# An Approach to Forming Dashboards for Business Process Indicators Analysis using Fuzzy and Semantic Technologies

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**Abstract.** This article considers development of the approach to forming dashboards for business process indicators analysis. The approach idea is based on the dashboard design problem, outlined in analyzed works, which propose a lot of recommendations and best practices, but have a lack of formal approaches to dashboard design definition for specific business process indicators. This study considers application of fuzzy and semantic technologies in order to provide description and analysis of relations between analyzed business process indicators, indicator's types, and visualization tools. It also considers event log processing of a workflow system, used to execute business processes, which indicators are measured. As a result of implementation and application of the proposed approach, recommendations for a dashboard's design, based on specific business processes and their performance indicators to be analyzed, can be obtained and implemented. The theoretical essentials, workflow scheme, and early results of the proposed approach are given, future research is outlined.

**Keywords:** Key Performance Indicator, Dashboard, Fuzzy Semantic Network, Event Log Processing, Business Intelligence.

## 1 Introduction

As an extremely popular organizational management approach, Business Process Management (BPM) includes a set of methods, techniques and tools, used for modeling, execution, and analysis of organization's business processes [1].

One of the important aspects of BPM lifecycle (which includes business process identification, discovery, analysis, redesign, implementation, monitoring and control) is the continuous analysis of business process indicators. This activity is focused on a set of Key Performance Indicators (KPI) and their target values, based on organization's business goals. Hence presentation of these KPIs, using various types of Business Intelligence (BI) dashboards and reports, provides visualization of business performance [2].

Usually, BI dashboards present KPIs in visual form using diagrams or plain images, such as using images of measuring tools (e.g. charts, gauges, graphs etc.). At the

same time, it's necessary to choose data visualization techniques, which are clear, easy interpretable, space efficient, attractive, and legible [3, 4].

Hence, the KPIs dashboard design problem becomes relevant, because it requires placing various visualization tools in a small space, while keeping them accessible and easy to understand [5, 6]. Therefore, in this study we propose the approach to forming dashboards for business process KPIs analysis.

## 2 Related Work

This section briefly discusses the existing body of other works, related to the dashboard design problem.

Author of [6] proposed two main principles, which define the choice of one or another visualization tool:

- It has to be the best tool for displaying data of a certain type on a dashboard.
- It has to be capable of serving its purpose even when its size is changed in order to place it into a small place.

Besides the recommendations above, work [6] notes the basic mistakes of dashboard design. The most common errors are associated with the choice of inappropriate visualization tools.

Eckerson and Hammond [7] outlined, that the most appropriate visualization tools, used to create dashboards, are bar charts, line charts, pie charts, and gauges.

Another research [4] also notes that bar charts, line charts, and gauges are the most efficient visualization tools, which are proper for a quick comparison.

KPIs, which are used to measure business performance, are often grouped into the categories of quality, time, flexibility, and cost [8]. To illustrate KPIs values of each category, it's recommended to use considered visualization tools, such as bar charts, line charts, gauges etc [4, 7].

In the best practice of dashboard design [9] Briggs proposed four types of KPIs:

- Quantitative. These are KPIs with a very specific number and where knowing this number is critical (e.g. number of orders, number of sales).
- Directional. These are KPIs where the direction that values are trending is more important than comparing these values (e.g. time spent to fulfill order).
- Category. These are KPIs that display a distribution of various categories within an entire value (e.g. sales by product).
- Actionable. These KPIs have target values associated with them, as well as actions that happen if actual values go up or down beyond this target values (e.g. department costs, supply costs).

Despite various recommendations for visualization tools usage [6-9], the dashboard design still depends on individual users' preferences, which are quite subjective.

Therefore, the dashboard design problem should be formalized, and the approach to forming dashboards for business process KPIs analysis should be elaborated.

