# Principles of the Knowledge Base Formation as a Part of Intellectual Decision Support System in Innovative Projects Management

Liliya Chernyakhovskaya
*Computer science and robotics department*
*Ufa state aviation technical university*
Ufa, Russia
lrchern@yandex.ru

Nataliya Nikulina
*Computer science and robotics department*
*Ufa state aviation technical university*
Ufa, Russia
nikulinano@outlook.com

Anna Malakhova
*Computer science and robotics department*
*Ufa state aviation technical university*
Ufa, Russia
aimalakhova@gmail.com

*Abstract*—**According to methodology of decision making support in innovative projects management, developed on the previous stages of the research, a method of expert's knowledge formalization based on the decision making support ontology, was developed. The method allows to integrate the means of ontological analysis and knowledge representation in the knowledge base creation for decision making support in problem situations. Knowledge base is structured according to the set of classes selected by the results of ontological analysis. Knowledge, which logical system is ordered, is presented in the module of rules. Decomposition of the rule base is performed in accordance with the hierarchy of objects established as a result of modelling. Empirical knowledge for solving the problems of innovative projects management is presented in the form of cases for providing recommendations that can be adapted to a concrete problem situation.**

***Keywords—knowledge base, intellectual decision making support, innovative projects management, ontological engineering, knowledge management, decision making rules, cases of problem situations***

## I. Introduction

One of the main conditions for passing the country's economy to an innovative development cause is to increase the innovative activity in business. The state pursues an active policy for promoting the growth of innovative activity for companies and increasing the effectiveness of its innovations. In recent years, a number of important measures have been implemented in the framework of innovation policy for encouraging the companies to innovate and to develop various tools for supporting technological modernization, but with some improvements, the overall progress in this area remains unstable [1].

Multifaceted activity nature, presence of fundamental differences in developing conditions and levels of various Russian economy sectors exclude the possibility of building a universal innovative development model suitable for each enterprise. Do not forget that the last step is directly for the companies, which should independently determine specific ways and forms of its innovations.

At the previous stages of the authors research [2, 3], a methodology for forming the systems, providing information and intellectual decision-making support in innovative projects management, was formed. It is based on the system of intellectual management principles, including:

*1)* a principle of building a unified information environment for the innovative projects management in conditions of uncertainty and the risk in problem situations;

*2)* a principle of developing a knowledge base in a unified information environment based on the technology of distributed knowledge processing with the use of shared ontology for users and experts interaction in innovative projects management;

*3)* a principle of developing an information and algorithmic decision-making support for projects management in conditions of uncertainty and risk using knowledge base, decision making mathematical models, as well as artificial intelligence methods.

Methodology is focused on organization of processes management and providing the intellectual decision making support in problem situations. Decision making and realizing in problem situations (PS) – is one of the most difficult management aspects [4]. Decisions in PS conditions are often taken in a various operation situations, including critical, and within a limited time, which does not remove the requirements to decisions validity, full and effective use of all opportunities available to decision makers (DM). In such terms, a comprehensive, objective assessment of situation and its development prospects, a clear understanding of the directions and activity objectives, knowing the capabilities and resources necessary to manage the situation, as well to form a variant leading to a solution, are required [5]. Thus, the purpose of intellectual management is to help a group of project participants in making decisions based on knowledge management.

Such support is particularly relevant for innovative projects management in various activity fields, due to a priori high degree of such projects novelty and uniqueness and uncertainty in estimating the problem situations consequences [6]. A structured knowledge system presence will prevent the negative error consequences in problem situations solving and ensure a stable project implementation according to the set goals.

## II. Developing the Knowledge Base Structure as a Part of IDSS in Innovative Projects Management

As a part of the research possibility of using the intellectual knowledge management technologies to improve the efficiency of the project "Reconstruction and technical

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re-equipment of the production base of PJSC "UEC-UMPA" for producing the components and assemblies of the helicopter engines such as TV3-117 and VK-2500", is considered [7]. This project is one of the large Program stages for organizing a serial production of helicopter engines in the Russian Federation [8].

