A GENERIC RELATIONAL DATABASE-DRIVEN, FORMAL EVALUATION FRAMEWORK FOR ASSESSING KEY PERFORMANCE INDICATORS IN RESEARCH PUBLISHING

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Abstract

Universities and accompanying faculties, competing to ensure the highest possible quality and status, face the challenge of being continuously evaluated and ranked, both internally and externally. One of the many criteria in such evaluation is the assessment of key performance indicators (KPIs) vis-à-vis published research papers. The general aim of this paper is the definition of a formal KPI evaluation framework for assessing the research publications (published papers and books), written by researchers in universities, faculties, and other research-oriented institutions. It is accomplished in two steps: (1) by proposing a conceptual and logical design of a generic relational database that can provide a solid foundation for acquisition and management of all relevant data related to research publications, based on the projected corresponding Enhanced Entity-Relationship (EE-R) diagram (a conceptual design) and the resulting relational database schema (a logical design); and (2) by addressing relevant KPIs via Structured Query Language (SQL) scripts/queries using the standard SQL notation against the resultant relational design. Since the proposed framework is both generic and platform-independent, it can be easily implemented in various relational database management systems (DBMSs) to provide significant insights into the research performances of the academic staff vis-à-vis their published research publications.

Keywords: scientific research, key performance indicators (KPIs), relational database design, EE-R diagram, relational schema, SQL queries.

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Introduction

Despite the legendary Wernher von Braun's[6] funny quote claiming that "Research is what I'm doing when I don't know what I'm doing", research is considered a "formalized curiosity" (Zora Neale Hurston[7]) that "creates new knowledge" (Neil Armstrong[8]), by "turning the unknown into reality" (Steven Magee[9]). According to the OECD (2015), research is "creative and systematic work undertaken to increase the stock of knowledge", which includes the gathering, organizing, and analysis of data, facts, and prior knowledge using scientific methods, approaches, and tools to gain a new, better, and improved knowledge of a topic, phenomenon, or a problem. Over time, the results of scientific research have significantly affected individual people's lives, communities, humanity, as well as the world in which we exist. This awareness has resulted in a sustained demand among policy- and decision-makers for keeping records of not only the scientific research itself, but also of the level and nature of both human and financial resources that various countries, research institutions, universities, and faculties devote to such endeavors, as a first step toward understanding how to direct such resources on the road to the fulfillment of specific goals.

It has long been recognized that knowledge is a direct product of scientific research. Its production, exploitation, and dissemination are critical to economic growth, development, and global well-being. The widespread adoption and proliferation of new information technologies in the last few decades vastly improved the capability of generating, manipulating, and distilling information so that it becomes knowledge, bringing to the forefront the issue of how knowledge is created, nurtured, and used for competitive advantage. The need for continuous and improved measurement of scientific achievements in various fields is central to all of this. Therefore, there is an ongoing necessity to produce indicators that can quantify performance and other associated outputs of scientific research, with a particular focus on data needed for assessment, monitoring, and policy-making reasons. Aside from promoting a suitable environment for scientific output creation, dispersion,

[6] Wernher von Braun (1912-1977), was a German-American aerospace engineer and space architect.

[7] Zora Neale Hurston (1891-1960), was an American author, anthropologist, and filmmaker.

[8] Neil Armstrong (1930-2012), was an American astronaut and aeronautical engineer, naval aviator, test pilot, university professor, and the first person to walk on the Moon.

[9] Steven Magee is a world leading expert on ground-based solar radiation and human health.

and commercialization, there is a growing interest from higher education institutions in better understanding how scientific research creates values and contributes to the assessment of scientific institutions, ultimately leading to a knowledge-based economy, along with economic growth, productivity, and competitiveness.

Many universities throughout the world are still attempting to establish themselves as leaders in scientific research and teaching, on a local, regional, or global scale. The increasing prevalence of science and technology in all areas of human life, as well as the rising importance of higher education both in defining the future of the young generation and in developing societies, made it necessary to change and update educational strategic plans, educational policies, educational structure, and institutional guidelines, as well. One of the most effective ways for universities to attain international recognition and distinction in scientific research and education is the adoption and implementation of relevant Key Performance Indicators (KPIs) that are synchronized with current strategic plans. Such KPIs can significantly help universities and other research institutions to grow in a long term.

On the other hand, it is noteworthy to point out that the career advancement of academic staff is usually based mostly on their research performance regarding the published research papers and other publications (books, textbooks, monographs, encyclopedias, handbooks, technical reports, dictionaries...), even in non-research-intensive universities, although a significant portion of their time is spent on teaching activities that represent a prevailing component of their workload. This is yet another reason to foster the adoption and implementation of research-based KPIs within universities.

Figuring out the way how the generation and diffusion of knowledge contribute to the prosperity of universities and other research centers, economic progress, and overall well-being, entails the creation, management, maintenance, and usage of a solid evidence base. In addition, internationally comparable statistics are needed to support this evidence requirement. In this context, the paper proposes a generic framework for the acquisition of data related to research papers in a form of a relational database design, based on a corresponding conceptual model (E-R diagram) and the resulting relational database schema. Moreover, the paper summarizes some of the most relevant KPIs regarding research papers and proposes corresponding SQL scripts of the queries for extracting those KPIs out of the hypothetically implemented relational database, using the standard SQL notation. The benefits of such an approach are quite obvious since the proposed framework is both generic and platform-independent and it can be easily implemented in various relational database management systems (DBMSs), both within university information

systems and as a standalone software application, to provide significant insights into the research performances of the academic staff vis-à-vis their published research papers.

