A Meta-model for Key Performance Indicators in Higher Education

Savić, Goran; Segedinac, Milan; Čeliković, Milan; and Luković, Ivan

Abstract: ***We propose a software solution for representing diverse sets of key performance indicators in higher education. Our solution addresses both the heterogeneity and the common structure of key performance indicators. To tackle the issue of heterogeneity, we employ metamodeling and propose a meta-model that is expressive and generic enough to represent any set of key performance indicators in higher education. The proposed meta-model is more abstract than any specific key performance indicators set, and the sets are considered as models, which are instances of the proposed meta-model. We address the heterogeneity in calculating the key performance indicators' values by representing them with mathematical formulas and utilizing an expression language that allows for their dynamic evaluation. We verified the solution by representing typical key performance indicator sets and developing a software application prototype that enables the creation, monitoring, and further development of key performance indicator sets. The verification confirms the wide applicability of our proposed solution.***

Index Terms: ***Key performance indicators, Higher education, Metamodeling, Information system, Quality control, Case study***

1. INTRODUCTION

KEY Performance Indicators (KPIs) are essential tools for assessing the quality of higher education institutions (HEIs). KPI is a piece of information that is regularly collected to track the system's performance. As such, they inform us how well the system is functioning, and monitoring them is an important aspect of quality control [5]. KPIs can be effectively used in HEIs to provide information on how satisfied different stakeholders are with the higher education sector and to what extent educational goals have been achieved within the HEIs [33], allowing for continuous assessment of the HEI's quality level. Each HEI must select the KPIs that will be tracked and define the procedures for collecting relevant data. Additionally, a HEI should establish benchmarks for the KPIs that will be used in planning its future activities. KPI sets commonly used in higher education include indicators such as HEI financing, research influence, student opportunities, awards received, internationalization, graduate employment rates, industry connections, and historical reputation. Some KPI sets are specific to HEIs and study programs in a particular country, while others offer criteria that are applicable worldwide.

Due to the nature of the domain, KPIs in higher education are highly heterogeneous. Nevertheless, they all follow a similar structure. Cuenin [13], after researching 70 universities in 15 countries, explains that any KPI is a numerical value derived in various ways to measure system performance. Cave et al. [7] advocate that KPI values are calculated using formulas. Therefore, each KPI has a name and falls into a category, and there is a formula used to calculate it, along with a set of parameters used in the calculation. For example, a KPI that measures the ratio between the number of students and teachers in a HEI falls into the category of academic staff and is calculated by evaluating the formula:

$$StudentToStaffRatio = \frac{p_1 + p_2 + p_3}{p_4 + p_5 + p_6} \quad (1)$$

where the parameters are as follows: *p1* – number of undergraduate students, *p2* – number of master's students, *p3* – number of PhD students, *p4* – number of assistant professors, *p5* – number of associate professors, and *p6* – number of full professors.

There is currently no universal set of key performance indicators (KPIs) that can be applied to all higher education institutions (HEIs) in any context [47]. Instead, multiple KPI sets are maintained by government institutions, academic

Manuscript received January 27, 2023.

Goran Savić, University of Novi Sad, Faculty of Technical Sciences, Trg Dositeja Obradovića 6, Novi Sad, Serbia (e-mail: savicg@uns.ac.rs)

Milan Segedinac, Corresponding Author, University of Novi Sad, Faculty of Technical Sciences, Trg Dositeja Obradovića 6, Novi Sad, Serbia (e-mail: msegedinac@uns.ac.rs)

Milan Čeliković, University of Novi Sad, Faculty of Technical Sciences, Trg Dositeja Obradovića 6, Novi Sad, Serbia (e-mail: milancel@uns.ac.rs)

Ivan Luković, University of Belgrade, Faculty of Organizational Sciences, Jove Ilića 154, Belgrade, Serbia (e-mail: ivan.lukovic@fon.bg.ac.rs).

societies, or journals. In addition to ranking HEIs themselves, there is a strong need for ranking other subjects of higher education, such as study programs. Managing such diverse HEI data, including data acquisition, monitoring, and analytics, is a challenging task, even at the level of a single country. Cuenin [13] criticizes this diversity of KPI types and their usage, as it hinders measuring and comparing performance in HE. Different types of KPIs have been developed so far [22; 8; 29], as presented in [47]. In trying to identify the most important KPIs for higher education, Palomares-Montero and García-Aracil [41], as well as Montoneri et al. [38], after thorough studies, conclude that there is no wide consensus on this topic. Similarly, Tasić [47] explains that worldwide organizations, such as UNESCO and OECD, publish guidelines for using relevant KPIs in the evaluation of HE institutions, but opinions differ as to which KPIs are the most effective.

Due to differences in ranking methodologies and the interpretation of results, there is a need for a more generalized software system capable of handling the heterogeneity of HEIs and their KPI rankings. The objective of this research is to develop a software solution for representing arbitrary HE KPIs, considering both their heterogeneity and common structure. Given the strong diversity of KPI data models, we have opted for a meta-modelling approach, proposing a meta-model for representing KPIs in higher education. The meta-model aims to be expressive and generic enough to represent any KPI set, including organized lists utilized for ranking HEIs, such as the Shanghai ranking [46]. The proposed meta-model operates at a higher level of abstraction than any specific KPI set, with the particular KPI sets being considered as instances of the meta-model.

Another crucial feature of our meta-model is the capability to represent KPI values by using mathematical formulas, similar to the abovementioned one for student-to-staff ratio. Instead of having formulas hard-coded within the programming code, we store formula parameters within the meta-data model. That way the formulas can later be modified even by an end-user with no need to alter the programming code.

Our proposed meta-model is consistent with the procedure for ranking educational institutions presented in [53], which explains that the ranking methodology aggregates an institution's outputs into a single and comparable numerical indicator. First, raw data is collected, which is then used to calculate the values of individual KPIs. These values are then multiplied by weighting coefficients and summed up to obtain a final ranking value. Our meta-model is capable of supporting such numerical KPI values. The formula parameters within the meta-model represent individual performance data, which are combined with coefficients and arithmetic operators to derive the final ranking value.

In terms of ranking different subjects, [28] explains that the types of indicators depend on the intended level of ranking - whether it is for a study programme, an educational institution, or the entire higher education system. Our meta-model is agnostic to the level and type of ranking subject, allowing for use in any hierarchy of educational units and learning opportunities.

To harness the advantages of the meta-model in practical applications and to verify its suitability, we developed a software prototype for managing and monitoring KPIs in HEIs. The application enables the administration of HEIs and arbitrary KPI sets that measure their performance, designed in accordance with the proposed KPI meta-model. The performance is programmatically calculated using formulas, parameters, and the values stored in the KPI models. These features are expected to support heterogeneous and evolving KPI systems in HEIs over the long term.

Therefore, the paper's contributions are:

1. A flexible representation of KPI sets,
2. Dynamic evaluation of KPI values based on formally represented formulas, and
3. A meta-model-compliant software application for managing KPIs.

We have verified the effectiveness of our meta-model and the proposed software application through three case studies, which are presented in Section 4. These case studies include the Shanghai list, Webometrics, and KPIs for Serbian higher education. In each case, the KPIs were represented using our meta-model and administered within the software application.

The paper is organized as follows. We give an overview of KPI sets in the following section. In the third section, we present our meta-model in detail. The abovementioned case studies that verify the expressivity of our model are discussed in the fourth section. In the fifth section, we present the software application for administrating the HEIs performance. In the final section, we give the concluding remarks and indicate the tracks for future research.

2. Related Work

This section presents the current state in the field of educational KPIs, university rankings, and software support for the design and utilization of KPIs in HE. Such a summary should help the reader to understand our motivation for designing a generic model of educational KPIs, as well as the reasons for the solution we propose.

Quality indicators (Qis) can roughly be categorized into quantitative (the ones that are being expressed numerically) and qualitative (those that are represented by narrative descriptions)[28]. For example, number of enrolled students is a quantitative indicator, while the history of the educational institution is a qualitative one.

The choice of adequate QIs in education largely depends on the organizational level to which they relate, namely whether they describe study programmes, educational institutions, or educational systems in general [28]. Hence, Kells [30] divides QIs in higher education into two categories: 1) indicators that are being used by the educational HEIs, and 2) indicators that are being used by the state. Similarly, Taylor [49] regards that the QIs in higher education can be defined at different levels: 1) international indicators, that serve for comparing the performance of HEIs in different countries, 2) national QI systems that allow quality control in higher education in a single country, and 3) institutional performance indicators that allow performance assessment in particular educational institutions, such as universities and departments.

