Semantic Representation of Key Performance Indicators Categories for Prioritization

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Abstract: Key Performance Indicators (KPIs) are crucial tools that are remarkably used to evaluate business performance. Recently, the management of KPIs has fascinated the focus of both academic and business professionals, and that lead to the development of research on various methods dealing with issues such as modeling, maintenance, and expressiveness of KPIs. As a need for organizations and processes to adapt to continuously changing demands, the KPIs used to measure their effectiveness evolve too. In order to make KPI management easier, this research aims to define the best sequence of KPIs evaluation based on semantic relations. After an extensive analysis of the literature on KPIs ontologies, it proposes the idea of KPIs prioritization on the basis of relations among different categories of kpis established by a KPIs ontology. Our approach can be used independently from the particular KPI's management strategy being employed.

1 INTRODUCTION

Due to the modern data society, businesses and institutions can now access a great deal of information in many different forms. The appropriate use of the available data can result in changes to an organization's processes, systems, and procedures because continuous business improvement is needed. Different factors, such as adjustments to the company's business strategy, the fixing of identified problems, changes to the law, or technical advancements, might bring about changes (Cognini et al., 2018). Companies realized that they needed to be agile, flexible, and focused on their business strategy in order to succeed in a dynamic environment with competitors, shorter product lifecycles, and intense price pressures when third-party countries are bringing costs down (Ferreira et al., 2017; Cortes et al., 2016; Sahno et al., 2015; Haponava and Al-Jibouri, 2012).

In recent years, businesses have suffered from failing to retain customers and a lack of funding. The company's performance must be high to accomplish those goals, and goods or services must be produced or delivered at the right places, at the proper time, in the appropriate amount, and for the suitable clientele, (Konsta and Plomaritou, 2012; Azapagic, 2003). The use of key performance indicators (KPIs), a contemporary technique, helps to sustain high levels of manufacturing performance (Tsai and Cheng, 2012). Following and monitoring the proper metrics in real-time, organizations are able to identify and comprehend constraints, assess worker and machine efficiency, set higher targets, and accomplish them by moving forward. The ability to measure performance enables one to identify performance concerns, determine how well one is progressing toward one's objectives, and provide precise instructions for resolving issues (Horváthová et al., 2015). provide a novel semantic framework for describing performance indicators that helps create and maintain a concise and reliable lexicon(Diamantini et al., 2016).

To identify the areas that need to be addressed, it is essential to evaluate how well business operations are performing. In every business sector, Key Performance Indicators (KPIs) have been widely used and defined inside information systems. It makes sense that there would be substantial and in-depth research on this subject given how important KPIs are. Despite this, there is no established framework for the definition and application of KPIs. In (Domínguez et al., 2019) the author discussed this problem and suggested a solution.

In this study we provide a semantic approach to the problem of KPI advancement management. Key Performance Indicator (KPI) advancement management is a crucial aspect of business success, as it helps

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organizations to track and measure the metrics that are most critical to their performance. By regularly monitoring these KPIs, businesses can gain valuable insights into their operations and make data-driven decisions to drive improvement. The first step in KPI advancement management is to identify the right KPIs for the organization. This will vary depending on the specific business and its goals, but could include metrics such as customer satisfaction, employee engagement, and financial performance. Once the KPIs have been identified, it is important to establish goals and targets for each one, to provide a clear understanding of what success looks like. Next, organizations need to implement a system for tracking and measuring their KPIs on a regular basis. KPI advancement management specifically suggests adopting the idea of a KPI prioritization as the best KPIs evaluation order to consider for a given class of KPIs. The prioritization order is then derived by semantic relations among different categories of KPIs as modeled in an ontology. The primary goal of the long-term research project is to provide a universal framework for managing KPIs advancement.

The rest of the paper is organized al follows: Section 2 is devoted to a throughout analysis of related work about ontologies of KPIs; in Section 3 the proposed methodology is discussed. Finally, Section 4 draws some conclusions and future work.