This paper is divided into seven different sections. The "Related research" section summarizes the most appealing research made on this topic recently. In the subsequent section titled "On performance management and Key Performance Indicators", a brief introduction to performance management, KPIs, and research-oriented KPIs is being given. The fourth section "Data and methodology" focuses on the data and methodology used, along with the explanation of which aspects of scientific research are being addressed. The two major constituent parts of the relational database design, i.e. the conceptual model (EE-R diagram) and the logical model (the relational database schema), are being subject to the section "Relational database design". In the sixth section entitled "Definition of research paper-related KPIs using SQL scripts", the authors provide a set of SQL scripts, suitable for evaluating the most prominent KPIs of the scientific research vis-à-vis the published research papers. The last section concludes.

Related research

The practice has already confirmed that measuring the right KPIs is vital to the health and success of any business. However, when it comes to scientific research at research-oriented institutions, especially universities and faculties, the research made on this topic is quite scarce and obscure. Most of the research carried out on KPIs in higher education institutions refers to the assessment of the quality of teaching and the quality of academic study programs. What follows is a brief and chronologically ordered review of some of the most prominent research made recently.

In her master's thesis, Wang (2010) distinguishes between two major dimensions of performance management in universities (academic performance and managerial performance) including the four sub-dimensions under those two dimensions (education, research, finances, and human resources). According to her, performance measurements in universities should include four types of measures, i.e. input measures, process measures, output measures, and outcome measures. She elaborates on various research-related KPIs and also proposes the inclusion of qualitative KPIs in addition to quantitative ones.

Based on a combination of both descriptive and deductive methods, and applying factor analysis to survey results, Azma (2010) identifies more than 150 KPIs and presents three conceptual frameworks suitable for the evaluation of the universities' performance.

Terkla (2011) analyzed the dashboards of 66 colleges and universities and categorized her findings, pointing out the most popular areas of measurement, i.e. those found on more than 50% of the dashboards.

The research, carried out by Kongsmak *et al*. (2013), which was based on a questionnaire survey, deals with the perception of research excellence among researchers in Thailand and Japan. For the study, they focused on three crucial research questions, including what counts as excellence, how to measure excellence, and how to support excellence. Their research suggests that the purely bibliometric approach, which has been used for decades to evaluate individual research performance, is quite inadequate in summarizing the quality of the scientific performance.

The primary goals of the paper written by Rajkaran & Mammen (2014) were to develop consensus-based KPIs for academic departments in a specific South African public higher education institution, as well as to identify challenges to achieving them. Questionnaires and interviews were used for the study, based on a sample that included a representative number of academics and members of the university administration team. The analyzed data provided a starting point for determining optimal KPIs for university departments in the short-, medium-, and long term. The article also pointed out several issues that had to be resolved so the defined KPIs could be addressed successfully.

Recognizing the fact that higher education is the main factor contributing to the competitiveness of nations, Petrov & Kamenova-Timareva (2014) propose a framework for the evaluation of the higher education institutions' performance using the concept of KPIs.

The research made by Zhu (2015) perceives the performance of university teachers as a twofold function: the first one takes into account the skills, opportunities, motivation, and environment, while the second one relies on individual factors, organizational factors, and working factors. Based on the gradient levels' analysis of 33 sub-qualities of university teachers, the research aims at establishing a performance assessment index system and assessment method.

In their paper, Al-Turki *et al*. (2015) are focusing on the process of modification of existing KPIs that were developed to satisfy the needs of a specific, highly ranked university, situated in the Middle East region.

Cadez *et al*. (2017) investigated the relationship between research productivity, research performance, and teaching quality. Their findings, based on a large cross-disciplinary sample of academics within a research-oriented university, suggest that research productivity is not related to teaching quality, whereas research quality is positively related to teaching quality.

In their work, Anuradha *et al*. (2018) focus on the Academic Performance Indicators (APIs) of college teachers in India, which are quantitative measures of the growth of a student, a teacher, and an institution. Those KPIs have been elaborated in four categories, including continuous improvement/professional growth, interactions with industry, student development, and administrative commitment.

Chang (2019) focused on the exploration of performance evaluation reform regarding teachers in private universities and colleges in China, based on the "KPI + Competency" dual-track system, to build a new performance management system for private college teachers.

Alomary (2020) elaborates on the adoption of KPIs in the higher education system in Saudi Arabia to measure the performance of universities in this country.

All of the previously reported research endeavors confirm that KPIs used for measuring the performance of higher education institutions, and especially KPIs oriented toward measuring the performance of scientific research, have recently become of utmost importance, since they are a highly significant tool in the complex process of selection and breeding of research staff in universities and other research-oriented institutions, as well as for their overall ranking, regardless of their status (private or public), the country of origin (throughout the world), or KPIs' nature (qualitative or quantitative).