During the innovative project execution analysis one of the main problems faced by all, without exception, decision makers, acting as project managers at any level of the organization structure, was identified. This problem is related to selection and appointment of the executors with not only certain professional knowledge and skills, but also the qualities necessary to work in a team. In this case, a most difficult situation seems to be for the DM, which is both the executor, responsible for obtaining one of the project results or completing some project stage, and the manager who must correctly identify the executors for the assigned complex of project tasks. It is well known that not always one person can combine the qualities of a good leader and a professional in the subject area. In this case, the generalized knowledge and experience will help to avoid mistakes or at least reduce the negative consequences.

The peculiarity of the proposed methodology is a possibility for a unique "filling" of the models and methods content, depending on the specifics of the project, the data and knowledge about the composition of its stages, the list of estimating indicators and evaluating methods, allowing to automate the decision making process, as well as to create algorithmic support and software for decision making processes, adaptable to a specific industry and project.

Knowledge base in the intellectual decision support system is developed on the basis of integrated ontology logical model [9], using two models of knowledge representation – in the form of decision making rules and in the form of problem situations cases (fig. 1).

As a knowledge source perform the data contained in project documentation, moreover, are considered as the current project documents, and also the data contained in the document sets on previously closed projects. This approach allows to accumulate in the knowledge base both positive and negative experience of decision making in problem situations arising during the innovative projects implementation in concrete industry.

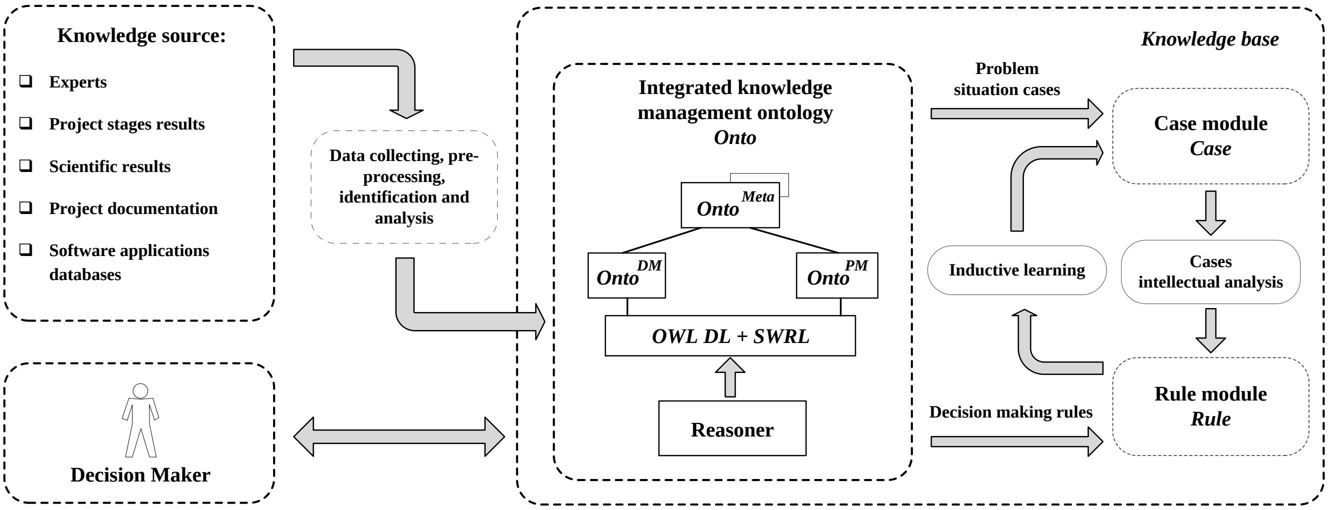


Fig. 1. Knowledge base structure as a part of IDSS

Like the experts can act as the project team participants, managers and users, members of the project management office, enterprise management representatives with sufficient qualification, knowledge and experience in PS decision making , as well as experts of subject area and field of knowledge engineering. This is actually for innovative projects, as the number of project stakeholders varies depending on the execution specifics. It is important to consolidate and not to lose the existing corporate experience in innovative projects management and decision making in problem situations similar to those arising in the current project.

At the modern level of project management there is a possibility for complex automation of project management processes, which obliges to analyze and process data on the project stages and phases contained in software applications. All mentioned above together with the actual project and studies results serve as the basis for the knowledge base building. By the results of data collecting, processing, identification and analysis knowledge is recorded in an integrated ontology, which is a central element of the knowledge base and includes the decision making support tasks, models and methods ontology and the project management ontology. This approach allows to take into account the requirements to theory and technology of distributed knowledge processing and use modern languages of decision making rules representation in problem situations [10].

