devices	-
3.	Production of food, drinks and tobacco	-	23.	Other production	10
4.	Textile industry	-	24.	Recycling	-
5.	Leather industry	-	25.	Power supply	-
6.	Wood processing	1	26.	Gas supply	-
7.	Paper industry	1	27.	Water supply	-
8.	Publishing industry	-	28.	Construction	-
9.	Printing industry	3	29.	Trade	-
10.	Production of coal and oil processing	-	30.	Hotels and restaurants	-
11.	Nuclear industry	-	31.	Transport and communications	-
12.	Chemical industry	-	32.	Finances	-
13.	Pharmaceutical industry	-	33.	Information technologies	-
14.	Rubber and plastic products	5	34.	Engineering	-
15.	Non-metal products	11	35.	Other services	-
16.	Concrete, cement, etc. industry	-	36.	Administration	-
17.	Metal products	44	37.	Education	-
18.	Machines and equipment	14	38.	Health	-
19.	Electrical and optical equipment	9	39.	Other social services	-
20.	Shipbuilding	-			

Table 2 Number of organizations and employees
Tablica 2. Veličine organizacija i broj zaposlenih

ORGANIZATION CATEGORY	SIZE (number of employees)	NUMBER OF ORGANIZATIONS
S ₁	< 50	40
S ₂	51 - 100	32
S ₃	101 - 250	22
S ₄	251 - 500	4

The importance of small organizations is clearly obvious in the economy of other countries as well. In early 2000, the Great Britain government agency report showed that 99,8 % of business systems throughout Great Britain were classified as small and medium-sized business systems, covering about 56 % of total employees in the country [13]. According to the U.S. Census Bureau statistics, 98 % organisations in the USA have about 20 employees. If this is amended with the fact that over 30 % of total sale in the USA is conducted by organizations having less than 100 employees, and considering the already stated data on small and medium sized organizations in Croatia and in Europe, the economic justification of conducting the research on possible implementation of the 6σ-programs in small organizations can be confirmed.

3

Investigation of actual situation in implementation of the "Six Sigma" in small organizations

Istraživanje trenutnog stanja u primjeni metodologije "šest sigma" u malim organizacijama

3.1

Implementing "Six Sigma" in small organizations in the Republic of Croatia

Primjena "šest sigma" metodologije u malim organizacijama Republike Hrvatske

Investigation on the 6σ-program conducted in organizations showed a low level of implementation and general knowledge of the respondents (the most responsible employees in the organization). Of the 98 respondents, only 32 heard about the 6σ-program (Figure 2). The respondents had "heard" about the 6σ-program mostly in seminars on quality management systems and read about it in professional journals, as shown in Figure 3.

Figure 3 explains where the employees heard about the 6σ-program a) in seminars; b) from references; c) from mass media; d) from certification institutions e) other. Of the 32 organizations, in which the top management has been informed about the "Six Sigma" methodology, only 4 state they are partially implementing the methodology through statistical techniques and improvement plans, and 3 organizations have just started the implementation (pending decision on systematic implementation). In other (25 organizations) there is no systematic implementation.

Figure 4 shows the areas of implementation of the "Six Sigma" program, according to opinions of the respondents who confirmed to have heard about the program. It is clear

Tablica 3 Klasifikacija veličine organizacija
Table 3. Classification of organizations as per assets

CRITERION	ORGANIZATION STATUS			
	Small	Medium		Large
	If not exceeding two of three criteria	If exceeding two of three criteria	If never exceeding two criteria	If exceeding two of three criteria
Total assets	27 000 000	27 000 000	108 000 000	108 000 000
Total revenue	54 000 000	54 000 000	216 000 000	216 000 000
Number of employees	50	50	250	250

Note: Sums are expressed in Croatian Kuna, in accordance with the Croatian Accounting Act, OG 146/2005

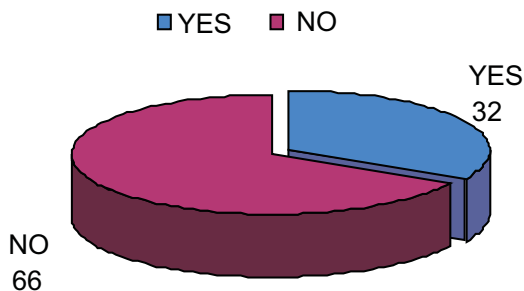


Figure 2 General info about "Six Sigma" technology
Slika 2. Opća informiranost o "šest sigma" metodologiji