On performance management and Key Performance Indicators

According to Harris *et al*. (2003), Performance Management (PM) is "the process of ensuring that a set of activities and outputs meets an organization's goals effectively and efficiently. Performance management can focus on the performance of an organization, a department, an employee, or the processes in place to manage particular tasks." A comprehensive and well-executed performance management system incorporating elements such as performance appraisals and processes to manage underperformance is an important component of developing employees, departments, and whole organizations. It is a well-established, all-encompassing term used to describe the practice that drives decisions about performance, rewards, promotions, disciplinary procedures, terminations, transfers, and development needs within an organization. Performance management is a much broader concept than performance measurement since it aims to improve organizational, functional, team, and individual performances. So far, a few performance measurement frameworks, such as the Balanced Scorecard (BSC) approach, which was originally developed for the business sector, have been adapted for performance management in research-oriented

institutions, despite the existing risk of incompletely capturing the essence of such organization type's fundamental operations. However, since research-oriented institutions are generally characterized by a varying number of versatile primary goals, the appliance of any traditional performance measurement approach may not be quite appropriate. The performance of research-oriented institutions can be assessed by the extent to which each of their fundamental operations is sustained toward the fulfillment of their unique goals.

When it comes to answering the question "What are KPIs?" perhaps it is more straightforward to consider what isn't a KPI? A Key Performance Indicator (KPI) is not a piece of information that should be known just because the organization may need to refer to it. Also, it is not something that should be presented simply because that is what the others are monitoring regularly. At last, it is not a measure of something that cannot be managed or utilized in making decisions. KPIs are performance metrics that can be tracked, measured, and analyzed. KPIs are not goals themselves, but rather measures used to evaluate the factors that are crucial or critical to the success of an organization. They are measurable quantitative leading indicators that show how well an organization or their particular departments or even individuals are performing vis-à-vis their key objectives, goals, and priorities. KPIs' importance cannot be underestimated, because they are much more than simply statistics that are being reported. They help in understanding and measuring the performance and health of a given organization, as well as to find out whether the organization is heading in the right direction based on the adopted strategy, allowing the management team to make necessary modifications in operations to reach organizational strategic goals and performance targets. Knowing and evaluating the proper KPIs can help the management team to accomplish the predefined organizational goals faster and more efficiently. Monitoring the performance by using KPIs is an efficient strategy that allows organizations to gain a competitive advantage over their competitors.

In universities and other higher education institutions, specific KPIs are used to understand how an institution, study program, department, faculty, course, or even a particular student or professor/lecturer is progressing toward the projected goals. Besides in the field of scientific research (to be widely recognized research and knowledge exchange center), KPIs can be defined and assessed regarding many other aspects, roughly broken down into the following categories: education (outstanding teaching & learning), community services (support of various programs for the students), international cooperation, university environment, administration & finances (endowments & expenses), human resources, student success,

admission & enrollments, faculty & staff, facilities & resources (excellence in services and infrastructure), sustainability (CO_2 emissions, electricity spending, water consumption…), internationalization, development, and alumni, etc. All of these can be further divided into many sub-categories (Petrov & Kamenova-Timareva, 2014, pp. 114–119; SQU, 2018; Spear, 2019; UCC, 2020; Ordenes, 2021; NEIU, 2022). No matter how many KPI categories are assessed, setting up an insightful university KPI system requires five main components: (1) setting up accurate and realistic goals, following the SMART strategy (Specific, Measurable, Achievable, Relevant, and Time-Bound); (2) defining at least one performance measure/KPI for each identified goal; (3) effective and accurate data collection/acquisition, storage, and management; (4) automated process of extracting information from data and computing the values of relevant KPIs (e.g. KPI dashboard software, reporting software, database-driven analytics); (5) evaluation of the obtained KPIs' values (results) against the predefined goals to set new goals or adjust previous ones (Petrov & Kamenova-Timareva, 2014, p. 114; InsightSoftware, 2021).

Research is an essential activity for all research-oriented institutions. Developing KPIs for measuring the success of scientific research is crucial in creating a culture wherein scientific achievement is both recognized and appreciated. They also offer the additional function of propelling an organization toward objectives that would otherwise be idled by day-to-day activities or stagnate due to a lack of commitment and a lack of comparison of actual outcomes to intended/projected results.

Data and methodology

This research is focused solely on addressing the research-oriented KPIs related to research papers and books, published by academic staff/researchers. It is based on data/facts about commonly utilized research-oriented KPIs, found in several self-evaluation reports (SER, 2015; SER, 2018; SER, 2021), other relevant documents dealing with KPIs in universities (SQU, 2018; UoE, 2019; UoT, –), as well as the metadata found with eprints.uklo.edu.mk online institutional repository of research outputs (ePrints, –). The data/facts have been gathered (identified, selected, and analyzed) using the method of observation. The usage of collected data/facts follows the induction approach since they are used to identify common patterns, and to come up with a conceptual framework as a general conclusion, in a bottom-up manner: the final, high-level solution is gained by combining several low-level solutions addressing specific aspects. The specification of research-oriented KPIs follows the relational database design

methodology, including the first two phases: the conceptual design (EE-R diagram) and the logical design (relational database schema) (Bagui & Earp, 2011; Teorey *et al*., 2011).

