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Chapter

Business Process Linguistic Modeling: Theory and Practice Part I: BPLM Strategy Creator

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Abstract

The business activities provided within any firm or company should be checked and controlled continuously, while two principal approaches should be applied: (a) qualitative monitoring, (b) quantitative evaluations, while KPI indicators play a role of principle importance within business quantitative evaluation in order to make adequate decisions. However, adequate applications form KPI creation and further processing seem to be very significant and important. We have designed a conceptual model of application denoted as BPLM Strategy Creator in form of expert system (ES) operating based on principles closely related to business process linguistic modeling approach, where linguistic sets and PBPL Equation play a role of principle importance. Our contribution contains such application description from qualitative, quantitative and design point of view. The ES qualitative description contains references to appropriate math relations and algorithms postulated within a subsequent section. Both sections are accompanied by the case study, which indicates how the math relations and algorithms might be applied within BPLM Strategy Creator functionality. However, those sections are accompanied by ES structure and functionality description as well, which represent the BPLM Strategy Creator mean or facility.

Keywords: key performance, indicators, business, process, linguistic, modeling

1. Introduction

The triple known as" people, planet, profit [1] has been chosen as a slogan by many modern businesses, trying to win the support of people and governments. The triple directs organizations to focus not only on the economic value, but also on the social and environmental value [1]. The new focus of organizations stimulates the search for the right measures of organizational success or key performance indicators (KPIs). The KPIs are used almost for any domain of our life, including medicine, education, services and green computing [2]. However, this is only one side of the coin. On the other hand, there are many applications, which enable creating and processing of KPI indicators [3–5].

There are many different tools for KPI generation and processing, but the BSC Designer is considered to be a standardized tool applied, when quantifying business strategy aspects ad relations (BSC Designer). However, there are many different KPI generating tools, which enable establishing objectives performance measurement system through KPIs selection and setting up targets for measuring each KPI and creating SMO (Strategic Management Office) within firm or company as well, while that tool is denoted as Virtual Strategy Creator [6]. All the above-mentioned applications denoted as strategy creators are designed and implemented based different approaches and principles, while the most common ARIS Business Strategy Creator is designed and implemented based on methodology established by Prof. Scheer, while that methodology represents standard in strategy creation and processing [7]. However, there are various approaches, which might be applied to business strategy creator design and implementation [8, 9] as well, while one of them is denoted as business process modeling linguistic approach (BPLM approach), where *linguistic sets* and Principle *Businesses Process Linguistic Modeling Equation* (PBPL Equation) [10, 11] represent the categories of principle importance and are being applied in designing of business strategy creator described within that contribution. The above-mentioned approach is based on sematic analysis related to content of supporting documents for business strategy creation and processing, while that analysis is being done in two phases. In the first phase, two categories of analyzed documents are created: (a) the first category of documents is applied for description of business strategy qualitative aspects and (b) the second category of documents is applied for description of business strategy quantitative aspects incl. Creation and processing of KPI indicators. The applications operating based on that principle had been searched, however no similar applications were found and therefore development of our own approach and methodology was getting started.

The contribution main goal is to design a conceptual model of business strategy creator, which should operate based on business process linguistic modeling principles (hereinafter known as BPLM Strategy Creator). In order to achieve, the main goal, three partial aims should be postulated and fulfilled: (a) to define the BPLM Strategy Creator structure and functionality from qualitative point of view (see also Section 4.1) – it seems to be the first partial aim, (b) to define appropriate math relations and algorithms concerned with linguistic modeling aspects applied in quantification of BPLM Strategy Creator functionality (see also Section 4.2) - it seems to be the second partial aim, (c) to define the BPLM Strategy Creator design and implementation via adequate expert system, the knowledge-base of which contains a set of knowledge represented by appropriate semantic networks (SNWs) and reference databases ((RDBs) (see also Section 4.4) - it seems to be the third partial aim. However, an appropriate case study creates an integral part of that contribution, the aim of which is to show how the derived math relations and algorithms should be applied related to BPLM Strategy Creator functionality (see also Section 4.3).

2. State of the art

2.1 KPI indicator creation and processing, methods and tools

Any firm or company is starting business based on its own business mission statement, business objectives and with the use of appropriate business process. All those categories are being transformed to the firm or company business strategy, which usually consists of two principal sections [12, 13]:

- The first section is concerned with qualitative aspects described via text in natural language (TNL text) and the second one, which is described via set business performance indicators (hereinafter known as KPI indicators). However, both of the above-mentioned section is being prepared based on appropriate documents, which contain adequate supporting data as well, while their content has to be undertaken to preliminary semantic analysis, first of all. This type of semantic analysis indicates, which outgoing documents are closely related to the first and to the second section.

- Subsequently both of those document types are being undertaken to deeper semantic analysis and assigned to the first or the second section. However, the second section document semantic analysis results represent various text string and numeric data stored within sets denoted as the linguistic sets and they usually seem to be market research and the firm or company internal resources analysis results, which create basis for generation of so called initial KPI indicators. On the other hand, the above-mentioned linguistic sets represent the principle elements of linguistic business and business process modeling approach as well, while that approach will be applied, when deriving appropriate math relations and algorithms needed for business strategy creator design and implementation conceptual model discussed in Section 4, while the business strategy creator application program should be implemented and operated with use of graph database algorithms and procedures.

- In general, the KPIs are measures that a sector or organization uses to define success and track progress in meeting its strategic goals. This focus on strategic or long-term goals is what distinguishes KPIs from the wider array of "performance indicators" (PIs) that do not necessarily rise to the attention of policymakers or the public, but may be important for public sector managers [14–16], KPIs are not created in a vacuum. KPIs, thus, should not be thought of as standalone measures, but rather as the product of strategic thinking, analysis and negotiation around policy problems and responses. A useful tool to help conceptualize this production process is the "logic model." In strategic planning, logic models are used commonly to describe the logical linkages between problems and their solutions. The model lays out a three-stage process for [7]:

  ○ Identifying the problem (s), or the community need.

  ○ Developing policies or measures to address the problem (s) and

  ○ Articulating the desired goals—the end-state of affairs or vision for the future.

Strategic planning is a high-level exercise, typically conducted by ministry planning departments in consultation with program managers, staff responsible for stakeholders to define or sharpen focus on strategic goals and policy responses. It is at the program or activity level, however, where the budget comes into focus, and where, ultimately, performance indicators, including KPIs, are most commonly established. Other strategyzer offers real time and asynchronous collaboration to keep everyone on the same page, and one centralized place to collaborate on the firm or company strategy the other Strategic Planning software aggregates historical business performance data and helps with creating

predictive models of future performance based on specified business objectives and resource allocations [17].

2.2 KPI modeling

2.2.1 KPI modeling issues

The KPI modeling seems to be one of the most important actions closely related to KPI indicator processing and they have to indicate appropriate properties in order to be denoted as the good KPIs.

However, those properties may be seen as the first aspects concerned with KPI validation as well, while they night be postulated as follows [2].

- KPI should be in a quantifiable form.

- KPI needs to be sensitive to changes of the business process state.

- KPI should be linear, (d) a KPI should be semantically reliable,

- KPI should be efficient,

- KPI should be oriented to improvement, not to conformance to plans

However, the above-mentioned KPI indicator properties seem to be only one side concerned with KPI indicator modeling [15, 16].

The second aspect is closely related to KPI attributes postulated as KPI name, Type, Scale, Source, Owner, Threshold, and Hardness.

The third aspect is the performance indicator expression. It is "a mathematical statement over a performance indicator evaluated to a numerical, qualitative or Boolean value for a time point, for the organization, unit or agent. For example, P I27 $\leq$ 48h."

The **fourth aspect** concerned with KPI formalization is the performance indicator expression. It is "a mathematical statement over a performance indicator. The authors suggest specifying the required values of KPIs as constraints coming from goals. The authors claim that they integrate the performance view with the process, organization and agent-oriented views. However, there is no information about the process semantics used for modeling and no evidence about validation of the PI properties. In any case, the authors write about the process views of the real organizations, not about the abstract processes that are proposed [9, 15, 16].

2.2.2 KPI modeling approaches and methods

2.2.2.1 MetricM method

The method MetricM [18] "is built upon and extends an enterprise modelling approach to benefit from he reuse of modelling concepts to provide relevant organizational context, including business objectives, organizational roles and responsibilities." The method can be adapted to any enterprise modeling approach. The modeling language.

MetricML used in MetricM "adds essential concepts to modelling performance indicators and semantics to key modelling concepts." The concept Indicator is used to present a KPI.

The MetricML Indicator metatype is used for modeling its relations to other indicator types, to reference object types representing organizational context and to goal types [2].

2.2.2.2 Attribute approach

An alternative "attribute" approach conceptualizes performance indicator as (meta-) attribute of metatypes (e. g "average throughput time" of a business process type or "average number of employees" of an organizational unit type). Alternative approach for KPI modeling in our method is used. MetricM uses declarative models. The model of underlying processes needed for validation of KPI properties are not used in MetricM. The two approaches, presented above, build upon ideas of many earlier approaches to KPI modeling. The general tendency is to postpone the validation of the KPI properties to the moment when the process model of the organization is ready.

2.2.2.3 Semantics synchronous and asynchronous modeling

However, the KPIs are defined at a different level of abstraction, namely at the tactical and strategic level, i.e. at the level of observable states of the system and the asynchronous modeling does not provide the right level of abstraction [15, 16].

The synchronous modeling semantics is based on the CSP parallel composition operator defined by Hoare [19]. The operator defines that an event from environment is accepted by the model if all processes of this model are able to accept it. Otherwise, the event is refused.

Although there were many applications of the CSP parallel composition operator in the architecture description languages [20] in programming languages [21] only after the extension of this operator for machines with data, made by McNeile [22] the operator became practical for business system modeling. The Protocol Modeling proposed in enables coping with complexity of business modeling. The reason is that the synchronous semantics decreases the data space of models.

2.2.2.4 KPI indicator linguistic modeling approach

This approach is based on existence of linguistic sets, while they represent KPI modeling static aspects. However, there are many relations among those linguistic sets as well, while they are quantified via PBPL Equation [10, 11, 23, 24]. This approach is discussed in Section 4 in more details.