2 LITERATURE STUDY

2.1 Towards a Framework for KPI Evolution

Towards a Framework for KPI Evolution (Domınguez et al., 2020), provides the emphasis on the concepts of a conceptual framework, including a pattern-driven KPI evolution specification and a KPI evolution meta-model composed of two interconnected views. Firstly, the structural view of the meta-model provides the basis to design meta-information for the KPI's evolution, and secondly, the execution view concerns the applications built on the given structural views. Moreover, the approach presented in a study (Domınguez et al., 2020) is broad enough to be used independently of the particular KPIs management strategy being adopted. Several areas requiring additional research must be addressed to develop this general framework. The integration of the proposal within other KPIs management approaches must also be investigated to ascertain how proposed approach are properly incorporated into these approaches. Some of the KPI strategies are briefly discussed below, and Table 1 provides some ontology-based techniques.

2.2 A Lightweight Version of National Performance Indicator Ontology (NPIonto)

Oarabile Sebubi et al. (Sebubi et al., 2019) proposed a model that was created to meet the domain needs for Botswana's development agenda, which calls for a consolidated indicator framework with distinct connection mappings and data definitions, as well as data disaggregation and consideration of PIs' multi-dimensional features. The model was conceptualized using the official development agenda documents as a foundation and developed using the Knowledge Model Development (KMD) methodology. Domínguez et al. (Domínguez et al., 2019) primarily concentrate on this KPIs management element aims to deliver outstanding advantages like improving KPIs management knowledge or assisting users in selecting the best solution for their needs.

2.3 Implementation of Key Performance Indicators Selection Model as Part of the Enterprise Analysis Model

Kaganski et al. (Kaganski et al., 2017) proposed the findings of adopting the KPI selection model as part of the Enterprise Analysis Model (EAM). The model was put to the test by a private firm. The collection of KPIs that management should use was created. The suggested approach allows for time and resource savings during evaluation and metric selection.

2.4 Towards a KPI-Based Ontology for Condition Monitoring of Automation Systems

Pasic et al. (Pasic et al., 2019) presented a conceptual paradigm and condition monitoring ontology for automation systems. This ontology combines ISO standards for key performance indicators and condition monitoring (KPIs). Based on the proposed ontology in an industrial project, the author created a condition monitoring knowledge-based system for a centrifugal separator and reported the criteria to evaluate this work. This project aims to use semantic web query languages to link various knowledge-based systems engineering (MBSE) tools.

Table 1: Common Ontologies from the Literature.

Approach	Domain	Ontology Language Used
SUPER and SemBiz (Hoang et al., 2010)	Ontologies stack	WSMO
Jenz's BPM (RabahAzzam and Zhou, 2012)	Core business ontology; industry-specific ontology; organization-specific ontology	OWL
M3po Project (Thapar and Sharma, 2022)	M3po ontology	WSMO
Genesis (Shanthi Bala and Aghila, 2019)	Business OWL	OWL
CNO (Rajsiri et al., 2008)	Collaborative network ontology; Collaborative process ontology	OWL/SWRL
FlowMake (Andaloussi et al., 2020)	Graph-based Ontology	OWL
YAWL (Van Der Aalst and Ter Hofstede, 2005)	Specification of workflow and data perspective of business processes	WFMS
E-C-A Based (Ndadji et al., 2020)	Rule based process modeling to provide an integration layer between process modeling languages	SDL
ADEPT (Dadam and Reichert, 2009)	Rule-based ontology; designing and implementing multi-agent systems for workflows	SDL

2.5 Generalized KPI Models

A generalized KPI model proposed to improve business performance looked into the connection between institutional ownership and Malaysian publicly traded firms' financial performance (Ahmad and Jusoh, 2014). The Six Sigma method is a data-driven approach to process improvement that focuses on reducing defects and improving quality (Albliwi et al., 2015). Some other generalized rules-based approaches developed such as the McKinsey 7S framework tools used for analyzing and improving the effectiveness of organizations (Trompenaars and Coebergh, 2014).

2.6 Toward an Ontology-Based Model of Key Performance Indicators for Business Process Improvement

Ammar et al. (Amor and Ghannouchi, 2017) proposed a novel ontology to establish semantic linkages between all terms based on an actual business process. The author relied on the data mining technique to extract the most crucial information from data measurements. The application of the suggested contribution is demonstrated, and a case study in the field of healthcare is used to validate it. This study reveals that understanding KPIs from patient experience in the ED and interactions with other indicators are significant qualities for improving blood pressure.

