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# Optimization of enterprise analysis model for KPI selection

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**Abstract.** Nowadays, a number of methods and principles are available in literature for KPIs (key performance indicators) selection. However, they are facing with the same issue – lack of optimal procedures for selection of suitable metrics for particular company. The purpose of the study is to optimize enterprise analysis model (EAM) for KPIs selection and to reduce the time and resources necessary for the analysis of the enterprise. In the current study four outlier's detection methods for eliminating "outliers" in the answers are utilized. Furthermore, the experts from production and academic institutions are participating in evaluation and analysis of questionnaires. The optimized EAM is going to help simplifying the choice of KPIs, reducing the amount of data and optimizing the data flow. The optimized set of questions in EAM and KPIs that could be used in companies for improving their productivity are determined. The research is focused on SMEs (small and medium enterprises) and intention is to increase their competence on the market. The general procedure for KPIs selection/optimization for SME is pointed out.

**Key words:** key performance indicators (KPIs), KPIs selection model, enterprise analysis model (EAM), outlier's detection methods.

## 1. INTRODUCTION

The last two decades have seen profound change in the private sector's relationship with society and reconsideration of the links between state and market. The basic principles, on which private companies are expected to contribute to the public sector, are altered due to globalization accompanied and reinforced by social and economic reforms [1–3]. In comparison with other type of enterprises, the SMEs are showing good performance [4–7]. Nowadays, to be able to face all challenges and become winner in competition "be eaten or stay alive", companies need to deal within dynamic environment of fierce competition, shrinking budgets and heavy price pressures [8]. From one point of view, SMEs cannot effort high investments on research and development (R&D) like large enterprises or concerns, due to the financial aspects. From another point, the speed of the implementation of new technologies, approaches and methods are higher [9]. One of the methods that could help companies to improve the situation at production or eliminate difficulties, is the implementation and measurement of right KPIs.

It has been stated that companies which have developed and implemented sustainable practices, were able to improve product quality by following quality ratio, first pass yield and increased profits [10].

As a result, new trends/approaches that are becoming more popular, can be outlined – analytic hierarchy process (AHP) and SMART criteria synthesis for prioritizing company's KPIs, proposed by Shahin and Mahbod [11], where the pair-wise comparison has been done to judge the impact of the selected metrics on the company; the three components (academic, researching

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and supporting activities) that would simplify the importance of the metrics and AHP technic as selection methodology by Kadarsah [12]; Parmenter's 12-way model, which is based on four main stones, where the main focus is on the investigation and preliminary work [13]; questionnaire survey and confirmatory factor analysis (CFA) for data evaluation, where the consistency check of the data, received by analysing the questionnaires, has been performed by Yuan, Wang, Skibniewski and Li [14]; AHP based selection and prioritization methodology for leading KPIs by Podgorski [15].

## 2. KPI SELECTION MODEL

In [16] it is attempted to combine the advantages of the existing models and to avoid the disadvantages pointed out above. The proposed model can be divided into three phases:
(1) enterprise analysis model (EAM);
(2) data collection;
(3) data analysis and implementation.

The KPIs selection process is performed as follows:

- analysis of the enterprise. The EAM as a first phase of the selection is used to collect not only the general information about the company where study has been conducted, but also outline the weak spots faced by the management of the enterprise. The questionnaire is filled in by the employees, based on their position at the company (different amount and different questions). This allows to feature KPIs selection for particular company or type of companies, etc.;
- data collection for the analysis. A web-based questionnaire is composed as a rule – this enables to collect and analyse data more quickly and with higher efficiency (manual data collection is considered for special cases). The collected data are verified and stored in the database (server-cloud);
- data analysis. Sorting and grouping by numbers of respondents, applying weights. The answers are being analysed and evaluated by their importance (the answers are ranked by the 6-point scale, where 1 means that the answer is critical and needs to be taken into account and 6 means that the situation described in the question is not critical for the company);
- KPIs selection. The package of KPIs is selected by the expert group and two approaches: SMARTER criteria and fuzzy analytical hierarchy process (AHP);
- KPIs' implementation (the selected package of metrics is implemented by the company based on their ranks).

In addition, it is wise to mention that, independent from the used approach, the whole process of selecting KPIs is a continuous process. Management should not stop, when the package of metrics has been selected and implemented. The situation in the world is changing rapidly and new trends appear. We can see the same in production: new machines and robots, and the level of automatization is rising. There are new enterprise resource planning (ERP) systems, new manufacturing processes, new approaches etc. Due to these factors, the metrics that had to be followed in the beginning do not have to be analysed at present. As the process is continuous and the whole procedure of the KPIs' selection needs to be repeated by the management during a time frame, the optimization of the EAM is required.

