Quality and Effectiveness Evaluation of the Geological Services Using CEDAC Method

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The paper deals with the development of the case-specific model for evaluation of quality and effectiveness of service provision and its systematic improvement. The modified version of the CEDAC (Cause-and-Effect Diagram with the Addition of Cards) method was applied for this purpose in the organization providing services in the field of environmental geology, and the EGEOS-PSI (Environmental Geology Service – Project Success Improvement) model was developed, which uses indicators of quality and effectiveness of the environmental geology services provision. The research was based on the case studies analysis of the existing projects in the organisation where preconditions of the effects (causes) on the project results were studied. Brainstorming was used to identify all the possible criteria (causes) affecting quality and effectiveness of the provided services and define the related KPSI (Key Project Success Indicators) for all the criteria while their importance was taken into account. The application of the proposed model enables to identify weaknesses in the processes of geological service provision and define effective improvements on the base of the results of quality and effectiveness evaluation. The proposed model can be applied in organisations providing services in the field of geology or other project organisation in order to improve their processes and project results while characteristics of individual services need to be taken into account in defining criteria and indicators of quality and effectiveness.

Key words: *Quality, Effectivity, Evaluation, Geological service, Key Project Success Indicator, Brainstorming, CEDAC, Improvement*

Introduction

The management of the prosperous organisations is aware of the fact that quality and efficiency are considered as a critical success factor. Quality and effectiveness evaluation of service provision process is essential for its management in the context of the PDCA (Plan, Do, Check and Act) cycle. Environmental geology services do not belong to traditional services. Project in the field of environmental geology is characterised by complexity as there are multiple simultaneously running processes (Cehlár et al., 2011). In order to improve quality and efficiency of the geological services, there is a need to implement suitable methods and tools and understand the key drivers affecting processes and results of environmental geologic projects.

According to (ISO, 2015) service is an output of an organisation with at least one activity necessarily performed between organisation and customer. There are many classifications of the services in the literature. Taken into account the nature of environmental geological services, we present the service classification according to (Lovelock & Wright, 1998), who classified services based on both the nature of the services act – tangible, intangible and who or what is the direct recipient of the service process – people, possession. Thus environmental geology service activities can be classified as follows:

- Tangible actions of service – remediation of soil or groundwater contaminated especially in the industrial estates (for example, hydrogeology and geochemistry).
- Intangible actions of service – laboratory analysis of water and soil, assessment of geological burden, processing geological project and reports, etc.
- Intangible actions of service, where recipients are people – consulting in the field of geology, engineering, etc.

Quality is defined as the degree to which a set of inherent characteristics of objects fulfil requirements (ISO, 2015). It means that quality level is a relative indicator reflecting the degree of the customer`s requirements fulfilment. Quality is related to effectiveness (Kang & James, 2006).

There is a popular quote from Peter Drucker in the management science: "Efficiency is doing things right; effectiveness is doing the right things" (BrainyQuotes, 2001). The term efficiency in context with the organisation has already appeared in Taylor`s publication "Conversations and Gospel of Efficiency" described in (Hays, 1959). Taylor tried to solve "nonefficiency" of day-to-day organisation activities. Defining the terms "effectiveness" and "efficiency" is difficult because there are many opinions, approaches and specific areas of

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use (Zajarskas & Ruževičius, 2010; CPE, 2017). We can talk about effectiveness in the fields of economy, social science, organisation theory, and also about efficiency in these fields, while in some cases and sources these terms are replaced.

Evaluation of effectiveness is a part of the organisation's optimisation methods, such as process audits or performance indicator system such as "Balanced Scorecard" (BSC).

In order to avoid discussion about the correctness of the used term "effectiveness" in our paper, the meaning of both words are explained in context with quality management system according to ISO 9001:2015 and project management according to ISO 10006:2017:

- Efficiency is a relationship between the result achieved and the resources used.
- Effectiveness is an extent to which planned activities are realised, and planned results are achieved.

Resulting from the definition mentioned above, we can use the term "effectiveness" in context with the monitoring of Key Performance Indicators KPI, respectively Key Project Success Indicators (KPSI).