2.7 Towards Measuring Key Performance Indicators of Semantic Business Processes

Wetzstein et al. (2008) present a key performance indicator-based approach to semantic business process performance management. The advantage of this method over previous work is that business analysts may completely specify KPIs during the process modeling phase since the necessary data, such as business objects and changes in their state, are available as semantic annotations of activities.

Table I shows the most common ontologies used in the literature for business organizations and their respective tasks. It can be observed that graph-based ontologies are mostly formed using OWL or similar tools. Also, OWL is a tool that can be used in various types of ontologies while many of the tools are domain specific. For instance, Service Description Language (SDL) can only be used in rule-based ontologies and web service modeling language (WSMO) can be applied in ontologies related to business structures.

3 METHODOLOGY

As businesses develop and grow, the management of quality and performance becomes crucial. To achieve success in businesses and enterprises, the consideration of factors that affect business has great importance in Business Process Management (BMP). That can be analyzed through dashboards, reports (Parmenter, 2015) supporting decision-makers in identifying opportunities for re-engineering the desired process and improvements. There are many processes involved in BPM to understand and measure the business indicators. In our proposed methodology for simplification and generalization, we comprise the whole BPM into three important parts (i.e., management, methodological approach, and technology). As concluded from the literature, there is a lot of research available for BPM to calculate the Key Performance Indicators (KPIs) in qualitative, quantitative, and semantic ways. But, proposal lack the ability to identify KPIs serialization based on priority in a semantic way. KPIs pertaining to a business process can be interrelated to each other, either directly or indirectly. For example, the sell price is directly related to the product cost. Consequently, this research aims to find the best sequence of KPIs evaluation based on semantic relations. The methodology has been graphically viewed in Figure 1.

3.1 Business Process Management (BPM)

Businesses are managed by high-level staff (managers) for the smooth flow of services and success. However, business process management involves several important steps and resources such as the creation, implementation, monitoring, and analysis of operational business processes, including people, organizations, software, documents, and other sources of information (Park et al., 2012). To simplify BPM in a generalized way, the BMP is summarized into three categories: management, methodological approach, and technology.

Management: A company's management team often defines processes, categorizes metrics, monitors performance and goals, and works to improve processes in order to meet market demands and provide valuable goods and services. Hereafter, the management team has extensive involvement in the conclusion of indicators.

Methodological Approaches (for BMP): Business process improvement is a continuous cycle that is a part of the BPM methodology. Using phases, actions, and procedures, aids businesses in improving their business operations. For example dynamic BPM, agile BMP, and social BMP. To design, select, monitor, and alter the business indicator depend on which methodological approach is adopted for business.

Technology (used for BMP): BPM technology is mostly software systems that can trace and record business processes to enhance analytics and business communication. This technology helps automate activities and track business projects and performance. In order to improve performance, quality, and efficiency, BPM technology essentially aids businesses in having a clear grasp of numerous processes within the organization. It helps in identifying the important business indicators.

3.2 Indicators (for Business)

To successfully evaluate a business for its performance, it is necessary to consider, analyze, and manage the factors/indicators that affect the quality, efficiency, and growth of the business. There are numerous indicators for BPM to be considered. Most of the indicators are generic and can be selected by any business accordingly, while others are specific and vary from business to business. Specific indicators are designed and selected by each business as per their requirements. In this study, indicators are divided into categories such as short-term indicators, long-term, quantitative, qualitative indicators see Table 2.

This research paper considers the generic indicators that are most common in every business activity to streamline the research model in a general perspective for the generalization and extraction of KPIs. In contrast, specifically selected KPIs for a business could not be suitable for others' consideration. The next step, the generalization of KPIs, is discussed in detail.