2.3 KPI indicator decomposition

The KPI indicators are designed and closely related to core business processes implemented and operated at strategic management level and have a nature of so called initial and primary KPI indicators, which should be decomposed to secondary and tertiary KPI indicators. The secondary indicators are closely related to main BP management at tactic level and the tertiary KPI indicators are closely related to subordinated and elementary BP management at operational level. This approach to KPI indicator decomposition is discussed in Section 4. However, the KPI decomposition is closely related to business dashboard existence [13, 25, 26].

A dashboard in business is a tool used to manage all the business information from a single point of access. It helps managers and employees to keep track of the company's KPIs and utilizes business intelligence to help companies make data-driven decisions.

There are 4 general subtypes of dashboards: (a) Strategic - focused on long-term strategies and high-level metrics, (b) Operational - shows shorter time frames and operational processes. (c) Analytical - contains vast amounts of data created by analysts and (d) Tactical - used by mid-management to track performance.

A strategic dashboard is a reporting tool for monitoring the long-term company strategy with the help of critical success factors. They're usually complex in their creation, provide an enterprise-wide impact to a business and are mainly used by senior-level management [27–29].

An analytical dashboard is a type of dashboard that contains a vast amount of data created and used. They supply a business with a comprehensive overview of data, with middle management being a crucial part of its usage.

A tactical dashboard is utilized in the analysis and monitoring of processes conducted by mid-level management, emphasizing the analysis.

Then an organization effectively tracks the performance of a company's goal and delivers analytic recommendations for future strategies [30].

3. Research methodology

In order to achieve the pre-defined main goal and appropriate partial aims a set of adequate research methods should be postulated and applied:

- Business process linguistic modeling (BPLM) approach, where the linguistic sets seem tio elements of principle importance and create basis for design and implementation of reference databases (RDBs) and semantic networks (SNWs), which represent the principal facilities for an appropriate knowledge-based (expert) system structure and functionality

- Design and implementation of an appropriate expert system (ES), where the knowledge stored in the ES knowledge base (ES-KB) are represented with the use of the above-mentioned RDBs and SNWs and a completed ES is being implemented via adequate application program.

- In order to manage that application program implementation the principles and elements of graph databases (GraphDb) are being applied for implementation purposes related to linguistic sets, RDBs and SNWs.

- The designed and implemented BPLM SC application should be utilized as a supporting tool, when designing and updating the actual BS strategy quantitative and qualitative aspects

4. Results

The business process linguistic modeling (BPLM) system represents a complex tool applied for BP linguistic modeling, which consists of the following subsystems: (a) BPLM Strategy Creator, (b) BPLM process analysis and design, (c) BPLM process implementation, which should contain tools for creating of *BP configuration model* (information and knowledge-based support and BP execution model, which includes BP operation and controlling. The BPLM Strategy Creator discussed within presented contribution seems to be the first important component related to the above-mentioned BPLM System.

4.1 BPLM strategy creator – structure and functionality BPLM strategy creator – structure and functionality – qualitative view

4.1.1 Strategic management level

Any business is getting started by business mission statement and business objectives and adequate business process establishment. Those three categories create an integral part of any business strategy. However, before we determine a set of business quantitative and qualitative indicators, real possibilities should be known to apply our business results at an appropriate market area and collect initial information. Usually, the information is stored at different media and documents. However, we have to make a preliminary document content semantic analysis in order to gain a required information and this is an initial action, which should be done with the use of the proposed BPLM Strategy Creator. This type of the document semantic analysis enables providing the document categorization and show use which documents should create basis for processing of business strategy qualitative aspects. Furthermore, we are interested in those documents, which contain data closely related to business strategy quantitative aspects, which might be quantified via indicators denoted as key performance indicators (KPI indicators). However, they usually are not in that form and shape as we need. Therefore, we have to provide the second type of document analysis in order to extract required data – usually denoted as the initial data, which should inform us which products related to our business could be accepted by the market, in which quantity and quality and what about financial assets could be gained. This data type could create content of sets $\{[Y^{Totfin}_{Assetst}]\}$, $\{[Y^{Totmat}_{Assetst}]\}$. Because the data are of a linguist nature those sets are denoted as linguistic sets. The linguistic set $\{[Y^{Totfin}_{Assetst}]\}$, contains data closely related to financial assets and the linguistic set contains data closely related to material assets[1]. This is only one side of the coin, while we to know what about investments (financial costs) are needed in order to pro produce the above-mentioned output products and they are stored within $\{[X^{Totfin}_{Costs}(0)]\}$, $\{[X^{Totmat}_{Costs}(0)]\}$ linguistic sets. The data represent the first BPLM Strategy creator output, which is called the **basic output** as well, while the financial costs play a role of principal importance, but are not sufficient for production getting started. We have to know what about customers will buy our products, what about human resources with required theoretical knowledge and practical skills, and what about production technological devices and tools are needed, as well. This types of data are being stored in further linguistic sets. The linguistic set $\{[SAD(i,j)]\}$ quantifies potential customers denoted as mainframe customers, the linguistic set $\{[HR(i,j)]\}$ quantifies mainframe human resources and the $\{[TECH(i,j)]\}$ linguistic set quantifies mainframe production technological devices and tools. A qualifier "mainframe" indicates that the linguistic set content is not specified in more details. When adding that linguist sets to the above-mentioned basic output we get the **initial BPLM** Strategy creator output, while formula (1) might be postulated

$$\{[KPI(0)]\} = \left\{\left[Y^{Totfin}_{Assetst}\right]\right\}, \left\{\left[Y^{Totmat}_{Assetst}\right], \left[X^{Totfin}_{Costs}(0)\right]\right\},$$
$$\left\{\left[X^{Totmat}_{Costs}(0)\right], [SAD(i,j)], [HR(i,j)], [TECH(i,j)]\right\} \tag{1}$$

which represent so called the **total initial KPI** indicators.

_____

[1] How many pieces of the actual output products could be produced.

This is the first partial output of the proposed BPLM Strategy creator, which indicates the basic possibilities of our business. However, no business within any firm company might be provided without adequate core, main, subordinated and elementary business processes (BP), while each of those BPs is represent by its own static structure, metrics and dynamic functionality (performance) as well, while the data create basis for determination of the firm or company internal resources and the data are stored within technical and economic standards, which has each firm or company and based on the data a set of appropriate correction coefficients might be calculated. When multiplying the data contained in the above-mentioned linguistic sets with those coefficients, real item values concerned production, customers, human resources, financial and production technology devices and tools might be obtained, based on which our business might be functional and efficient. However, an appropriate algorithm development is the aim of future work as well, while this is a basic principle of for calculation real values of partial KPI indicators and the total KPI indicator/All the above-mentioned KPI indicators are denoted as **primary KPI indicators** and formula (2) might be postulated.

$$\text{KPI}_{\text{prim}}(0)) = \{[\text{KPI}(0)]\} \otimes \{[\text{CBS}(0,1)]\} \tag{2}$$

where $\{[\text{KPI}(0)]\}$ is a linguistic set specified via formula (1) and $\{[\text{CBS}(0,1)]\}$ is a linguistic set, the subsets of which might quantify adequate core business processes.

It means, we can get BPLM Strategy creator (BPLM SC system) output represented by formula (3).

$$\forall \text{CBP} \,\exists\, \text{KPIprim}(0) \Rightarrow \text{CBP} \Leftrightarrow \text{KPI}_{\text{prim}}(0)) \tag{3}$$

which says that for any core business process (CBP) might be assigned one total KPI indicator and this is the most important results related to the BPLM SC system functionality and create basis for determination of further KPI indicator values valid for strategic management level and their decomposition related to tactic and operational level.

4.1.2 Tactic management level

The KPI indicators postulated for strategic management level are represented by formulas (25, 26, 28, 29) and (30) create basis for their further decomposition related to tactic management level, where we are operating with main business processes subordinated to appropriate core processes implemented and operated at strategic management level. However, at that level should be the BSC perspectives respected as well.

4.1.2.1 Customer's perspective

The Customer's perspective indicates which of production output product classes (PPCs) will be assigned to which customers, while appropriate contract sets are being created and the linguistic sets applied for quantification of individual customers are postulated via formula (18) and formulas (43–48) and (49, 50) indicate which PPCs will be assigned to which customers, while the first decomposed KPI indicator quantified via $\{[\text{CONTRACTB}(i)]\}$ linguistic set is derived (see also formula (2)), while the $\{[\text{SAD}(i,j)]\}$ linguistic set, which quantifies the mainframe customers creates basis for those purposes.

4.1.2.2 Internal BP perspective

A preparation of contract KPIs represents an initial step of KPI decomposition. In the next step pre-defined PPCs should be produced, appropriate internal BPs should be getting started and operated in order to achieve that aim. As a result of that, the $\{[BP\ (i,\ j_6)]\}$ should be added to formula (51), while the next KPI indicator concerned with internal BP perspective denoted as KPI (i, 3) = {[CONTRACTD (i)]} is derived (see also formula (55), while the $\{[BP\ (i,\ j_6)]\}$ linguistic set, which quantifies the mainframe customers creates basis for those purposes.

4.1.2.3 Financial perspective

A production of pre-defined PPCs and appropriate BPs functionality require an adequate material and financial support, and the production generates closely related assets while both of the above-mentioned support types are being quantified via outgoing linguistic sets $\{[X^{Totfinmanp}_{Costs}\ (0)], [X^{Totmamanpt}_{Costs}\ (0)],$ $[Y^{Totfinmanp}_{Assetst}], [Y^{Totmatmanp}_{Assetst}]\}$ (see also formula (9). With respect to those issues the principal financial perspective KPI indicator denoted as {KPImanp (1)} might be derived.

4.1.2.4 Education and growth and technical perspective

Adequate human and technological resources are required, in order to assure a proper and efficient functionality of BP, while further supplementary KPI indicators KPI (i, 4) = {[CONTRACTE (i)]} might be derived based on similar principles/, while the [HR (i, j)], [TECH (i, j)]} linguistic set, which quantifies the mainframe customers creates basis for those purposes. With respect to previous considerations a set of appropriate KPI indicators related to tactic management level (see also **Table 1**).

4.1.3 Operational management level

However, the tactic management level KPI indicators postulated within **Table 1** are closely related to main BP implemented and operated at that level and to BSC perspectives as well, while the operational management level KPI indicators are closely related to selected business process and its external and internal metrics.