Indicators can also be categorized by the aspect of higher education to which they relate, and, according to this classification schema, there are 1) input indicators, 2) output indicators, 3) process indicators, and 4) indicators of the outcome. [4; 6; 7]. For a QI system to be considered useful, whether it is defined on the international, national or institutional level, all four above-mentioned aspects have to be covered [1].

One of the most important measures of quality in higher education is key performance indicators (KPIs). They are sets of metrics that measure aspects of the system that are of key importance for its future success [42]. As such, they are being used to assess the current state of the system and to determine the future tracks of development. KPIs are being measured by numerical values, but they can also be used to represent some features of the system that are harder to represent numerically, like the students' satisfaction [47]. A well-defined KPI set allows institutions to prioritize resources and consolidate their business processes to achieve the desired results [2].

There is a long-lasting debate about the most adequate KPIs in the HEIs and about the ranking criteria that they define. It is very difficult to keep consistent KPI sets, mostly because they should reflect the goals of different stakeholders that often have conflicting goals. KPI sets in higher education measure multiple dimensions of the HEIs, but there is no consensus about which key indicators represent such a high-dimensional structure in the most optimal way [41].

The importance of KPIs has been recognized in higher education systems, so several European countries have been moving to measuring and funding HEIs based on performance [34; 15]. However, there is no unique system of KPIs applicable to every aspect of higher education. Instead, with varying purposes and areas of application, they are defined in different ways [33].

KPIs for HEIs can be roughly classified into two categories [32]:

1. Academic – in these KPIs, the assessment focuses on the achievement of the teachers and researchers employed at the HEIs.
2. Nonacademic – these KPIs assess students' and alumni's achievement.

KPI sets for higher education institutions typically encompass both academic and nonacademic KPIs while emphasizing one or the other. Tasić in [47] gives an overview of various KPI sets, developed either to select relevant criteria for measuring HE performance or for ranking between institutions.

Tavenas [48] gives an overall categorization of KPIs in higher education. He identifies 1) KPIs that measure the quality of the enrolled students, such as students' high school grades, 2) students' performance KPIs such as graduation rate, 3) KPIs that indicate the level of research, like the ratio of the number of teachers involved in research projects, 4) research productivity KPIs, like the teachers' citation index, 5) indicators of the income, such as the ratio of the operational budget and the number of students, and 6) management KPIs, such as the representation of the HEIs in the government bodies.

Palomares-Montero and García-Aracil [41] presents a list of 39 relevant KPIs, made by systematizing inputs received from the domain experts. The same authors in [17] created a review of the KPIs currently used by 16 organizations and institutions. Another review was given in [10], where the authors consulted experts and analysed different national systems to identify 72 indicators organized upon 18 dimensions. In [44], 5 institutions are compared against support for 20 selected KPIs. Besides these reviews of the existing indicators, it is worth mentioning that [10] establishes a new KPI set with 9 groups consisting of 24 indicators in total.

KPI sets are particularly relevant in the context of ranking HE institutions, which is an especially popular topic since the beginning of the new millennium [21]. Many KPI sets have been developed to support the ranking of institutions within the same country, while there are also a few ranking systems designed to be used worldwide [16]. Some of the most prominent KPI sets designed for worldwide ranking, are Shanghai Ranking, U-Multirank, Webometrics, Times Higher Education, and Quacquarelli Symonds (QS).

Shanghai Ranking (Academic Ranking of World Universities – ARWU) [46] gives a global ranking of the universities worldwide starting from 2004. This ranking system was designed to allow the comparison of Chinese universities against the most renowned world universities and it reflects three basic principles [35]: (1) The use of carefully selected objective criteria, (2) Internationally comparable data that users can verify on their own, and (3) Avoiding any subjective indicators.

The indicators, according to this ranking system can be classified into four categories, i.e. quality of education, quality of faculty, research output, and size of institution. The quality of education category represents the number of alumni members who have received Nobel and Fields prizes. The quality of faculty category counts the number of staff members who have received Nobel and Fields prizes and the number of those that are highly cited in some of the 21 wide subject areas. Research output is the number of articles published in Nature and Science journals, and articles indexed by SCIE and/or SSCI lists. Finally, the size of the institution measures the performance of the institution relative to its size. The final score is calculated as the weighted sum of these simple indicators. Since this ranking system takes into consideration just the HEIs with alumni members who have received the most prestigious awards (e.g., Nobel prize) or have published their research in the most prominent journals (e.g., Nature or Science), it is evident that this ranking system ranks just the world's top HEIs and not all the HEIs in the world.

A different and somewhat more multidimensional approach is given by U-multirank, a European ranking initiative to give transparency about diverse HEIs [52]. This ranking system takes into consideration five categories of indicators. The system of indicators itself is highly complex, so only the most important representatives of each category will be given as illustration: Teaching and Learning (overall learning experience, and quality of courses and teaching based on survey), Research (research publications and citation rate), Knowledge transfer (income from private sources and co-publications with industrial partners), International orientation (opportunities to study abroad and international doctorate degrees), and Regional engagement (student internships in the region and regional joint publications). As such, U-multirank gives a more complete picture of the educational process than such ranking systems like ARWU, simply by taking into consideration more diverse indicators set. Also, compared to other ranking systems, U-multirank gives a relatively higher level of freedom by allowing the users to define how relevant each indicator is for calculating the overall rank.

Another important ranking system is the Webometrics Ranking of World Universities (WRWU) [14]. This ranking system gives full coverage of HEIs irrespective of the discipline and country. It categorises the indicators into three categories: (1) Visibility – number of subnets linking to the institution's web pages, (2) Transparency – number of citations from the top 110 employed at the institution, (3) Excellence – number of papers in top 10% most cited journal. Although this ranking system is simpler than ARWU and U-multirank, its advantage is that data required for its indicators can be more easily collected and does not require any additional form of assessment.

Times Higher Education (THE) World University Rankings [50] ranking (is a ranking system consisting of 13 KPIs organized into 5 categories: Teaching, Research, Citations, International outlook, and Industry income. The teaching category represents the learning environment. The most important KPI in it is the Reputation survey, and some other important KPIs are the Doctorate-to-bachelor ratio and Staff-to-student ratio. Research is a category which encompasses the KPIs that measure the volume, income and reputation of the research conducted in the HEI. Again, the most important KPI is the Reputation survey, while other KPIs measure research income and productivity. Citations represent the influence of the HEI on the academic community and the KPI in it quantifies the number of citations. International outlook covers the international collaboration of students and staff as well as the internationalization of research. It contains the KPIs that measure the proportion of international students and staff as well as a KPI that quantifies international collaboration. Industry income as the last THE category measures the knowledge transfer to the industry.

THE publishes the main ranking once a year which grades universities worldwide. Additionally, several sub-rankings are also being published annually. They rank universities based on certain characteristics like age, geographical location and size, performance in particular domains related to education, performance in certain disciplines, reputation scores, etc. As a well-balanced ranking system that encompasses both academic and non-academic KPIs, THE ranking system is considered the second most influential HEIs ranking system, surpassed in popularity only by ARWU.

QS world university ranking is a HEIS ranking published once a year by Quacquarelli Symonds, based upon six indicators. The academic peer review indicator is the most important one, taking 40% of the overall score and its evaluation is based on an internal global academic survey. It is also the most controversial indicator since it uses the combination of a purchased mailing list, suggestions and applications to ask academics about the best universities. The faculty/Student ratio indicator measures teaching commitment. It is a well-accepted indicator present in most of the indicator sets and it takes 20% of the overall score. Citations per faculty indicator take 20% of the overall score, just as the previous one, and it measures the research factor. Employer reputation, as the next indicator, is obtained in a similar way as the academic peer review, differing in the fact that the survey is being filled by the recruiters that hire graduates. It takes 10% of the overall score. The international student ratio is the measurement of the diversity of the student community and it takes 5% of the overall score. Finally, the International staff ratio is very similar to the previous one and it measures the diversity of the staff. Just like the previous one, this indicator takes 5% of the overall score. QS rankings differ from the other ones mostly in the emphasis it puts on academic peer review. The other indicators are very similar to the indicators present in other indicator sets.