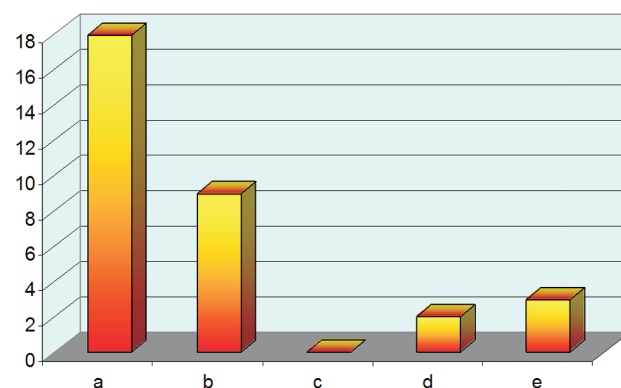


Figure 3 Where employees heard about the 6σ-program
Slika 3. Kako su ispitanici čuli za 6σ-program

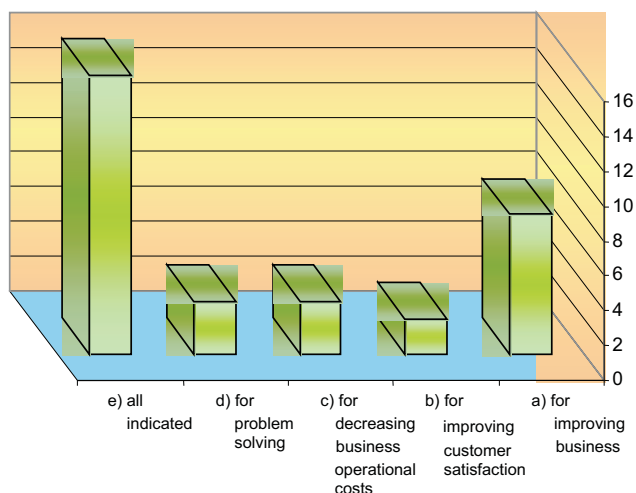


Figure 4 Where is the "Six Sigma" applied?
Slika 4. Gdje se koristi "Šest sigma" program?

that the respondents recognize its role and the majority stated that the program is used with all options provided, i.e.: system improvement, problem solution, decreasing operational costs and issues relation to customer satisfaction.

3.2 Experience from implementation of the "Six Sigma" in small organizations in Great Britain

Iskustva u primjeni 6 σ -programa u malim organizacijama Velike Britanije

Following the research conducted in Croatia and identification of the most influential factors of non-implementation of the 6 σ -program in small Croatian organizations and predicting its "mass" implementation, below are the results of the Centre for Research in Six Sigma and Process Improvement (CRISSPI), and the Glasgow Caledonian Business School (Scotland – Great Britain).

In order to investigate experience in implementation of the 6 σ -programs in small and medium organizations (i.e. SMEs - Small and Medium-Sized Enterprises), a method of random stratified sampling was used on a population of 3500 production SMEs to separate a sample of 400 organizations that received a questionnaire. Sixty-six (66) completed questionnaires were returned which is 16,5 % of the total quantity sent. Of the returned questionnaires 6 were invalid. This research included participants from different types of industries: chemical, textile, mechanical engineering, food, power, pharmaceuticals,... etc. The majority of organizations had from 50 to 150 employees and 10 % of organizations answered they had from 150 to 200 employees. None of the micro organizations (under 10 employees) completed the questionnaire.

General conclusions of the conducted research are the following:

1. Only 16 of 60 SMEs (about 27 %) have been involved in the 6 σ -program. These organizations have, on average, been using the 6 σ -program for over a year.
2. Over 80 % of investigated organizations have had a structured quality management system for over 9 years. An interesting detail is that many organizations consider ISO 9000 the utmost achievement of product and service standards.
3. About 25 % organizations have partial or full Total Quality Management (TQM).

4. About 5 % organizations have been using the principles of "Lean" production.
5. Table 4 shows the main reasons for not implementing the 6 σ -program.