BSC perspective	Tactic management evel KPI indicators	Outgoing linguistic sets
Financial perspective	{KPImanp (1)} = $[X^{Totfinmsnp}_{Assets}\ (0)]/$ $[[X^{Totfinmanp}_{Costs}\ (0)]$	{KPI (0)}
Customer's perspective	KPI (i, 1) = {[CONTRACTB (i)]}	{[SAD (i, j)]} {[CUST (i, j)]}
Internal BP perspective	KPI (i, 3) = {[CONTRACTD (i)]}	{[PCP (i, j)]}
Education and growth perspective	KPI (i, 4) = {[CONTRACTE (i)]}	{[HR (i, j)]}
Technical perspective	KPI (i, 5) = {[CONTRACTF (i)]}	{[TECH (i, j)]}

Source: The Authors.

Table 1.
KPI indicators related to tactic management level.

In general, any business process (BP) is characterized via its own internal and external metrics, while the BP external metrics deals with BP inputs and outputs and the internal metrics deals with appropriate human resources, production technological devices and tools. However, the BP external metrics KPI indicators include BP material input costs, BP financial input cost, BP production output material assets and production output financial assets as well, while the internal metrics KPI indicators include human resources theoretical knowledge and practical skill data together with adequate financial costs and assets. On the other hand, the internal metrics technological resources include production technological devices and tools (material aspects) and production technological devices and tools (financial costs and asset aspects).

4.2 BPLM strategy creator – structure and functionality – quantitative view

4.2.1 General overview

The BPLM Strategy Creator (BPLM SC) application represent a relatively independent system, which consist of several subsystems, components and modules postulated as follows:

- the first subsystem should provide selecting of adequate documents closely related to BS qualitative and quantitative aspects and their semantic analysis together with the data storage and processing, which has been generated as a result of the above-mentioned semantic analysis while it is denoted as the BPLM SC 01 Data and document preparation subsystem

- This subsystem contains two components, while the BPLM SC 01–01 component should enable involving the data and document segments concerned with BS qualitative aspects to adequate BS qualitative documents and the BPLM SC 01–02 component enable converting the data and document segments concerned with BS quantitative aspects to adequate BS KPI indicators.

- the second subsystem should provide investigation of the core business process, which create an integral part BS creation and generation of initial KPI indicators and a decomposition of them for tactic and operational management level, while it consists of BPLM SC 02–01 component, which should provide investigation of the core business process from functional point of view, where the core business process (CBP) metrics plays a role of principle importance and the BPLM SC 02–02 component should provide the KPI indicator decomposition related to tactic and operation management level

- the third subsystem should provide BS quantitative aspect simulation and optimization and consists of two components BPLM SC 03–01 component, which should provide the BS KPI indicator and core process simulation and BPLM SC 03–02 component, which should provide the BS KPI indicator and core process optimization.

4.3 KPI indicator quantification, generation and decomposition

4.3.1 KPI indicator quantification

In general, the BP performance is being quantified via key performance indicators (hereinafter known as KPI indicators), which might have a very heterogeneous

or varied structure, features, and values. However, the KPI Indicator quantification is a process closely related to the firm or company strategic level and result the **initial KPI indicator** items and values as well, while Consideration no.1 enables deriving them.

5. Consideration no.1 Determination of KPI initial indicators

When considering a top core business process (hereinafter known as CB Process), a vertical structure of which is quantified via linguistic set $\{[CBS(i, j)]\}$, where.

$i = 0,1, 2,3 \ldots n$ is a serial number of the actual business process (BP) within BP vertical structure set.

$j = 0,1,2,3 \ldots m_1$ is a serial number of business process function (BPF) within selected BP.

Because the core BP is at the top of BP vertical structure index $i = 0$ and $j = 0$ the top business process is being quantified via $\{[CBS(0, 1)]\}$ linguistic set its performance quantified via KPI indicator with respect to formula (4).

$$\{KPI(0)\} = \left\{ \left[X^{Totfin}_{Costs}(0) \right], \left[X^{Totmat}_{Costs}(0) \right], \left[Y^{Totfin}_{Assetst} \right], \left[Y^{Totmat}_{Assetst} \right] \right\} \quad (4)$$

Where
$[X^{Totfin}_{Costs}(0)]$ is a linguistic subset, which contains elements closely related to CB Process functionality input financial costs

$[X^{Totmat}_{Costs}(0)]$ is a linguistic subset, which contains elements closely related to CB Process functionality entire input material quantity

$[X^{Totmat}_{Assets}(0)]$ is a linguistic subset, which contains elements closely related to CB Process functionality entire output material quantity

$[X^{Totfin}_{Assets}(0)]$ is a linguistic subset, which contains elements closely related to CB Process functionality entire output financial assets

However, a content of linguistic subsets, which create an integral part for $\{KPI(0)\}$ represents data closely related to market research and the firm or company internal resources analysis as well.

The above-mentioned quantification of the core BP is being done at the strategic management level, while a similar quantification of business processes (BPs) should be done at tactic and operational management levels too.

Let us consider the PBPL equation in a general form with respect to formula (3) and let us assign the linguistic sets with respect to formula (3), while formulas (5) up to (8) might be postulated.

$$\{[Petx(i, j)]\} = \{[[X^{Totfin}_{Costs}(0)], [X^{Totmat}_{Costs}(0)]\} \quad (5)$$

$$\{[Pe(i, j)]\} = \{[CBS(0, 1)]\} \quad (6)$$

$$\{[Tbex(i, j)]\} = \left\{ [X^{Totmat}_{Assets}(0)], [X^{Totfin}_{Assets}(0)] \right\} \quad (7)$$

where
The $[[X^{Totfin}_{Costs}(0)]$ and $[X^{Totmat}_{Costs}(0)]\}$ linguistic sets represent initial inputs for core BP quantified via $\{[CBS(0, 1)]\}$ linguistic set and the $\{[X^{Totmat}_{Assets}(0)], [X^{Totfin}_{Assets}(0)]\}$ linguistic sets represent subsequent outputs from BP quantified via $\{[CBS(0, 1)]\}$ linguistic set.

The $\{[Retx(i, j)]\}$ linguistic set represents relations among the above-mentioned linguistic sets with respect to formula (2d).

$$\{[\text{Retx}(i,j)]\} = \{[\text{X}^{\text{Totmat}}_{\text{Assets}}(0)], [\text{X}^{\text{Totfin}}_{\text{Assets}}(0)], [\text{CBS}(0,1)], [[\text{X}^{\text{Totfin}}_{\text{Costs}}(0)],$$
$$[\text{X}^{\text{Totmat}}_{\text{Costs}}(0)]\}$$

$$(8)$$

With respect to the above-mentioned formulas the **Primary KPI indicators** might be postulated and have a nature of linguistic sets as well (see also formulas 9, 10).

$$\{\text{KPI}(1)\} = [\text{X}^{\text{Totfin}}_{\text{Assets}}(0)]/[[\text{X}^{\text{Totfin}}_{\text{Costs}}(0)] \qquad (9)$$

$$\{\text{KPI}(2)\} = [\text{X}^{\text{Totmat}}_{\text{Assets}}(0)]/[[\text{X}^{\text{Totmat}}_{\text{Costs}}(0)] \qquad (10)$$

However, those KPI indicators create basis for generation of further KPIs and their decomposition as well, while they have a linguistic set nature. As mentioned above the initial KPI indicators are being quantified via linguistic sets with respect to formulas (9) and (10). However, they are generated at strategic management level and are closely related to core BP quantified via linguistic set $\{[\text{CBS}(0,1)]\}$ as well, while formula (3) is extended about $\{[\text{CBS}(0,1)]\}$ linguistic set and formula (11) might be postulated.

$$\{\text{KPI}(0)\} = \{[\text{X}^{\text{Totfin}}_{\text{Costs}}(0)], [\text{X}^{\text{Totmat}}_{\text{Costs}}(0)], [\text{Y}^{\text{Totfin}}_{\text{Assetst}}], [\text{Y}^{\text{Totmat}}_{\text{Assetst}}], [\text{CBS}(0,1)]\}\}$$

$$(11)$$

5.1 Determination of KPI primary indicators

5.1.1 Consideration no. 2

With respect the above-mentioned issues two types of KPI initial indicators are being postulated (see also formula):

$$\{\text{KPI}_{\text{manp}}(0)\} = \{[\text{X}^{\text{Totfinmanp}}_{\text{Costs}}(0)], [\text{X}^{\text{Totmamanpt}}_{\text{Costs}}(0)], [\text{Y}^{\text{Totfinmanp}}_{\text{Assetst}}],$$
$$[\text{Y}^{\text{Totmatmanp}}_{\text{Assetst}}]\}$$

$$(12)$$

$$\{\text{KPI}_{\text{machp}}(0)\} = \{[\text{X}^{\text{Totfinmachp}}_{\text{Costs}}(0)], [\text{X}^{\text{Totmamachp}}_{\text{Costs}}(0)], [\text{Y}^{\text{Totfinmachp}}_{\text{Assetst}}],$$
$$[\text{Y}^{\text{Totmatmachp}}_{\text{Assetst}}]\}$$

$$(13)$$

where
the manp index is concerned with utility glass manually oriented production and the manchp index is concerned with utility glass machinery oriented production.

We shall discuss the KPI indicator quantification; generation and decomposition problems for glass utility manual production, while the derived formulas and algorithms might be applied for machinery oriented utility glass production as well.

The partial KPI indicators (see also formulas 14 and 15) indicate financial (Totfinmanp) and material (Totmatmanp) assets and costs and they considered to be results of market and the firm or company internal resources and they might represent initial manual inputs.

$$\{\text{KPImanp}(1)\} = [\text{X}^{\text{Totfinmsnp}}_{\text{Assets}}(0)]/[[\text{X}^{\text{Totfinmanp}}_{\text{Costs}}(0)] \qquad (14)$$

$$\{KPImanp\,(2)\} = \left[X^{Totmatmanp}_{Assets}\,(0)\right]/\left[\left[X^{Totmatmanp}_{Costs}\,(0)\right]\right] \qquad (15)$$

When looking at formula (11), we might see that the initial KPI (0) indicator is closely related to the glass utility production process (GUP process), which seems to be the core process and is being quantified via $\{[GUPC\,(0,1)]\}$ linguistic set and formula (11) is converted to formula (16).

$$\{KPI\,(0)\} = \{\left[X^{Totfin}_{Costs}\,(0)\right], \left[X^{Totmat}_{Costs}\,(0)\right], \left[Y^{Totfin}_{Assetst}\right], \left[Y^{Totmat}_{Assetst}\right]$$
$$[GUPC\,(0,1)]\}\} \qquad (16)$$

However, the core process denoted as GUP process consists of main process quantified via appropriate linguistic sets postulated as follows as well.