Besides worldwide ranking systems, there have been different KPI systems developed for ranking institutions at the national level [31, 16, 47]. U.S. News and World Report magazine ranks more than 1400 USA universities through 24 indicators with different weighting coefficients. The indicators with the highest weights are graduation and retention rates, faculty resources, and peer assessment survey. Canada's universities have been ranked by Maclean's magazine. The ranking includes more than 50 of Canada's larger universities and it is based on 14 KPIs split into 5 categories, i.e. students and classes (weighting coefficient 28%), teaching staff (24%), resources (20%), student support (13%), and reputation (15%). The Good University Guide [20], combines data from different sources, such as government bodies and independent questionaries, to rank universities in Australia. This ranking is multidimensional – a university gets up to 5 stars in every of 5 categories in total. The ranking system is available online allowing users to compare universities by different criteria. Yearly information on the ranking of UK universities can be found in the Good University Guide [51] published by the Times magazine. This ranking system uses data from government agencies for higher education to calculate 8 KPIs: student satisfaction, quality of research, input standards, student-to-staff ratio, costs, graduation rate, undergraduate-to-graduate students ratio, and post-graduation opportunities. In Germany, the Center for Higher Education [12] collects data on national universities and rank them by their educational and research area. There are more than 30 areas and KPIs are separately defined for every area. Besides this review of national ranking systems presented in [47], it is worth mentioning another one conducted by HSV [23], which includes rankings for Sweden, as well as some more rankings for USA, Australia, and UK.

Since this research was conducted as a part of the PESHES project for implementing performance evaluation for HEIs in Serbia [43], the KPI model developed solely for Serbian HEIs will be described here and used later as one of the case study models. This KPI model is based on previous research efforts performed on Serbian HE data, while some of the findings were presented in [24, 25, 26, 19]. It consists of composite quantitative performance indicators organized into 11 categories. The success rate in the student recruitment category encompasses the indicators of the attractiveness of a study programme and it contains the indicators like the number of applications per enrolment place and freshmen's average grades from high school. The internationalization of HEIs category contains indicators that measure the international visibility of a HEI and contains such indicators as the percent of foreign students. HE outcomes encompass the indicators that measure the efficiency of a HEI and some indicators from it are the percentage of students that graduate from their study programmes and the average grades that students have. Capacity for PhD studies – this category contains indicators that measure the capacity a HEI has for holding PhD studies. There are indicators like the ratio of potential PhD mentors against the overall number of academic staff. Academic staff is a category with indicators that measure the quality and availability of academic staff in a HEI and it contains indicators like the ratio of the number of academic staff to the number of students. Research outcomes indicate how successful the HEI is in scientific research and there are indicators like the average number of scientific papers published in SCI-indexed journals and the number of conferences organized by the HEI. The non-academic staff category measures the availability of non-academic staff in the HEI and holds indicators like the ratio of the numbers of non-academic staff against academic staff and the ratio of the number of non-academic staff and the number of students. The infrastructure category encompasses the indicators of the infrastructural quality of the HEI, and it holds the indicators like the ratio of the surface area of the HEI against the number of students. The financial resources category gathers the indicators that measure the financial status of the institution and holds such indicators as the ratio of the total investment in infrastructure per year against the number of students. Student employability, as the last proposed category, measures the success of students in the labour market and holds indicators like the ratio of unemployed graduate students against the number of students that graduate per year.

The presented KPI sets show that there is high variability in this domain. Similar conclusions can be found in [54, 41]. Palomares-Montero and García-Aracil [17] identify this problem of KPI sets diversity and advocate for the systematization of existing KPIs. They conclude that the educational society has to take a more holistic approach which takes into account different stakeholders, their heterogeneity and interests. Jesson and Mayston [27] and Blank [3] explain that KPI sets have been developed by defining a conceptual framework and selecting the indicators. Our study follows this holistic approach and opts for building a conceptual model of KPI sets. Our solution is neutral to selecting particular indicators for two reasons: (1) the field is very diverse and it is not possible to define some one-size-fits-all set of indicators, and (2) a software solution, in general, should not introduce new constraints in the field, but rather adapt to the current state and allow the community to apply its current principles using the benefits of a digital environment. This follows the idea expressed in [23], that static indicators do not answer users' needs, because by selecting the indicators one predefines parameters of quality in advance, instead of letting users specify relevant quality characteristics on their own. Hence, our meta-model can be considered as a conceptual framework which specifies the relevant aspects of any indicator – ranking object, indicator parameters, a mathematical formula which combines parameters, an indicator itself, and its categorization. Such a framework provides uniformly managing diverse KPI sets and gives guidelines for creating new indicators. Since there is no consensus on the most relevant indicators in the field, we do not strive for it, but just like proposed in [23], we rather allow users to specify arbitrary indicators.

As we consider software solutions for representing and managing KPIs, there is also strong heterogeneity in the software applications used for tracking KPIs in the HEIs. Some of the KPI sets, such as U-Multirank, offer software applications for tracking KPIs. By being tightly coupled with the KPI sets, they restrict the end-users to the predefined indicators. To avoid that limitation, many educational institutions decide to use other software tools that give them more freedom in choosing their KPIs [39]. So, The Saxion University of Applied Sciences uses Power BI for monitoring KPIs, and the Polytechnic Institute of Portalegre uses IBM Cognos. Even though this approach gives the HEIs more flexibility, such software systems are typically expensive, are not specialized for the above-mentioned task and require highly skilled developers. The other approach, favoured by some large HEIs is to develop their own KPI-tracking software systems. The University of Twente and the University Institute of Lisbon, for example, have developed their own planning and control systems, and tracking KPIs modules are parts of them. This approach is very flexible, but, since it requires a specialized team of developers it is highly costly and smaller HEIs often cannot afford it.

Gašpar & Rezić [18] have proposed another approach, which is to develop software that would provide a simple and fast method for managing KPIs applicable to a wide spectrum of HEIs. It is a flexible web application with an extendible set of indicators organized into categories and described by metadata. The value of an indicator is calculated by entering a nominator and a denominator, allowing simple indicators to be represented. We build on top of that approach, but with proposing a more generic solution with a powerful language for specifying the formulas for the KPIs that allows very complex indicators to be represented. That way we have obtained a highly flexible solution for tracking KPIs applicable to any ranking system and object.

3. A META-MODEL OF KPIS

As explained, the abovementioned KPI sets vary in size, purpose, categories and indicators. Our goal is to provide a unified data model for representing an arbitrary KPI set no matter its particular characteristics. As this model stands on a higher abstraction level in comparison to particular KPI sets, we call our model a meta-model. Particular KPI sets can be considered then as models which are instances of our meta-model. The particular KPI set can be defined by setting up data in accordance with our meta-model, such as the list of categories, indicators, parameters, formulas, etc.

The requirements we set for our meta-model are to be:

1. Expressive – the meta-model must be able to express various KPI sets; and
2. Generic – the meta-model must not depend on any particular KPI set.

Our meta-model consists of two parts. The first part represents a higher education institution and its structure. To support an arbitrary HEIs structure and different ranking objects, the meta-model relies on an abstract representation of the educational process which applies to a wide range of educational institutions and organizational elements (universities, departments, study programmes, modules, etc.). For this purpose, we used the existing model of Metadata for Learning Opportunities - ECTS IP/CC [11], which is expressive enough to represent all these educational opportunities. The specification follows the ECTS student mobility model and allows for representing an arbitrary structure of educational institutions. There is a hierarchy of learning opportunities which represent any kind of organizational unit or educational activity which may be assigned with ECTS points. Taking ECTS IC/PP specification as a basis for this part of the model ensures wide support for all kinds of educational institutions and their internal organizations. This part of the model is shown in Figure 1.

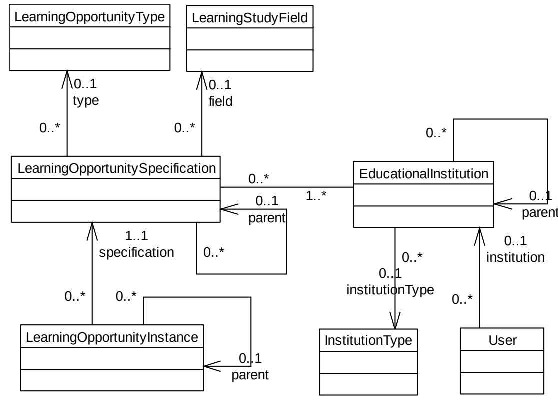


Figure 1: Meta-model of educational institution and learning opportunities

The model covers various types of educational opportunities by using the *LearningOpportunity-Specification* entity. Using its parent association, this entity allows for a flexible hierarchical organization of opportunities and can represent study programmes, modules, courses, etc. The opportunities are classified based on their type (*LearningOpportunityType* entity) and study field (LearningStudyField entity). Every opportunity can be present in multiple instances, which is provided by the *LearningOpportunityInstance* entity. For example, there will be multiple realizations of study programmes, one for every generation of students. We can notice that learning opportunity instances are also hierarchically organized using the self-referencing *parent* association. Similar to the *parent* association in the *LearningOpportunitySpecification* entity, this relationship allows for flexible organization of learning opportunities.

