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Model for Assessing the Level of Knowledge Convergence in Multinational Projects

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ABSTRACT In modern conditions, knowledge management acquires a new meaning and becomes one of the decisive factors for success in the project implementation. Knowledge transfer is significantly complicated in international projects. This requires an in-depth analysis of different participants` project management systems, identifying their differences and determining the ability to converge (convergence) through knowledge transfer. The paper proposes the model for assessing the convergence level of project management systems, which includes a fuzzy assessment of the factors influencing the ability of the system to transfer knowledge, as well as assessing the rate of convergence (approximation) in projects. The results of the study shows that the proposed methods allow identifying "bottlenecks" of knowledge transfer processes in multinational projects and determining a strategy to increase the level of knowledge systems convergence at the project initial stage. Evaluation of the accuracy and reliability of the proposed methods prove the adequacy of their applications for forecasting new project convergence level.

KEYWORDS Knowledge Transfer; Multinational Projects; Convergence; Fuzzy Logic.

I. INTRODUCTION

THE rapid digitalization of society with transition to remote operations and emergence of new accessible adapted information technologies in all areas leads to accumulation of significant information amounts. As a result, there are new opportunities for the accumulation, processing and storage of new knowledge in various information systems.

The project management (PM) is not an exception and international cooperation is becoming one of the main factors of its success. In such projects knowledge is formed in various project management systems (PMS) and methodologies used in different stakeholder organizations. It may be a reason of delays in project implementation due to overspending time on the transformation and adaptation of project knowledge in new projects. To speed up these processes, a clearly defined knowledge management (KM) procedure in international projects is needed. At the same time, the processes of KM systems integration to international projects occupy a large amount of the total project implementation time. Sometimes they run out with the project completion and become ineffective. To reduce the time for adaptation and knowledge transfer, it is possible to assess the convergence of existing stakeholder systems and determine the value of their proximity (convergence) and ability to integrate, which may significantly reduce resources to ensure their effective interaction.

II. RELATED WORKS

A brief overview of the ideas of what Knowledge Management is, shows the domain`s diversity and variety. J. Girard [1] listed over 100 definitions of KM, which may be useful for projects of different types depending on the subject domain.

KM features in multinational projects are also widely represented in various studies, e.g., T. Davenport [2] defined that the processes related to knowledge identification, capturing, developing, sharing, and using it in projects are of the highest significance, especially in multiproject environments.

KM systems and processes in project management are widely represented in the recent works. S. Geng et al. [3] proposed to develop a framework to integrate organizational knowledge development with project selection. D. Shrikant [4] examined the use of knowledge in society and explained how projects can benefit from it by the creating a rational order through storyboarding. Applied research by R. Narazaki et al. [5] solved a class of problems involving KM in PM during the whole project lifecycle with a unique artifact. In the work of P.

Edwards, P. Vaz-Serra and M. Edwards [6] a theoretical framework for defining knowledge was considered together with knowledge transformation and knowledge creation processes.

Now, as PM has been applied on a wide scale in different industries, acquiring the lessons learned from past projects is necessary. However, the issue of wise practical reusage of the knowledge gathered from completed projects becomes more and more actual.

The issue of preserving knowledge in projects was considered in [7]: M. Dülgerler and M. Negri [7] looked at the relevance of KM as a means of improving business performance through lessons learned and through a case study in the construction industry.

The issue of accumulated knowledge reuse of the implemented projects was also considered in X. Ren, X. Deng and L. Liang [8]: the results of investigation how project nature affects the effectiveness of knowledge transfer between projects in project-based organizations (PBOs) indicated that the similarity of projects could promote the interproject communication and improve transfer intention, which further influences knowledge transfer effectiveness positively within PBOs.

Araujo, V.d.A.A.d., et al. provided a better understanding that the success of projects depends on the relationship with teams and knowledge transfer processes between them [9].

Also, the crucial importance of implementing the KM transfer to other projects for successful project implementation and management was identified by Pereira, L., Santos, J., Dias, Á., & Costa [10].