Earlier we've proposed the approach to forming dashboards for business process state analysis [5], which formalizes a dashboard design procedure with considering various visualization tools and their impact on the dashboard's informativeness. However in [5] we didn't consider the impact of relations between analyzed KPIs, KPI types, and various visualization tools on the dashboard's design.

## 3 Proposed Approach

According to the proposed approach, the relations between analyzed KPIs, KPI types, and visualization tools could be represented using a fuzzy semantic network.

A semantic network is a graph structure for representing knowledge in patterns of interconnected nodes and edges [10]. In semantic networks concepts and relations are appeared at nodes and edges respectively. In fuzzy semantic networks considered in [10] relations are augmented by a fuzzy membership function $\mu \in [0,1]$.

Therefore, the set of nodes includes subsets of analyzed indicators $KPI_i \in KPIs$, KPI types $KPIType_j \in KPITypes$, and visualization tools $VisTool_k \in VisTools$.

Network's edges represent following fuzzy relations between KPIs, KPI types, and visualization tools (see figure 1):

- "type is" relation, $\mu(KPI_i, KPIType_j): KPIs \times KPITypes \to [0,1]$.
- "displayed by" relation, $\mu(KPIType_j, VisTool_k): KPITypes \times VisTools \to [0,1]$.

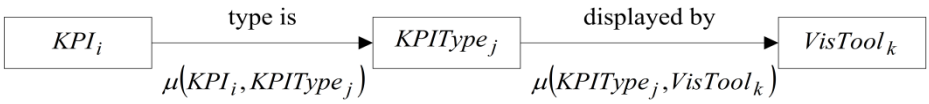


**Fig. 1.** Relations between KPIs, KPI types, and visualization tools

Values $\mu(KPIType_j, VisTool_k)$ represent individual user's preferences for using certain visualization tools. They also may be based on the best practice [9], where for the each KPI type the ideal chart is defined.

Values $\mu(KPI_i, KPIType_j)$ depend on the specific values of KPI and information it communicates (according to the four types of KPIs outlined above) in the following manner:

- If the value of $KPI_i$ is scalar, and it goes up or down beyond a target value [9], its type $KPIType_j$ should be Actionable. Otherwise its type $KPIType_j$ should be Directional, in order to display the direction of change [9].
- If the value of $KPI_i$ is vector, which components represent parts of a 100% [6], its type $KPIType_j$ should be Category. Otherwise its type $KPIType_j$ should be Quantitative, in order to display the comparable quantitative data effectively [6, 9].

Therefore, changes of the indicator $KPI_i$ of business process, which is performed using a BPM system, could be described using following event [11]:

$$event = \left(eventID, caseID, KPI_i, timeStamp, e_{val}, KPIType_j\right), \quad (1)$$

where $eventID$ – the unique identifier of the event; $caseID$ – the unique identifier of the business process instance; $timeStamp$ – the timestamp of the event occurrence; $e_{val}$ – the value of $KPI_i$.

According to the event log structure (1), values $\mu\left(KPI_i, KPIType_j\right)$ could be defined using event log processing by the following formula:

$$\mu\left(KPI_i, KPIType_j\right) = \frac{\text{count}\left(KPIType_j\right)}{\max\limits_{l \in 1,p}\left\{\text{count}\left(KPIType_l\right)\right\}}, \quad (2)$$

where $\text{count}\left(KPIType_j\right)$ – the number of records in event log, where $KPI_i$ type is $KPIType_j$; $p$ – the number of types $KPIType_l$ related to $KPI_i$ in event log.

Thereby, degrees of membership $\mu\left(KPI_i, KPIType_j\right)$ and, hence, the dashboard's design may change in time, depending on the current content of the event log.

The relation between KPIs and visualization tools is defined by the following max-min composition of fuzzy relations "type is" and "displayed by":

$$\mu\left(KPI_i, VisTool_k\right) = \max_{j \in 1,m}\left\{\min\left\{\mu\left(KPI_i, KPIType_j\right), \mu\left(KPIType_j, VisTool_k\right)\right\}\right\}, \quad (3)$$

where $m$ – the number of nodes, which represent KPI types.