Learning opportunities are provided by an educational institution, represented by the *EducationalInstitution* entity. We can notice that an opportunity can be delivered by multiple educational institutions (e.g. multidisciplinary study programmes). The institutions are also hierarchically organized (see its *parent* association) and classified by the *InstitutionType* entity. That way each institution can represent its organizational hierarchy with the corresponding hierarchy depth (e.g. faculties, departments, chairs). In addition, the model allows for storing a list of users from the particular institution using the *User* entity.

The second part of our model formally describes the KPIs structure to provide support for an arbitrary model of KPIs. Figure 2 displays this part of the model.

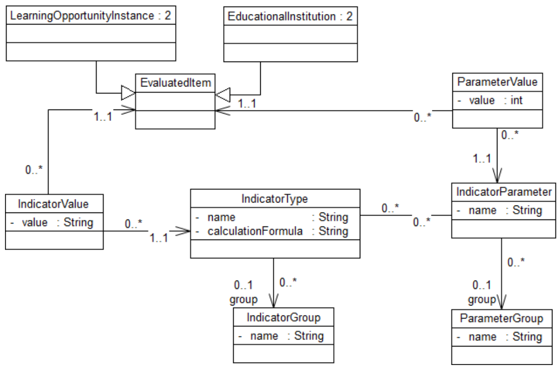


Figure 2: Meta-model of KPIs

An indicator is represented by the *IndicatorType* entity. *IndicatorGroup* allows for the grouping of indicators into categories. An indicator value can be calculated based on multiple indicator parameters. For example, the student-to-staff ratio in an institution is calculated by combining 6 parameters (see the example in the Introduction). Such individual parameters are represented by the *IndicatorParameter* entity. To support different KPI models, our meta-model provides the *ParameterGroup* entity, which gathers the parameters that belong to the same KPI model. For example, all the parameters from the Shanghai Ranking KPI model belong to the same group. The *CalculationFormula* field within the *IndicatorType* entity specifies a mathematical formula for combining parameters to get the final indicator value. The formula is stored as a string and it is on the model implementor to provide the calculation based on this textual formula. One solution for this issue is presented in section 5, which gives the details of our prototype of a software application for managing KPIs.

The above-described part of the model specifies how an indicator is calculated. For getting the final KPI value for a particular institution or a learning opportunity, we need to specify the parameter value (*ParameterValue* entity). When these parameter values are applied to the calculation formula, a final, aggregated KPI value is calculated and stored within the value field of the *IndicatorValue* entity. Given that a KPI may refer to a particular learning opportunity within an educational institution or to the institution as a whole, we introduced a new *EvaluatedItem* entity as a supper class of *LearningOpportunityInstance* and *Educational-Institution*.

Hence, the presented meta-model, due to its generic classification of educational opportunities, allows measuring the performance of arbitrary ranking objects. The independence of any particular KPI set, as one of the meta-model requirements, is achieved by dynamically defined KPIs, parameters, and their formula-based values. Concerning another requirement, i.e. model expressiveness, this meta-model is appropriate for describing all KPI ranking systems that apply mathematical formulas to HEIs data. On the other hand, this is the main limitation of our meta-model, since every indicator must be reduced to a single mathematical expression. In addition, these formulas are not decomposed into separate model entities but rather represented by a single monolithic string. The string is required to be defined in the mXparser expression language [40], making the meta-model tied to the particular software technology. Plans for overcoming these limitations will be addressed in the last section. One more potential limitation should be mentioned. The proposed model classifies indicators in a two-level hierarchy where an indicator belongs to exactly one indicator group. Hence, the model does not support a more complex grouping of indicators, but the experience being collected shows that our solution suits the purpose.

4. *CASE STUDY ON REPRESENTING KPI MODELS USING THE PROPOSED META-MODEL*

In this section, we assess the fulfilment of the meta-model requirements by instantiating three representative KPI sets from our meta-model. We selected three representative KPI models for evaluation of our meta-model:

1. Shanghai Ranking;
2. Webometrics Ranking of World Universities (WRWU); and
3. KPI model for Serbian HEI.

Shanghai Ranking and WRWU were chosen due to their global popularity, while the support for Serbian HEIs was from the very beginning one of the key requirements for this research within the PESHES project. The chosen KPI sets should evaluate if our meta-model can represent both simple models, such as WRWU, through medium-size ones like Shangai Ranking, to complex ones such as our KPI model for Serbian HEI. The rest of the section presents these three instances of our meta-model. In the end, we compare them and summarize the study.

3.1 Webometrics Ranking of World Universities KPI model

We start the evaluation with the simplest KPI set - Webometrics Ranking of World Universities. The instance of our meta-model for the Webometrics KPI model is shown in Figure 3.

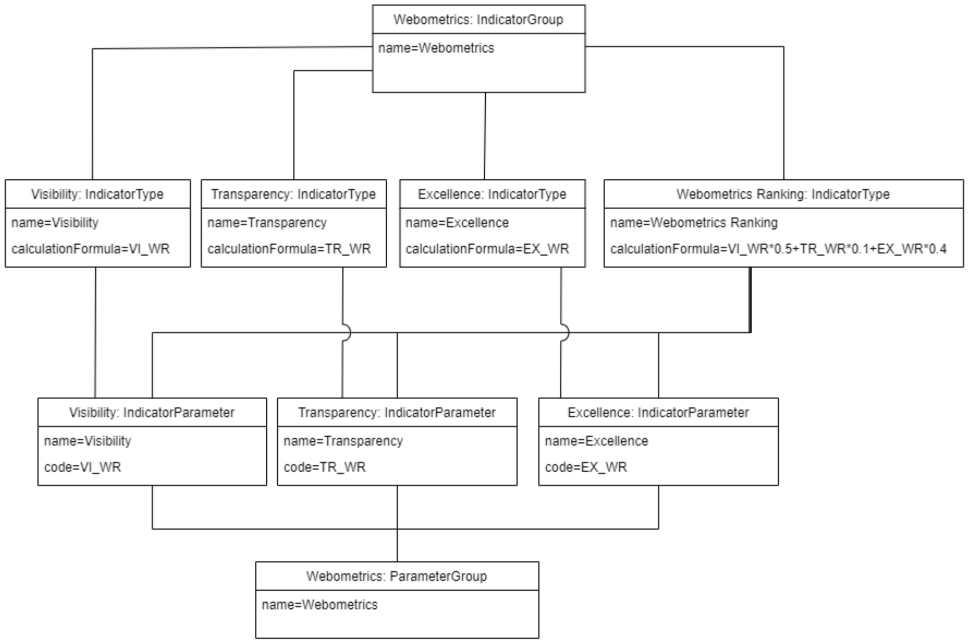


Figure 3: Model of Webometrics Ranking of World Universities KPIs represented using the proposed meta-model

Since it aims to be a general KPI set applicable to a diverse set of scenarios, it consists only of 4 indicators, i.e. *Visibility*, *Transparency*, *Excellence*, and *Webometrics Ranking*. The former three indicators consist only of a single value. This means that there is no need for representing them using a formula, but they can be represented with a single constant value. These values are modeled using three corresponding parameters – *Visibility*, *Transparency*, and *Excellence*. The parameters are represented as the instances of the *IndicatorParameter* entity and grouped in the *Webometrics* parameter group. All the indicators are calculated from these three parameters. The parameters are directly mapped to the indicator types of the same name. We see that calculation formulas in this case contain only a direct value of the corresponding parameter. The fourth indicator, *Webometrics Ranking* is an aggregation of the other three indicators. Hence, it can be represented by a mathematical formula which combines the parameters used by other indicators. We see that every parameter in the calculation formula has a different weight, i.e. 0.5, 0.1, and 0.4. The *Webometrics IndicatorGroup* instance represents a group these indicators belong to.

3.2 Shangai Ranking KPI Model

The Shangai Ranking KPI set is more complex and it consists of 6 indicators organized in 4 categories. Although it has been designed for worldwide ranking, this KPI set is more specific than WRWU and requires a much larger number of parameters. We have instantiated our meta-model to represent data from Shangai Ranking KPI model. Due to limited space, in Figure 4 we present an object diagram of the Size Performance indicator from the Shangai Ranking KPI model.