More specifically, this research takes into account the following, frequently addressed aspects of publishing research publications:

- Authors/researchers;
- Research papers: journal papers, proceedings papers, book chapters;
- Publications: books, conference proceedings, and journals;
- Citations of research papers in books and other research papers;
- Academic meetings (conferences, congresses, symposiums);
- Indexation of research publications in relevant databases;
- Researchers' membership in editorial/advisory boards of journals, as well as in organizing and program committees of academic meetings;

Having minded this, the paper is strictly oriented toward the KPIs that reflect a spectrum of significant "internal" aspects of the scientific research, i.e. the KPIs used in the process of a scientific research assessment from the perspective of a particular university/faculty, rather than external aspects, which measure how outer subjects (potentially interested public audience) validate the scientific research, such as Journal Citation Reports (JCR) impact factor, Source-Normalized Impact per Paper (SNIP), SCImago Journal Rank (SJR), relative citation rates, *h*-index, full-text downloads, altmetrics, webometrics, etc.

Relational database design

In this section, the focus is put on the conceptual and logical design of a relational database that can represent a solid basis for obtaining relevant KPIs regarding several important aspects of publishing research publications. The proposed design can be easily modified (adapted, upgraded, and/or enhanced) to capture additional KPIs that are relevant for other types of research institutions, as well.

Conceptual design

The EE-R diagram, shown in Figure 1, encompasses all the entities and relationships between them, involved in the process of publishing scientific publications (research papers and books). For simplicity reasons, only the relationships' attributes are displayed. Relationships' degree, cardinality, and modality are also shown.

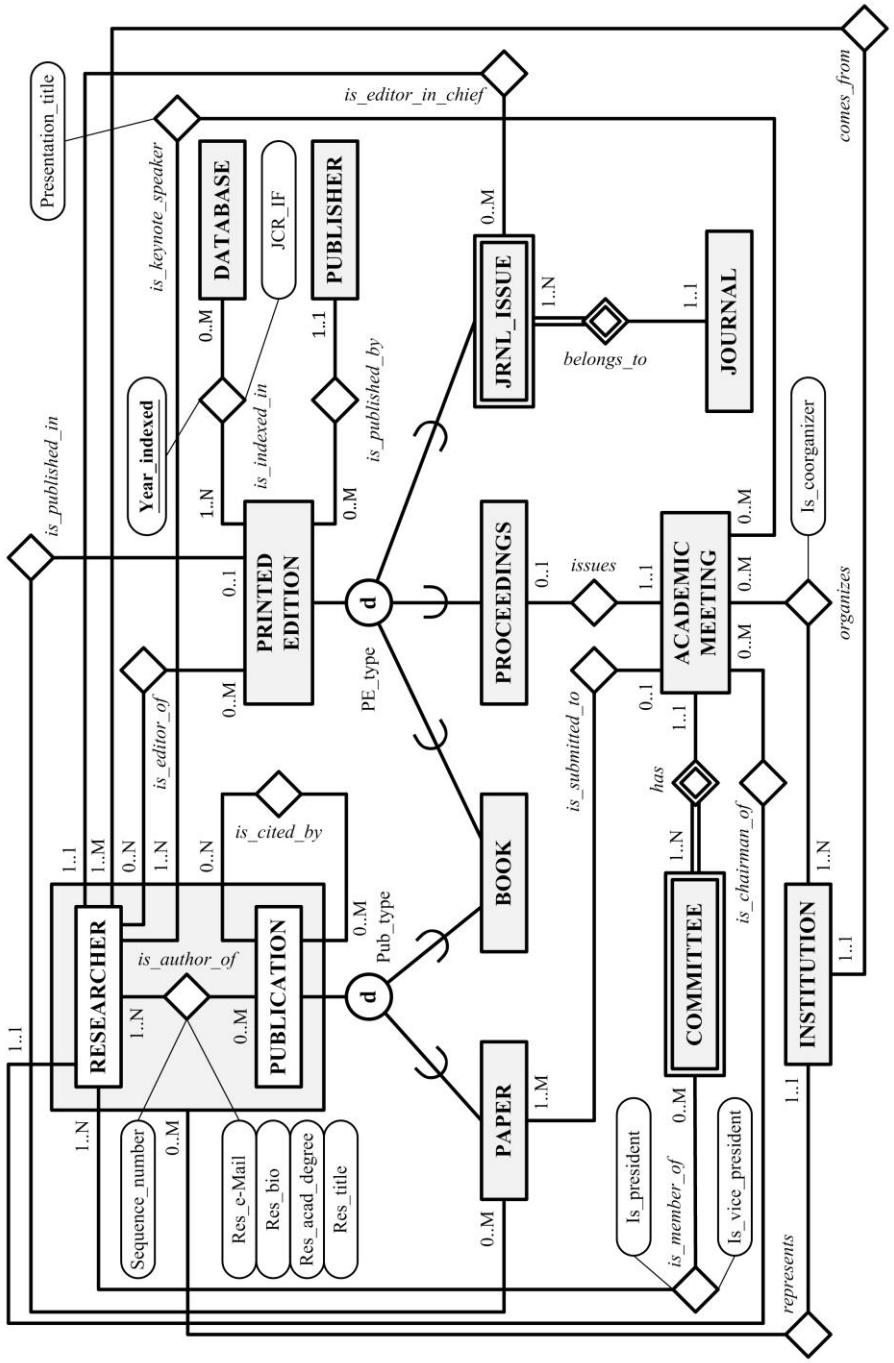

Figure 1: Conceptual design (EE-R diagram) of a relational database suitable for capturing research-oriented KPIs about scientific publications, rotated counterclockwise (Source: Authors' representation)

The key attributes of identified entity types portrayed in Figure 1, along with their corresponding non-key attributes, are given in Table 1. Key attributes are bolded and underlined with a solid line. Partial key attributes of weak entity types are bolded and underlined with a dotted line. Since the subtypes inherit the attributes from their corresponding supertype, only their specific attributes are presented in Table 1.