## 3. ENTERPRISE ANALYSIS MODEL

The EAM is used to analyse the enterprise, to discover and to understand the critical spots. The following EAM goals can be outlined [17] as follows:

- getting the general information about the enterprise (field of action, number of employees, etc.);
- discovering the critical spots (based on the answers of the questions).
- providing the information which data should be collected based on the critical spots to eliminate the amount of unnecessary data (as there are links between KPIs and questions).

The proposed selection model of KPIs eliminates the main disadvantages of the previous concepts [11,12,18] as selection of the metrics is based on the issues discovered by the EAM after implementation in the studied company.

The model is based on traditional questionnaire for management and company's workers. The main goal is to bring out the bottlenecks and weaknesses in the production and general processes of the enterprise by analysing the answers. The questionnaire is one of the oldest and more commonly used tools for data collection. The advantages of this approach are availability (cheap and easy to establish) and quality of the answers (additional training is not necessary for the participants).

Simplified concept of the EAM has been illustrated in Fig. 1.

The questionnaire includes mapping the enterprise, there will be formed questions about certain fields of the company. General information regarding objectives, missions, visions, location of the enterprise etc. is received by the answers. More than 70 research papers with similar topics were studied to prepare this survey. Questions were divided into 15 categories, where

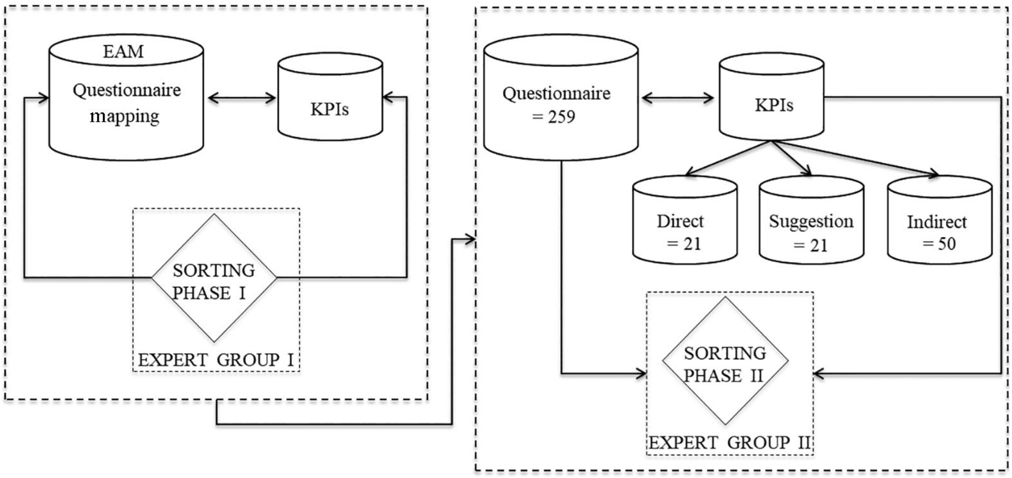


**Fig. 1.** The concept of the EAM.

each category had a different number of constructs. Constructs were linked to each group to simplify categorization. More than 40 different scales were used for the answers [19].

All questions have been composed based on the previous researches, which in case of the current study has higher impact on the final results due to the fact that questions describe different situations in the company. Furthermore, the questions or issues can be declared as common problems in the companies in general. By answering the questions, management will understand, what kind of problems they have in the company and based on that, what are the measures that have to be taken to change the situation in a positive way.

The KPIs for the study were selected after working through the analysis of different researches in that field (over 70 articles). The questions were linked with KPIs that would be worth investigation after data collection. In turn, the KPIs were divided into 3 groups to simplify linking:

(1) direct KPIs – indicators, which were in explicit correlation with the answers;
(2) indirect KPIs – indicators, which were connected with more than one question;
(3) suggested KPIs – indicators, which were proposed to the management for further study.

Indirect KPIs can be specified by answering at least two questions. For example, employee satisfaction can be followed only by knowing the staff turnover, availability of trainings and benefits etc.

To eliminate misunderstanding and provide better effectiveness of survey, logical connection between next pairs were established and tested:

- constructs + questions;
- questions + KPIs.

According to Fig. 1, sorting was performed in two phases by using web tool “Optimal Workshop”. It enabled to save time not only on establishing the sorting process (input) but also on performing the evaluations (output). During the first stage, raw version of subjects was tested. The main task for the expert group was to match the left side (constructs/questions) with the right side (questions/KPIs). The case study group consisted of 10 researchers: 7 from different industrial companies, 2 from university and 1 from competence centre with no direct connection with the study, but with necessary knowledge and experience in that field. If questions or KPIs were matched with objects in a wrong way, the formulation of questions was changed or questions were replaced by more suitable ones.