Table 4 Main reasons for not implementing the "Six Sigma" program
Tablica 4. Glavni razlozi za nekorisćenje 6 σ -program

Main Reasons	Organizations %
Unaware of the 6 σ -program	50 %
Insufficient resources	32 %
Existing quality programs are satisfactory	27 %
Insufficient benefits of the program	7 %
Nor required by the customers - clients	4 %
Currently analyzing and evaluating possible application	4 %

6. It was noticed that over 35 % of organizations which stated that they had been using the 6 σ -program do not have the Six Sigma Project Champions, less than 10 % have Yellow Belts, only one organization (about 6 %) has the Master Black Belt and about 35 % of organizations uses the Green Belt system.
7. Table 5 shows the percentage of organizations that have been using certain key parameters in the 6 σ -program projects.

Table 5 Most used parameters in "Six Sigma"
Tablica 5. Parametri koji se koriste najčešće u 6 σ

6 σ parameters	Percentage of organizations using the parameters
Claims and complaints of the customers	94 %
Percentage of production waste	81 %
Costs of low quality	75 %
Level of non-complied products	75 %
Process capability	63 %

8. It was noticed that a very small number of organizations had been using the 6 σ -program in production, only 12,5 %.
9. It was also noticed that for problem solving and continuous system improvements the majority of organizations (about 73 %) use the DMAIC methodology. A very small number of organizations (about 13 %) use the Design for the 6 σ -program (DFSS). Only one organization (6 %) uses both methodologies, the DMAIC and the DFSS.
10. An important part of this research was to define the number of implemented projects of the 6 σ -program within organizations (as of the beginning of implementation), and the benefits the projects resulted with. Although the 6 σ -program is a novelty to the majority of British organizations, Table 6 gives details on the number of realized projects. About 62 % of organizations made profit from the projects, which was from 0 to 250 000 pounds sterling a year. Four organizations (25 %) had never registered any profit from the 6 σ projects.

Table 6 Number of realized projects
Tablica 6. Broj realiziranih projekata

Number of projects	Organizations %
1-5	69 %
5-10	25 %
>10	6 %

- The most popular and most frequently used techniques and tools in the 6σ-program are the following: the Histogram, the FMEA, the process capability analysis, the Flowchart, Control cards and the Poka - Yoke.
- A scale from 1 to 5 was used by organizations to evaluate benefits from the implementation of the 6σ projects, where 1 meant no benefits and 5 indicated extraordinary benefits. Table 7 summarizes key benefits achieved by implementation of the 6σ projects and average evaluation of those benefits. The largest benefit was achieved in the following areas: decrease of variations within the process, increase of profitability, decrease of operational costs and decrease of costs of poor quality (COPQ).

Table 7 Key benefits from projects
Tablica 7. Ključne koristi od 6σ projekata

Item	Key benefits	Average benefit
1.	Decrease of process variations	4,067
2.	Increase of profitability	3,733
3.	Decrease of operational costs	3,667
4.	Decrease of costs of poor quality	3,600
5.	Increase of production	3,533
6.	Decrease of time steps	3,467
7.	Decrease of customers' complaints	3,456
8.	Increase of sale	3,333
9.	Decrease of control and monitoring	3,267

- The respondents ranked 11 critical success factors (CSFs) for a successful implementation of the 6σ-program in British production SMEs. Ranking was made with grades 1 to 5 of which: 1= the least critical; 2 = less critical; 3 = critical; 4 = very critical; 5 = the most critical.

This research used the CSFs of the 6σ-program taken from the existing TQM and 6σ references. The critical success factors of the 6σ-program are:

- Engaging the management (board) (A)
- Organizational infrastructure (B)
- Cultural changes within the organization (C)
- Training (D)
- Connecting the 6σ-program with the customers (E)
- Connecting the 6σ-program with the business strategy (F)
- Connecting the 6σ-program with the employees (G)
- Connecting the 6σ-program with the suppliers (H)
- Understanding the 6σ-program (I)
- Skills and abilities of the project management (J)
- Selecting and choosing the priority projects (K).

Figure 5 illustrates critical success factors for the successful implementation of the 6σ-program in British

production SMEs. The most important factors shown are: engaging the top management (A), connecting the 6σ-program with the customers (E) and connecting the 6σ-program with the organization business strategy (F).