Table 1: Key attributes and non-key attributes of entity types

Entity type	Attribute
RESEARCHER	**Researcher_ID** Res_name Res_mid_name Res_surname Res_ORCID Res_gender Res_title_now Res_degree_now Res_e-Mail_now Res_bio_now Res_birthdate Res_birthplace Res_country
PUBLISHER	**Publisher_ID** P-sher_name P-sher_address P-sher website
PUBLICATION (supertype)	**Publication_ID** Pub_type (e.g. Paper, Book) Pub_title Classification (Frascati_field, Frascati_area, Frascati_discipline)
PRINTED_EDITION (supertype)	**PE_ID** PE_type (e.g. Book, Proceedings, Journal issue) PE_title PE_format (e.g. A4, B5…) PE_binding (e.g. hardcover, paperback) PE_pub_date PE_pub_year PE_total_pages
DATABASE	**Database_ID** D-base_name D-base_disciplines D-base_website

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INSTITUTION	**Institution_ID** Inst_type (e.g. Faculty, University, Institute, Laboratory…) Inst_name Inst_address Inst_postcode Inst_city Inst_country Inst_e-Mail Inst_website Inst_phones
ACADEMIC_MEETING	**Meeting_ID** Meet_type (e.g. Conference, Symposium, Congress) Meet_title Meet_acronym Meet_place Meet_city Meet_country Meet_date_from Meet_date_to Meet_website
COMMITTEE (weak entity type)	**Comm_ID** Comm_type (e.g. Program committee, Organizing committee)
PAPER (subtype of PUBLICATION)	Paper_DOI Paper_abstract Paper_keywords Paper_pdf From_page To_page
BOOK (a shared subtype of PUBLICATION and PRINTED_EDITION)	Book_title Book_ISBN Book_e-ISBN Book_type (e.g. textbook, manual, monograph, encyclopedia, handbook, technical report, dictionary…)
JRNL_ISSUE (subtype + weak entity type)	**Volume** **Issue**
JOURNAL	**Journal_ID** Jrnl_title Jrnl_e-ISSN Jrnl_print-ISSN Jrnl_website
PROCEEDINGS (subtype)	Proc_title Proc_ISBN Proc_e-ISBN Proc_e-ISSN Proc_print-ISSN

Logical design

Given the EE-R diagram, previously introduced in Figure 1, and the list of all key and non-key attributes of the identified entity types given in Table 1, the logical design of the relational database can be incurred by transforming the conceptual design into the following relational schema:

- INSTITUTION (**Institution_ID**, Inst_type, Inst_name, Inst_address, Inst_postcode, Inst_city, Inst_country, Inst_e-Mail, Inst_website, Inst_phones)

- RESEARCHER (**Researcher_ID**, Res_name, Res_mid_name, Res_surname, Res_ORCID, Res_gender, Res_title_now, Res_degree_now, Res_e-Mail_now, Res_bio_now, Res_birthdate, Res_birthplace, Res_country, *Institution_ID**)

- PUBLISHER (**Publisher_ID**, P-sher_name, P-sher_address, P-sher_website)

- DATABASE (**Database_ID**, D-base_name, D-base_disciplines, D-base_website)

- ACADEMIC_MEETING (**Meeting_ID**, Meet_type, Meet_title, Meet_acronym, Meet_place, Meet_city, Meet_country, Meet_date_from, Meet_date_to, Meet_year, Meet_website, *Chairman_ID**)

- COMMITTEE (**Meeting_ID***, **Comm_ID**, Comm_type)

- PUBLICATION (**Publication_ID**, Pub_type, Pub_title, Pub_language, Frascati_field, Frascati_area, Frascati_discipline)

- PRINTED_EDITION (**PE_ID**, PE_type, PE_title, PE_format, PE_binding, PE_pub_date, PE_pub_year, PE_total_pages)

- PAPER (**Publication_ID***, Paper_DOI, Paper_abstract, Paper_keywords, Paper_pdf, From_page, To_page, *Meeting_ID**, *PE_ID**)

- BOOK (**Publication_ID***, **PE_ID***, Book_title, Book_ISBN, Book_e-ISBN, Book_type, *Publisher_ID**)

- JOURNAL (**Journal_ID**, Jrnl_title, Jrnl_e-ISSN, Jrnl_print-ISSN, Jrnl_website)

- JRNL_ISSUE (**PE_ID***, **Journal_ID***, **Volume**, **Issue**, *Editor_in_Chief_ID**, *Publisher_ID**)

- PROCEEDINGS (**PE_ID***, Proc_title, Proc_ISBN, Proc_e-ISBN, Proc_e-ISSN, Proc_print-ISSN, *Meeting_ID**, *Publisher_ID**)