3.3 Key Performance Indicators (KPIs)

A KPI is a quantifiable statistic that shows how well a business is accomplishing its important business goals. To extract the generalized form of KPIs, which are able to be considered by all types of businesses, the generalized and refined indicators are selected by BPM. In order to select the most generalized KPIs, we selected the common business indicator categories that are included in almost every BPM. The common categories include long-term, quantitative, dependent, independent, cost, time, productivity, quality, high-level, and low-level indicators. Whereas short-term, qualitative, external, and internal indicators are specific to the business type, short-term indicators are

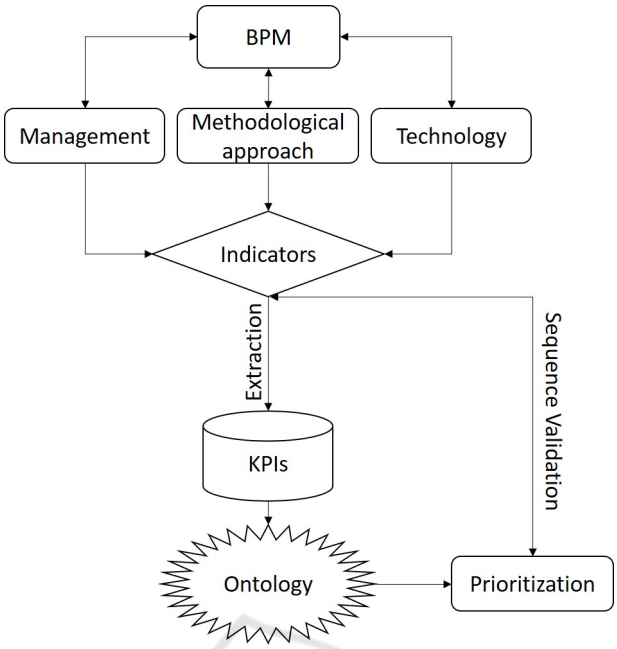

Figure 1: Proposed Methodology.

Table 2: General Categories of Business Indicators Assessed in Process Management.

Abbreviation	**Category of business indicator**	**Description**
STI	Short term indicators	Those business indicators that are set for short-term goals e.g., production target for tomorrow
LTI	Long term indicators	Those business indicators that are selected for long-term goals e.g., product quality
QI I	Qualitative indicators	Those indicators that belong to the relationship e.g., customer satisfaction
QI II	Quantitative indicators	The business indicators that can be evaluated and assigned value e.g., delivery time
DI	Dependent indicators	The indicators which depend on other indicators e.g., the delivery time depends on the employ efficiency
II	Independent indicators	The indicators that can be evaluated independently e.g., investment
CI	Cost indicators	these indicators allow you to evaluate the process involved in economic resources, e.g., production cost per unit
TI	Time indicators	Indicators that represent and evaluate the time of different processes e.g., minimum delivery time
PI	Productivity indicators	Productivity the indicator allows you to evaluate the operational efficiency e.g., percentage downtime
QI III	Quality indicators	These indicators measure the quality of production and effectiveness of the process e.g., the number of errors occurred
HLI	High level indicators	These indicators usually show the overall performance of the business e.g., annual growth
LLI	Low level indicators	Low-level indicators are selected to evaluate the team-wise performance of the employee e.g., employee progress
EI	External indicators	External indicators again target high-level performance e.g., collective goal achievement
II	Internal indicators	Internal indicators target low-level performance e.g., team-wise performance

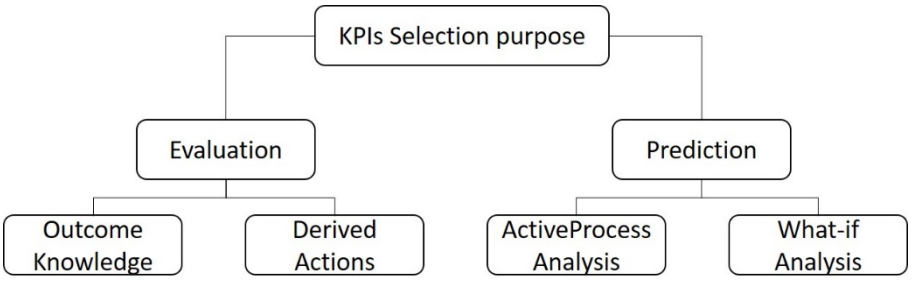

Figure 2: KPIs selection based on the purpose and requirement of organization.