The process of effectiveness evaluation includes knowledge of current state and knowledge of standard as well as comparing and formulation of the results. Thus the evaluation of any entity is a comparison of what exists with what should be – with some opinion on the quality optimum, for example, based on Kano model (Turisová, 2015; Mandzik, 2016). Evaluation of service quality and effectiveness is crucial for targeted improvement (Nenadál, 2001).

According to (Zeithaml et al., 1990) service quality is a difference between customer expectation of service and perception of service. To evaluate service quality, it is essential to define the characteristics affecting customer perception. The processes and activities are those, which affect the qualitative level of provided service and therefore main characteristics of processes need to be defined. This fact is reflected in the GAP Model of Service Quality introduced by (Parasuraman et al., 1985), which includes five possible GAPs within the processes of service provision. This model is the basis of the SERVQUAL method for quality service evaluation, which defines five dimensions and twenty-two characteristics of service quality (Parasuraman et al., 1988). Hower the SERVQUAL is not considered as a universal method for service quality evaluation. There are many modified version of these model in the literature. In some cases, only a partial adjustment of the quality characteristics is required, but other service sectors may need a complete change of dimensions and quality characteristics (Buttle, 1996). For our study, the SERVQUAL does not offer relevant dimensions and characteristics for the service quality evaluation.

Services in the field of environmental geology have specific characteristics. Processes of environmental geology service provision are complex and have an impact on the society. According to (Lajczykova & Zgodavova, 2013) defining project success is often associated with "deliver outcomes on time and planned budget". However, are those the success factors that are most important in the case of environmental geology projects from the perspective of all stakeholders? For identification of project success indicators from the perspectives of quality and efficiency and their systematic evaluation and improvement, the less known CEDAC (Cause-and-Effect Diagram with the Addition of Cards) method was modified, and the EGEOS-PSI (Environmental Geology Service – Project Success Improvement) method was developed.

Cause-and-Effect Diagram with the Addition of Cards

The CEDAC is a unique and straightforward approach for creative, participative problem-solving technique and it is also a tool for continual systematic improvement. The CEDAC method was first developed and used in Japan by the Standardisation Study Group of Sumitomo Electric Industries, and it was introduced and applied in many Japanese, North American and European companies, e. g. Weyerhaeuser, Pratt & Whitney, Allied Signal, Timken, Newell Rubbermaid, GM of Canada and many other production companies worldwide (GPT, 1996). The "father" of the method is Ryuji Fukuda who was honoured with the prestigious Deming Prize for his contribution to the field of productivity and quality improvement. He published the CEDAC in his book entitled CEDAC: A Tool for Systematic Continuous Improvement.

For improving quality and effectiveness of the services, it is essential to target the right problems, get the right people involved in solving them and make sure that the solution work, what is enabled by the CEDAC application in every organisation. The CEDAC encompasses three tools for continuous, systematic improvement: window analysis (for problems identification), CEDAC diagram (a modification of the classic fishbone diagram for analysing standard problems and developing standards), window development (for ensuring adherence to standards) (Fukuda, 1989).

Window analysis (1st stage of the CEDAC) is used for the study of specific data on different nonconforming results and categorisation of the data according to their management. Data are categorised according to the characteristics "Known", "Unknown", "Practiced" and "Unpracticed" into categories A-D, which are represented in Table 1 (Lajczyková, 2010). According to (Fukuda, 1989) favourable environment occurs when two conditions are met: (1) Proper practices (standards) have to be established, respected and practised, (2) All stakeholders have to understand these procedures and manage them in practice accurately.

Tab. 1. KPIs used in the organisation before the EGEOS-PSI implementation.