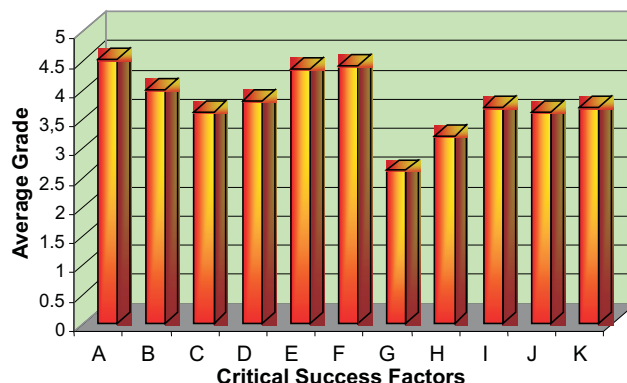


Figure 5 Key factors for success at application of six sigma program in British organizations

Slika 5. Ključni faktori uspjeha za primjenu 6σ-programa u britanskim organizacijama

3.3

Experience from implementation of the "Six Sigma" in small organizations in Finland

Iskustva u primjeni 6σ-programa u malim organizacijama Finske

Similar to Great Britain, the economy of Finland has been increasingly reporting about the Six Sigma and its implementation in small organizations. The study [11] "Successful Deployment of Six sigma Within a Small to Medium", transfers the most important experiences.

Today, the 6σ is considered the most important initiative in improving quality in Finland. Many companies, including Nokia, ABB, Kemira Pigments, Perlos and Eimo, use the 6σ methodology in their operation. Companies like Nokia were excellent leaders – the true promoters of 6σ in Finnish industry.

One of the main tasks to encourage implementation of the 6σ in Finland is to make SMEs believe into superiority of the 6σ, demonstrate all benefits, importance of the methods and technologies used in the 6σ-program, and demistify the belief that 6σ is suitable only for large multinational companies.

According to the conducted study the successful implementation of the 6σ-program in SMEs is influenced by the following factors:

- Voice of the customer (the client)
- Devotion of the management
- Business making strategy
- Devotion of employees
- Sufficient funds/means
- Implementation plan
- Efficient documentation.

1. Voice of the Customer

Research has confirmed the "voice of the customer" to be one of the most important factors, the basis of the entire 6σ methodology in organizations of all sizes, but also the one easily and frequently forgotten. Sometimes the "voice of the customer" is difficult to understand, determine or measure.

It is forgotten because the people working on industry

projects are technologically oriented engineers and not humanists.

The reason for lacking of conditions for cooperation with the clients may be money but also poor motivation. We should know how to measure the customers' satisfaction, what techniques to use, etc.

2. Devotion of the Management

Like in all other work, the role of top management should not be underestimated. If there is no devotion of the "top", which in small organizations is usually one single person, the implementation of the 6 σ -program will not be the part of strategic activities and will not "reach" other employees.

3. Role of the Strategy

Role of the strategy is often underestimated. In some small organizations, completion of the Six Sigma has not been related to the company strategy. In worst cases the strategy is completely missing or is unknown to the employees.

Implementation of the 6 σ -program should not be a separate project but a part of the company strategy. All activities, including the 6 σ -program have to be based on the company strategy.

4. Devotion of Employees

Knowledge about the strategy is one of the main factors in determining devotion of the employees. If the employees are familiar with the strategy and the goals of the organization, the 6 σ -program has a great chance to succeed.

Devotion of the employees is one of the most important factors of successful implementation of the 6 σ -program.

5. Sufficient funds/means

If there is devotion of the top management and if the 6 σ -program has been integrated into the organization strategy, the funds/means for implementation of the 6 σ -program will be provided automatically.

The "sufficient funds/means" include sufficient:

- financial support, money
- people, knowledge, enthusiasm
- managerial skills
- time.

How to determine the funds/means are sufficient? The traditional method includes calculations and analysis conducted by the financial department. In the real world of Six Sigma sufficient funds/means are the cost of a certain level but also actions ensuring results, savings and success. Financial funds necessary for implementation of the 6 σ -program should not be considered costs but investments.

Small organizations may have hard time finding sufficient funds. During the period of successful operation (when there are enough funds) the problem may occur of finding human resources for implementation of the 6 σ -program. It is also known that the 6 σ experts are hard to find.

6. Implementation Plan

To be certain that the implementation of the 6 σ -program produces the desired results, the main condition is to ensure a good implementation plan, in which the role of the top management should not be neglected. The implementation process of the 6 σ -program should be based on facts and knowledge, and not on intuition, emotion and happiness.

7. Efficient documentation

Today, documentation is one of the main management factors. Due to highly developed technology, it is easy to collect, classify and process large quantities of different information, and produce different documents on the operation process.

Due to the excess of information there is a question of efficient documenting, priorities and forms of information.

Documenting must be well planned and included into the implementation plan. Being a logical method with advanced tools, the 6 σ helps the user to find important data, include them in documents and manage them.