5.1.2 Determination of Production process *primary KPI indicators*

Now, let us analyze appropriate main processes denoted as **Production** quantified via $\{[PROD\,(i, j_1)]\}$ linguistic set in order to determine the partial KPI indicators, while the initial KPI indicator value could create basis for those purposes. It might be done via following steps:

Step 1

Before providing KPI indicator quantification several auxiliary linguistic subset content should be determined. It might be done within Step 1 and Step 2.

$$\left\{\left[Y^{Totfinmanp}_{Assetst}\,(0)\right]\right\} = \{[Mark\_res\_assets\_fin\,(0)], [Mark\_res\_costs\_fin(0)]\} \qquad (17)$$

$$\left\{\left[Y^{Totfmatmanp}_{Assetst}\,(0)\right]\right\} = \{[Mark\_res\_assets\_mat\,(0)], [Mark\_res\_costs\_mat(0)]\} \qquad (18)$$

A word Mark_res, which creates basis of an appropriate linguistic set name indicates that items and values contained in there are initial input data acquired as a result of market research.

Step 2

Determination of $\{[PCPFin\,(i, j)], [PCPMat\,(i, j)]\}$ linguistic sets, which are closely related to the firm or company real internal material and financial resources. The normalized internal resource values are postulated within the firm technical and economic standards (Int_res_fin_val_act (0), Int_res_fin_mat _act (0), while based on those values a value of Int_res_fin_koef (0) koeficient, which indicates what about a quantity of financial and material assets might be achieved, when applying real firm or company internal resources (see also formulas (19–22).

$$\{[PCP\,(i, j)]\} = \{[PCPFin\,(i, j)], [PCPMat\,(i, j)]\} \qquad (19)$$

$$[PCPFin\,(i, j)] = [Int\_res\_fin\_val\_req\,(0), Int\_res\_fin\_val\_act\,(0), Int\_res\_fin\_koef(0)] \qquad (20)$$

$$[PCPMat\,(i, j)] = [Int\_res\_mat\_val\_req\,(0), Int\_res\_mat\_val\_act(0), Int\_res\_mat\_koef(0)] \qquad (21)$$

$$\{[Pe\,(i, j2)]\} = \{[PCP\,(i, j)]\} \qquad (22)$$

For $\{[Petx\,(i, j_1)]\}$ linguistic set content see also formula (2a) and for $\{[Pe\,(i, j2)]\}$ linguistic set content see also formula (24).

$$\{[\text{Petx}\,(i, j1)]\} = \left\{\left[Y^{\text{Totfinmanp}}_{\text{Assetst}}\,(0)\right], \left[Y^{\text{Totfmatmanp}}_{\text{Assetst}}\,(0)\right]\right\} \tag{23}$$

When applying the PBPL Equation its general form, (see also formula (24)) formula (25) might be postulated.

$$\{[\text{Petx}\,(i, j1)]\} \otimes \{[\text{Pe}\,(i, j2)]\} = \{[\text{Tbex}\,(i, j)]\} \otimes \{[\text{Ret}\,(i, j)]\} \tag{24}$$

After installment of previous relations into formula (24) formula (25) might be postulated.

$$\left\{\left[Y^{\text{Totfinmanp}}_{\text{Assetst}}\,(0)\right], \left[Y^{\text{Totfmatmanp}}_{\text{Assetst}}\,(0)\right]\right\} \otimes \{[\text{PCP}\,(i, j)]\} = \{[\text{Tbex}\,(i, j)]\} \otimes \{[\text{Ret}\,(i, j)]\} \tag{25}$$

where
the $\{[\text{Tbex}\,(i, j)]\}$ linguistic contains data closely related to quantity of financial and material asset generated based on the actual firm or company internal resources.

$$\{[\text{Tbex}\,(i, j)]\} = \{[\text{Mark\_res\_assets\_fin\_ires}(0)], [\text{Mark\_res\_assets\_mat\_ires}(0)],\} \tag{26}$$

$$\{[\text{Retx}\,(i, j)]\} = \{[\text{Mark\_res\_assets\_fin\_ires}(0)], [\text{Mark\_res\_costs\_fin}(0)], \\ [\text{Mark\_res\_assets\_fin\_ires}(0)], [\text{Mark\_res\_costs\_fin}(0)]\} \tag{27}$$

the $\{[\text{Retx}\,(i, j)]\}$ linguistic contains data closely related to quantity of financial and material asset generated based on the actual firm or company internal resources with respect to appropriate financial and material costs.

In general, the above-mentioned algorithm enables determining KPIprod (0, 1)} and KPIprod (0, 2)}, while formulas (28) and (29) might be postulated.

$$\{\text{KPIprod}\,(0, 1)\} = \{[\text{Tbex}\,(i, j1)]\} \tag{28}$$

$$\{\text{KPIprod}\,(0, 2)\} = \{[\text{Retx}\,(i, j2)]\} \tag{29}$$

where
$\{\text{KPIprod}\,(0, 1)\} = \{[\text{Tbex}\,(i, j1)]\}$ –the first Primary KPI indicator, which indicates real possibilities of the firm or company business represented by financial and material assets with respect to the firm or company production internal resources.

$\{\text{KPIprod}\,(0, 2)\} = \{[\text{Retx}\,(i, j2)]\}$ – the second Primary KPI indicator, which indicates real possibilities of the firm or company business represented by financial and material assets with respect to the firm or company production financial and material cost. With respect to the above-mentioned issues the following clause might be postulated:

At the strategic management level, the Production main process might be quantified via $\{[\text{PROD}\,(i, j_1)]\}$ linguistic set and two KPI indicators could be postulated, which indicate that process functionality (performance) (see also formulas (28) and (29) and (30).

$$\{[\text{PROD}\,(i, j1)]\} = \{\text{KPIprod}\,(1, 2)\} = \{\text{KPIprod}\,(0, 1)\} \otimes \{\text{KPIprod}\,(0, 2)\} \tag{30}$$

However, the similar sequence of steps (algorithm) might be applied when quantifying and generating KPI indicators for further main processes, sales and

distribution, HR, technological and financial management at the strategic management level.

At strategic management level, a set of core BP are implemented and operated and quantified via appropriate linguistic sets, e.g. the Sales and Distribution BP is quantified via $\{[SAD\,(i,j)]\}$, where the *main frame customer*s play a role of principle importance and are being quantified via $[MFRC\,(i,j)]$. When applying PBPL equation adequate KPI indicators might be derived.

$$\{[PROD\,(i,j1)]\} \otimes \{[MFRC\,(i,j)]\} \otimes \{[SAD\,(i,j)]\} = \{[Tbex\,(i,j)]\} \otimes \{[Retx\,(i,j)]\} \tag{31}$$

$$\{[Tbex\,(i,j)]\} = \{[PROD\,(i,j1)],[MFRC\,(i,j)]\} \tag{32}$$

$$\{[Retx\,(i,j)]] = \{[PROD\,(i,j1)],[MFRC\,(i,j)],[SAD\,(i,j)]\} \tag{33}$$

$$\{KPIsad(0,1)\} = [Tbex\,(i,j)]\} \tag{34}$$

$$\{KPIsad\,(0,2)\} = [Retx\,(i,j)]] \tag{35}$$

$$\{KPIsad\,(0) = \{KPIsad(0,1)\} \otimes \{KPIsad(0,2)\} \tag{36}$$

However, at strategic management level, a set of core BP are implemented and operated and quantified via appropriate linguistic sets, e.g. Human resources (HR} management is quantified via $\{[HR\,(i,j)]\}$ as well where the *main frame human resources* play a role of principle importance and are being quantified via $[HRC\,(i,j)]$. When applying PBPL equation adequate KPI indicators might be derived.

$$\{[PROD\,(i,j1)]\} \otimes \{[HRC\,(i,j)]\} \otimes \{[HR\,(i,j)]\} = \{[Tbex\,(i,j)]\} \otimes \{[Retx\,(i,j)]\} \tag{37}$$

$$\{[Tbex\,(i,j)]\} = \{[PROD\,(i,j1)],[HRC\,(i,j)]\} \tag{38}$$

$$\{[Retx\,(i,j)]\} = \{[PROD\,(i,j1)],[MFRC\,(i,j)],[HR\,(i,j)]\} \tag{39}$$

$$\{KPIhr(0,1)\} = \{[Tbex\,(i,j)]\} \tag{40}$$

$$\{KPIhr\,(0,2)\} = \{[Retx\,(i,j)]\} \tag{41}$$

$$\{KPIhr\,(0) = \{KPIsad(0,1)\} \otimes \{KPIsad(0,2)\} \tag{42}$$

Finally, at strategic management level, a set of core BP are implemented and operated (see also **Table 1**) and quantified via appropriate linguistic sets, e.g. Technological TECH management is quantified via $\{[TECHN\,(i,j)]\}$ as well where the *main frame technological devices and tools* play a role of principle importance and are being quantified via $[TECHNC\,(i,j)]$. When applying PBPL equation adequate KPI indicators might be derived.

$$\{[PROD\,(i,j1)]\} \otimes \{[TECNC(i,j)]\} \otimes \{[TECH\,(i,j)]\} = \{[Tbex\,(i,j)]\} \otimes \{[Retx\,(i,j)]\} \tag{43}$$

$$\{[Tbex\,(i,j)]\} = \{[PROD\,(i,j1)],[TECHNC\,(i,j)]\} \tag{44}$$

$$\{[Retx\,(i,j)]\} = \{[PROD\,(i,j1)],[TECHNC\,(i,j)],[TECH\,(i,j)]\} \tag{45}$$

$$\{KPItech(0,1)\} = [Tbex\,(i,j)]\} \tag{46}$$

$$\{KPItech\,(0,2)\} = \{[Retx\,(i,j)]\} \tag{47}$$

$$\{KPItech\,(0) = \{KPItech(0,1)\} \otimes \{KPItech(0,2)\} \tag{48}$$

In order to create a complex set of KPI indicators related to business processes implemented and operated at tactic and operational management level, an

appropriate decomposition of primary KPI indicators related to performance of those processes to should be done. However, the KPI indicator decomposition for tactic level will be explained based on Consideration 3 and the KPI indicator decomposition for operational level will be explained based on Consideration 4 as well, while the Consideration no. 3 results the **secondary KPI indicators** and the Consideration no. 4 results the **tertiary KPI indicators** and both considerations are described within subsequent sections.