Category	Description of the event	Nature of the situation
A	Established – Known – Practiced	Ideal situation
B	Established – Known – Unpracticed	Problem with practice
C	Established – Unknown – Unpracticed	Problem with communication
D	Not established – Unknown – Unpracticed	Problem with standardisation

CEDAC diagram (2nd stage of the CEDAC) analysis the problem from two perspectives: from the view of the causes of the problem (Fishbone diagram is used) and subsequently from the viewpoint of improvement (improvement cards are used). Thus two sets of cards are added by the employees to the fishbone. One set of cards are known as fact (causes) cards, and another set is known as solution cards (Mahadevan, 2009). The side effect of a CEDAC diagram is a quantified description of the problem, with agreed and visual quantified target and continually updated results on the progress of achieving it. The solution cards are placed on the right of the fact cards. Those cards ensure that the facts are collected and organised before solutions are devised. The solutions are then selected and evaluated, and test results are recorded on the effect side. Each potential solution uses “a dots” system to discern various solutions: a) single dot (•) – the idea is of interest; b) two dots (••) – the idea is under the preparation; three dots (•••) – the idea is under the test. The successful improvement ideas are incorporated into the new standardised project procedures (Lisiecka & Burka, 2016).

Window development (3rd stage of the CEDAC) examines the actions of a CEDAC diagram and focuses on compliance with standards. In other words, this tool is designed to ensure, that every employee correctly understands and respects standard. Window development uses numerical method for effectiveness evaluation of the standard (Moore, 2007)**.**

On the base of the literature analysis, it is possible to conclude that CEDAC was used in many fields of the production to solve various problems (for example, the effect of inputs variability on the output, problem analysis and standard development). It is assumed that its application within the research in the field of environmental geology will be suitable and will help to extend its use in the non-production sector.

Methodology

Research methodology is based on the case studies analysis of the existing projects in the organisation providing services in the field of environmental geology, which served for the preparing of the model for further research. Case studies relate to the contracts of the Environmental and Geology Division (EGD). During 2012 – 2013, the major projects aimed at solving past environmental burdens were monitored. In 2013, further research developed the algorithm for the situations awareness and improvement of projects success (S) and thus for improving the Quality (Q), Effectiveness (E), Efficiency (I) and Traceability (T) (Zgodavová et al., 2001). This step was based on the review of project documentation and subsequent processing of the case studies. Direct application of the model and ongoing projects evaluation using EGEOS-PSI model took place during 2013 – 2017.

The proposed EGEOS-PSI model was developed on the basis of the CEDAC method for evaluation of quality and effectivity of the service provision and its improvement. Correct setting of indicators are crucial for the evaluation of the service provision process and targeted improvement. The aim was to monitor indicators, which affect rentability, customer perception and intensification of the remediation process and find other possibilities for improvement. In the case organisation, application of the CEDAC method enabled to define the Key Project Success Indicators from the perspective of quality and effectiveness which are most important for the stakeholders of environmental geology projects. In the case of projects, it is more suitable to replace the term Key Performance Indicators (KPIs) with the term Key Project Success Indicators (KPSIs) according to ISO 9004:2009 as a common term for criteria used to measure the results (financial and non-financial) of a project (Parker, 2013; ISO, 2009).

The CEDAC method application consists of three stages. For the research two stages of the CEDAC was applied for creation of the EGEOS-PSI in following steps:

- Forming of the project team involving the customer on the base of the principles of CDPM (Customer-Driven Project Management) and delegation of the project team leader. The aim is to include the employees in all steps of the CEDAC application.
- Defining the primary attributes of improvement. The attributes of improvement were the quality and effectiveness of the service provider. The project gives the duration of service provision and schedule of its realisation.

- Reviewing the case studies (selected projects of the organisation) and familiarisation with the processes realised within the case studies to understand main criteria affecting the project success.
- Leading of the brainstorming session to identify the effects on project success by the reviewed case studies and clustering the effects into individual categories. Definition of the related KPSIs in each category and weight estimation of the KPSIs taken into account the voice of the customer.
- Target value setting of the defined KPSIs and determination of the measurement method (frequency, responsibility, etc.) for estimation of the real value of the KPSIs.
- Proposal for the improvements by the project team and their categorisation according to their feasibility (using "dots" system).
- Implementation of the improvements and create new standards.