- ORGANIZES (**Institution_ID***, **Meeting_ID***, Is_coorganizer)

- IS_KEYNOTE_SPEAKER (**Researcher_ID***, **Meeting_ID***, Presentation_title)

- IS_AUTHOR_OF (**Researcher_ID***, **Publication_ID***, Res_e-Mail, Res_bio, Res_acad_degree, Res_title, Sequence_number, *Institution_ID**)

- IS_MEMBER_OF (**Researcher_ID***, **Meeting_ID***, **Comm_ID***, Is_president, Is_vice_president)

- IS_INDEXED_IN (**PE_ID***, **Database_ID***, **Year_indexed**, JCR_IF)

- IS_EDITOR_OF (**Researcher_ID***, **PE_ID***)

- IS_CITED_BY (**Publication_ID***, **Citing_publication_ID***)

In the above relational database schema, primary keys are bolded and underlined with a solid line. Primary keys, which are also foreign keys or are parts of a foreign key, are denoted by an asterisk (*). Pure foreign keys are written in italics, underlined with a dotted line, and denoted by an asterisk (*). All the relations are already in a Third Normal Form (3NF).

Definition of research-related KPIs using SQL scripts

Table 2 contains definitions and standard SQL specifications of some of the most prospective research-oriented KPIs that can be yielded from the proposed logical database design.

Table 2: Specification of SQL scripts for addressing research-oriented KPIs

1.	KPI Description	Total number of researchers from <*institution_name*> that were members of academic meetings' <*committee_type*> (c.comm_type = 'Organizing committee' | 'Program committee'), held in the period from <*year1*> to <*year2*>
	SQL Specification	`SELECT COUNT(*) AS Membership_in_academic_meeting_committees FROM Is_member_of imo, Researcher r, Academic_meeting am, Committee c, Institution i WHERE (imo.researcher_ID = r.researcher_ID) AND (imo.meeting_ID = am.meeting_ID) AND (imo.meeting_ID = c.meeting_ID) AND (imo.comm_ID = c.comm_ID) AND (r.institution_ID = i.institution_ID) AND (c.comm_type = '<committee_type>') AND (i.inst_name = '<institution_name>') AND (am.meet_year >= <year1> AND am.meet_year <= <year2>);`
2.	KPI Description	Total number of academic meetings organized/co-organized (o.is_coorganizer = 'False' | 'True') by <*institution_name*> in the period from <*year1*> to <*year2*>
	SQL Specification	`SELECT COUNT(*) AS Number_of_academic_meetings FROM Organizes o, Institution i, Academic_meeting am WHERE o.institution_ID = i.institution_ID AND o.meeting_ID = am.meeting_ID AND i.inst_name = '<institution_name>' AND o.is_coorganizer = 'False' | 'True' AND (am.meet_year >= <year1> AND am.meet_year <= <year2>);`
3.	KPI Description	Total number of researchers from <*institution_name*> who were keynote speakers at academic meetings held in the period from <*year1*> to <*year2*>
	SQL Specification	`SELECT COUNT(*) AS Number_of_keynote_speakers FROM Is_keynote_speaker iks, Researcher r, Institution i, Academic_meeting am WHERE (iks.researcher_ID = r.researcher_ID) AND (iks.meeting_ID = am.meeting_ID) AND (r.institution_ID = i.institution_ID) AND (i.inst_name = '<institution_name>') AND (am.meet_year >= <year1> AND am.meet_year <= <year2>);`

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4.	KPI Description	Total number of researchers from <*institution_name*> who were editor-in-chief of a scientific journal in the period from <*year1*> to <*year2*>
	SQL Specification	`SELECT COUNT(DISTINCT ji.editor_in_chief_ID) AS Number_of_Editors_in_Chief FROM Jrnl_issue ji, Journal j, Researcher r, Institution i, Printed_edition pe WHERE (ji.journal_ID = j.journal_ID) AND (ji.editor_in_chief_ID = r.researcher_ID) AND (r.institution_ID = i.institution_ID) AND (ji.PE_ID = pe.PE_ID) AND (i.inst_name = '<institution_name>') AND (pe.PE_pub_year >= <year1> AND pe.PE_pub_year <= <year2>);`
5.	KPI Description	Total number of researchers from <*institution_name*> who published a research paper in a book, i.e. a book chapter (pe_type = 'Book'), in a proceedings (pe_type = 'Proceedings'), or in a journal (pe_type = 'Journal') in the period from <*year1*> to <*year2*>, and were listed as <*seq_number*> author.
	SQL Specification	`SELECT COUNT(DISTINCT(iao.researcher_ID)) AS Number_of_researchers_who_published_a_paper FROM Is_author_of iao, Researcher r, Publication pub, Institution i, Paper p, Printed_edition pe WHERE (iao.researcher_ID = r.researcher_ID) AND (iao.publication_ID = pub.publication_ID) AND (iao.institution_ID = i.institution_ID) AND (pub.publication_ID = p.publication_ID) AND (p.PE_ID = pe.PE_ID) AND (pe.pe_type = '<pe_type>') AND (iao.sequence_number = <seq_number>) AND (i.inst_name = '<institution_name>') AND (pe.PE_pub_year >= <year1> AND pe.PE_pub_year <= <year2>);`
6.	KPI Description	Total number of researchers from <*institution_name*> who published a book in the period from <*year1*> to <*year2*>
	SQL Specification	`SELECT COUNT(DISTINCT iao.researcher_ID) AS Number_of_researchers_who_published_a_book FROM Is_author_of iao, Researcher r, Publication pub, Institution i, Book b, Printed_edition pe WHERE (iao.researcher_ID = r.researcher_ID) AND (iao.publication_ID = pub.publication_ID) AND (iao.institution_ID = i.institution_ID) AND (pub.publication_ID = b.publication_ID) AND (b.PE_ID = pe.PE_ID) AND (pub.pub_type = 'Book') AND (i.inst_name = '<institution_name>') AND (pe.PE_pub_year >= <year1> AND pe.PE_pub_year <= <year2>);`

