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MODEL OF THE PROCESS FOR EVALUATING THE LEVEL OF INTERNATIONALIZATION OF THE SCIENTIFIC INSTITUTION ACTIVITIES

The article outlines the reasons for the lack of software tools and analytical platforms for evaluating the level of internationalization of scientific institutions and provides arguments for the feasibility of their creation. To eliminate the contradiction between the generally recognized importance of such evaluation and the absence of the specified means, a model of the process for evaluating the level of internationalization of scientific institutions is proposed. The model contains a description of the context of the main process, its two-level decomposition and a list and purpose of intermediate artifacts. Such a model can be used as the basis for developing a software framework for automating routine tasks of a research or practical and experimental nature in the development and testing of methodologies for evaluating the level of internationalization of scientific institutions.

Keywords: internationalization of scientific institutions; evaluation of the level of internationalization; model of the process of evaluating the level of internationalization; software engineering.

Introduction

The concept of internationalization of scientific activity emerged in the last decades of the last century as a result of the process of globalization of the world economy. The concepts of internationalization and globalization are not identical or even synonymous, although they are sometimes used interchangeably. A more balanced approach assumes that internationalization implies the presence of nations and nation-states and their movement towards interaction with other nations, cultures, etc. in the context of scientific activity, while globalization is simply “the flow of technologies, economy, knowledge, people, ideas across borders” [1].

Measuring the level of internationalization of scientific activity is a difficult problem due to the complexity and diversity of the phenomenon itself. This can be a global, national, regional, industry level or institutional level. At the same time, several stages (phases) of involvement in internationalization are distinguished, where the initial one involves a simple expansion in joint programs and events, and the advanced one (mature) involves the formation of a scientific and event agenda [1, 2].

Therefore, the unambiguous choice of indicators that would reflect the level of internationalization is a problem. Various authors [3, 4] reasonably propose such sets, for example, 186 and 35 indicators, respectively, to evaluate the level of internationalization of universities, which are of known interest, however, do not constitute their universal list.

At the same time, contrary to the opinion that there is no “ideal data set” for evaluation the productivity of universities [5, 6], there are publicly recognized, although not ideal, practices for evaluation their productivity (and not internationalization) in the form of rating systems, such as ARWU, THE WUR, SCImago or CWTS Leiden Ranking [7-10].

Therefore, given the generally recognized importance of evaluation the level of internationaliza-tion, it can be hoped that the introduction of the practice of building sound, albeit imperfect, systems for evaluation the level of internationalization of scientific institutions could be useful for both resea-rch and management applications.

Purpose and objectives of the study

The purpose of this study is to build a model of the process of evaluation the level of internationalization, which can be used as the basis for developing a software framework for automating routine tasks, research or practical and experimental nature, accompanying the construction of a system for evaluation the level of internationalization of scientific institutions.

Such an evaluation system is a framework for supporting the formation of a methodology and calculating the level of internationalization of scientific and research institutions.

Without limiting the generality of the consideration, it can be assumed that institutions belong to a certain, for example, national or regional academy of sciences, which in their activities are guided, in addition to their own policy and strategy of internationalization, by common guidelines and work in a common legal field. If this is not the case, then the specified institutions are guided, in addition to their own policy and strategy of internationalization, by market expectations and work in a common field of international law.

Since determining the level of internationalization of scientific and research institutions makes sense only from the point of view of a certain common, for example, industry, strategy, it is accepted that the evaluation of the level of internationalization occurs in the presence of a single (at this stage of development of the industry) option of the internationalization strategy. It is believed that the internationalization strategy of each individual scientific and research institution does not contradict the common strategy.

Since public consensus on the methodology for calculating the internationalization level evaluation is a necessary condition for the significance of the internationalization level evaluation process, to ensure it, it is advisable to adopt the following system boundaries:

- the actual Program System of Level Evaluation (PSLE);
- Executive Expert Group (EEG), responsible for creating and agreeing on the methodology (methodology, method of calculating) of the internationalization level;
- Stakeholders Community (SC), with advisory powers regarding the coordination of the methodology;
- Public area (PA), where the current results of the internationalization level evaluation are published as well as methodology and calculated scores.