Thus, to define the set of visualization tools, used to build the dashboard, the following optimization problem should be solved:

$$\begin{gathered} \sum_{i=1}^{n}\sum_{k=1}^{q}\mu\left(KPI_i, VisTool_k\right)\cdot x_{ik} \to \max, \\ \sum_{k=1}^{q} x_{ik} = 1, \ \forall i \in \overline{1,n}, \\ \sum_{i=1}^{n}\sum_{k=1}^{q} s_k \cdot x_{ik} \le 1, \\ x_{ik} \in \{0,1\}, \ \forall i \in \overline{1,n}, \ \forall k \in \overline{1,q}, \end{gathered} \quad (4)$$

where $s_k$ – the preferable part of the dashboard's space, where the visualization tool $VisTool_k$ should be placed, $s_k \in [0,1]$; $x_{ik}$ – the binary value, that demonstrates whether the visualization tool $VisTool_k$ is selected to represent the $KPI_i$.

The workflow scheme of forming dashboard for business process KPIs analysis using proposed approach is shown in figure 2 in the form of BPMN diagram. Besides development of the tool, which implements the proposed approach, and integration with the BPM system and BI dashboards tool, the structure of BPM system's event log should be customized according to the proposed event structure (1).

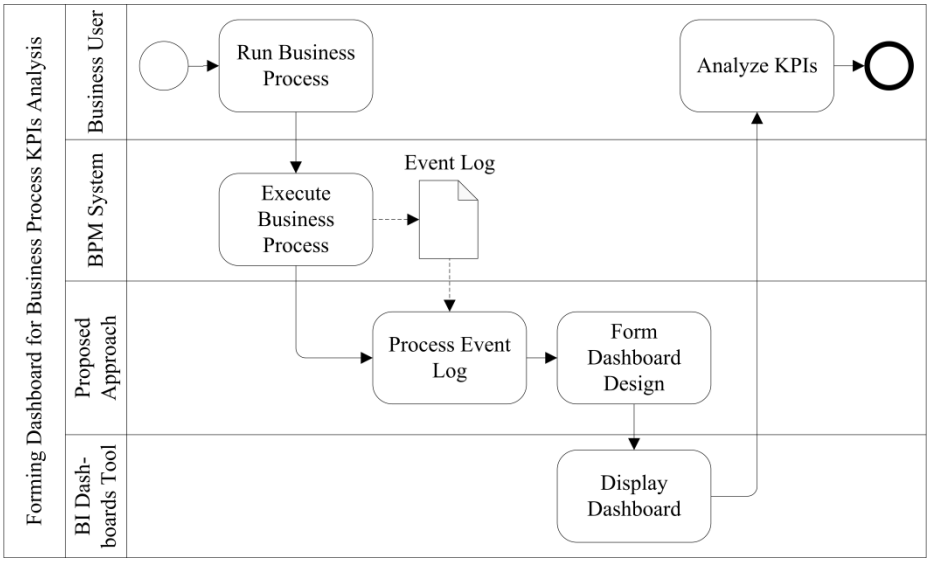


**Fig. 2.** Workflow scheme of forming dashboard for business process KPIs analysis using proposed approach

## 4 Results

This section outlines the example of application of the proposed approach. The example values $\mu(KPIType_j, VisTool_k)$, obtained with accordance to the best practice [9], are given in table 1.

**Table 1.** The example values $\mu(KPIType_j, VisTool_k)$

| $\mu(KPIType_j, VisTool_k)$ | Gauge | Pie chart | Line chart | Bar chart |
|---|---|---|---|---|
| Quantitative | 0,38 | 0,38 | 0,75 | 1,00 |
| Directional | 0,20 | 0,20 | 1,00 | 0,60 |
| Category | 0,57 | 1,00 | 0,86 | 0,43 |
| Actionable | 1,00 | 0,22 | 0,22 | 0,78 |

Let's assume that we've already processed the event log and obtained values (see table 2) $\mu(KPI_i, KPIType_j)$ for some KPIs of the product supply business process, according to the Supply-Chain Operations Reference (SCOR) model [5].