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7.	KPI Description	Total number of authorships of research papers, written by researchers from <*institution_name*> in the period from <*year1*> to <*year2*>
	SQL Specification	`SELECT COUNT(DISTINCT iao.researcher_ID + iao.publication_ID) AS Number_of_authorships_of_papers FROM Is_author_of iao, Researcher r, Publication pub, Institution i, Paper p, Printed_edition pe WHERE (iao.researcher_ID = r.researcher_ID) AND (iao.publication_ID = pub.publication_ID) AND (iao.institution_ID = i.institution_ID) AND (pub.publication_ID = p.publication_ID) AND (p.PE_ID = pe.PE_ID) AND (pub.pub_type = 'Paper') AND (i.inst_name = '<institution_name>') AND (pe.PE_pub_year >= <year1> AND pe.PE_pub_year <= <year2>);`
8.	KPI Description	Total number of distinct research paper titles, written by researchers from <*institution_name*> in the period from <*year1*> to <*year2*>
	SQL Specification	`SELECT COUNT(DISTINCT iao.publication_ID) AS Number_of_distinct_paper_titles FROM Is_author_of iao, Publication pub, Institution i, Paper p, Printed_edition pe WHERE (iao.publication_ID = pub.publication_ID) AND (iao.institution_ID = i.institution_ID) AND (pub.publication_ID = p.publication_ID) AND (p.PE_ID = pe.PE_ID) AND (pub.pub_type = 'Paper') AND (i.inst_name = '<institution_name>') AND (pe.PE_pub_year >= <year1> AND pe.PE_pub_year <= <year2>);`
9.	KPI Description	Total number of distinct book titles, written by researchers from <*institution_name*> in the period from <*year1*> to <*year2*>
	SQL Specification	`SELECT COUNT(DISTINCT iao.publication_ID) AS Number_of_distinct_book_titles FROM Is_author_of iao, Researcher r, Publication pub, Institution i, Book b, Printed_edition pe WHERE (iao.researcher_ID = r.researcher_ID) AND (iao.publication_ID = pub.publication_ID) AND (iao.institution_ID = i.institution_ID) AND (pub.publication_ID = b.publication_ID) AND (b.PE_ID = pe.PE_ID) AND (pub.pub_type = 'Book') AND (i.inst_name = '<institution_name>') AND (pe.PE_pub_year >= <year1> AND pe.PE_pub_year <= <year2>);`

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10.	KPI Description	Total number of distinct paper titles written by the researchers from <*institution_name*>, which were published in publications indexed in <*sci_database*> in the period from <*year1*> to <*year2*>
	SQL Specification	`SELECT COUNT(DISTINCT iao.publication_ID) AS Total_number_of_papers_indexed_in_a_database FROM Is_author_of iao, Researcher r, Publication pub, Institution i, Paper p, Printed_edition pe, Is_indexed_in iii, DatabaseSci d WHERE (iao.researcher_ID = r.researcher_ID) AND (iao.publication_ID = pub.publication_ID) AND (iao.institution_ID = i.institution_ID) AND (pub.publication_ID = p.publication_ID) AND (p.PE_ID = pe.PE_ID) AND (pe.PE_ID = iii.PE_ID) AND (iii.database_ID = d.database_ID) AND (pub.pub_type = 'Paper') AND (i.inst_name = '<institution_name>') AND (d.dbase_name = '<sci_database>') AND (pe.PE_pub_year >= <year1> AND pe.PE_pub_year <= <year2>);`
11.	KPI Description	Total number of researchers from <*institution_name*> who were chairmen of academic meetings in the period from <*date1*> to <*date2*>
	SQL Specification	`SELECT COUNT(*) AS Number_of_chairmen FROM Academic_meeting am, Researcher r, Organizes o, Institution i WHERE (am.chairman_ID = r.researcher_ID) AND (o.institution_ID = i.institution_ID) AND (o.meeting_ID = am.meeting_ID) AND (i.inst_name = '<institution_name>') AND (am.meet_year >= <year1> AND am.meet_year <= <year2>);`
12.	KPI Description	Total number of researchers from <*institution_name*> who were members of editorial board of <*publication_type*> (pe.PE_type = 'Book' | 'Proceedings' | 'Journal') in the period from <*year1*> to <*year2*>
	SQL Specification	`SELECT COUNT(*) AS Members_of_editorial_board FROM Is_editor_of ieo, Researcher r, Printed_edition pe, Institution i WHERE (ieo.researcher_ID = r.researcher_ID) AND (ieo.PE_ID = pe.PE_ID) AND (r.institution_ID = i.institution_ID) AND (pe.PE_type = '< publication_type >') AND (i.inst_name = '<institution_name>') AND (pe.PE_pub_year >= <year1> AND pe.PE_pub_year <= <year2>);`