Modeling methodology and notation

The model of the process of evaluation the level of internationalization of research institutions is built on the basis of a process approach, which consists in structuring the modeling object according to the elements of its activity. Such models are also called functional models, and the following basic principles are used for their construction and presentation:

- the principle of abstraction, which consists in highlighting essential elements of the system and neglecting non-essential ones;
- the principle of formalization, which consists in the need for a clear methodological approach to representing the system, establishing and adhering to certain formal rules;
- the principle of coherence, which consists in the validity and coherence of elements;
- the principle of decomposition, which involves presenting activities by dividing complex processes into components;
- the principle of hierarchical ordering, which involves a tree-like presentation of the decomposition results.

The following model of the system for evaluation the level of internationalization of research institutions is built on the basis of a process approach and contains:

- information about processes: procedures (functions, work), the implementation of which allows achieving a result in our case is evaluating the level of internationalization of research institutions;
- information about the structure of processes;
- information about the sequence of process execution;

- information about input objects necessary for the implementation of processes;
- information about output objects that are the result of the implementation of processes;
- information about mechanisms for controlling the implementation of processes;
- information about mechanisms for provision: means, resources by which processes are implemented.

To present the model for evaluation the level of internationalization of research institutions, the Eriksson-Penker extension [11] of the Unified Modeling Language UML [12] is used. It involves the use of a set of stereotypes to represent processes, resources, rules and objectives of activities, in particular:

<<process>> - an activity that results in a change in state or the creation of new resources. Processes are regulated by rules;

<<resource>> – resources used, consumed, improved or produced by processes;

<<goal>> – the goal of the process (activity).

The Eriksson-Penker extensions provide a representation of a process using UML by stereotypically mapping activities onto <<process>>. In this approach, a process accepts input resources from the left side and outputs resources from the right side, stereotypes <<in>> and <<out>> respectively on arcs, as can be seen from Fig. 1.

The main objects used in a process model are:

- goal objects, <<goal>> – resources related to the activity (process) through a dependency with the <<achieve>> stereotype. They will always be located on top of the process in diagrams;
- control objects – resources that control the process. Related to the activity (process) through a dependency with the <<control>> stereotype. They will always be located on top of the process in diagrams;
- support mechanism objects – resources that participate in the process, but are not consumed or improved as a result of the process. Related to the activity (process) through dependencies with the <<implement>> and <<coord>> stereotypes. In the diagrams, they will always be located at the bottom of the process;
- input objects – resources that are fed to the process input. Related to the activity (process) through dependencies with the <<in>> stereotype. In the diagrams, they will always be located on the left side of the process, so in the diagrams, the <<in>> stereotype will be omitted;
- output objects – resources produced or improved during the process. Related to the activity (process) through dependencies with the <<out>> stereotype. In the diagrams, they will always be located on the right side of the process, so in the diagrams, the <<out>> stereotype will be omitted.

The main process environment

The system for evaluating the Level of Internationalization of a Research Institution (IRI level Evaluation System, ES), as can be seen from Fig. 1, is an activity or process for specification and calculation of the Level of Internationalization (LI) of Research Scientific Institutions (RSI).

The purpose of the activity is the implementation of the research institution's internationalization policy (Implementation of internationalization policy), which is reflected by the stereotype <<goal>>. It is determined by the criteria for establishing the compliance of the designed methodology with the current internationalization strategy.

The implementation of the activity is guided by the research institution's Internationalization Strategy (IS), which is reflected by connection with the resource <<control>>, - a set of provisions of a regulatory, managerial, technical, etc. nature, relevant to the community of stakeholders.

The following resources are fed to input (stereotype <<in>>) of the LI of RSI process:

- a list of RSI, the level of internationalization of which needs to be determined (Research Institutions list, RI list);
- data on activities that can characterize the level of internationalization of the specified RSI (IRI Data). In general, the composition of the required data is unknown in advance and may change over time.

The following resources are fed from output (stereotype <<out>>) process:

- evaluation of the level of internationalization of research institutes (Assessment of IRI level), which is a resource that contains a list of research institutes together with evaluations of the level of internationalization, and can have a categorical, numerical, graphical, etc. representation;
- methodology for determining the level of internationalization of research institutes (Methodology).