The conducted research in the Finnish SMEs resulted in the following reasons for "non-implementation of the 6 σ -program in our company":

1. "suitable only for large multinational companies"
2. "too American"
3. "nothing new"
4. "inadequate for our type of work"
5. "difficult to understand, too complicated technology"
6. "too theoretical"
7. "statistical tools are difficult and impossible to apply"
8. "lack of funds"
9. "no time"
10. "too expensive, costs too much"
11. "not accepted by the top management"
12. "higher quality improvement systems already exist".

Following the study [12], considering the reasons for non-implementation of the 6 σ -program in the Finnish economy SMEs it can be concluded the following:

"These reasons may sound like clichés but they have all been stated seriously. Therefore, a lot has been done, but there is still much more to do to overcome prejudices and to make path for the Six Sigma into the small organizations. Many references, good examples from other SMEs from, if possible, their own countries and sectors will be the best promotion for the Six Sigma in its route to achieve a more successful business.

The role of large multinational companies from their own countries is also important. For example, in Finland the role of Nokia was and will be the most important."

4

Investigating possibilities for wider implementation of the "Six Sigma" in smaller organizations using the Delphi method

Istraživanje mogućnosti početka "masovnije" primjene 6 σ -programa u malim organizacijama RH metodom "Delphi"

The majority of answers to the question: "What time would you estimate your company to start implementing the 6 σ -program?" related to the period of 3 to 4 years and 5 to 8 (although some answers were rather pessimistic, Figure 6). Therefore, research was conducted in cooperation with the competent experts to achieve more objective information on when "mass" implementation of the 6 σ -program in small organizations in Croatia may be expected. Estimates and analysis were conducted using the "Delphi" method.

The "Delphi" method is a method of intuitive anticipation, with a basic idea to use the ability of an expert, expressed through professional experience, knowledge and intuition, in a rational way. The method is based on conducting a survey with experts in a certain area in order to collect information which is then using a determined

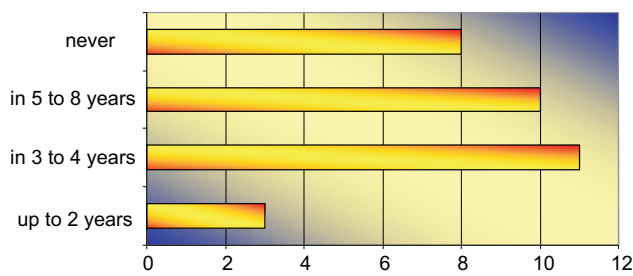


Figure 6 Which time will your company start implementing "six sigma" in?
Slika 6. U kojem periodu će Vaša tvrtka krenuti u primjenu 6σ-programa?

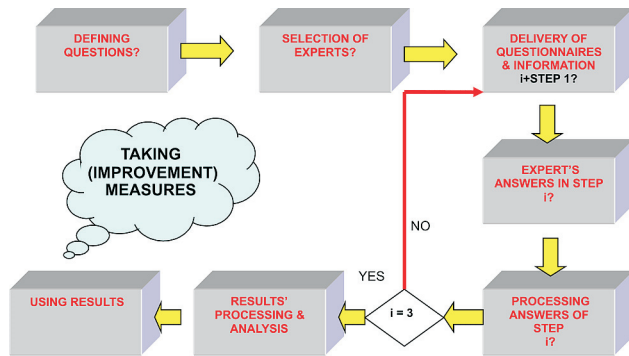


Figure 7 Information flow at "Delphi" prediction
Slika 7. Tijek informacija "Delphi" predviđanja

methodology converted into anticipation of an event. This is not a method of prediction but the method of systematic search for expert opinion, used for prediction. The method has been developed by RAND corporation in the USA.

DELPHI method implementation procedure (Figure 7):

1. Defining questions the experts should answer to create prediction of a certain event
2. Selection of a group of experts to be surveyed (practical experience reports about 5 to 10 experts being sufficient)
3. Delivery of the questionnaire to each expert. The questionnaire contains clear instructions on the application of the "Delphi" method
4. Answering questions by experts completes the first step and their role ends
5. Editing and statistical processing of the achieved results per each question
6. Creation of the second step questionnaire
7. Delivery of the second step questionnaire to each expert.
8. Processing, analysis and comments related to the second step
9. Creation of the third step questionnaire
10. Processing and analysis of the results received by experts
11. Using results.