Knowledge whose logical system is ordered is presented in the rules module using the Semantic Web Rule Language (SWRL). Using SWRL-rules is a simple and convenient mean for introducing the productive nature knowledge into the ontological model. SWRL is the extension of the OWL language – when forming the antecedent and consequent parts of the rule, the objects of developed OWL DL ontology are used. Thus, integration of the rules into the ontology semantic network is supported, since while the rules developing are used the predicates defined in ontology in terms of forming the class hierarchy axioms, describing the association relationships and the axioms imposed on the class properties.

Obtained rules are written in ontology in the following form:

$$Rule\!: C_1(?x) \wedge C_2(?y) \wedge P_1(?x, ?y) \wedge C_3(?x, ?z) \rightarrow C_2(?z, ?y), \quad (1)$$

where $(C_1, C_2, C_3) \in C$, $C$ – a class in *OWL DL*;
$P_1 \in P$, $x$, $y$ – individuals or variables;
$z$ – variables or values.

The syntax for SWRL abstracts from any exchange syntax for OWL and thus facilitates access to and evaluation of the language. This syntax extends the abstract syntax of OWL described in the OWL Semantics and Abstract Syntax document [OWL S&AS]. Even this abstract syntax is not particularly readable for rules. Examples will thus often be given in an informal syntax. This informal syntax will neither be given an exact syntax nor a mapping to any of the fully-specified syntaxes for SWRL [11].

A rule axiom consists of an antecedent (body) and a consequent (head), each of which consists of a (possibly empty) set of atoms. Informally, a rule may be read as meaning that if the antecedent holds (is "true"), then the consequent must also hold.

An ability to work with SWRL rules has already been implemented in many ontology editors, including Protégé. SWRL rules do not contain specific objects, but only refer to them, which makes it possible to apply the same rule to a number of object groups. A fragment of decision making rules developed for the project in the project management ontology is presented in fig. 2.

Rules, formulated in ontology, express casual relations between the events classes that arise during the innovative project execution and are the PS causes, the problem situations themselves and the actions that should be taken by the DM to solve such problem situations. For example, mentioned above rules contain typical project risks, identified on the previous stages of research and belonging to the different risk groups, the failure consequences and causes, measures to detect and prevent these risks.