For the determination of overall effectiveness E_{SUM} of the service provision the equation Eq. (1) was used, where *Ei* is the value of the *i*th KPSI, *wi* is the weight of the *i*th KPSI and *n* is a number of KPSIs.

$$E_{SUM} = \sum_{i=1}^{n}(Ei.wi) \qquad (1)$$

where

$$E_i = \frac{R_i}{P_i} \qquad (2)$$

for indicators, where increasing of R-value (↑) increases the effectiveness

$$E_i = \frac{P_i}{R_i} \qquad (3)$$

for indicators, where decreasing of R-value (↓) increases the effectiveness

R – real value
P – planned value

Case study: Application of the proposed EGEOS-PSI model

The mission of the organisation providing services in the field of environmental geology is rational exploitation of the geological structure. Accompanying negative function (and simultaneously project risks) can cause geological hazards e.g. unexpected subsidence, faults and destructive landslides, as well as a burden on the environment (contamination of water, soil, air or degradation of their ecological stability, etc.), utilisation of especially non-renewable or heavily renewable resources, etc. (Lajczyková & Zgodavová, 2013). The main processes of geological service provision can be simply described in the following sequential order:

- Design of geological services (technical consulting, e.g. designing projects using environmental technologies and pollution control, geological surveys, hydrological mapping, etc.).
- Realisation of geological services, including activities such as exploration drilling, geological surveys, engineering services and supporting activities e.g. remediation, technical testing and analysis, and of course the processing results (evaluating geological projects and processing final reports, processing and evaluating data from laboratory analysis, calculating, results evaluating, assembling diagnosis and other evaluating geological structures).
- Providing the results of geological surveys.

Primary activities in the EGD (Environment and Geology Division) of the case organisation are: geological surveys, design works, consulting works, environmental remediation works, laboratory works. Projects in the field of environmental geology are complex consisting of many processes. Control of these processes takes place according to the general principles of project management. Case study represents the organisation project in the field of environmental burdens removal. Process description of project realisation is defined in EGD working procedure. The working procedure is a controlled document of the second level within the established and certified Integrated Management System (IMS). IMS includes the Quality Management System in accordance with ISO 9001:2015, Environmental Management System by ISO 14001:2015 and Health and Safety Management System by OHSAS 18001:2007 in the monitored case organisation. The EGD working procedure refers to the controlled documentation of the second level (the corporate directions, etc.) and IMS manual (the first level in the structure of controlled documented information in the analysed company). The purpose of the working procedure is to determine principles, procedures and responsibilities for the service realisation in the EGD. The working procedure objectives are:

- to create the conditions for compliance with requirements specified in the contracts;
- to satisfy the needs and expectations of customers and stakeholders;
- to comply with legal and other requirements;
- to minimise environmental aspects and safety hazards.

Evaluation of quality and effectiveness of the geological services before the implementation of the EGEOS-PSI was realised according to the procedure of the EGD, which focused mostly on the evaluation of customer satisfaction after the completion of the project and criteria resulting from the contract. The KPIs (Key Performance Indicators) monitored by EGD before the EGEOS-PSI implementation are listed in Table 2.

Tab. 2. KPIs used in the organisation before the EGEOS-PSI implementation (Zgodavová & Lajczyková, 2013).

Quality			**Effectiveness**
Findings from control days during the project implementation	The level of customer satisfaction after the completion of the contract	The level of criteria in the contract (geological structures contamination, etc.)	The level of economic effectiveness

The brainstorming enabled to define criteria and KPSIs for the evaluation of quality and effectiveness of the service provision. Criteria were classified into following categories: 5M (Manpower, Machines, Materials, Methods, and Measurement), Environment, and Effectiveness. According to measurement units the defined KPSIs are classified into the following categories: Finance, Time, and Quality. The degree of KPSIs effect on project result is different, and the brainstorming also enabled to determine the weight of the individual KPSIs. The following KPSIs were defined in the research according to Table 3.

Tab. 3. KPSIs using in the organisation after the EGEOS-PSI implementation.