The main mechanism for implementing activities at all stages is the Experts' executive group. Another mechanism is the Expert community of stakeholders which performs an advisory function

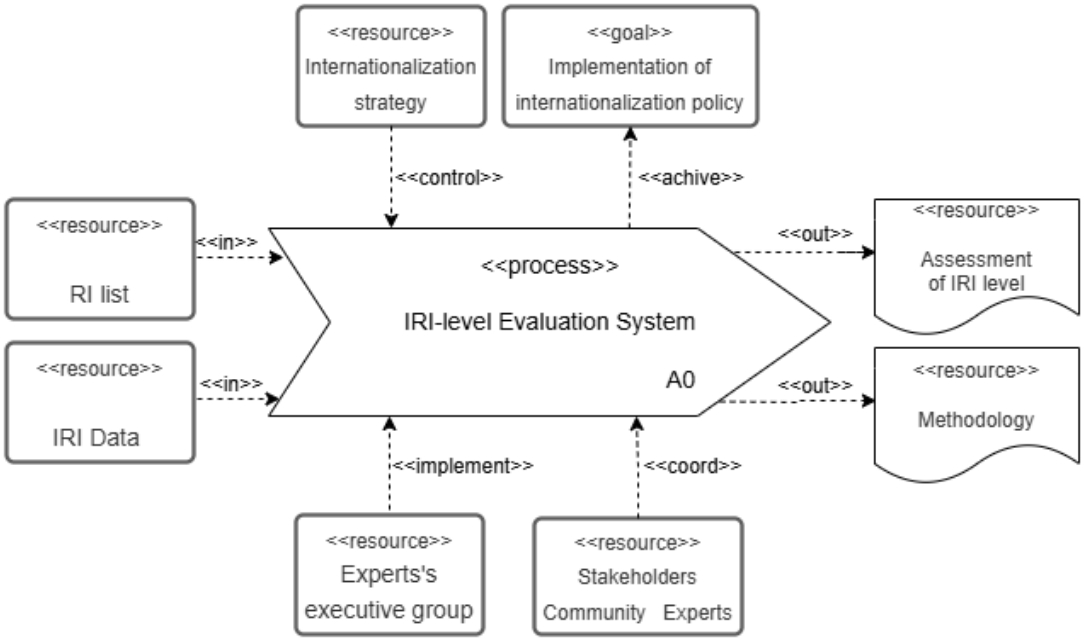

Fig. 1. Context diagram of the model

of coordinating activities in the sense of complying with quality requirements and finding consensus solutions, acceptable to stakeholders.

General structure of the model

As a result of the analysis of the activities required for the evaluation of the LI of the RSI, a model was built, the hierarchical structure of which is presented in Fig. 2. The main process is IRI level Evaluation System, designated as A0, which, as a result of decomposition, can be represented as four sub-processes:

- design of the system for evaluating the level of internationalization of the RSI (Design ES) – A1;
- study of the evaluation system (Study ES) – A2;
- acceptance of the current state of the IL RSI evaluation system as meeting the quality criteria (Acceptance ES) – B1;
- use of the specified IL RSI evaluation system (Usage ES) – A3.

Decomposition of the process of designing the LI RSI evaluation system A1 (Design ES), contains four processes:

- A1.1 – Choice of dimensions;
- A1.2 – Choice of indicators;
- A1.3 – Choice of the needed data;
- A1.4 – Choice of the type of ordering and aggregation;

The process of studying the LI RSI evaluation system A2 (Study ES), is represented by the next processes:

- A2.1 – Normalisation;
- A2.2 – Weighting;
- A2.3 – Aggregation of advantages and ordering (Aggregation);

- A2.4 – Checkup of the properties of the current evaluation option (Checkup). This process may contain various expert or statistical test procedures to determine compliance with quality criteria.

Process B1 is structurally simple.

The decomposition of the process of using the specified evaluation system (Usage ES) A3, contains four processes:

- A3.1 – estimation (calculation) of the level of internationalization of the RSI (Estimated IRI);
- A3.2 – graphical representation of the results of the evaluation of the RSI (Visualisation of results);
- A3.3 – description of the methodology of the evaluation of the RSI (Description of the methodology);
- A3.4 – publication of the results of the evaluation of the RSI (Publication of results).