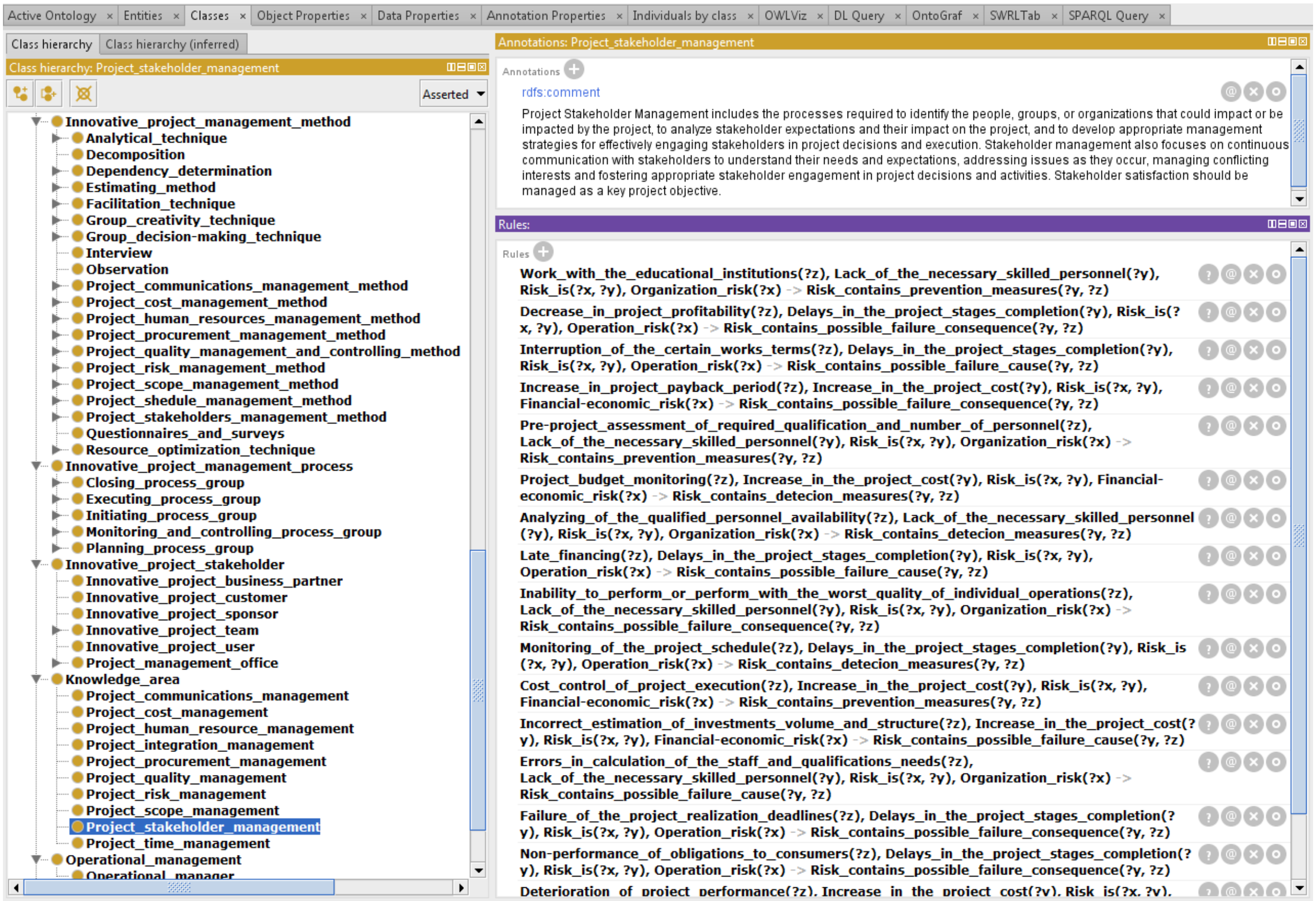


Fig. 2. Fragment of the decision making rules in ontology

Thus, we propose an algorithm for knowledge obtaining from the ontology based on the rules and on the rules logical inference mechanism, the result of which is a generation of messages about problem situations, decision making or event management by issuing commands to perform control actions.

In addition, it is offered to fix in integrated ontology problem situations and decisions taken on them, which took place during the innovative projects development in the form of problem situations cases. Rules for these problem situations have not yet been formulated due to the lack of sufficient decision making examples. Ontological analysis allows to reveal the most essential signs of problem situations, to classify cases on various bases, to generalize and specify a separate, inconsistent and incomplete information. This approach will allow managers and team members of subsequent projects also contact them in the case of similar problems arising by adapting them to a specific problem situation.

An important point while building a knowledge base is the presence in the rules and cases instructions to the project participants, who performed given actions, or should implement proposed recommendations and be responsible for its realization.

For example, the following problem situation case was recorded within the project:

***Problem level*** *– middle.*
***Problem description*** *– Risk in the equipment delivery terms failure by the supplier that might affect the object commissioning term.*
***Problem registration date*** *– 20.01.19.*
***Decision making proposal –*** *Sending the specialists to the equipment manufacturer for inspecting its industry.*
***Official person (DM)*** *– Technical director.*
***Decision term*** *– 15.02.19.*
***Decision status*** *– on the control.*

This case will be presented in a case module of the ontological knowledge base as an individual of the class "***Case with category N***" with the corresponding data types values.

In order to use and share effectively the knowledge in the base, it is necessary to ensure that the model is regularly replicated and that the rules and cases modules are kept up to date. The cases analysis, correction and replenishment are carried out basing on ontology and establishing the contradictions between the rules and the outdated cases.

Rule base adaptation and training is carried out on the base of the cases intellectual analysis results and generalization of the identified cases stable structures in the form of new rules, which include:

- searching for the cases similar to the current problem situation;
- applying the found cases to solve the problem;
- evaluating the effectiveness of decision making results;
- saving a new case for the current problem in the knowledge base;
- if found cases was used successfully for the current problem situation, considering the question of conversation them into the decision making rules;
- implementing the intellectual case analysis and adding new rules to the knowledge base.