<table>
<tr><td rowspan="6">Effectiveness</td><td>related to material, products; labour and service costs ↓</td></tr>
<tr><td>(1) Material costs; (2) Energy costs; (3) Product costs (Cost of equipment procurement, Other costs related to product; (4) Cost of transport; (5) Costs of cooperation; (6) Service costs (Costs of repairing, Costs of revision and preventive maintenance, Cost of equipment calibration, Cost of services in the field of control and examination); (7) Costs of nonconforming deliveries and services; (8) Costs of reworks; (9) Costs of delays (Cost of delays caused by supplier, Costs of delays caused by the customer, Cost of service delivery delays); (10) Labor costs (Costs per employee, Employee training costs).</td></tr>
<tr><td>related to time fulfilment ↓</td></tr>
<tr><td>(11) Fulfilment of work schedule, (12) Fulfilment of project schedule; (13) Delays caused by the customer; (14) Delay caused by the supplier.</td></tr>
<tr><td>related to quality ↓↑</td></tr>
<tr><td>(15) Number of official complaints; (16) Number of comments of external supervision; (17) Number of complaints related to nonconformity during the service provision; (18) Changes in documentation after customer requirement review; (19) Changes in documented information by customer requirement during the service provision; (20) Customer satisfaction; (21) Stakeholder satisfaction.</td></tr>
</table>

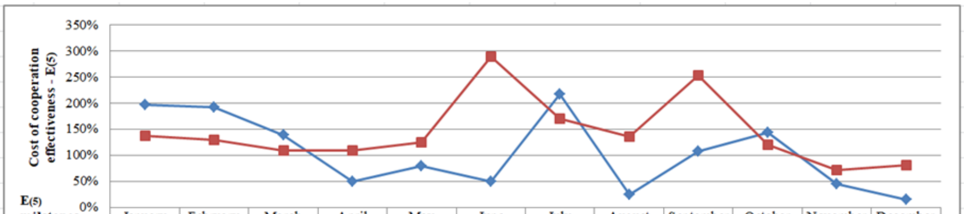
Figure 1 shows as an example of the selected KPSI number (5) "Cost of cooperation" with the planned and real values in 2016 and 2017 and the improvement solution, which was under the testing according to the "dots" marking system. Months from January to December represent milestones of the project and efficiency is shown as a percentage. The CEDAC diagram enables to present the deviation from the target values. After the implementation of an improvement, it is easy to monitor its effect.

In the case of this indicator, there is an improvement of effectiveness level. In 2016, the effectiveness was only 67 %, and in 2017 it increased to the level of 114 %. The improvement solution was implemented as a standard.

Milestones	*P [EUR]*	*R [EUR]*	*P [EUR]*	*R [EUR]*
January	800	405	600	438
February	1000	520	800	617
March	1500	1081	1200	1096
April	750	1496	1500	1380
May	550	694	1000	805
June	700	1415	1200	415
July	800	367	800	470
August	300	1200	800	587
September	700	646	800	315
October	700	489	1000	835
November	800	1800	1500	2110
December	300	2000	2000	2479
Cost/year	8100	12113	13200	11547
E_5(sum)	67%		114%	

Cost of cooperation

Customer involvement is needed. Clear defining what will be ensured by the customer within the cooperation on his property where the services are provided while the next stage of the work schedule according to project documentation is discussed.



	January	February	March	April	May	June	July	August	September	October	November	December
2016	198%	192%	139%	50%	79%	49%	218%	25%	108%	143%	44%	15%
2017	137%	130%	109%	109%	124%	289%	170%	136%	254%	120%	71%	81%

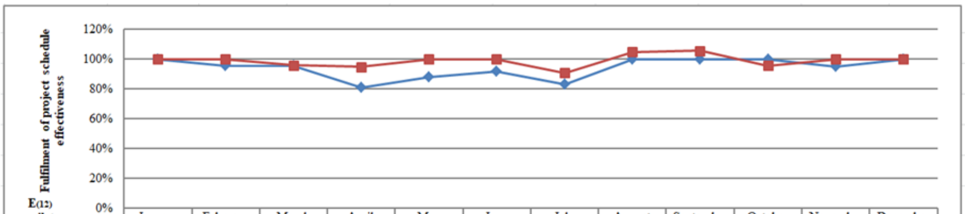
Fig. 1. Detail of project monitoring by CEDAC diagram for the "Costs of cooperation.".