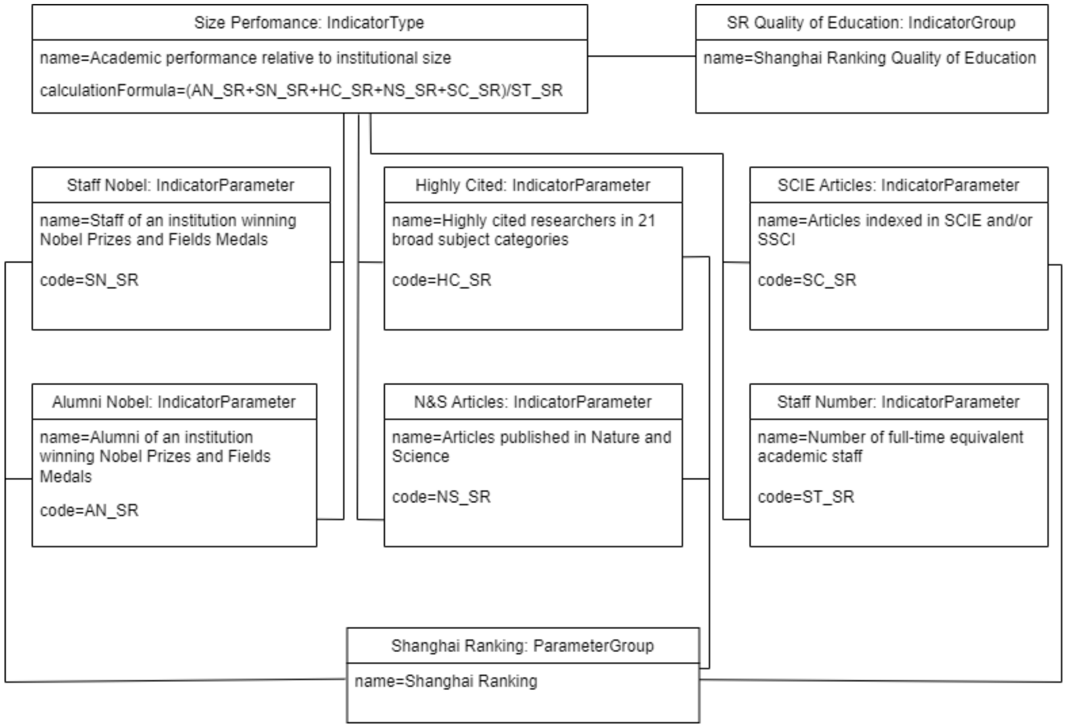


Figure 4: Model of Shangai Ranking KPI represented using the proposed meta-model

The *Size Performance* indicator is represented as an instance of the *IndicatorType* entity. It is based on 6 parameters, following the rule specified in the *CalculationFormula* attribute. As presented in the corresponding data field on the diagram, the size performance is calculated by summing up the number of alumni who got the Nobel prize, the number of staff who won the same prize, the number of highly cited researchers, the number of articles published in two top-rated journals (i.e. Nature and Science), and the number of articles published in the SCIE and/or SSCI indexed journals. The final indicator value is calculated by dividing this sum by the number of institution staff. The parameters are all instances of the *IndicatorParameter* entity. Their code refers to a unique parameter name, which can later be used in the calculation formula. The indicator belongs to the *Shangai Ranking Quality of Education* group, which is represented by the *IndicatorGroup* entity. Similarly, all the parameters related to the Shangai Ranking KPI model are grouped under the *ParameterGroup* instance named *Shangai Ranking*.

Besides the indicator group displayed in Figure 4, our instance for the Shangai Ranking KPI set contains three more indicator groups, i.e. *SR Quality of Faculty*, *SR Research Output*, and *SR Size of Institution*, making it 4 indicator groups in total. Along with the presented *Size Performance* indicator type, 5 more indicator types are created in the model: *Alumni* (Alumni of an institution winning Nobel Prizes and Fields Medals), *Award* (Staff of an institution winning Nobel Prizes and Fields Medals), *HiCi* (Highly cited researchers in 21 broad subject categories), *N&S* (Articles published in Nature and Science), and *SCI* (Articles Indexed in SCIE and/or SSCI). Every indicator type is calculated using the formula which involves multiple indicator parameters. For example, the *N&S* indicator is calculated using the formula $p1 + p2*0.5 + p3 * 0.25 + p4 * 0.1$, where *p1* is the number of articles published in Nature and Science, *p2* is the number of articles in N&S with first author affiliation, *p3* is the number of articles in N&S with next author affiliation, and *p4* is a number of articles in N&S with other author affiliation. In total, we created *32* indicator parameters which participate in the calculation formula for 6 Shangai ranking indicators.

3.3 Model of KPIs for Serbian HE

We have also instantiated the proposed meta-model on the KPI model for the Serbian higher education system. Since there are no official models of KPIs for Serbian HE, we took the most recent unofficial one developed within the PESHES project. This KPI set was designed to cover various aspects of Serbian HE which led to quite a complex model consisting of 11 groups of indicators, which are calculated using 183 indicator parameters. Figure 5 presents a part of the object model for Serbian KPIs.

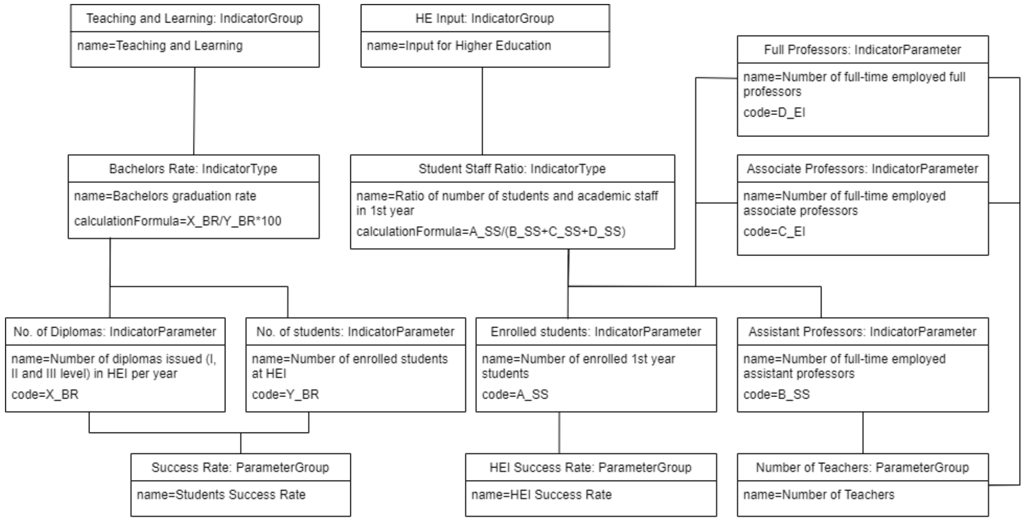


Figure 5: Model of KPIs for Serbian HE represented using the proposed meta-model

In Figure 5, the two representative indicators are presented – the percent of graduated bachelors, and student-to-stuff ratio. Following our meta-model, these indicators are represented by the *IndicatorType* entity. The value of the first indicator is calculated using two parameters, i.e. number of diplomas issued in HEI per year, and the total number of students enrolled at HEI. Student-to-staff ratio is calculated using four parameters. The number of students enrolled in the first year is divided by the total number of professors at HEI. We can notice that the model stores the number of assistants, associates, and full professors as three separate parameters. As in the previously presented KPI models, indicators and parameters are categorized using the *IndicatorGroup* and *ParameterGroup* entities, respectively.

The three case studies show some common traits of all the considered KPI sets. They establish a taxonomy of KPIs, categorize them and define how their values are being calculated. The calculation combines the values of the separately stored parameters which are collected for a HEI. Still, the presented KPI sets differ in their complexity. While the WRWU KPI set consists of only four indicators, the Serbian KPI set and ARWU are much more complex and compass dozens of heterogeneous KPIs. Yet our meta-model is expressive enough to represent all of them regardless of their peculiarities. With regard to calculating the final indicator values, it turns out that each of them can be reduced to a single mathematical formula. The presented case studies give strong evidence that our approach applies to a wide range of different KPI sets. Still, further formal verification of our meta-model is needed to prove its overall applicability. That verification will include more formal evaluation methods, as well as other domain and modelling experts.