Thus, mentioned above problem situation case can be transformed into the decision making rules of the following kind:

***Rule 1:*** *Production_risk(?x), Risk_is(?x, ?y), Equipment_delivery_terms_failure_by_the_supplier_that might_affect_the_object_commissioning_term(?y), Sending_specialists_to_the_equipment_manufacturer_ for_inspecting_its_industry(?z) –> Risk_has_Action(?y, ?z)*

***Rule 2:*** *Production_risk(?x), Risk_is(?x, ?y), Equipment_delivery_terms_failure_by_the_supplier_that might_affect_the_object_commissioning_term(?y), Sending_specialists_to_the_equipment_manufacturer_ for_inspecting_its_industry(?z), Risk_has_Action(?y, ?z), Technical_director(?a) –> Action_has_Executor(?z, ?a)*

## III. Approach to the Problem Situations Rules and Cases Classification in the Knowledge Base of IDSS

Modules of rules and cases in the knowledge base are structured in accordance with the set of classes identified by the results of the innovative projects management processes ontological analysis. Within the context of the considered knowledge management approach, is proposed to build a certain set of knowledge classifications, contained in the rules and cases, taking into account various aspects of decision making during project management. Such structure of the knowledge base will in practice ensure the most effective search, application and sharing of knowledge.

Initially, two types of the rules are defined: rules that specify the relations structure between the subject area object classes using object properties of classes, and the rules that define restrictions for classes individuals. Rules, belonging to the first type, are usually created with the use of expert knowledge and project management regulatory documents, for example:

***Rule 2.1:***
*has_Information_Innovation(?x, ?c),*
*has_Organozation_Innovative_Activity(?x, ?d),*
*has_Technical_Innovation(?x, ?a),*
*has_Technology_Innovation(?x, ?b) –> Inn_Project(?x)*

***Rule 2.2:***
*Problem_situation(?x), Problem_solving(?solv), connected_With(?x, ?PrSp), connected_With(?x, ?com), has_Alternatives(?x, ?v), has_Criterion(?x, ?c), has_Decision(?x, ?d), has_Text_Description(?x, ?b), is_Recognition(?x, ?a) –> has_Problem_Solving(?x, ?solv)*

Second type rules are formulated using data about the classes individuals, for example:

***Rule 3.1:***
*Alternative(?v), has_Advantages(?v, "Low"),*
*has_Consistency(?v, "High"),*
*has_Disadvantages(?v, "Middle"),*
*has_Preference(?v, "Low") –>*
*has_Rating_of_the_alternative(?v, "Middle")*

Rules, belonging to the second type, are built in the form of hierarchy. It is proposed to build a hierarchical knowledge base in such a way that the rule class can be a top-level class or a subclass associated with one object of the subject area. Decomposition of the rule base is performed in accordance with the hierarchy of objects established as a modeling result. Thus, each rule includes a limited number of input variables. The object hierarchy of the knowledge base is organized according to the meta-models of knowledge representation based on the principle of inheritance, which means building new classes based on existing ones with the ability to add or predefine the data and methods (for example, in the process of learning new knowledge).

As part of the research, special attention is paid to the problem situations classification according to *A Guide to the project management body of knowledge* (*PMBoK*) [12], which is an international standard in the field of project management. *PMBOK* has 49 project management processes, which are divided into 5 process groups (initiating, planning, executing, monitoring and controlling, closing).

According to the results of the analysis, it was noted that the processes are distributed among process groups and knowledge areas irregularly – there are three variants of crossing the knowledge areas with a certain set of processes from the project management process groups (fig. 3):

*1)* knowledge area covers a full set of project life cycle processes;

*2)* knowledge area covers a process core directly related to the project implementation (planning + executing + monitoring and controlling);

*3)* knowledge area covers only planning, monitoring and controlling processes.

Thus, we think it is important to classify the encountered decision making rules and problem situation cases from the perspective of referring them to the mentioned knowledge areas and project stages (process groups). According to this approach, it is possible to distinguish the decision making rules, intended for different users (project manager, executor, resource owner, etc.) in different situations related to different knowledge areas.