The human aspects in knowledge transfer processes were presented by Zhang, Z. and Min, M. The results were based on multiple-source survey of new product development (NPD) project managers and their subordinates in China and proved that the project manager knowledge hiding was positively associated with subordinates' turnover intentions, challenge-related stress and hindrance-related stress [11].

Therefore, the next important issue of KM in projects is the assessment of the possibility of knowledge transfer taking into account the multinational projects factors.

H. Solli-Sæther, J. T. Karlsen and K. van Oorschot [12] highlighted the specifics of knowledge transfer in multinational projects. The research indicates three interesting findings. First, the differences in organizational culture (not national culture) prevent knowledge sharing. Second, a strategic misalignment made knowledge sharing difficult. Third, knowledge protection by patenting and privacy barely influences the knowledge sharing processes. Therefore, an important issue remains determination of influence factors and the value degree in the project.

X. Ren et al. [13] showed that the organizational context (meeting system, reward system and shared culture) and project characteristics (similarity and urgency) are previously affecting social relations (communication, trust and reciprocity) between project teams, and their social relations further influence the effectiveness of interproject knowledge transfer. The influencing factors were widely represented in J.T. Karlsen and P. Gottschalk [14]. Mentioned empirical research presents factors which affect knowledge transfer in information technology (IT) projects. The factors evaluated in this research are information technology, systems and procedures, and culture. Research results show that total project success is related to the extent of culture for effective knowledge transfer. Therefore, the identification and assessment of impact factors are important components in achieving project success.

S. Spalek recommended four steps in order to effectively facilitate project knowledge transfer in the company. The center of realization is PMO whose role is to act as an architect of the overall solution and facilitator of knowledge transfers within and between the different levels using data repository, incentive, and reporting systems [15].

Various approaches are already used in projects to assess the effectiveness and success of knowledge transfer.

C. Van Waveren, L. Oerlemans and T. Pretorius presented a general analysis of the development of approaches and methods of knowledge transfer. Authors demonstrated how to deal with unstructured proliferation of knowledge transfer mechanisms by empirically categorizing these transfer mechanisms, thereby reducing the number of mechanisms to groups that share a common characteristic [16].

Regarding to quantitative assessment methods of collaborative research projects networks, M. Takahashi, M. Indulska and J. Steen [17] proposed to use the multiple regression quadratic assignment procedure (MRQAP) and meta-analysis. It allows indicating that the network's relational characteristics (tie strength) and structural characteristics (network range) are important determinants of knowledge transfer at the fuzzy front end of innovation.

A. Terhorst et al. [18] proposed the system of assessment of explicit and implicit knowledge in the project. Authors used exponential random graph modeling to examine both tacit and explicit knowledge sharing in two early-stage open innovation projects. Results showed that autonomous motivation promotes tacit knowledge sharing, suggesting that managers need to promote a team culture that satisfies members' needs for autonomy, competence, and relatedness.

Another approach to assessing the knowledge movement is proposed in H. Wu et al. [19], where the authors integrate social network analysis and main path analysis to investigate progress in megaproject management (MPM) from the perspective of knowledge diffusion.

I. Kononenko et al. [26] developed an integrated method to solve the problem of forming the PM guide. The method includes the two main stages: 1) selecting the existing project management approach; 2) forming the specialized management by adjusting and modifying the selected basis.

The model of the participants' values convergence assessment presented in [20] was the ground of using it to measure other projects parameters.

Thus, the issue of assessing the system`s ability to perceive transferred knowledge in the project and, depending on this, the determination of the transfer rate remains insufficiently studied.

III. MATERIAL AND METHODS

The main research methods are the determination of β-convergence, which uses models of "growth-initial level regressions", statistical and fuzzy logic methods. Saaty method is used to assess the significance of KM factors and to scale the research model.

A. CONCEPTUAL MODEL FOR ASSESSING THE KNOWLEDGE CONVERGENCE IN MULTINATIONAL PROJECTS

Convergence in multinational projects is understood as the approximation of the PMSs parameters to ensure the successful projects implementation.

The model determines the level of KM systems convergence by assessing the readiness and ability of system elements to converge for effective interaction between project participants and success achievement.

Therefore, KM systems` convergence integrated indicator, which would not depend on the previous projects` statistical data, is proposed. To solve this problem, L. Zadeh`s fuzzy set theory [21] can be used.