5. Application for Managing KPIs

An important part of the proposed meta-model is supporting a dynamic calculation of KPI's value based on various parameters. To evaluate this meta-model feature, as well as to show its applicability in real-world scenarios, we have developed a prototype of the software application for managing HEI KPIs [36]. The prototype has been developed as a multi-tier web application with the backend layer in Java/Spring and the front end in Angular. Data are persisted in a relational database, i.e. MySQL.

The prototype consists of the following features:

1. Managing HEIs and their learning opportunities;
2. Creating an arbitrary KPI model based on the proposed KPI meta-model;
3. Managing particular values of KPI parameters in a HEI (e.g. number of students in the institution), and
4. Calculating final KPIs based on parameter values and formulas.

The module for managing HEIs allows for listing all the HEIs, as well as adding, deleting and removing the institutions. Within an institution's edit page, its hierarchical organization can be specified. This module also provides the management of the institution's study programmes. Similar to administering institutions, one can list, add, edit or remove study programmes.

The second module in the prototype provides a list of indicator types and their groups. Besides creating an indicator type and placing it within a group, indicator parameters can be administered. Furthermore, the calculation procedure for the final indicator value is defined by combining the parameters using a mathematical formula.

Parameter values are managed within a separate set of features. In contrast to the above mention general specification of the indicators and their parameters, the values relate to the particular learning opportunities implemented in the specific school year. For every parameter, a user enters its value for the particular institution or study programme. Based on the entered parameter values and previously defined mathematical formulas, the application automatically calculates and displays the final indicator values which are assigned to the institution and programmes.

In the rest of this section, we present how these main features are implemented in the prototype. Figure 6 shows a web page for administering educational institutions. The application allows for managing institutions' organizational structure and learning opportunities, i.e. faculties and study programmes.

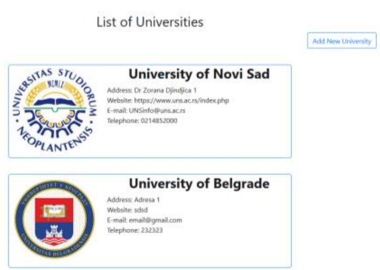


Figure 6: A page for administering educational institutions

The page for administering a single university is displayed in Figure 7. We see that the presented university contains a list of its faculties and study programmes. The displayed data can be edited on separate pages for editing the university, faculty, and study programme, respectively. Due to limited space, we omit to present the screenshots of these pages.

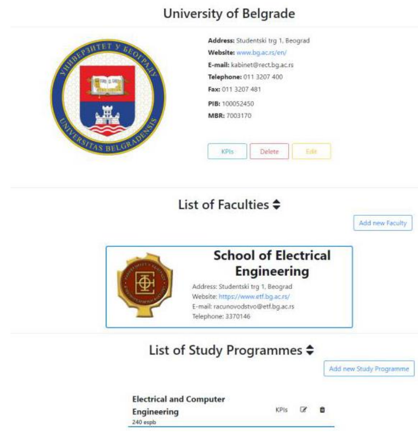


Figure 7: A page for editing one educational institution

Although the proposed meta-model supports an arbitrary organizational structure, due to simpler UI the current version of the developed prototype is constrained to specifying only faculties, departments and study programmes.

Within the prototype, a new KPI model can be defined by setting its indicator types. The corresponding page that lists indicator types is shown in Figure 8.

Indicator Types

Name	Description	Group	Formula
Post-doc positions	The number of post-doc positions relative to the number of academic staff.	Research	(p1/p2)*100
Income from private sources	Research revenues and knowledge transfer revenues from private sources.	Knowledge transfer	(p1/p2)/p3*100
Spin-offs	The number of spin-offs (i.e. firms established on the basis of a formal knowledge transfer arrangement).	Knowledge transfer	(p1/p2)*100
Foreign language bachelor programmes	The percentage of bachelor programmes that are offered in a foreing language.	International orientation	(p1/p2)*100

Figure 8: A page for administering indicator types

Adding and editing a single indicator type is done on a separate page which is shown in Figure 9.

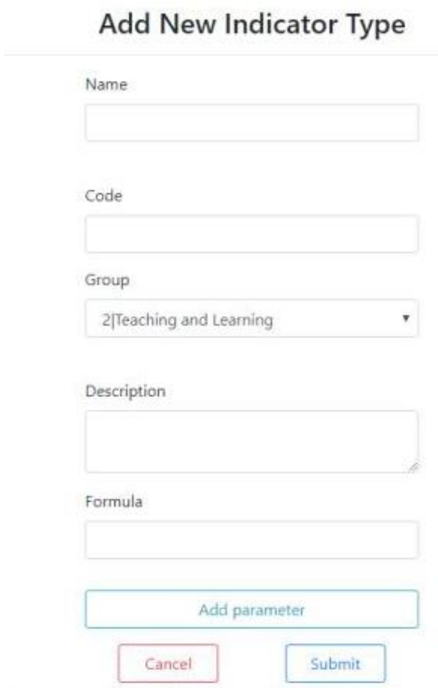


Figure 9: A page for adding an indicator type

We see that there is a formula field for every indicator type. The formula is entered as an arithmetic combination of multiple parameters. Parameters are added dynamically and every parameter is entered separately. This is shown in Figure 10.

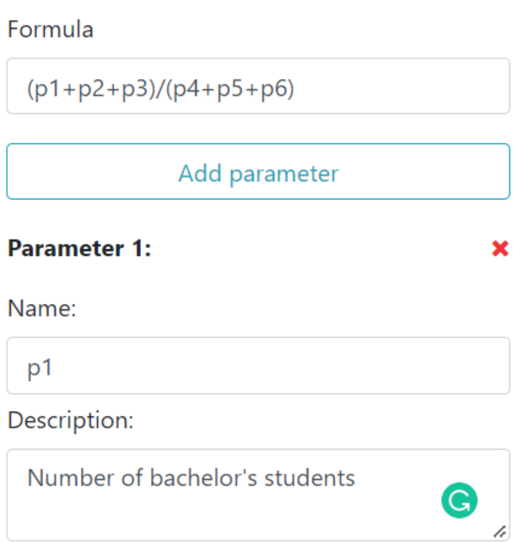


Figure 10: A page for entering the formula and its parameters

Based on the specified indicator types, one can define KPIs for the particular institution. Such KPIs specify real values for all the parameters defined within the indicator type formula. As shown in Figure 11, the value is entered for every parameter.

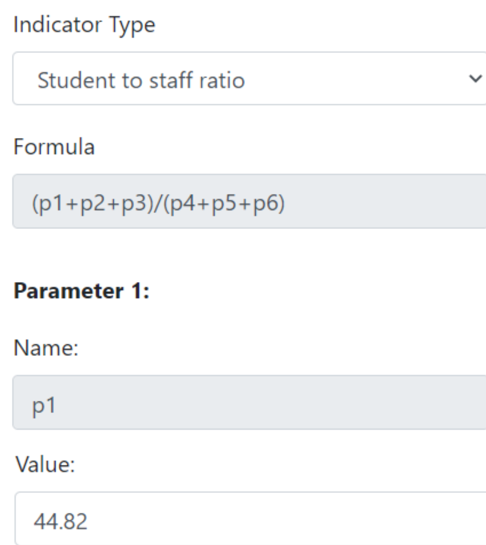


Figure 11: A page for entering a KPI and its parameter values

The application calculates the indicator values based on the indicator type formula (see Figure 10) and previously entered parameter values (see Figure 11). The software prototype uses the mXparser Java library [40] for parsing formula strings and calculating the KPI final value. This library provides an evaluation of mathematic formulas represented as text. The page that displays the final calculated values of the specified indicators is shown in Figure 12.

Name	Start date	End date	Value
Citation rate	01.01.2022.	31.12.2022.	55.00
Bachelors graduation rate	01.01.2022.	31.12.2022.	9.09
Scientific capacity	01.01.2022.	31.12.2022.	0.50

Figure 12: A page for managing KPIs

The presented prototype does not fully utilize all the features of the meta-model. It has been implemented to address the needs and current practices of Serbian HE. For example, the application user interface allows for three hierarchical levels within an educational institution, while the meta-model itself supports an unlimited number of levels. Then, ranking objects are study programmes and faculties only, although the meta-model does not set such constraints. In addition, usability can be improved. Currently, every HEI has its indicators, instead of providing some shared indicators that could be used by multiple institutions. Tracking the history of indicators, as well as support for importing raw data from different sources should also be implemented to accomplish a complete ready-to-use software solution.