Answers to the question on when a certain event will happen may be:

- One determined year
- A several year period.

The details given in this way are statistically processed.

For this case the research included 5 experts. Their task was to provide an answer on when the event x_i will happen, i.e. to give an estimated, pessimistic and optimistic time when, in their opinion, the Croatian economy (SMEs) may experience "mass" implementation of the 6σ-program.

To investigate possibilities of mass implementation of the 6σ-program in SMEs, the "Delphi" method was used. Although the respondents had been well acquainted with the issues related to the question asked, they were additionally supported with the following:

- Brief description of the 6σ-program
- Review of successful results of the 6σ-program worldwide
- Difficulties in implementation of the 6σ-program in SMEs.

The questionnaire of the first prediction step, including the mentioned descriptions, was delivered to the experts, who predicted the expected (m_i), optimistic (o_i) and pessimistic (p_i) time for the stated event. In this case event (x) is subject to deployment β . For such deployment, the answer's expected value \bar{t}_i and the variance σ_i^2 of every expert solves:

$$\bar{t}_i = \frac{\gamma_1 \cdot o_i + \gamma_2 \cdot m_i + \gamma_3 \cdot p_i}{\gamma_1 + \gamma_2 + \gamma_3} \quad (4.1)$$

$$\sigma_i^2 = \frac{(p_i - o_i)^2}{\gamma_4} \quad (4.2)$$

In 4.1, $\gamma_1, \gamma_2, \gamma_3$ follow the "Pert" method, and $\gamma_1 = 1, \gamma_2 = 4, \gamma_3 = 1$.

As the answers of all experts (n) are equally important, the total expected value and the variance are calculated as follows:

$$\bar{t}_n = \frac{1}{n} \cdot \sum_{i=1}^n \bar{t}_i \quad (4.3)$$

$$\sigma_n^2 = \frac{1}{n} \cdot \left[\sum_{i=1}^n \sigma_i^2 + \sum_{i=1}^n (\bar{t}_i - \bar{t}_n)^2 \right] \quad (4.4)$$

Answers provided in the first step have been processed and shown in Table 8. The analysis shows the following: the realization of the defined event x_i is predicted from 2012 to 2015, i.e. in 5 to 8 years, starting as of 2007.

Solutions 4.3 i 4.4 are used to separately calculate the expected value and the variance of each individual answer, according to the data obtained in expert surveys, and the total expected value and the variance for the expected event. Details are shown in Table 9.

Total expected value and the variance for the expected event:

$$\bar{t}_n = \frac{1}{n} \cdot \sum_{i=1}^n \bar{t}_i = 6,56,$$

$$\sigma_n^2 = \frac{1}{n} \cdot \left[\sum_{i=1}^n \sigma_i^2 + \sum_{i=1}^n (\bar{t}_i - \bar{t}_n)^2 \right] = 0,3724.$$

Table 9 includes individual statistic indicators, and Table 10 includes total values.

In Step 1, experts are given questionnaires which are the same as those for Step 1, and the statistical data resulting from answers given by all experts in Step 1. With answers and statistically analyzed details on answers available from all experts, experts provide Step 2 cycles (Table 11).

Table 8 Answers of experts for the Step 1 questionnaire of the Delphi method
Tablica 8. Odgovori stručnjaka na upitnik za 1. krug metode "Delphi"

DELPHI Method Step 1 Questionnaire									Coordinator: Živko Kondić		
How many years will the "mass" implementation of the 6σ-program in Croatian SMEs begin in?	0	1	2	3	4	5	6	7	8	9	10
The year which can be marked as the start of "mass" implementation of the 6σ-program in Croatian SMEs?	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Expert S ₁						o		m	p		
Expert S ₂							o	m	p		
Expert S ₃						o	m	p			
Expert S ₄						o	m	p			
Expert S ₅							o	m	p		

Note: The year marked with "0" represents the year of prediction.