Time delays cause financial losses. Therefore, it is essential to reduce delays as much as possible. Figure 2 shows as an example of the selected KPSI number (12) "Fulfilment of project schedule ", with the planned and real values in 2016 and 2017 and the improvement solution, which was under the testing according to the "dots" marking system. In 2016, there were 36 days of delay mostly caused by the suppliers which had a negative impact on the final service delivery on time. The implementation of the improvement enabled to decrease this delay significantly. Finally, the improvement solution was implemented as a standard.

Milestones	*P [days]*	*R [days]*	*P [days]*	*R [days]*
January	19	19	21	21
February	21	22	20	21
March	21	22	23	23
April	21	26	18	19
May	22	25	21	21
June	22	24	22	23
July	20	24	20	21
August	22	22	22	23
September	20	20	19	18
October	21	21	22	24
November	20	21	20	20
December	21	21	19	19
Days/year	231	267	247	253
E_{12}(sum)	87%		98%	

Fulfilment of project schedule

Systematic human resource management, team building and, where necessary expanding the team.



	January	February	March	April	May	June	July	August	September	October	November	December
2016	100%	95%	95%	81%	88%	92%	83%	100%	100%	100%	95%	100%
2017	100%	100%	96%	95%	100%	100%	91%	105%	106%	96%	100%	100%

Fig. 2. Detail of project monitoring by CEDAC diagram for the "Fulfilment of the project schedule."

The inspection plan was created for easy recording of data for each milestone, including KPSIs divided into three groups according to Table 3. Table 4 shows the example of the overall inspection plan.

Tab. 4. Example of an overall inspection plan for the year 2016.

KPSI identification card		**Results card**		**Improvement card**		**Dots marking system**
Effectiveness	w_i	**Plan 2016**	**Real 2016**	**P/R % R/P %**	**Notes**	
related to material, products; labour and service costs	0.50					
(1), (2), (3), (4)	…					
(5) Costs of cooperation	0.05	8,100 [EUR]	12,113 [EUR]	67 %	Customer involvement is needed. Clear defining what will be ensured by the customer within the cooperation on his property where the services are provided while the next stage of the work schedule according to project documentation is discussed.	● ● ●
(6), (7), (8), (9), (10)	…					
related to time fulfilment	0.20					
(11)	…					
(12) Fulfilment of the project schedule	0.04	231 days	261 days	87 %	Systematic human resource management, team building and, where necessary expanding the team.	● ● ●
(13), (14)	…					
Related to quality	0.30					
(15), (16), (17. (18), 19), (20), (21)						

Overall effectiveness of the managing this project on the base of partial values of effectiveness is shown in Table 5. In 2017, overall effectiveness in comparing with 2016 increased by 16 %.

Tab. 5. Overall assessment of inspection plan using CEDAC.

Year	**2016**	**2017**
	Overall effectiveness of project management E_{sum} [%] according to Eq. 1	
[%]	81	97

Results and Discussion

Despite highly developed integrated management systems in the organisation and achieving a high quality of the products and project results, the organisation must be prepared for the evolving competition in the area of interest and the tightening up criteria for evaluation of environmental burdens. The organisation, which has a lot of "tacit knowledge", have to know how to transform them into useful information. The organisation must improve the quality of the resulting solutions, innovate procedures and learn to continue activities improvement and successful achievement in competitive surroundings. Based on the details that we have monitored during 2016 – 2017 and continuously analysed using EGEOS-PSI model, we found a major strategic task to improve "performance" of the organisation´s management system:

- To implement the standard ISO 9004:2018 (after the revision 9004:2009).
- To apply the principles and practices of project´s quality management according to ISO 10006:2017.
- To manage risks using ISO 31000:2009 respectively revised ISO 31000:2018.
- To utilise Barkley´s & Saylor´s, 2001 methodology "Customer-Driven Project Management" extended by the tools and methods of quality management and quality engineering as CEDAC method.
- To apply monitoring by KPSIs and proceed with the EGEOS-PSI methodology.

The EGEOS-PSI methodology is based on the CEDAC method. Therefore it can be considered as a suitable method for evaluation of quality and effectiveness for an organisation operating in the field of geology. The KPSIs and their weights can vary depending on the nature of the provided service.

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