5.2 KPI indicator decomposition

5.2.1 KPI decomposition related to tactic level

5.2.1.1 Determination of Production process *secondary KPI indicators*
Consideration no. 3

The previous section deals with initial KPI indicator generation and determination of primary KPI indicators for strategic management level. In that section, we shall discuss the KPI indicator decomposition for tactic level, which is based on the following consideration. The outgoing linguistic sets and KPI indicators for KPI decomposition related to tactic level are quantified via formulas (26, 27, 28, 29 and 30). With respect to the above-mentioned issues the following clause might be postulated:
At the strategic management level, the Production main process might be quantified via {[PROD (i, j₁)]} linguistic set and two KPI indicators could be postulated, which indicate that process functionality (performance) (see also formulas (28) and (29) and (30).

However, the similar sequence of steps (algorithm) might be applied when quantifying and generating KPI indicators for further main processes, sales and distribution, HR, technological and financial management at the strategic management level.

The KPI indicators postulated for strategic management level are represented by formulas (25, 26, (28, 29) and (30) create basis for their further decomposition related to tactic management level.

Let us select the [Mark_res_assets_mat _ires(0)] subset from {[Tbex (i, j)]} and assign it to market required output products quantified via {[MROP (i, j)]}, while formulas (28 and 29) might be postulated:

$$[\text{Mark\_res\_assets\_mat\_ires}(0)] \subseteq \{[\text{Tbex}\,(i, j)]\} \qquad (49)$$

$$[\text{Mark\_res\_assets\_mat\_ires}(0)] = \{[\text{MROP}\,(i, j)]\}, \qquad (50)$$

The {[MROP (i, j)]} contains subsets applied for quantification market required output products classes, e.g. utility glass article classes – bowls, bottles, vases, etc.

$$\{[\text{MROP}\,(i, j)]\} = \{[\text{MROP}\,(i, 1)], [\text{MROP}\,(i, 2)]\ldots.\{[\text{MROP}\,(i, m_1)]\} \qquad (51)$$

Where.
Index m_1 is a number of article classes.

Furthermore, let us create a selected linguistic set $\{[\text{MROP}_{sel}\,(i, j)]\}$, a content of which is created by selected classes of $[\text{MROP}_{sel}\,(i, j)]$, [MROP (i, 1)], [MROP (i, 2)], [MROP (i,3)], as for instance (see also formula (53)).

$$\{[\text{MROP}_{sel}\,(i, j)]\}, = \{[\text{MROP}\,(i, 1)], [\text{MROP}\,(i, 2)], [\text{MROP}\,(i, 3)]\} \qquad (52)$$

and let us postulate the $\{CUST\ (i, j_2)]\}$ linguistic set, the content of which create data concerned with the customers.

$$\{[CUST\ (i, j_2)]\} = \{[CUST\ (i, 1)], [CUST\ (i, 2)], \ldots..[CUST\ (i, m_{2)]}\} \qquad (53)$$

where Index $m_{2\ means}$ a number of customers.

In the next step, an appropriate $\{[MROP_{sel}\ (i, j)]\}$ set for each customer will be assigned, while formula (19) might be postulated.

$$\forall\{[CUST\ (i, j_2)]\}\ \exists\ \{[MROP_{sel}\ (i, j)]\} \Rightarrow \{[CUST\ (i, j_2)]\} \Leftrightarrow \{[MROP_{sel}\ (i, j)]\} \qquad (54)$$

In the next step we shall assign to each $\{[MROP_{sel}\ (i, j)]\}$ set a $\{[MROP_{selfinass}\ (i, j_3)]\}$ and $\{[MROP_{selcosts}\ (i, j_4)]\}$, where $\{[MROP_{selfinass}\ (i, j)]\}$ set quantifies the financial assets related to selected class of any market required output products.

$\{[MROP_{selfincosts}\ (i, j)]\}$ set quantifies the material costs related to selected class of any market required output products.

$$\{[CUST\ (i, j_2)]\} \otimes \{[MROP_{sel}\ (i, j3)]\} \otimes \{[MROP_{selfinass}\ (i, j4)]\} \otimes \{[MROP_{selfincosts}\ (i, j5)]\}$$
$$= \{[Tbexc\ (i, j)]\} \otimes \{[Retxc\ (i, j)]\}$$

$$\qquad (55)$$

$$\{[Tbexc\ (i, j)]\} = \{[CUST\ (i, j_2)], \{[MROP_{sel}\ (i, j2)]\} \qquad (56)$$

$$\{[CONTRACTB\ (i)]\} = \Pi\ \{[CUST\ (i, j_2)], \{[MROP_{sel}\ (i, j)]\} \qquad (57)$$

$j = 1\ldots_{m3}$
$j_2 = 1\ldots_{m2}$

The $\{[CONTRACTB\ (i)]\}$ linguistic set quantifies the basic contract, which indicates relations among customers and selected market required output products, incl. Financial costs and financial assets.

$$\{[Retxc\ (i, j)]\} = \{[CUST\ (i, j_2)], [MROP_{sel}\ (i, j)], [MROP_{selfinass}\ (i, j)], [MROP_{selfincosts}\ (i, j)]\}$$

$$\{[CONTRACTC(i)]\} == \Pi\ \{[CUST\ (i, j_2)], [MROP_{sel}\ (i, j_3)], [MROP_{selfinass}\ (i, j_4)],$$
$$[MROP_{selfincosts}\ (i, j5)]\}$$

$$\qquad (58)$$

$j = 1\ldots_{m3}\quad j_3 = 1\ldots_{m3}\quad j_4 = 1\ldots_{m4}\quad j_5 = 1\ldots_{m5}$
$j_2 = 1\ldots_{m2}$

Before, we make the final step we have to assign an appropriate group of business processes to each group of selected market required output products, while formula (70) might be postulated.

$$\forall\{[MROP_{sel}\ (i, j)]\}\ \exists\ \{[BP\ (I, j_6)]\} \Rightarrow \{[MROP_{sel}\ (i, j)], \Leftrightarrow \{[[BP\ (I, j_6)]\} \qquad (59)$$

$$\{[MROP_{sel}\ (i, j)], [BP\ (I, j_6)]\} = \{[Tbexbp\ (i, j)]\} \otimes \{[Retxbp\ (i, j)]\} \qquad (60)$$

$\{[Tbexbp\ (i, j)]\} = \{[[BP\ (I, j_6)]\}$ – list of BP groups needed for production of market required output products quantified via $\{[MROP_{sel}\ (i, j)]$,

$$\{[Retxbp\ (i, j)]\} = \{[MROP_{sel}\ (i, j)], \{[[BP\ (I, j_6)]\} \qquad (61)$$

Formula (24) indicates a list of relations among BP groups and market required output product group.

$$\{[\text{CONTRACTD (i)}]\} = \Pi \{[\text{CUST (i, j}_2)], \{[\text{MROP}_{\text{sel}} (\text{i, j}_3)], [\text{MROP}_{\text{selfinass}} (\text{i, j}_4)],$$
$$[[\text{BP (I, j}_6)]\}$$

(62)

$j = 1...m_3, \quad j_2 = 1.....m_{2}, \quad j_3 = 1....m_3, \quad j_4 = 1....m_4, \quad j_5 = 1....m_5, \quad j_6 = 1....m_6,$
Finally, adequate KPI indicators will be defined.

$$\text{KPI (i, 1)} = \{[\text{CONTRACTB (i)}]\} \qquad (63)$$

$$\text{KPI (i, 2)} = \{[\text{CONTRACTC (i)}]\} \qquad (64)$$

$$\text{KPI (i, 3)} = \{[\text{CONTRACTD (i)}]\} \qquad (65)$$

KPI (i, 3) indicator creates basis for decomposition related to operational level.

5.2.2 KPI indicator decomposition related to operational management level - consideration no. 4

5.2.2.1 Determination of Production process **tertiary KPI indicators**

Let us consider the $\{[\text{CONTRACTD (i)}]\}$ linguistic set (see also formula (57)), which quantifies order submitted to an appropriate firm or company organization unit to produce adequate products quantified via $\{[\text{MROP}_{\text{sel}} (\text{i, j}_3)]\}$ and with the use of business processes (BP), which create an integral part of a given BP group. One of those processes will be selected and demonstrated how the KPI (i, 3) indicator should be decomposed in order to describe the selected BP functionality and performance, first of all. In general any BP is represented by its own internal and external metrics, while the external metrics is concerned with BP outputs and inputs and the BP internal metrics is closely related to appropriate production human resources, production devices and production tools and those aspects are quantified via given linguistic sets.However, that decomposition will be done within several steps as well.