Table 9 Statistical parameters obtained by predictions from experts' answers
Tablica 9. Statistički pokazatelji dobiveni predviđanjem prema odgovorima stručnjaka

STATISTICAL PARAMETERS INDIVIDUAL RESULTS										Coordinator: Živko Kondić	
Step	Expert S ₁		Expert S ₂		Expert S ₃		Expert S ₄		Expert S ₅		
	\bar{t}_1	σ_1^2	\bar{t}_2	σ_2^2	\bar{t}_3	σ_3^2	\bar{t}_4	σ_4^2	\bar{t}_5	σ_5^2	
1	6,8	0,025	7	0,11	6	0,11	6	0,11	7	0,11	
2	6,1	0,25	7	0,11	6	0,11	6	0,11	6,1	0,25	
3	6	0,11	7	0,11	6	0,11	6	0,11	6	0,11	

Tablica 10 Osnovni statistički pokazatelji za tri kruga predviđanja
Table 10. Basic statistical parameters for three prediction steps

STATISTICAL PARAMETERS RESULTING FROM PREDICTIONS TOTAL VALUE								Coordinator: Živko Kondić		
Step	Arithmetic Mean			Variance			Standard deviation			
	\bar{t}_n			σ_n^2			σ_n			
1	6,56			0,3724			0,61			
2	6,24			0,13144			0,55			
3	6,18			0,2598			0,51			

Table 11 Experts' answers for the Delphi method 2nd Questionnaire
Tablica 11. Odgovori stručnjaka na upitnik za 2. krug metode Delphi

DELPHI Method Step 2 Questionnaire									Coordinator: Živko Kondić		
How many years will the "mass" implementation of the 6σ-program in Croatian SMEs begin in?	0	1	2	3	4	5	6	7	8	9	10
The year which can be marked as the start of "mass" implementation of the 6σ-program in Croatian SMEs?	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Expert S ₁						o	m		p		
Expert S ₂							o	m	p		
Expert S ₃						o	m	p			
Expert S ₄						o	m	p			
Expert S ₅						o	m	p			

Note: The year marked with "0" represents a year of prediction.

Table 12 Experts' answers to Delphi Method Step 3
Tablica 12. Odgovori stručnjaka na upitnik za 3. krug metode "Delphi"

DELPHI Method Step 3 Questionnaire									Coordinator: Živko Kondić		
How many years will the "mass" implementation of the 6σ-program in Croatian SMEs begin in?	0	1	2	3	4	5	6	7	8	9	10
The year which can be marked as the start of "mass" implementation of the 6σ-program in Croatian SMEs?	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Expert S ₁						o	m	p			
Expert S ₂							o	m	p		
Expert S ₃						o	m	p			
Expert S ₄						o	m	p			
Expert S ₅						o	m	p			

Note: The year marked with "0" represents a year of prediction.

Analysis of the Step 2 answers results in prediction of x_1 event for the period from 2012 to 2015, i.e. in 5 to 8 years, starting from 2007. Data resulting from the experts' survey on the researched event were statistically processed using the same procedure as in Step 1, and the results are shown in Table 11.

In Step 3 the experts are provided with the same questionnaires as in Step 1 and Step 2, accompanied with the statistical parameters of Step 2. Based on those data, experts provide their answers to the question asked. Answering questions in Step 3 completes the work of experts (Table 12).

Analysis of answers provided by experts in Step 3 shows that mass implementation of the 6σ-program in Croatian SMEs should be expected from 2012 to 2014, i.e. in 5 to 7 years, as of 2007. The results were statistically processed and are shown in Tables 9 and 13.

Calculation of the expected value and the variance can also result in determining the probability of events for certain years. Since the experts' responses comply with the standard classification, using forms 4.5 and 4.6 [9, 10], probabilities of the investigated event x_1 are calculated from 2007 to 2017. Table 13 shows calculated values of event x_1 .

$$Y = \frac{\bar{t}_i - \bar{t}_n}{\sigma} \tag{4.5}$$

Editing of the 4.5 formula results in:

$$L(Y) = \frac{1}{\sqrt{2\pi}} \cdot \int_0^Y e^{-\frac{y^2}{2}} dy \tag{4.6}$$

The function is called the Laplace's function. Tables show values of this function for different Y values.

In Table 13 for 2011, number 4 results from taking the difference from 2011 and the year the prediction was made for – 2007. In the year stated in the table, for value $Y = -5$ the probability $P = 1 - 0,9999 = 0,0001$ is solved. The presented probability diagram (Figure 8) shows calculated values for different periods.

Based on predictions of the selected experts, the average time predicted for realization of event x_1 is 6,8

years.

Finally, it could be concluded that predictions provided by experts are realistic and can be realized provided all preliminary 6σ-program conditions have been fulfilled on the top management level and inside economic environment, and if larger distortions on the global market, caused by globalization, do not appear.