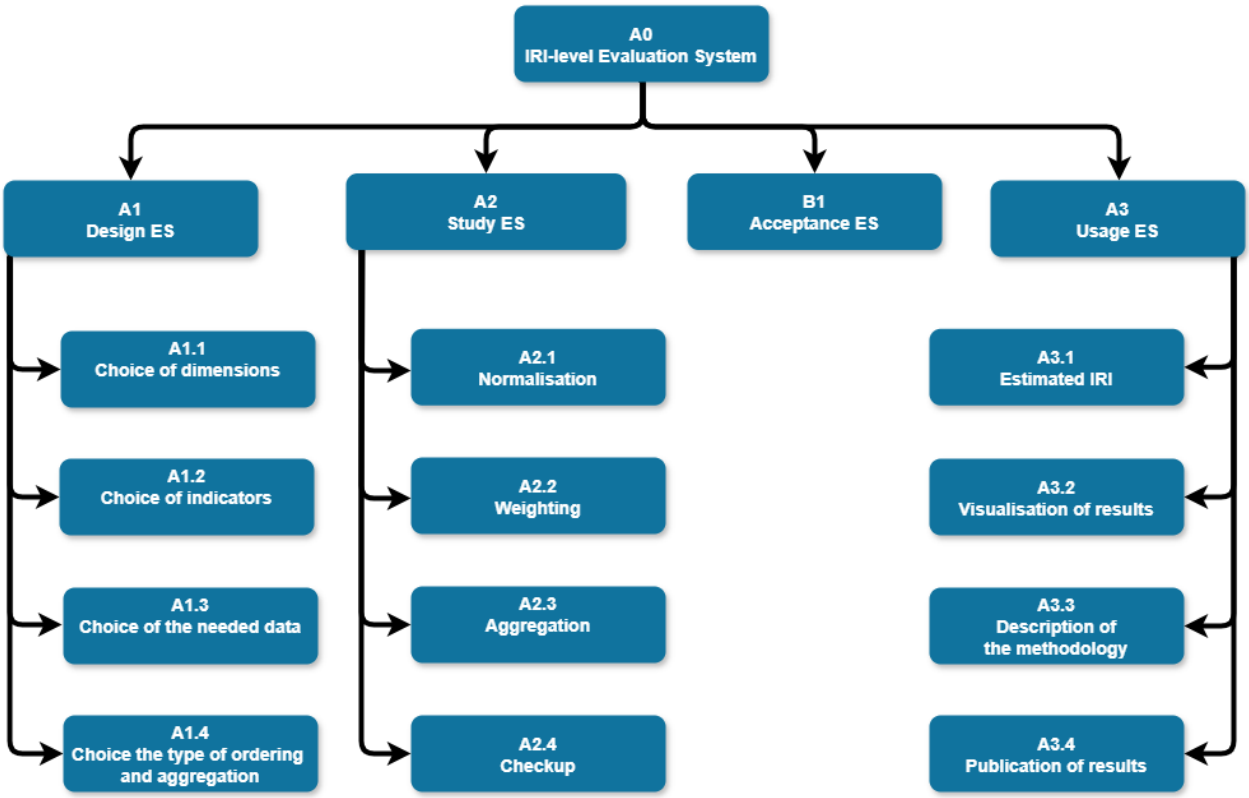

Fig. 2. Model node tree

The structure of the IRI level Evaluation System process

As can be seen in Fig. 3, the evaluation of the RSI consists of four stages: the design processes (Design ES); the study of the evaluation system (Study ES); the acceptance of its current state as meeting the quality criteria (Acceptance ES) B1; and the use of the specified evaluation system (Usage ES).

Input resources, the list of RSI and data on their activities (RI list and IRI Data) are available at each stage for full or partial use, therefore they are not shown in the diagram.

The same applies to the: target object - Implementation of internationalization policy; the control object - Internationalisation strategy; and the mechanisms of provision - the Experts' executive group and the Expert community of stakeholders.

The input of the evaluation system design process Design ES, node A1, in addition to RI list and IRI Data, may also include recommendations. The Recommendations resource, created during the execution of the Study ES process, node A2. This resource should be taken into account if its receipt is accompanied by the transfer of a control flow from the process of accepting the current state of the evaluation system Acceptance ES, node B1.