Table 3: KPIs and its Evaluation Parameters along with Datatypes.

KPIs Categories	Evaluation Datatypes
Long-Term	Descriptive (string), Measured (Double), Measured (integer)
Quantitative	Measured (Double), Measured (integer)
Dependent	N/A
Independent	N/A
Cost	Currency (string)
Time	Time (integer)
Productivity	Percentage (double)
Quality	Grading (string)
High-Level	Describe (string)
Low-Level	Grading (string)

bound to the goals on an hourly basis and do not meet the generic nature of an indicator. Qualitative indicators depend on qualitative data, which varies from business to business. External and internal indicators are mostly covered by high-level and low-level indicators, which are consequently excluded from generalized indicators. In the end, generalized KPIs are obtained based on generalized categories of indicators and the purpose of the selection.

3.4 KPIs Selection Purpose

KPIs are selected by the high authorities in BPM according to the predefined purpose. Additionally, the selection process also depends on the available information regarding involved activities, processes, goals, and achievements of the business. However, KPIs are mainly used for the purposes defined in Figure 2.

3.5 Generalization of KPIs

The aim of our proposed methodology is to design a generalized framework that helps all types of businesses in their BPM. It is important to design the categories of indicators for the extraction of the predefined groups of generic KPIs to achieve the aforementioned goal.

3.6 KPIs Evaluation

After the selection of KPIs categories and subcategories, the second step is to select the correct evaluation mechanism. Consequently, the implementation of a specific KPI needs the evaluation parameters to perform the exact analysis. Table 3 explains the assessment evaluation and its data types for selected categories of KPIs.

3.6.1 Outcome Knowledge

KPI outcome knowledge is a critical component of successful business management and decision-making. By having a deep understanding of KPIs and their outcomes, organizations can make informed decisions, track progress, and continually improve their performance.

3.6.2 Derived Actions

Derived KPIs actions are powerful tools for business management and decision-making, providing a more comprehensive understanding of a particular aspect of the organization. By effectively using derived KPIs, organizations can make informed decisions, track progress, and continually improve their performance.

3.7 KPIs Prediction

KPI prediction involves analyzing past performance data, identifying trends and patterns, and using statistical models to make predictions about future values. The accuracy of KPI predictions depends on the quality and availability of historical data, the choice of appropriate predictive models, and the ability to accurately capture and account for relevant external factors that may affect future performance.