5.2.2.2 BP external metrics KPI indicators

Step 3
In that step, a group of selected products should be created, which is an integral part of products quantified via $\{[\text{MROP}_{\text{sel}} (\text{i, j}_3)]\}$ linguistic set, while formula (66) might be postulated.

$$\{[\text{MROP}_{\text{sel\_bp}} (\text{i, j}_3)]\} \subseteq \{[\text{MROP}_{\text{sel}} (\text{i, j}_3)]\} \qquad (66)$$

Those products should be produced with the use of the selected BP (see also formula (67)).

$$\{[\text{BP (i, j7)}]\}\} \in [[\text{BPG (i, j}_6)]\} \qquad (67)$$

Now, we have to select set input materials needed for production of the above-mentioned products. We shall apply the $[\text{MROP}_{\text{selfincosts}} (\text{i, j})]\}$ linguistic set for those purposes, the content of consists of two subsets with respect to formula.

$$[\text{MROP}_{\text{selfincosts}} (\text{i, j})]\} = \{[[\text{MROP1}_{\text{selfincosts}} (\text{i, j})], [[\text{MROP2}_{\text{selmatcosts}} (\text{i, j})]\} \qquad (68)$$

Where the linguistic $[[MROP1_{selfincosts}(i,j)]$ subset quantifies financial costs and the $[MROP2_{selmatcosts}(i,j)]$ subset quantifies material costs and create basis for preparation that subset which contains material data needed for production of the above-mentioned products

$$\{[MROP1_{sel\_bp}(i,j_3)]\} \subseteq \{[MROP_{sel\_bp}(i,j_3)]\} \tag{69}$$

$$[MROP2_{selmatcosts}(i,j)]\{[MROP_{sel\_bp}(i,j_3)]\}\{[[MROP1_{selfincosts}(i,j)],[MROP_{selfinass}(i,j)] \tag{70}$$

5.2.2.3 Applying of PBPL equation solutions

Step 4

When applying the PBPL Equation, KPI indicator for the selected BP functionality and performance might be derived, while the modified PBPL Equation is postulated with respect to formula (61).

$$\{[MROP2_{selmatcosts}(i,j)],[MROP1_{selfincosts}(i,j)],[MROP_{selfinass}(i,j)],[MROP_{selmatass}(i,j)]\}$$
$$\otimes [MROP_{sel\_bp}(i,j_3)] = \{[Tbex(i,j_8)]\} \otimes \{[Retx(i,j_9)]\} \tag{71}$$

5.2.2.4 PBPL equation solution results

Step 5

$$\{[Tbex(i,j_8)]\} = ([MROP_{selmatass}(i,j)],[MROP2_{selmatcosts}(i,j)]\} \tag{72}$$

$$\{[Retx(i,j_8)]\} = \{[MROP2_{selmatcosts}(i,j)],[MROP1_{selfincosts}(i,j)],[MROP_{selfinass}(i,j)],$$
$$[MROP_{selmatass}(i,j)]\} \tag{73}$$

5.2.2.5 BP external metrics KPI indicators

Step 6

When dealing with BP External metrics KPI Indicators, so called basic and external KPI indicators will be defined.

$$KPIemb(i,3) = \{[Tbex(i,j_8)]\} = ([MROP_{selmatass}(i,j)],[MROP2_{selmatcosts}(i,j)]\} \tag{74}$$

$$KPIemext(i,3) = \{[Retx(i,j_8)]\} = \{[MROP2_{selmatcosts}(i,j)],[MROP1_{selfincosts}(i,j)],$$
$$[MROP_{selfinass}(i,j)][MROP_{selmatass}(i,j)]\} \tag{75}$$

$$KPIem = KPIemb(i,3) \otimes KPIemb(i,3) \tag{76}$$

5.2.2.6 BP Internal metrics KPI Indicators

Step 7

The similar algorithm might be applied, when deriving BP Internal metrics KPI Indicators.

5.3 Case study

5.3.1 Determination of production process KPI indicators

The case study aim is to show how the derived math formulas and relations should be applied in a practice, when calculating actual data. The algorithm proposed within previous sections is passing through the following main phases:

- Determination of initial KPI indicators

- Determination of primary KPI indicators

- Determination of secondary KPI indicators

- Determination of tertiary KPI indicators

Furthermore, appropriate phases will be explained in more details.

5.3.2 Determination of initial KPI indicators

Before that phase is being activated a set of adequate data should be prepared, while the data are categorized as the market research results and the firm or company internal resources. The market research results inform us about possibilities how to apply our production in market and give us information how many products is the market able to accept and in which structure and what about financial assets might be generated as a result of that acceptance. However, the information related to adequate costs plays a role of principle importance as well. It means, we are able to answer the question related to the linguistic set content postulated within formulas (77–80)[2, 3, 4, 5].

$$\left[Y^{\text{Totmat}}_{\text{Assetst}} \right] \} = [100000 \text{ pp}], \tag{77}$$

$$\left[Y^{\text{Totfin}}_{\text{Assetst}} \right] = [1000000 \text{ Euros}] \tag{78}$$

$$\left[X^{\text{Totfin}}_{\text{Costs}} (0) \right] = [200000 \text{ Euros}] \tag{79}$$

$$\left[X^{\text{Totmat}}_{\text{Costs}} (0) \right] = [50000 \text{ Euros}] \tag{80}$$

With respect to those issues, the initial KPI indicator postulated via formula one might be indicated as follows:

$$\{ KPI (0) \} = \left\{ \left[X^{\text{Totfin}}_{\text{Costs}} (0) \right], \left[X^{\text{Totmat}}_{\text{Costs}} (0) \right], \left[Y^{\text{Totfin}}_{\text{Assetst}} \right], \left[Y^{\text{Totmat}}_{\text{Assetst}} \right] \right\}$$
$$= \{ [100000 \text{ pp}], [1000000 \text{ Euros}], [200000 \text{ Euros}], [50000 \text{ Euros}] \} \tag{81}$$

_____

[2] Pp – number of products, which might be accepted in the market in pieces

[3] Financial assets, which could be achieved based on acceptance of the product piece amount at the market

[4] A need of total financial costs needed for production of products, while that number includes material, technological HR and operational costs

[5] This value represents costs for recruitment of adequate material inputs

After having applied formulas (77–80), we shall get values for primary KPI indicators, with respect to formulas (82) and (83).

$$\{KPI\ (1)\} = \{[1,000,000\ Euros], [200,000\ Euros]\} \tag{82}$$

$$\{KPI\ (2)\} = \{[100,000\ pp]\}, [50,000\ Euros]\} \tag{83}$$

$$\{KPI\ (0)\} = \{[1,000,000\ Euros], [200,000\ Euros], [100,000\ pp]\}, [50,000\ Euros],$$
$$[PROD(i, j_1)]\}$$

$$\tag{84}$$

This expression means that the primary KPI indicator s closely related to the production core process quantified via $[PROD\ (i, j_1)]\}$. However, that KPI indicator does not consider the firm or company real possibilities related to its internal resources.

As a result of that adequate coefficient should be determined. They might be calculated based on data contained within appropriate technical and economic norms with the use of the following consideration.

5.3.3 Determination of primary KPI indicators

However our disposals are 170,000 Euros only and an appropriate coefficient might be calculated based on formula

$$Coef = 170,000/200000 = 0,85 \tag{85}$$

Subsequently, we shall get s appropriate values related to {KPI (1)} and {KPI (2)} with the use of formula (8a) (8b). It means 1,000,000 x 0, 85, 200,000 x 0,85, 100,000 x 0,85 and 50,000 x0,85 and we get correct values for {KPI (1)} and {KPI (2)} indicators. Those indicators are denoted **as primary indicators** and they are closely related to core production process running at strategic management level and create bases for determination of the secondary KPI indicator values.

5.3.4 Determination of secondary KPI indicators

Let us consider the {KPI (2)} indicator values, which indicates that costs for production of [100,000 pp] are [50,000 Euros]]. Now, we shall try decomposing the {KPI (2)} related to actual contracts and groups of business processes assigned to those contracts. However, before we start doing that, we have to manage several auxiliary actions. The first one is closely related to market required output products quantified via {[MROP (i, j)]}. We shall do it within following steps:

Step 1 Determination of product number with respect to adequate Coef value.

$$[Mark\_res\_assets\_mat\_ires(0)] = \{[100,000\ pp]\ x\ 0,85 = 85,000\ pp \tag{86}$$

$$\{[MROP\ (i, j)]\} = 85,000\ pp \tag{87}$$

Step 2 The {[MROP (i, j)]} content will be divided into subordinated product classes.

$$[MROP\ (i, 1)] = [bowls = 30,000\ pp] \tag{88}$$

$$[MROP\ (i, 2)] = [bottles = 30,000\ pp] \tag{89}$$

$$[MROP\ (i, 3)] = [vases = 25,000\ pp] \tag{90}$$

and appropriate customers {[Cust (1)]}, {[Cust (2)]} and {[Cust(3)]} will be determined Subsequently, we shall assign selected product groups to adequate customers and will be generated adequate orders.

$$\{[\text{Cust (1)}]\} = \{[\text{bowls} = 30,000 \text{ pp}], [\text{bottles} = 30,000 \text{ pp}]\} \tag{91}$$

$$\{[\text{Cust (2)}]\} = \{[\text{bowls} = 30,000 \text{ pp}], [\text{vases} = 25,000 \text{ pp}]\} \tag{92}$$

$$\{[\text{Cust (2)}]\} = [\text{bottles} = 30,000 \text{ pp}], [\text{vases} = 25,000 \text{ pp}] \tag{93}$$

In that step we shall extend the orders and add the data concerned with adequate financial costs (see also formulas 94–97).

$$\{[\text{MROP}_{\text{selfinass}} (i, j)]\} = \left[X^{\text{Totmat}}_{\text{Costs}} (0)\right] \text{x Coef} = [50,000 \text{ Euros}] \text{ x } 0,85 \\ = [42,500 \text{ Euros}] \tag{94}$$

$$\{[\text{Cust (1)}]\} = \{[\text{bowls} = 30,000 \text{ pp}], [\text{bottles} = 30,000 \text{ pp}], [14,000 \text{ Euros}\} \tag{95}$$

$$\{[\text{Cust (2)}]\} = \{[\text{bowls} = 30,000 \text{ pp}], [\text{vases} = 25,000 \text{ pp}], [18,000 \text{ Euros}]\} \tag{96}$$

$$\{[\text{Cust (3)}]\} = [\text{bottles} = 30,000 \text{ pp}], [\text{vases} = 25,000 \text{ pp}], [10500]\} \tag{97}$$

and we shall create the basic order (CONTRACTC).

$$\{[\text{CONTRACTC}(i)]\} = \{[\text{Cust (1)}], [\text{Cust (2)}], \{\text{Cust (3)}]\} \tag{98}$$

However, a set of adequate business processes should be applied in order to manage production of products related to pre-defined orders or contracts as well, while formula (85) should be extended about linguistic sets, which quantify those groups of business processes – see also formula (50).

$$\{[\text{CONTRACTD (i)}]\} = \{[\text{Cust (1)}], \left[\text{BPG1} (i, j_{61})\right], [\text{Cust (2)}], \left[\text{BPG2} (i, j_{62})\right], \\ \{\text{Cust (3)}], \left[\text{BPG3} (i, j_6)\right]\} \tag{99}$$

With respect to the above-mentioned issues the KPI (i, 2) content is defined via formula (88) and KPI (i, 2) content is defined via formula (89) and we have derived a set of the **secondary KPI indicators.**

$$\text{KPI} (i, 2) = \{[\text{Cust (1)}], [\text{Cust (2)}], \{\text{Cust (3)}]\} \tag{100}$$

$$\text{KPI} (i, 3) = \{[\text{Cust (1)}], \left[\text{BPG1} (i, j_{61})\right], [\text{Cust (2)}], \left[\text{BPG2} (i, j_{62})\right], \{\text{Cust (3)}], \left[\text{BPG3} (i, j_6)\right]\} \tag{101}$$

Each business process group consists of appropriate business process quantified via adequate linguistic set (see also **Tables 2** and **3**).