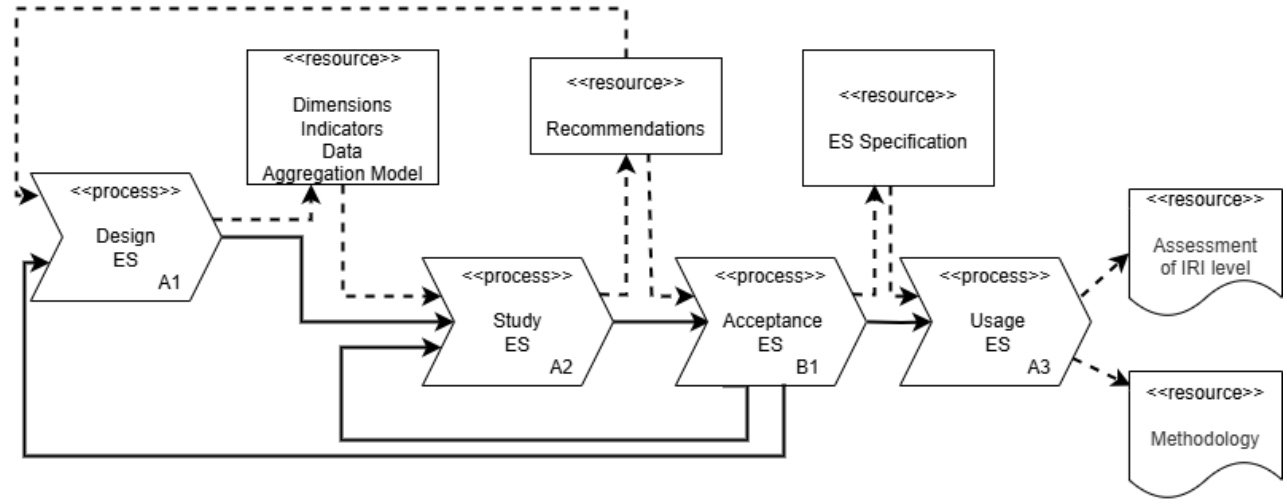

Fig. 3. Decomposition of process A0

The output of the Design ES process is the selected sets of dimensions and internationalization indicators, the method of aggregation of the advantages of the RSI and the method of their ordering, and the list of necessary data.

The control flow, after the execution of Design ES, is transferred to the Study ES process together with the resource-result of the execution of Design ES.

The Study ES process may receive a control flow from the process of accepting the current state of the evaluation system Acceptance ES, node B1, which means the need to find another version of the Recommendations resource.

The execution of the evaluation system study process (Study ES) leads to the construction of the Recommendations resource.

The Study ES process passes the control flow and the Recommendations resource to the Acceptance ES process.

If the Acceptance ES process determines that the quality criteria are not met, the control flow is passed to the Study ES processes to generate a new version of the Recommendations and/or the Design ES process to review the sets of dimensions, internationalization indicators, and methods of aggregation of benefits or ordering. If the quality criteria are met, the Recommendations are transformed into specifications (ES Specification resource) and passed, together with the control flow, to the ES Usage process (ES Usage, node A3).

The ES Usage process, using the ES Specification resource as its input, performs the IRI evaluation and generates the output resources – IRI level Assessment and Methodology.

The structure of the evaluation system design process (Design ES)

The design of the Internationalization Level Assessment System for the IRI, as can be seen from diagram A1 in Fig. 4, and consists of four stages. These are the Choice of dimensions' processes,