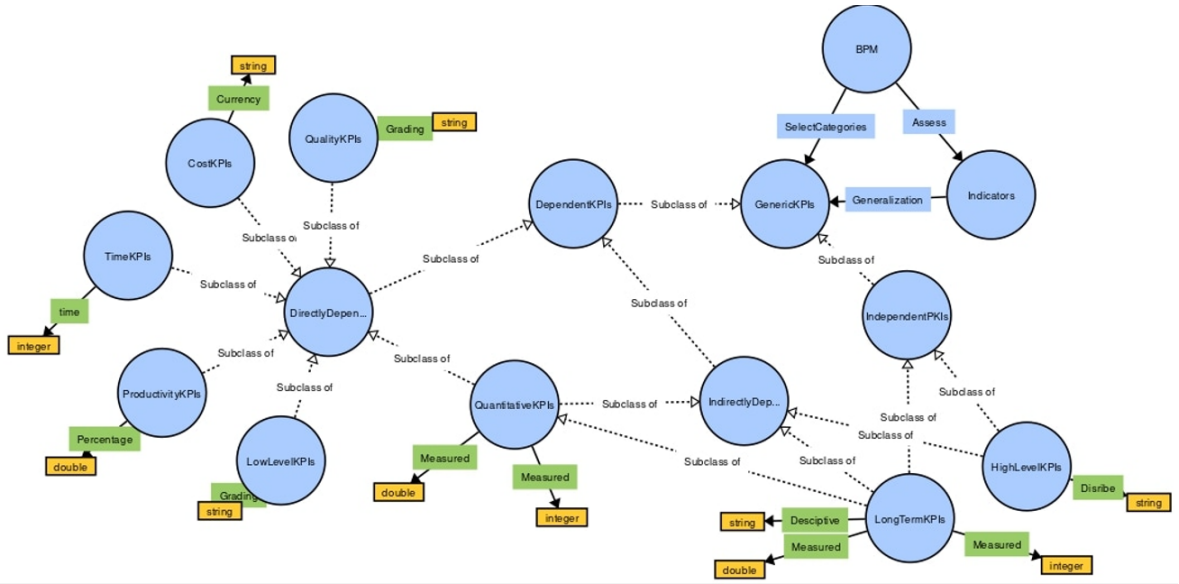

Figure 3: Main Ontology Graphical View.

3.7.1 Active Process Analysis

KPI active process analysis is an important tool for improving business processes and achieving strategic objectives. By regularly monitoring and evaluating KPIs, organizations can identify areas for improvement and make the changes necessary to optimize processes and increase efficiency.

3.7.2 If Analysis Failed

If a Key Performance Indicator (KPI) analysis fails, it means that the chosen KPIs were not effective in measuring the performance of the business processes they were designed to monitor. In such a scenario, there are several options that organizations can consider. Few are enumearated below:

Re-evaluate KPIs: The first option is to re-evaluate the KPIs that were used in the analysis. This may involve changing the KPIs, redefining their objectives, or adjusting the way they are measured.

Use Alternative Methodologies: If the KPI analysis fails, organizations can consider using alternative methodologies, such as process mapping, root cause analysis, or customer satisfaction surveys, to identify areas of improvement.

Monitor Progress: Finally, organizations should regularly monitor progress and evaluate the results of any changes made. This will help to determine whether the new approach is effective and whether further adjustments are necessary.

3.8 Ontology (for Semantic Representation)

This ontology offers all the data requirements for wise decision-making. As a result, it will enable the acquisition of some guidance regarding the selection and application of the proper category of KPIs in accordance with the requirements. To put it more precisely, it first aids the decision-making makers of the KPI category to be used for business process performance measurements. Second, the ontology operates at a degree of detail that is sufficient to give a thorough foundation for evaluating the relationships between every component of the business process. Figure 3 provides a graphical view of the ontology built by WebVOWL (Horridge et al., 2009).

Our ontology represents the generic categories of all related KPIs and aims at facilitating all types of business processes rather than focusing on a specific use case. The purpose of this ontology is to find the semantic relationship between the categories of generic KPIs which helps to find the execution order in case of sequential execution to avoid any bottleneck. More specifically, this ontology also provides the assessment tool for the evaluation of KPIs and their datatypes.

In order to take a more informed decision, it is important to get and represent more information. Therefore, we created three main classes (categories) and subclasses of the main KPIs class to relate the infor-

Table 4: KPIs categories and its Abbreviation.

Abbreviations	KPIs category	Abbreviation	KPIs category
ST-KPIs	Short-term KPIs	I-KPIs	Independent KPIs
LT-KPIs	Long-Term KPIs	C-KPIs	Cost KPIs
D-KPIs	Dependent KPIs	T-KPIs	Time KPIs
DD-KPIs	Directly Dependent KPIs	P-KPIs	Productivity KPIs
IDD-KPIs	Indirectly Dependent KPIs	Q-KPIs-II	Quality KPIs
Q-KPIs-I	Quantitative KPIs	LL-KPIs	Low-Level KPIs
HL-KPIs	High-Level KPIs	-	-

mation. The subclasses of the main KPIs classes are related according to their dependencies to linearize sequential order logically to achieve the aforementioned objective of this research. To get the order of execution after selecting a set of required categories we use a set-based representation which is explained in the following section.

3.9 Prioritization

For a BPM, it is important to select the potential KPIs from the generic categories as per the business requirements. But most importantly, the question arises in which order these KPIs need to be considered to achieve high performance. This research paper provides the solution to this question by establishing the semantic relationship between the generic categories of KPIs through our ontological representation. More specifically, we provide the evaluation order of KPIs as the results of the set-theoretic semantics of ontological relations. KPI Prioritization refers to the process of identify and prioritize the most important Key Performance Indicators (KPIs) for a business. It is a critical step in performance management as it helps organizations to focus on the metrics that are most relevant to their goals and objectives.