5.3.5 Determination of tertiary KPI indicators

Let us consider a group of business processes represented by **Tables 2** and **3** and let us select one of those business processes in order to derive the tertiary KPI indicators, which are closely related to BP external and internal metrics. Formulas (63 and 64) will be applied for those purposes. When installing adequate data in the

Product class value	BPG number	BP Number	BP Description	BP External metrics	
				Output prod assets	**Input mat. Costs**
[bowls = 30,000 pp]	[BPG1 (i, 1)],	BP (1,1)	BP (1,1) Description	[bowls = 10,000 pp]	1700 Euros
	[BPG1 (i, 2)],	BP (1,2)	BP (1,2) Description	[bowls = 10,000 pp]	1700 Euros
	[BPG1 (i, 3)],	BP (1,3)	BP (1,3) Description	[bowls = 10,000 pp]	1700 Euros
Source: The Authors.					

Table 2.
Business processes as the BP group members (external metrics).

Product class value	BPG number	BP Number	BP Description	BP Internal metrics		
				HR Costs	**Dev costs**	**Tool cost**
[bowls = 30,000 pp]	[BPG1 (i, 1)],	BP (1,1)	BP (1,1) Description	1100Euros	800	300
	[BPG1 (i, 2)],	BP (1,2)	BP (1,2) Description	1100Euros	800	300
	[BPG1 (i, 3)],	BP (1,3)	BP (1,3) Description	1100Euros	800	300
Source: The Authors.						

Table 3.
Business processes as the BP group members (internal metrics).

above-mentioned formulas we shall get partial KPI indicators related the selected BP external and internal metrics in form of adequate linguistic sets (see also formulas (91) and (92).

$$\{[KPIemb\,(i, 3)]\} = \{[BP\,(1, 1)]\,[bowls = 10,000\,pp], [1700\,Euros]\} \qquad (102)$$

$$\{[KPIimb\,(i, 3)]\} = \{[BP\,(1, 1)], [HRcosts = 1100\,Euros], [DEVcosts = 800],$$
$$[Toolcosts = 300\,Euros]\}$$
$$(103)$$

$$KPIter = KPIemb\,(i, 3) \otimes KPIemb\,(i, 3) \qquad (104)$$

A set of derived KPI indicators via formulas (91, 92, 93) is closely related so selected BP implemented and operated at operational management level and is denoted as **tertiary indicator set.**

5.3.6 Case study – summary

The case study previous sections deals with KPI indicator creation and decomposition steps, while those steps are closely related to three management levels: (a) strategic, (b) tactic, and (c) operational management level. In that section an overview summary with supplementary visual components will be done.

*5.3.6.1 Strategic management level*

In order to determine, the KPI indicators related to strategic management level, an appropriate data concerned with market research and internal resources needed for providing business. In that case, the business is closely related to the company, which deals with utility glass production, while there are two types of production: (a) manually oriented and (b) machinery oriented production. Further KPI explanations are closely related to manually oriented production, which is considered to be the core business process and the initial KPI indicator KPI (0) is assigned to that process. The KPI (0) indicator has a nature of top linguistic set, which consists of subordinated linguistic sets (see also formula (53).

$$\{KPImanp\ (0)\} = [Xtotfinmanpassets\ (0) = 1,000,000\ Euros],$$
$$[Xtotmatmanpassets\ (0) = 100,000\ pp], [Xtotmatmanpcosts\ (0) = 50,000\ Euros],$$
$$[Xtotfinmanpcosts\ (0) = 200,000\ Euros]\}$$

$$(105)$$

The KPImanp (0) indicator seems to be the initial KPI indicator and creates basis for deriving of primary KPI indicators calculated with respect of actual firm or company internal financial resources and represented by coefficient Coef. A set of initial KPI indicators is shown in **Figure 1**, while a set of the main initial KPI indicator KPImanp (0) is shown in **Figure 2** and its components are determined based on initial KPI indicators (see also **Figure 1**) and coefficient Coef (see also **Figure 2**).

5.3.6.2 Tactic management level

The main business processes and appropriate BSC perspectives should be investigated and discussed at tactic management level. Only two perspectives (customer's and internal BP) perspective are within that case study, while adequate
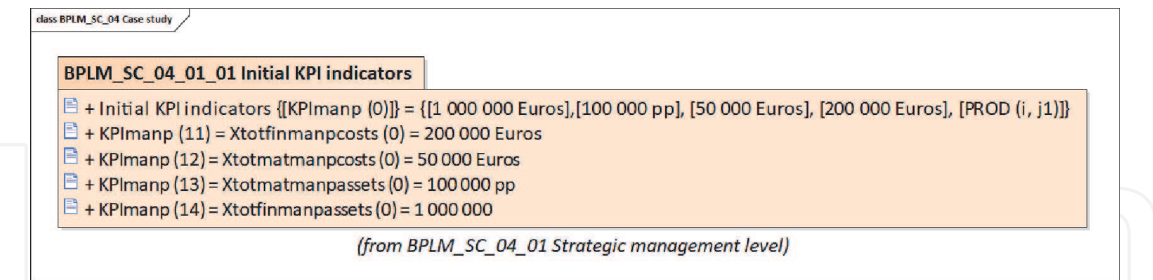
Figure 1.
*A set of initial KPI indicators. Source: The authors.*
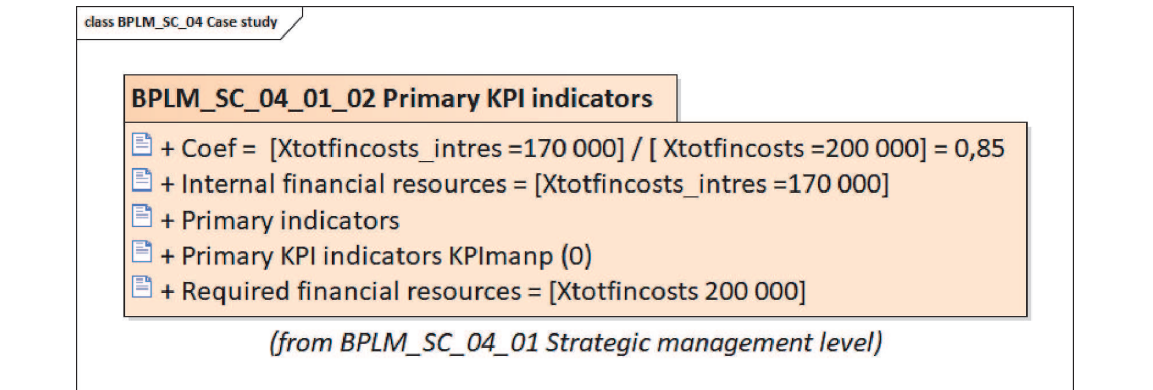
Figure 2.
Inputs for calculating the primary KPI indicators. Source: The authors.

primary KPI indicators represent outgoing inputs for those perspectives as well. The case study is divided in two levels at that management level. The *first level* is closely related to dividing the products to be produced and sold to adequate types and classes (bowls, bottles, vases) and assigned to pre-defined customers Customer 1, Customer 2 and Customer 3, while such assignment enables generating appropriate contract (CONTRACTCS C(I)). On the other hand a set of adequate internal BP is being assigned to assure production of articles, which create an integral part of the (CONTRACTCS C(I)) and creates an extended contract (CONTRACTCS D(I)) business process management point of view (see also **Figure 3**).

5.3.6.3 Operational management level

The subordinated or elementary business processes and their external and metrics should be investigated and discussed at operational management level. In
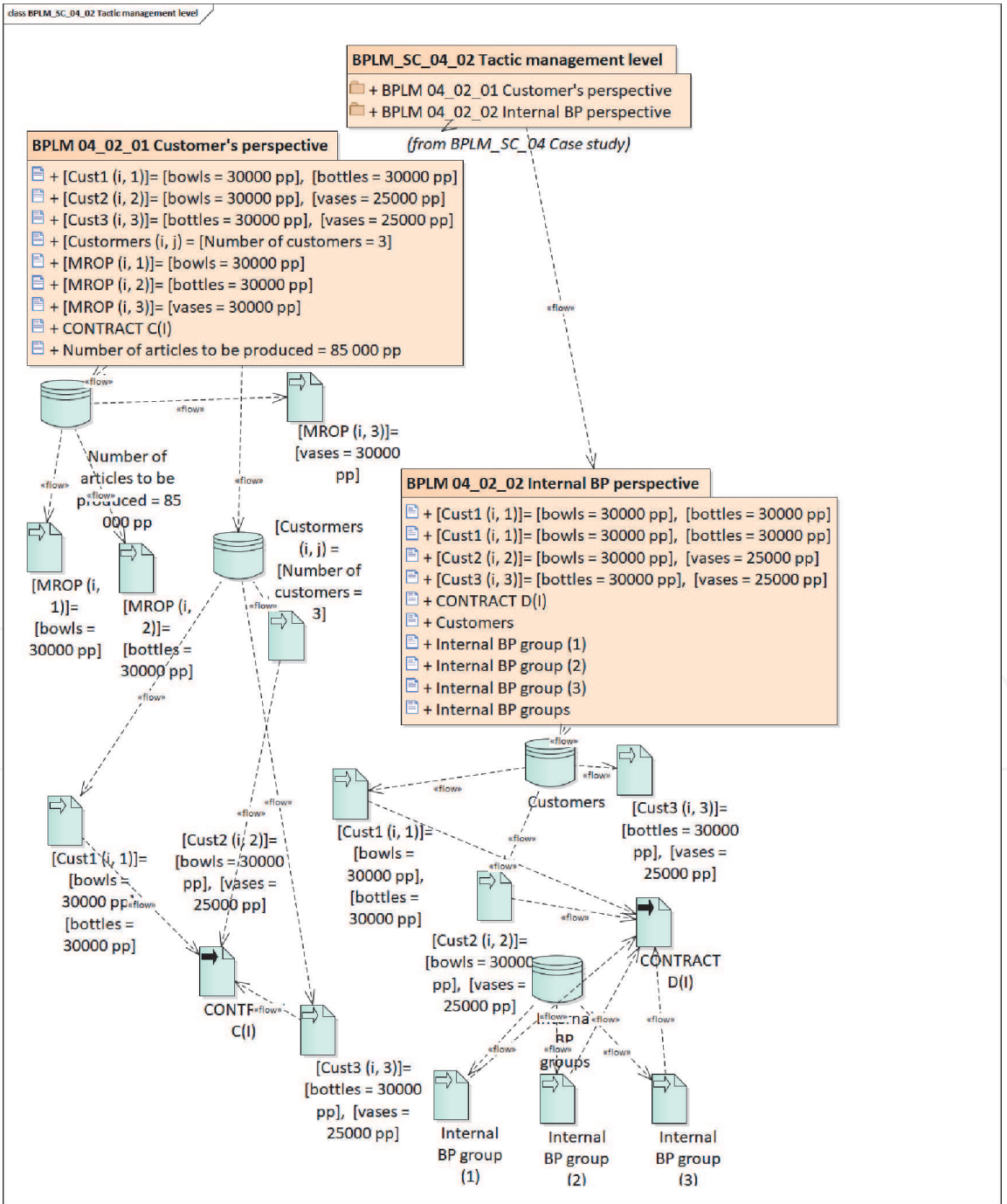
Figure 3.
Example of CONTRACTC (i) and CONTRACTD (i) development. Source: The authors.