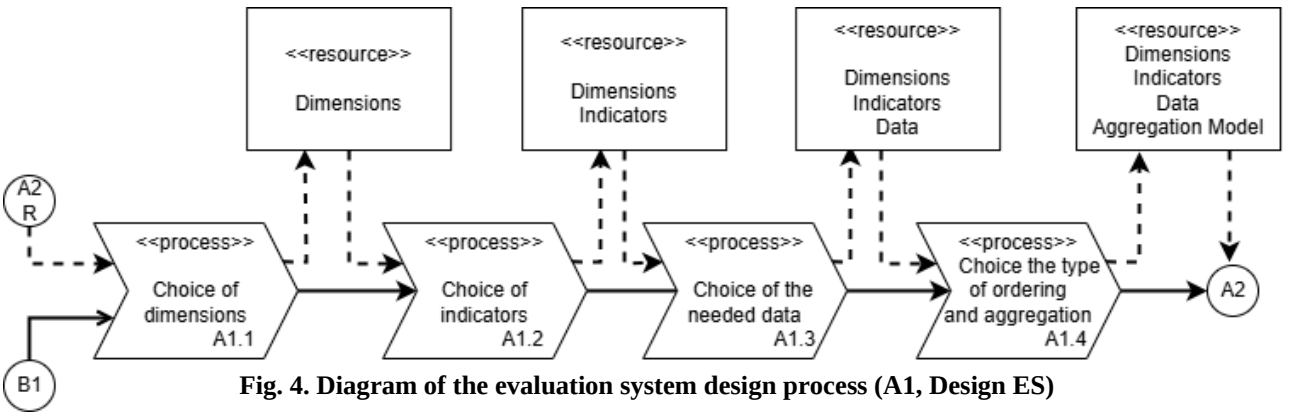

Fig. 4. Diagram of the evaluation system design process (A1, Design ES)

Choice of indicators processes, Choice of the needed data processes and Choice of the type of ordering and aggregation processes.

The resources of the process environment are available for each sub-process and therefore are not shown in the diagram.

On the input data RI list and IRI Data, when executing the Choice of dimensions' process, guided by the Internationalisation strategy, the Experts's executive group selects a set of internationalisation dimensions and coordinates the composition of this set with the Expert community of stakeholders. Thus, a set of internationalisation dimensions is formed the Dimensions resource. Here, each dimension is a composite meter (indicator) of the *n*-th level, the value of which is determined by the meters (indicators), possibly also composite, of the previous *(n-1)*-th level.

In the case of transfer of control from the B1 Acceptance ES process, the Recommendations resource generated by the A2 process is taken into account.

Further, in the Choice of indicators process, after receiving the control flow and input resources Dimensions, RI list and IRI Data, meters (indicators) are selected, if possible, necessary and sufficient to characterize each of the Dimensions Indicators of internationalization. At the output of the process a resource Dimensions Indicators, containing a set of indicators for each of the dimensions.

This resource, together with the RI list and IRI Data, is input to the Choice of the needed data process. The execution of the process at the output generates the Dimensions Indicators Data resource, which contains information about the composition and source of current data on the activities of the research institute with the RI list, in addition to a set of indicators for each of the dimensions of internationalization.

The process Choice the type of ordering and aggregation, based on the Internationalisation strategy and the input resource Dimensions Indicators Data, generates an output resource by adding to the input stream Aggregation Model – a method of aggregating the advantages of RSI by individual indicators and dimensions in evaluation the level of RSI internationalisation.

Structure of the process of studying the evaluation system (Study ES)

Study of the evaluation system of the level of RSI internationalisation, as can be seen from the process diagram A2 in Fig. 5, consists of four sub-processes: Data Normalisation (Normalisation); Data Weighting (Weighting); Aggregation of advantages (Aggregation); and clarification of the properties of the current evaluation option (Checkup).

At the input of the process there is the output resource of the process A1.4.

The Recommendations resource, initially empty, is supplemented or updated after the execution of each of the ES Study component subprocesses and, in this sense, functions as an output. However, the content of this resource is available to each subprocess as an input. It is considered to be transferred together with the control flow, and therefore is not shown as a separate connection in the diagram.

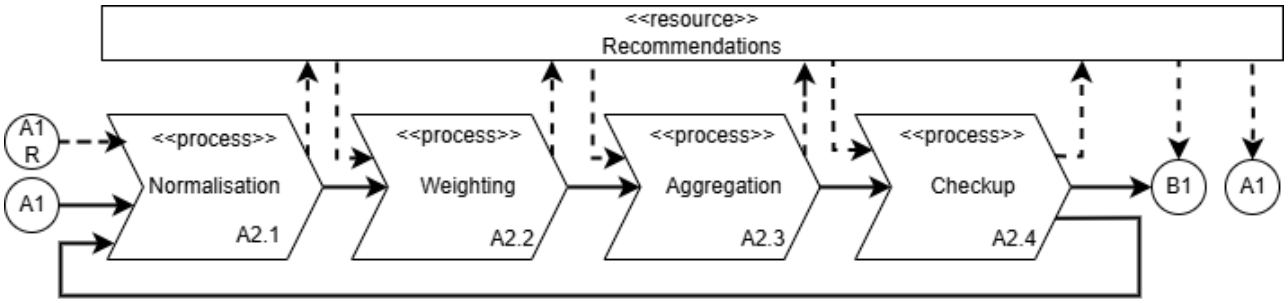

Fig. 5. Diagram of the evaluation system research process (A2, Study ES)

In the Data Normalization process; data is brought to one range (actually normalization); data outliers are detected and their impact is considered; the necessary transformations of indicators are considered.