Prediction conducted by the „Delphi“ method may be accepted as a significant aspect of development of SMEs development in Croatia, because current changes in the world are larger and faster, should be predicted and correctly directed into development and improvement of future activities. It should be pointed out that the conducted prediction does not replace, or excludes, planning, but provides a basis for realistic planning. In that sense activities should be planned in the Republic of Croatia to "seriously" implement the 6σ-program in SMEs in 6 to 7 years.

The intention remains to shorten this time in dependence of the economic situation and the SMEs' environment. The activities by which a sooner start may be initiated include:

- To design the 6σ-program adjustment model in SMEs
- To improve awareness of the organizations' top administration on the role and importance of the 6σ-program
- To organize seminars on issues relating to improvement and the 6σ-program for top management members and quality managers
- To provide a favourable "climate" in various economic societies and associations
- To insist on the support of the top administration bodies, relating to economy (the ministry, chambers, counties, etc.)
- To start the "pilot" projects in the selected organizations as soon as possible, and to publish results for the open public
- To organize targeted lectures on the 6σ-program in schools and colleges
- These and other activities would not only accelerate the beginning of mass implementation of the said methodology but would also create a considerable "critical body" of stakeholders acting as the implementation generator of the 6σ-program.

Table 13 Event Probability Calculation
Tablica 13. Izračunavanje vjerojatnosti zbiljanja događaja

EVENT PROBABILITY CALCULATION			
Year	Number of years	Event Probability	
		Value Y	Probability P
2011	4	$Y = \frac{4 - 6,18}{0,51} = -5$	$P = 1 - 0,9999 = 0,0001 = 0,1\%$
2012	5	$Y = \frac{5 - 6,18}{0,51} = -2,3$	$P = 1 - 0,9895 = 0,0205 = 2,05\%$
2013	6	$Y = \frac{6 - 6,18}{0,51} = -0,35$	$P = 1 - 0,6370 = 0,3630 = 36,30\%$
2014	7	$Y = \frac{7 - 6,18}{0,51} = 1,6$	$P = 0,9450 = 94,50\%$
2015	8	$Y = \frac{8 - 6,18}{0,51} = 3,50$	$P = 0,999 = 99,9\%$
2016	9	$Y = \frac{9 - 6,18}{0,51} = 5,5$	$P = 0,9999 = 99,99\%$

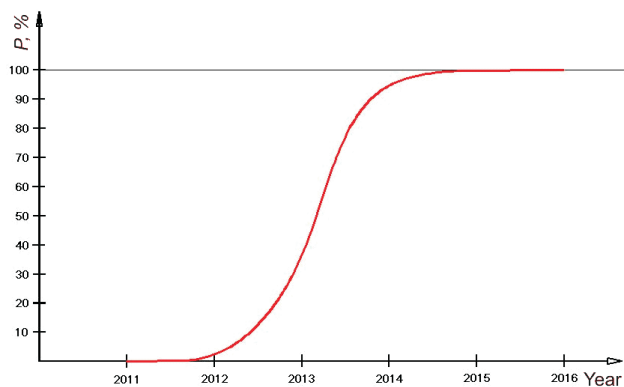


Figure 8 Probability for X_i at different periods

Slika 8. Vjerojatnost zbiljanja događaja x_i u različitim periodima

5 Conclusion Zaključak

Experience in implementation of the "Six Sigma" methodology in SMEs is scarce, both worldwide and in Croatian economy. We can sincerely say that in Croatian companies the systematic and organized implementation of the stated methodology is almost non-existent. Investigating the causes of such "poor" implementation in Croatian organizations resulted in the most influential factors being:

1. Insufficient engagement of top management
2. Size of the organization
3. Lack of knowledge.

In addition to these three factors, the lack of money and experts in small organizations has also been of significant importance.

Activities to significantly influence initiation of implementation as soon as possible:

- To design the 6σ -program adjustment model
- To improve awareness of the organizations' top administration on the role and importance of the 6σ -program

- To organize seminars on issues relating to improvement and the 6σ -program for top management members and quality managers
- To provide a favourable "climate" in various economic societies and associations
- To insist on the support of the top administration bodies, relating to economy (the ministry, chambers, counties, etc.)
- To start the "pilot" projects in the selected organizations as soon as possible, and to publish results for the open public
- To organize targeted lectures on the 6σ -program in schools and colleges.

These and other activities would not only accelerate the beginning of mass implementation of the said methodology but would also create a considerable "critical body" of stakeholders acting as the implementation generator of the 6σ -program.

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