6. Conclusion

A diversity of the dominant KPI sets in the HEI domain makes their uniform representation difficult. To tackle this issue, we have proposed a KPI meta-model, abstract enough to support the representation of diverse KPI sets. The meta-model specifies the KPIs structure as well as how the KPI values are calculated. In addition to this meta-model, we have presented a software application prototype that utilizes our approach and assesses the meta-model.

The main advantage of the developed KPI meta-model is that it is expressive enough to represent diverse KPI sets. Therefore, a single repository which relies on our meta-model can be used for storing different KPI sets, as shown in our application prototype. Such centralized management of different KPI sets enables performance monitoring in, a typically heterogeneous, educational community. Furthermore, the KPI sets represented by our meta-model are more suitable for constant improvements and evolution, since our approach allows adding new KPIs and updating the existing ones with no changes in the meta-model itself. One more characteristic of the proposed meta-model is that it generalizes the knowledge about the KPI sets and specifies a set of rules which can be applied when defining a new KPI set. Therefore it gives a conceptual model of KPIs. This can be utilized in the development of a new KPI model, for it allows the educators to take some ready-made KPIs directly from other KPI sets and appropriate them to their ones. To the best of our knowledge, currently, there is no other software system that would allow such flexibility.

Our approach will be most beneficial to decision-makers in higher education, i.e. (1) management of universities, departments, and study programmes, (2) government bodies for monitoring HE, and (3) global public organizations for ranking world universities. It meets their requirements for creating, monitoring and evolution of KPIs, no matter the particular KPI set(s) they use. In an ideal scenario, these institutions would have used uniform sets of well-defined and stable KPIs, but in practice, this is not the case. Typically, KPI sets are heterogeneous, dynamic and ever-evolving. This implies that relying on some predefined and static models of KPIs is not a sustainable option. Instead, we need a more flexible solution which supports creating arbitrary KPI sets. At the same time, the software solution must recognize the current practices in the field and the fact that institutions already use various existing KPIs. We have tried to address this issue by introducing this meta-model, which allows decision-makers to mix different existing KPI sets, create new ones, and in general use a data model which is open for modifications. In addition, since global decision-makers often work with diverse educational institutions which use different KPIs, our solution allows for centralizing the KPI management by gathering all of them into a single data model represented by our meta-model.

One limitation of the proposed approach is the fact that our meta-model requires each KPI value to be formally represented as a single mathematical formula which is being programmatically evaluated. Therefore, only quantitative features of the educational process can be represented by using this meta-model. Future research will deal with the possibility to represent qualitative aspects of the educational process as well. Another constraint of this meta-model is its reliance on mXparser expression language for representing mathematical formulas. This issue can be addressed either by decomposing formulas content into a structure of separate model entities, or by adding support for other popular expression languages.

For the time being, the presented software application prototype is an independent web application. Future research will include its integration with other educational services. In that way, the application will be fully utilized in planning and managing the educational process in HEIs. Besides, although the prototype relies on our meta-model, its implementation introduces some technical limitations which are not included in the meta-model itself. For example, the meta-model allows for an arbitrary number of hierarchical units within an educational institution, while the prototype supports only up to 3 sub-units. This should be addressed in further work, so the software application utilizes the full potential of the meta-model. Regarding the meta-model expressivity, it has been verified on 3 KPI sets, Shanghai ranking, Webometrics and Serbian HE KPI set. We have shown that it can be utilized for representing them, but in future, the meta-model will be additionally verified on other KPI sets.

Acknowledgement

This research was conducted within the project PESHES – Development and implementation of a system for performance evaluation for Serbian HEIs and system, Erasmus+ program, 2016 – 2019.

REFERENCES

[1] Ball, R., and Wilkinson, R. O. B. (1994). “The use and abuse of performance indicators in UK higher education“. Higher Education, 27(4), pp. 417–427.

[2] Ballard, P. J. (2013). Measuring performance excellence: Key performance indicators for institutions accepted into the academic quality improvement program (AQIP). PhD dissertation, Western Michigan University.

[3] Blank, R. K. (1993). “Developing a System of Education Indicators: Selecting, Implementing, and Reporting Indicators“. Educational Evaluation and Policy Analysis, 15(1), pp. 65–80.

[4] Borden, V., and Bottrill, K. (1994). “Performance Indicators: Histories, Definitions and Methods“. New Directions for Institutional Research, 8, pp. 5–21.

[5] Taylor Fitz-Gibbon, C. (1990), Performance indicators, BERA Dialogues (2), ISBN 978-1-85359-092-4.

[6] Carter, N., Klein, R., and Day, P. (1992). How organisations measure success: the use of performance indicators in government. London: Routledge.

[7] Cave, M., Hanney, S., and Kogan, M. (1991). The Use of Performance Indicators in Higher Education: A critical analysis of developing practice (2nd ed.). London: Jessica Kingsley.

[8] Cave, M., Hanney, S., Kogan, M., and Trevett, G. (1988). The Use of Performance Indicators in Higher Education: A critical analysis of developing practice. London: Jessica Kingsley Publishers.

[9] Chen, J.-K., and Chen, S. I. (2010). “A Pro-performance appraisal system for the university“. Expert Systems with Applications, 37(3), pp. 2108–2116. http://doi.org/10.1016/j.eswa.2009.07.063

[10] Chen, S.-H., Wang, H.-H., and Yang, K.-J. (2009). “Establishment and application of performance measure indicators for universities“. The TQM Journal, 21(3), pp. 220–235. http://doi.org/10.1108/17542730910953004

[11] CEN (2010). "ECTS Information Package." Course Catalogue MLO Application Profile.

[12] CHE - Centrum für Hochschulentwicklung gGmbH (2022). CHE University Ranking, available at https://www.che.de/en/ranking-germany/ (accessed 2022/08/30)

[13] Cuenin, S. (1987). The Uses of Performance Indicators in Universities: “An International Survey“. International Journal of Institutional Management in Higher Education, 11(2), pp. 149–162.

[14] Cybermetrics Lab (2022), Webometrics Ranking of World Universities (WRWU), available at http://cchs.csic.es/en/research-lab/cybermetrics-lab (accessed 2022/08/30).

[15] De Boer, H., Jongbloed, B., Benneworth, P., Cremonini, L., Kolster, R., Kottmann, A., Lemmens-Krug, K., and Vossensteyn, H. (2015), Performance-Based Funding and Performance Agreements in Fourteen Higher Education Systems; Center for Higher Education Policy Studies: Enschede, The Netherlands.

[16] Dill, D. D., and Soo, M. (2005). “Academic Quality, League Tables, and Public Policy: A Cross-National Analysis of University Ranking Systems“. Higher Education, 49(4), pp. 495–533. http://doi.org/10.1007/S10734-004-1746-8

[17] García-Aracil, A., and Palomares-Montero, D. (2010). “Examining benchmark indicator systems for the evaluation of higher education institutions“. Higher Education, 60(2), pp. 217–234. http://doi.org/10.1007/s10734-009-9296-8

[18] Gašpar, R. and Rezić, S. (2014). “Information technology and strategic management of universities“. Journal of Business and Economics 5 (11), pp. 1983-1996.

[19] GOMES (2009). Governance and Management Reform in Higher Education in Serbia (GOMES). Tempus project, project number 158926-TEMPUS-RS-TEMPUS-SMGR, University of Novi Sad, Serbia.

[20] Good Education Group (2022). The Good Universities Guide, available at https://www.gooduniversitiesguide.com.au (accessed 2022/08/30)

[21] Hazelkorn, E. (2011). Rankings and the Reshaping of Higher Education. Palgrave Macmilan.

[22] Higgins, J. C. (1989). “Performance measurement in Universities“. European Journal of Operational Research, 38(3), pp. 358–368.

[23] HSV. (2009). Ranking of universities and higher education institutions for student information purposes. Stockholm, Sweeden: Swedish National Agency for Higher Education.

[24] Ivančević, V., Ivković, V. and Luković, I., (2017a) “Integrating Open Data on Higher Education and Science in Serbia". In proceedings of 8th PSU-UNS International Conference on Engineering and Technology (PSU-UNS ICET 2017), Novi Sad, Serbia, June 8-10, 2017, University of Novi Sad, Faculty of Technical Sciences, Novi Sad, Serbia and Prince of Songkla University, Faculty of Engineering, Thailand, ISBN: 978-86-7892-934-2, pp. 1-5, in CD ROM.

[25] Ivančević, V., Ivković, V., and Luković, I. (2017b), “Open Data in an Analysis of Higher Education in Engineering and Technology in Serbia“. In proceedings of 45th SEFI Conference, September 18-21, 2017, Azores, Portugal, European Society of Engineering Education, ISBN 978-989-98875-7-2, pp. 1260-1267.