The Data Weighting process: examines the properties of the data in terms of their significance, determines the decision-making regarding the adopted scales, the admissibility of correlation and compensation of indicators.

The Aggregation process significantly depends on the results of the stages and already considered and determines the decision-making on the properties of the relationships for constructing the final ordering of RSI by the level of internationalization. Such properties may include, in particular, such relations as: transitivity, negative transitivity, reflexivity, irreflectivity, asymmetric, antisymmetric, completeness, strict completeness, etc.

The process of clarifying the properties of the current evaluation option (Checkup) may contain various expert and/or statistical test procedures to clarify the compliance of the selected parameters of the evaluation process with the relevant quality criteria.

The transfer of the control flow from A2.4 to process A2.1 occurs if not all of the selected parameters of the evaluation process meet the requirements of the relevant quality criteria.

The process of accepting the evaluation system (Acceptance ES)

The structurally simple process B1 of accepting the current state of the LI RSI evaluation system (Acceptance ES), presented in Fig. 3, receives the control flow from process A2 and the Recommendations resource formed in the process of research for compliance with the quality criteria. Here, in process B1, a final conclusion is made on the acceptance or rejection of the procedures for evaluation the level of internationalization reflected in the Recommendations resource.

If a decision is made to accept, then the current content of the Recommendations resource is converted into the ES Specification resource by supplementing it with elements important for the Usage ES process.

If a decision is made to reject, then the control flow is transferred to processes A1 and A2, where work continues on such a set of procedures for evaluation the level of internationalization (Recommendations resource) that would have been accepted by process B1.

Usage process (Usage ES)

The use of the specified system for evaluation the level of internationalization of the RSI, as can be seen from diagram A3 in Fig. 6, consists of four obvious subprocesses.

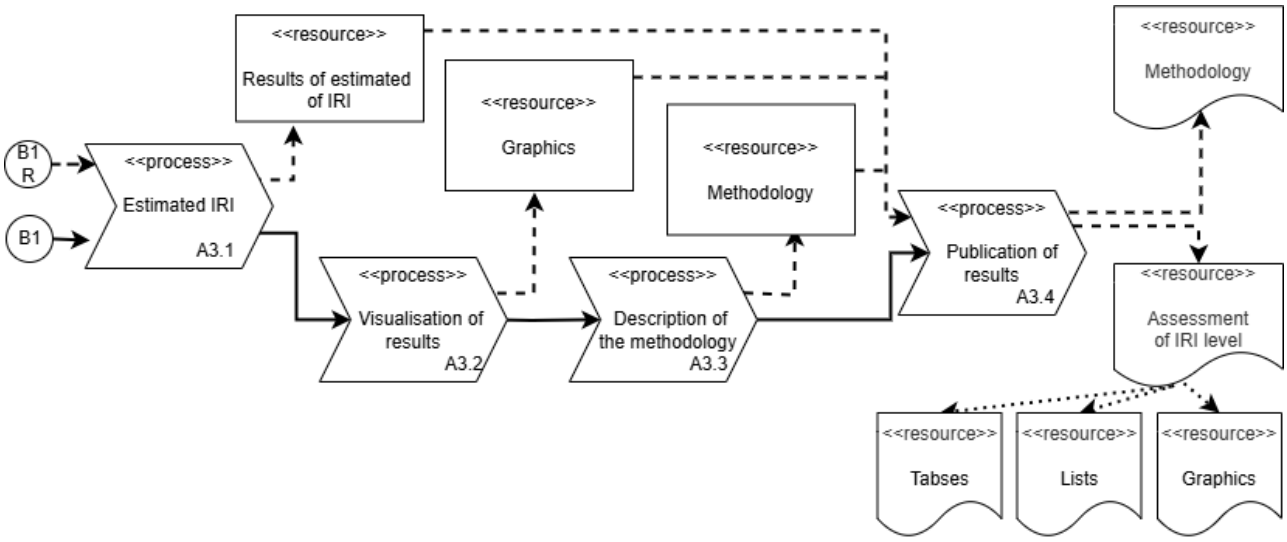

Fig. 6. Diagram of the process of using the evaluation system (A3, Usage ES)