**Table 2.** The example values $\mu(KPI_i, KPIType_j)$

| $\mu(KPI_i, KPIType_j)$ | Quantitative | Directional | Category | Actionable |
|---|---|---|---|---|
| Orders Supplied in Full ($OSF_{\%}$) | 0,42 | 0,17 | 0,08 | 1,00 |
| Cost to Supply (CS) | 1,00 | 0,75 | 0,25 | 0,50 |
| Supply Cycle Time (SCT) | 0,67 | 1,00 | 0,33 | 0,22 |

Now, using the formula (3), we can easily define the values $\mu(KPI_i, VisTool_k)$, outlined in table 3, and solve the optimization problem (4).

**Table 3.** The example values $\mu(KPI_i, VisTool_k)$

| $\mu(KPI_i, VisTool_k)$ | Gauge | Pie chart | Line chart | Bar chart |
|---|---|---|---|---|
| $OSF_{\%}$ | 1,00 | 0,38 | 0,48 | 0,78 |
| CS | 0,50 | 0,38 | 0,75 | 1,00 |
| SCT | 0,38 | 0,38 | 1,00 | 0,67 |

As a result, the following recommendations for the dashboard's design have been obtained:

- Use the gauge to represent $OSF_{\%}$ (takes about 15% of the dashboard space);
- Use the bar chart to represent CS (takes about 25% of the dashboard space);
- Use the line chart to represent SCT (takes about 60% of the dashboard space).

The possible dashboard design, which is corresponding to the obtained results, is shown in figure 3.

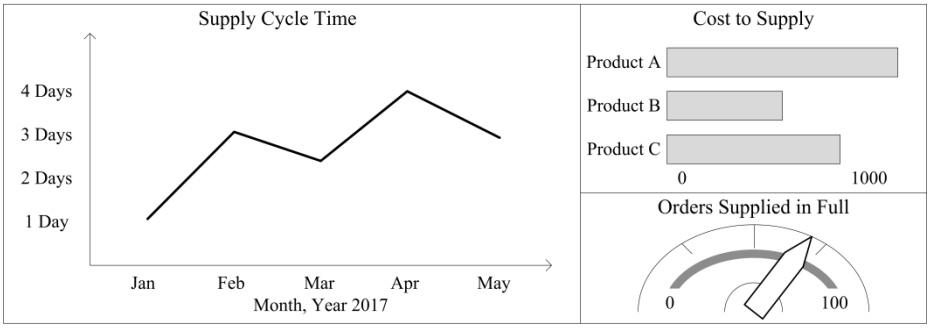


**Fig. 3.** Possible dashboard design according to the obtained results

## 5 Conclusion

In this paper, we've presented the approach to forming dashboards for business process KPIs analysis. This approach considers the impact of relations between analyzed KPIs, KPI types, and various visualization tools on the dashboard's design. It's based on application of fuzzy semantic network in order to describe and analyze relations between KPIs, KPI types, and various visualization tools. To obtain recommendations for the dashboard's design, we've proposed the optimization problem (4), which solution depends on the relations between the fuzzy semantic network's concepts.

Implementation of the proposed approach requires integration with the BPM system, customization and processing (2) of the BPM system's event log according to the proposed event structure (1). It's also required to elaborate the approach to provide integration and interoperability with various BI Dashboard tools.

Future study includes additional considerations on the dashboard's design, which may change in time and its history of changes should be traceable and accessible for the further analysis, selection of the BPM system and BI dashboards tool to be customized and integrated, implementation and application of the proposed approach, obtained results analysis and discussion.

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