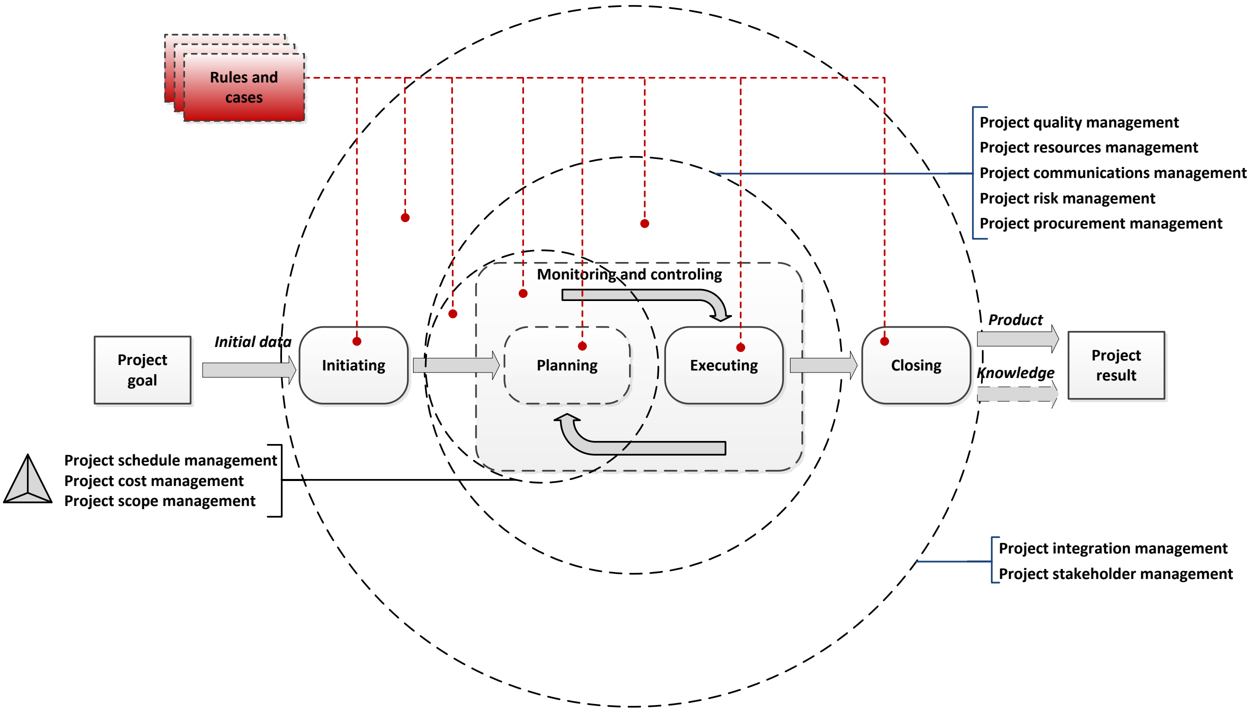


Fig. 3. Classification of the rules and cases by the process groups and knowledge areas

In addition, due to the presence in the knowledge base recommendations on the use of decision making mathematical models, methods and algorithms in the course of project management, a knowledge base contains various decision making rules in problem situations, arising while the innovative project management, and the rules of mathematical models classification.

A knowledge base checking through the systematic control in implementation conditions allows to detect and correct errors associated with the knowledge base incompleteness, and delete the conflicting and useless rules, which increases the system's accuracy and operating speed.

## IV. Conclusion

The article considers a possibility of using the knowledge management technologies to improve the innovative projects efficiency. A peculiarity of the proposed approach is a possibility for a unique filling of the knowledge base, depending on the specifics of the project, the data and knowledge about the composition of its stages, the list of estimating indicators and evaluating methods.

Knowledge base in the intellectual decision support system is developed on the basis of integrated ontology logical model, using two models of knowledge representation – in the form of decision making rules and in the form of problem situations cases. This approach to automate the decision making process, as well as to create algorithmic support and software for decision making processes, adaptable to a specific industry and project. Modules of rules and cases in the knowledge base are structured in accordance with the set of classes identified by the results of the innovative projects management processes ontological analysis. Within the context of the considered knowledge management approach, is proposed to build a whole set of knowledge classifications, contained in the rules and cases, taking into account various aspects of decision making during project management. Such structure of the knowledge base will in practice ensure the most effective search, application and sharing of knowledge.

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