The second phase was performed after improvements of the first phase. The main goal was to exclude further errors and to confirm, that previous review was done in a right way. The total number of questions, including corrective actions, was 259, which in turn were linked to 92 KPIs.

## 4. OPTIMIZATION OF EAM

The optimization of EAM is introduced based on workgroup’s long term experience in area of linear and nonlinear constrained optimization, covering design of materials, structures and manufacturing processes [20–23]. The optimization is performed with an aim to develop an effective enterprise analysis model, which enables to perform analysis in a reasonable time frame without remarkable loss in quality. For this reason, first a thoroughgoing set of questions and KPIs was composed and then, this set was limited to bounds allowing resource effective analysis. The optimization problem considered can be formulated as follows:

$$\begin{gathered} Min\ R_i \\ \text{subjected to} \\ KPI \leq KPI^* \\ \text{questions} \leq \text{questions*}, \\ PI > PI^* . \end{gathered} \tag{1}$$

In Eq. (1), $R_i$ stands for the resources (total time for analysis, working hours for completing the questionnaire, etc.), $KPI^*$ and questions* are estimated upper limits for the number of KPIs and questions, respectively. In order to keep model adequate, the information related to production PI should be retained upper critical limit $PI^*$. Optimization procedure was proposed in Eq. (1) to solve posed optimization problem.

In addition, during ranking phase, the ranked questions, received from experts, may contain outliers that have different impact on the data set when compared with others. Outliers may have critical impact on the data analysis. The goal was to optimize the questions by eliminating faulty answers from the total range [24]. Four different and simple outlier's detection methods were chosen:
(1) standard deviation method;
(2) modified Z-score method;
(3) Tukey's method;
(4) adjusted boxplot.

The basic steps of the proposed KPI selection/optimization procedure can be outlined as follows:

Step 1. Forming initial questionnaire, KPIs.
Step 1.1. Composing initial questionnaire based on literature, experts.
Step 1.2. Composing initial KPIs.
Step 1.3. Identifying links between constructs and questions.
Step 1.4. Identifying links between questions and KPIs.
Step 1.5. Classification of KPIs (direct, indirect, suggested).
Step 2. Applying an expert group to reduce questions, KPIs.
Step 2.1. Omitting questions unrelated or weakly related to KPIs.
Step 2.2. Omitting questions/KPIs, with no or weak impact on production.
Step 2.3. Ranking questions.
Step 3. Applying outlier's method for reducing questions, KPIs.
Step 3.1. Selection of outlier's methods.
Step 3.2. Employing the standard deviation method.
Step 3.3. Employing the Z-score method, modified Z-score method.
Step 3.4. Employing Tukey's method.
Step 3.5. Employing the adjusted boxplot method.
Step 3.6. Selection of outliers based on the results of applying outlier's methods.
Step 4. Estimating the final set of KPIs and questions.

Return back to Step 2 in case the number of questions and KPIs are still too huge to perform effectively in SME (KPI ≤ KPI*, questions ≤ questions*).

Note that contrary to the standard approach, in the case of the posed optimization problem, the initial solution is selected consciously infeasible. The first two constraints of Eq. (1) are not satisfied due to the thoroughgoing set of questions and KPIs considered as candidates for the final set.

## 5. CONCLUSIONS AND FURTHER STUDY

In the current study, the first phase (EAM) of KPIs selection model was described in detail. The EAM improvement problem was formulated as optimization problem. The optimization procedure, featured for particular problem, was developed. The outlier's detection methods were chosen for further study. Implementation of the optimization procedure allows to reduce time necessary for analysis of the enterprise. The selection model KPIs can be considered as foundation on which decisions and improvements would relay. Furthermore, it should simplify the work of management and make production more transparent. The future study is related to the application and refinement of the optimization procedure for KPIs' selection model.

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## Ettevõtte analüüsi mudeli optimeerimine võtmenäitajate valikuks

Sergei Kaganski, Martin Eerme ja Ernst Tungel

Käesoleva uurimistöö käigus tutvustati mõõdikute valimi mudelit, mis omakorda võimaldab genereerida vajalikke mõõdikuid ja ettevõtte analüüsi mudeli põhikontseptsioone. Püstitati mudeli optimeerimise probleem, mille eesmärgiks oli leida väikese ja keskmise suurusega ettevõtete kitsaskohad ning mille lahendamiseks töötati välja vastav protseduur. Ettevõtte analüüsi mudeli sorteerimisel kasutati veebitööriista Optimal Workshop. Küsimuste hindamise etapis, kõrvalekallete tuvastamiseks ja eemaldamiseks kasutati järgmisi meetodeid: standardhälve, modifitseeritud Z-skoor, Tukey meetod ja kohandatud boksplotmeetod.