Set-theoretic semantics defines the interpretation of concepts (resp. relations) in terms of sets of individuals (resp. set of pairs of individuals) of a domain. In the case of our problem, let us consider the three parent classes Directly Dependent KPIs, Indirectly Dependent KPIs, and Independent KPIs. The full logic specification of these categories prescribes to set a non-disjointness property among them. It means that in the corresponding Venn diagram the three sets representing those classes are overlapping. In order to fully specify the relationships among all the KPIs classes we first define the short forms of generic KPIs categories in Table 4.

KPIs categories relations are depicted through Venn Diagram as three-parent sets and their subsets (synthesized by their name for simplicity). Figure 4 represents the concept as an intersection among parent sets derived from the ontological representation of semantic information. As the usage (or calculation) order of the KPIs generic categories depends on their interdependency, therefore, the most dependent categories need to be considered first i.e., the regions $A \cap B \cap C$. Whereas, the KPIs categories that lie in $A \cap B$ or $B \cap C$ or $A \cap C$ need to be considered in the second order. Lastly, the KPIs categories in the region A or B or C will be considered in the end. The following extracted queue in Figure 4 shows the exact order of execution based on the generic KPIs categories. To optimize any business process during BPM, the managers need to select or update the potential KPIs from the generic categories as mentioned according to the business requirements. Secondly, the KPIs priority is to be assigned based on the following queue shown in Figure 5 to get high performance without any bottleneck.

3.9.1 Case Study

A case study on the semantic representation of Key Performance Indicator (KPI) categories for prioritization was conducted in a financial organization. The goal of the study was to develop a more efficient and effective method for prioritizing KPIs and aligning them with business goals. The first step of the study was to conduct a comprehensive review of existing KPIs and categorize them based on their relevance to the organization's goals and objectives. This process involved identifying all of the KPIs that were currently being used by the organization and grouping them into categories based on their relevance to specific business goals and objectives. Once the KPIs had been categorized, the next step was to semantically represent them using a graph-based approach. This involved creating a visual representation of the relationships between different KPIs and categories, with the goal of providing a clearer understanding of the relationships between different KPIs and the impact they had on the overall performance of the organization. The next step was to align them with the organization's goals and objectives which ensure that

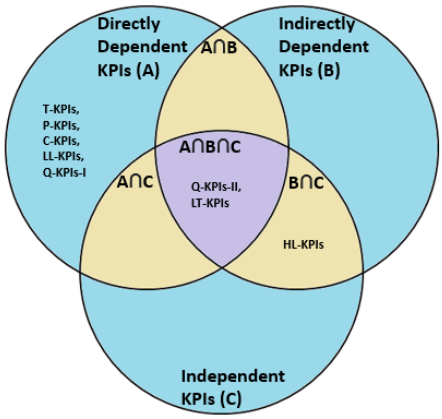

Figure 4: Venn diagram (KPIs categories relational representation).

Q-KPIs-II	LT-KPIs	HL-KPIs	T-KPIs	P-KPIs	C-KPIs	LL-KPIs	Q-KPIs-I

Figure 5: KPIs Execution Order.

the KPIs were aligned with the specific goals and objectives.

The case study demonstrated the value of using a semantic representation of KPIs for prioritization in a financial organization. This resulted in significant improvements in their ability to monitor and improve performance and has laid the foundation for further progress in the future.

4 CONCLUSIONS

In order to facilitate KPIs advancement management, this study has given a semantic approach and built methods based on set theory. In specific, we proposed using a notion of a KPI advancement pattern and a KPI advancement meta-model, made up of two interrelated views, to facilitate KPIs development. The long-term research project's main objective is to build a generic framework for handling KPIs advancement. The main highlights of this paper are: (i) Used a semantic ontology to express KPIs. (ii) KPI levels were chosen using the set theory concept. (iii) KPI Prioritization. In the future study, we will create a semantic Business Process (SBP) monitor and adapt an existing SBP modeling tool to incorporate the suggested technique as well.

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