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13.	KPI Description	Total number of citations of publications (papers and/or books), written by researchers from <*institution_name*>, in papers published in the period from <*year1*> to <*year2*>
	SQL Specification	SELECT COUNT(*) AS Citations_of_papers_and_books_in_papers FROM Is_cited_by icb, Publication pub, Publication cpub, Is_author_of iao, Researcher r, Institution i, Paper p, Printed_edition pe WHERE (icb.publication_ID = pub.Publication_ID) AND (icb.citing_publication_ID = cpub.Publication_ID) AND (icb.publication_ID = iao.publication_ID) AND (iao.researcher_ID = r.researcher_ID) AND (iao.institution_ID = i.institution_ID) AND (icb.citing_publication_ID = p.publication_ID) AND (p.PE_ID = pe.PE_ID) AND (i.inst_name = '<*institution_name*>') AND (pe.PE_pub_year >= <*year1*> AND pe.PE_pub_year <= <*year2*>);

Conclusion

In today's highly competitive world, all research-oriented institutions (universities, faculties, colleges, research institutes, research laboratories, and other organizations focused on scientific research) must maintain track of their real performance updates to lead the organization in the appropriate direction. The main substance in the process of human resource management in all research-oriented institutions is performance evaluation related to scientific research. The most successful ones have a performance measuring system already in place, based on the utilization of relevant KPIs, to have control over and enhance research processes. Building an assessment system based on KPIs to develop academic staff's competencies may encourage the continual development of university professors' performance and assure institutions' sustainability, stability, and competitiveness in a long run. Research-oriented institutions should define and always monitor those KPIs, as they represent metrics that should be defined, monitored, reported, and controlled for such organizations to be perceived as successful by their competitors, as well as by the overall scientific audience, in general. Those KPIs are established to ensure that organizations pay close attention to outcomes, responsibilities, and objectives because scientific research has recently been put under pressure. The stakes become quite high in terms of

delivering eminence, worth, quality, excellence, innovation, and financial results. Higher expectations from scientific research in research-oriented institutions imposed the use of KPIs as the main criterion for measuring both the success of academic staff and the overall organization's progress in achieving their targets/goals/objectives to be in line with their predefined mission and vision.

In this paper, a performance evaluation framework regarding research publications has been proposed, based on a relational database design methodology. After proposing a conceptual design of a relational database in a form of an EE-R diagram, a total of 13 representative research-related KPIs have been specified, along with the corresponding SQL queries against the proposed relational database schema. All of them utilize the COUNT(.) aggregation function to yield summary results; however, SQL queries can be easily modified to retrieve particular records, i.e. tabular data from the physical database.

The benefits of the hereby described approach are multiple: (1) the conceptual design allows quick and easy modifications in terms of adding new entity types, attributes, and relations, as well as updating or deleting the existing ones in the EE-R diagram, to meet the specific KPI requirements of any type of research-oriented institution, exactly and consistently; (2) any modifications in the conceptual design can be easily mapped into a corresponding logical design, which allows for quick and easy adaptation of the SQL scripts implementing the hereby addressed KPIs; (3) the logical design allows for specifying a range of additional research-oriented KPIs, based on the same data; (4) the hereby described relational database approach can serve as a solid foundation to develop and implement KPIs, other than research-oriented ones, to satisfy the needs of research-oriented institutions; (5) since the described approach and all resulting SQL scripts are platform-independent, they can be successfully implemented in various relational DBMSs; (6) the proposed approach can serve as a basis for building up either a stand-alone software application, a software module as an integral part of a previously deployed management information system, or a cloud-based software solution.

As per the limitations of this research, it should be notified that several research-oriented KPI categories and their corresponding sub-categories are not taken into account, such as the income from research calculated at the institutional level (e.g. average research income per Full-Time Equivalent (FTE) for academic and research staff; research income from the industry; the proportion of research grants and contracts awarded per proportion of academic staff costs; and total research income); KPIs related to adequate research facilities; membership in national academies of arts and sciences; tenured faculty staff; the M.Sc./MA and Ph.D./D.Sc. theses completed;

projects and their funding; national and international awards gained by researchers; membership of researchers in professional scientific bodies; patents' ownership; researchers' participation in projects; the number of spin-out companies; etc. Nonetheless, all of these shortcomings can be successfully addressed by simply expanding the hereby proposed conceptual and logical design.

When it comes to the performance of SQL queries' execution, which is a purely technical aspect, it should be pointed out that the intensive usage of INNER JOINs is likely to lead to its significant degradation, an issue that can be possibly resolved by the appliance of any denormalization techniques.

The hereby presented approach can be equally effectively applied in addressing KPIs in other spheres, such as business and economy, industry, education, etc. In the future, this research (particularly the proposed EE-R diagram) is going to be extended (a) to include several new supplementary entity types and relationships so that an additional set of research-oriented KPIs can be fully addressed, and (b) to enrich the existing entity types by adding extra attributes.

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