Each of the processes, such as: A3.1 - estimation (calculation) of the LI RSI (Estimated IRI); A3.2 - graphical representation of the evaluation results (Visualisation of results); A3.3 - description of the evaluation methodology (Description of the methodology), as a result of execution generates the corresponding resources indicated in the diagram. All these resources, together with the control flow, are fed to the input of the process A3.4 - publication of the results of the evaluation of the LI RSI (Publication of results), the output of which is the resources Methodology and Assessment of IRI

level. The last one can be presented in the form of, for example, tables, lists, or in graphical form. The presentation options are indicated by dotted lines connections.

Conclusion

1. The importance of evaluation the level of internationalization of scientific institutions is generally recognized, despite differences in the definition of the concept of internationalization and the complexity of the phenomenon itself.

2. Currently, there are no software tools to support efforts to develop and test methodologies for evaluation the level of internationalization. There are also no projects to evaluate the level of internationalization of scientific institutions, similar, for example, to the university ranking, where their performance is evaluated using various methodologies.

3. The model of the process of evaluation the level of internationalization is presented, which contains a description of the context of the process, a two-level decomposition of the main process as well as the list and purpose of intermediate artifacts.

4. The proposed model can be used as the basis for developing a software framework for automating routine tasks of a research or practical and experimental nature in the development and testing of evaluation methodologies.

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МОДЕЛЬ ПРОЦЕСУ ОЦІНЮВАННЯ РІВНЯ ІНТЕРНАЦІОНАЛІЗАЦІЇ ДІЯЛЬНОСТІ НАУКОВОЇ ІНСТИТУЦІЇ

Стаття підкреслює важливість оцінки рівня інтернаціоналізації наукових інституцій, незважаючи на відмінності у визначенні поняття інтернаціоналізації та складність самого явища. В той же час відсутні програмні засоби для підтримки зусиль з розробки та тестування методологій для оцінки рівня інтернаціоналізації. Також відсутні проєкти оцінки рівня інтернаціоналізації наукових установ, подібні, наприклад, до рейтингу університетів, де їх діяльність оцінюється за різними та часто несумісними методологіями.

Автори статті досліджують причини відсутності програмних засобів та аналітичних платформ для оцінки рівня інтернаціоналізації наукових установ та наведено аргументи щодо доцільності їх створення. Для усунення суперечності між загальновизнаною важливістю оцінювання рівня інтернаціоналізації та відсутністю цих інструментів запропоновано модель процесу оцінювання рівня інтернаціоналізації наукових установ.

Модель процесу оцінювання рівня інтернаціоналізації науково-дослідних установ побудовано на основі процесного підходу, який полягає у структуруванні об'єкта моделювання за елементами його діяльності. Такі моделі ще називають функціональними. Для представлення моделі оцінки рівня інтернаціоналізації науково-дослідних установ авторами запропоновано використання розширення Еріксона-Пенкера уніфікованої мови моделювання UML. У результаті аналізу заходів, необхідних для оцінки рівня інтернаціоналізації наукових установ, було побудовано модель ієрархічної структури, що передбачає використання набору стереотипів для представлення процесів, ресурсів, правил і цілей діяльності. Запропонована модель містить опис контексту основного процесу, його дворівневу декомпозицію та перелік і призначення проміжних артефактів.

Розроблена модель може бути використана як основа для розробки програмної основи для автоматизації рутинних завдань дослідницького або практично-експериментального характеру при розробці та апробації довільних методологій оцінки рівня інтернаціоналізації науково-дослідних установ.

Ключові слова: інтернаціоналізація діяльності наукових інституцій; оцінювання рівня інтернаціоналізації; модель процесу оцінювання рівня інтернаціоналізації; інженерія програмного забезпечення.