[26] Ivančević, V. and Luković, I. (2018), "National university rankings based on open data: A case study from Serbia". In Proceedings of 22nd International Conference on Knowledge-Based and Intelligent Information & Engineering Systems (KES 2018), Belgrade, Serbia, September 3-5, 2018, Procedia Computer Science 126, DOI: 10.1016/j.procs.2018.08.124, pp. 1516–1525

[27] Jesson, D. and Mayston, D. (1990). “Information, accountability and educational performance indicators“. C. T. Fitz-Gibbon (Ed.), Performance indicators, Clevedon: Multilingual Matters, pp. 77-87.

[28] Jongbloed, B., and Westerheijden, D. F. (1994). “Performance indicators and quality assessment in European higher education“. V. Borden and T. Banta (Eds.) Using Performance Indicators to Guide Strategic Decision Making, San Francisco: Jossey-Bass, pp. 37-50.

[29] Kaufman, R. (1988). “Preparing Useful Performance Indicators“. Training and Development Journal, 42(9), pp. 80–83.

[30] Kells, H. R. (1992). Performance Indicators for Higher Education: A Critical Review with Policy Recommendations. The International Bank for Reconstruction and Development, The World Bank.

[31] Kells, H. R. (1999). “National Higher Education Evaluation Systems: Methods for Analysis and Some Propositions for the Research and Policy Void“. Higher Education, 38(2), pp. 209–232.

[32] Lazić, Z. (2021), Quality assessment and improvement strategy model for higher education institutions in the technical-technological field, PhD dissertation, University of Kragujevac, Serbia

[33] Lazić Z., Đorđević A., and Gazizulina A. (2021) “Improvement of Quality of Higher Education Institutions as a Basis for Improvement of Quality of Life“. Sustainability. 13(8), 4149. https://doi.org/10.3390/su13084149

[34] Liefner, I (2003). “Funding, resource allocation, and performance in higher education systems“. Higher Education, 46, pp. 469–489.

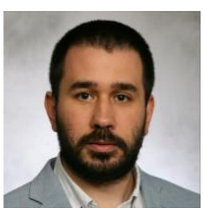
[35] Liu, N.C. and Cheng, Y. (2005) “The Academic Ranking of World Universities“, Higher Education in Europe, 30(2). pp. 127-136

[36] Luković, I., Čeliković. M., Segedinac, M., Savić, G., Kordić, S., Todorović, N., Vujanović, A., Ivković, V., Terzić, B., Lužanin, Z., Gajić, D., (2020), "PESHES – A software for evaluation and ranking of study programs and high education institutions in Serbia", Technical Solution, University of Novi Sad, Faculty of Technical Sciences, Novi Sad.

[37] Maingot, M., and Zeghal, D. (2008). “An Analysis of Voluntary Disclosure of Performance Indicators by Canadian Universities“. Tertiary Education and

Management, 14(4), pp. 269–283. http://doi.org/10.1080/13583880802481666
[38] Montoneri, B., Lin, T. T., Lee, C.-C., and Huang, S.-L. (2012). "Application of data envelopment analysis on the indicators contributing to learning and teaching performance". Teaching and Teacher Education, 28(3), pp. 382–395. http://doi.org/10.1016/j.tate.2011.11.006
[39] Mourato, J. and Patrício, M.T. (2019), "Evaluation and control process in higher education institutions: a comparative analysis", Quality Assurance in Education, Vol. 27 No. 3, pp. 269-284. https://doi.org/10.1108/QAE-02-2019-0019
[40] mXparser (2022), mXparser – Math Expressions Parser for JAVA Android C# .NET/MONO/Xamarin – Mathematical Formula Parser / Evaluator Library. Available at https://mathparser.org (accessed 2022/08/30).
[41] Palomares-Montero, D. and García-Aracil, A. (2011). "What are the key indicators for evaluating the activities of universities?" Research Evaluation, 20(5), pp. 353–363. http://doi.org/10.3152/095820211X13176484436096
[42] Parmenter, D. (2007). Key Performance Indicators - Developing, Implementing, and Using Winning KPIs. New Jersey: John Wiley & Sons, Inc.
[43] PESHES, (2019), PESHES Project – Development and Implementation of a system for performance evaluation for Serbian HEIs and system. Available at http://peshes.ius.bg.ac.rs (accessed 2022/08/30)
[44] Prades, A., & Rodríguez, S. (2008). A Proposal for a Performance Indicator Model for the Spanish Higher Education. EURASHE.
[45] Sarrico, C. S., Rosa, M. J., Teixeira, P. N., and Cardoso, M. F. (2010). "Assessing quality and evaluating performance in higher education: Worlds apart or complementary views?". Minerva, 48(1), pp. 35–54. http://doi.org/10.1007/s11024-010-9142-2
[46] Shanghai Ranking Consultancy (2022), Academic Ranking of World Universities. Available at https:// www.shanghairanking.com (accessed 2022/08/30).
[47] Tasić, N. (2017), Model of Key Performance Indicators of Higher Education Institutions, PhD dissertation, University of Novi Sad, Faculty of Technical Sciences, published in Serbian. Available at https://cris.uns.ac.rs (accessed 2022/08/30).
[48] Tavenas, F. (2004). Quality Assurance: A Reference System for Indicators and Evaluation Procedures. Brussels: European University Association.
[49] Taylor, J. (2014). "Informing or distracting? Guiding or driving? The use of performance indicators in higher education". M. E. Menon, D. Terkla, and P. Gibbs (Eds.) Global Perspectives on Higher Education. Using Data to Improve Higher Education, pp. 7–24. Rotterdam: Sense Publishers. http://doi.org/10.1007/978-94-6209-794-0_2
[50] Times Higher Education (2022), World University Rankings. Available at https://www.timeshighereducation.com/world-university-rankings/2022 (accessed 2022/08/30)
[51] Times Newspapers Limited, 2022. Good University Guide. Available at https://www.thetimes.co.uk/article/good-university-guide-in-full-tp6dzs7wn (accessed 2022/08/30)
[52] U-Multirank Consortium (2010), U-Multirank. Available at https://www.umultirank.org/ (accessed 2022/08/30).
[53] Usher, A. and Savino, M. (2007). "A global survey of university ranking and league tables". Higher Education in Europe, 32(1), pp. 5–15. http://doi.org/10.1080/03797720701618831
[54] Willms, D. J. and Kerckhoff, A. C. (1995). "The Challenge of Developing New Educational Indicators". Educational Evaluation and Policy Analysis, 17(1), pp. 113–131.

Goran Savić is a is an associate professor within the Department of Computing and Control, Faculty of Technical Sciences, University of Novi Sad. He received his M.Sc. degree in 2006 and a PhD degree in 2011, all in Computer Science from the University of Novi Sad, Faculty of Technical Sciences. His research interests are e-learning and enterprise information systems.



Milan Segedinac received his M.Sc. degree in 2008 and PhD in 2014 in Computer Science from the University of Novi Sad, Faculty of Technical Sciences. He holds an associate professor position at the same faculty. He has authored papers in international and national journals and conferences in the field of computer-enhanced education.

Milan Čeliković Milan Čeliković received his M.Sc. degree from the Faculty of Technical Sciences, at the University of Novi Sad in 2009. He received his Ph.D. degree in 2018, at the University of Novi Sad, Faculty of Technical Sciences. Currently, he works as an assistant professor at the Faculty of Technical Sciences at the University of Novi Sad, where he lectures several Computer Science and Informatics courses. His main research interests are focused on: Databases, Database management systems, Information Systems and Software Engineering.

Ivan Luković received his diploma degree (5 years) in Informatics from the Faculty of Military and Technical Sciences in Zagreb in 1990. He completed his M.Sc (former Mr, 2 years) degree at the University of Belgrade, Faculty of Electrical Engineering in 1993, and his PhD at the University of Novi Sad, Faculty of Technical Sciences in 1996. Currently, he works as a Full Professor at the Faculty of Organizational Sciences of the University of Belgrade, where he lectures in several Computer Science and Informatics courses. His research interests are related to Database Systems, Business Intelligence Systems, and Software Engineering. He is the author or co-author of over 200 papers, 4 books, and 30 industry projects and software solutions in the area. He created a new set of B.Sc. and M.Sc. study programs in Information Engineering, i.e., Data Science, at the Faculty of Technical Sciences. The programs were accredited for the first time in 2015. Currently, he is the Chair of the Managing Board of the Computer Science and Information Systems (ComSIS) journal.