general, BP external metrics deals with BP material inputs, while appropriate material costs play a role of principle importance. However, this is only one side of the coin, while the BP output products create an integral part of BP external metrics as well. The KPI indicator closely related to BP external metrics is postulated via formula (106). In order to express adequate numerical values the secondary KPI indicators concerned to output products and input materials should be applied.

$$KPIBP\,(1) = \{[KPI\_BPemet\,(i,j)]\} = \{[MATfincosts\,(i,j)], [MROPselmatassets\,(i,j)],$$
$$[MROPselfinassets\,(i,j)]\}$$

(106)

However, any BP is represented by its internal metrics as well, while he KPI indicator closely related to BP external metrics is postulated via formula (107). In order to express adequate numerical values the secondary KPI indicators concerned to output products and input materials should be applied.

$$KPIBP\,(2) = \{[KPI\_BPimet\,(i,j)]\} = \{[(DEV\_costs\,(i,j11), (DEV\_assets\,(i,j12)],$$
$$[(TOOL\_costs(i,j21), (TOOL\_assets(i,j22)], \{[(HR\_costs\,(i,j31), (HR\_assets\,(i,j32)]\}$$

(107)

The total business process KPI indicator value might be postulated with respect to formula (56). A detailed visualization of the above-mentioned KPI indicator components are shown in **Figure 4**.

However, The sets [(DEV_assets (i,j12)] and [(TOOL_assets(i,j22)] are closely related to depreciation and amortization of devices and tools, as while, [(HR_assets (i,j32)] are closely related to extra contributions generated by employees.
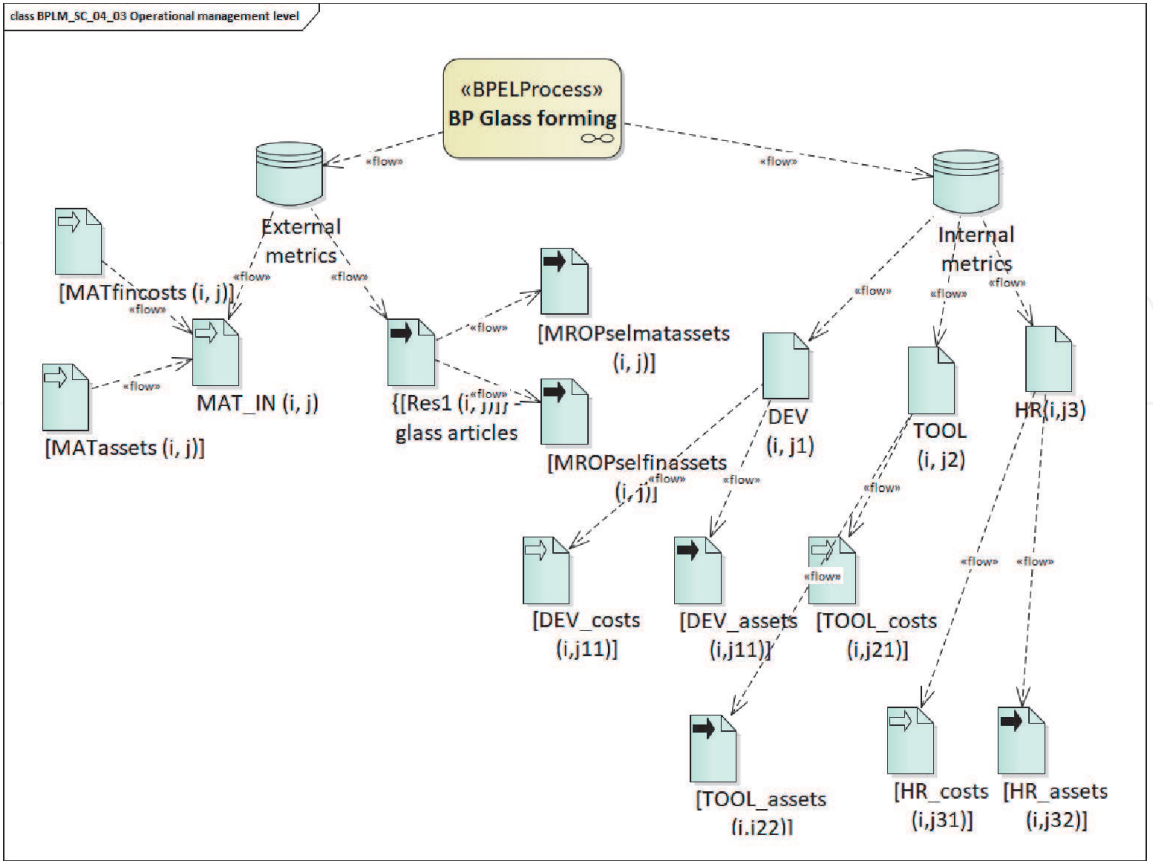
Figure 4.
A detailed visualization of BP KPI indicator components. Source: The authors.

5.4 Design and implementation model

5.4.1 General overview

The BPLM Strategy Creator should be implemented and operated like aim oriented knowledge based or expert system (ES), which consist of an appropriate knowledge base (KB) and inference engine (IE). Both of two subsystems consist of three components closely related to strategic, tactic and operational management levels. However, knowledge contained within KB are being represented via adequate reference databases (RDBs) and semantic networks (SNWs) as well, while IE should enable retrieval and presentation of knowledge contained in ES-KB and generation of new (primary) knowledge based on knowledge actually contained within ES-KB. An interaction between RDBs and SNWs provide transformations rules converted into appropriate transformation functions.

BPLM Strategy Creator is being implemented and operated via adequate knowledge based (expert system), which consists of two subsystems denoted as BPLM_01_06_06_01 ES Knowledge Base and BPLM_01_06_06_02 ES Inference Engine. The Knowledge Base subsystem operates over knowledge base, which contains adequate knowledge, while the Inference Engine subsystem provides retrieval and presentation of knowledge contained within knowledge base and new knowledge discovery based on existed one [25].

When considering the knowledge-based content, we have to talk about knowledge representation. The knowledge representation principle applied within that project is based on existence of reference databases (RDBs), transformation rules (TRrules), transformation tools (TRtools) and semantic networks (SNWs) and is closely related to an appropriate management level (strategic, tactic, operation.

5.4.2 BPLM ES knowledge base

The BPLM ES Knowledge Base functionality is being assured via four modules: (a) Data preparation (b) Reference Database (RDBs) (c) Creation, Semantic Network (SNWs) creation and (d) Import of SNWs to Knowledge Base. The Data preparation component is running within four subordinated steps and modules: (a-1) Data extraction, (a-2) Data transformation, (a-3) RDBs update, (a-4) SNWs creation.

In the first step, an appropriate data is extracted from various documents or they are prepared as a result of the document semantic analysis, while *in the second step* their structure should be transformed to adequate RDBs structure and stored to the RDBs and pre-defined SNWs pointers are being generated. Afterwards, *in the third step*, all the above –mentioned data are stored to linguistic sets and prepared RDBs subsequently. In the fourth step appropriate SNWs are being created and stored to BPLM ES Knowledge base.

5.4.3 BPLM ES inference engine

The BPLM ES Knowledge Base functionality is being assured via four modules: (a) KB content retrieval, (b) Knowledge discovery and (c) Presentation layer. The KB content retrieval operates based on Knowledge general and detailed requirement, which enables selection of appropriate knowledge records, while the selected knowledge record content is visualize via Presentation layer, which consist of the following modules: (c-1) Strategic layer, (c-2) Tactic layer, (c-3) Operational layer and (c-4) Analytical layer

6. Conclusion

We have developed the BPLM Strategy Creator conceptual model, which should operate with several types of KPI indicators and which should provide the KPI creation at strategy management level and decompose them to tactic and operational management levels. With respect to that fact, we define the *initial KPI indicators* created based on research market results, regardless the firm or company internal resources. Afterwards, an appropriate *analysis of the firm or company internal resources* should be provided[6], the results of which could enable generating of so called primary KPI indicators, which reflect real possibilities in providing the firm or company business with respect it actual internal resources. However, the initial and primary KPI indicators should be generated at strategic management level as well, while they create basis for determination of KPI indicators at tactic (*secondary KPI indicators*) and operational management level (*tertiary KPI indicators*). The secondary and tertiary KPI indicators seem to be results of adequate KPI decomposition.

When considering the BPLM Strategy Creator implementation aspects, we have designed structure and functionality of an appropriate expert system (ES), which should be implemented with use of graph databases (GraphDB) based on an adequate logical and physical model[7].

The ES should contain an inference engine, which could contain a presentation layer, which should enable the KPI visualizing in form, which is very closed to text in natural language (TNL text) supplied by adequate graphical information and this is considered to be main significance related to the BPLM Strategy creator utilization in a practice.

Acknowledgements

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[6] A development of that type component should be a subject of future work.

[7] A development of ES logical and physical model should be a subject of future work.

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