The convergence process is modeled using an analytical expert evaluation apparatus for linguistic approximation of membership functions, i.e., indeterminate parameters of input criteria and output variables using informal rules of their description.

The application of fuzzy set theory allows us to formalize the decision-making process in a multidimensional fuzzy environment. It is proposed to use the linguistic variables apparatus to formalize the functional criteria for assessing the level of knowledge convergence in multinational projects, and to present these criteria in the form of an aggregate factor determined with the formula of double convolution:

$$Q^n = \sum_{i=1}^{n} w_i \sum_{j=1}^{m} \alpha_j \cdot \mu_{ij}(x_i), \qquad (1)$$

where α_j – the nodal points of the standard classifier; w_i – weight of the i-th criterion in the convolution; $\mu_{ij}(x_i)$ – the value of the membership function of the j-th qualitative level relative to the current value of the i-th criterion.

To study the level of convergence in dynamics, β-convergence is considered. The dependent variable is the growth rate, and the independent one is the initial level of the indicator (knowledge convergence level). The simplest regression of this type is:

$$y_i = \alpha + \beta \cdot ln(Q_{it-T}^n) + \varepsilon, \qquad (2)$$

where Q_{it-T}^n – the level of convergence of the project at the time that preceded the current time t by T periods (usually the initial period of a multinational project or other time important for project development); α – constant; β – the coefficient to be estimated; y_i – average convergence rate of the PMS of the i-th participant for T periods, which are defined as the ratio $\frac{ln(Q_{it}^n)}{ln(Q_{it-T}^n)}$; ε – a random deviation [22].

An indicator of the convergence presence is the value of the coefficient β. If $\beta < 0$, the high level of the indicator at the beginning of the project correlates with relatively lower growth rates. The theory of β-convergence shows that relatively weak participants in the initial period of development, as usual, are characterized by higher growth rate.

The method of assessing knowledge convergence in multinational projects may be implemented as sequence of the following stages:

1. Determining the multinational projects` factor space for the convergence level estimation.
2. Defining the boundaries of the scale and terms for each factor.
3. Formation of a functional criteria matrix for assessing the convergence level in multinational projects.
4. Generation of linguistic variables to formalize information on convergence events in multinational projects.
5. Calculation of criteria scales with Saaty method.
6. Calculation of integrated convergence level in multinational projects according to functional criteria.
7. Functional convergence criteria formalization with polynomial coefficients calculation.
8. Error estimation of the numerical experiment on convergence management in multinational projects.
9. Evaluation of the obtained polynomial adequacy for the convergence management system.
10. Estimation of convergence model accuracy with Fisher's criterion.

The core of this method is the knowledge convergence level assessment in multinational projects. It should be noted that the assessment can be carried out regardless of the project`s domain.

The general system of convergence assessment in multinational projects consists of three groups of metrics (criteria): project, contextual and geographical. These criteria allow us to compare the participants` knowledge systems convergence from the management standpoint.

A group of *project metrics* (criteria) reflect aspects of management: general and professional standards, management methodologies, etc.

The group of *contextual metrics* (criteria) include the convergence characteristics depending on the environment (internal) implementation of international projects. The following values are used as contextual metrics: language barrier, culture and values, personal views and worldview, trust and teamwork, etc.

The group of *geographical metrics* (criteria) reflects the characteristics of convergence, which change over time and depend on the environment of the project. The following are accepted as geographical metrics: project investment support by the state, infrastructure level, political stability, tax system, etc.

Based on the defined groups, the basic equation for estimating the convergence level in multinational projects is:

$$Q_{int} = \sum_{i=1}^{3} w_i \cdot z_i = w_1 \cdot z_1 + w_2 \cdot z_2 + w_3 \cdot z_3, \qquad (3)$$

where w_i – convergence factor`s weight; $z_i$ – parameter`s fuzzy value.

Note that the relationship between input and output indicators to determine the level of convergence of the project can be represented by the following functional dependencies:

$$Q = f_Q(z_1, z_2, z_3), \qquad (4)$$

where

$$z_1 = f_{z_1}(y_1, y_2, y_3, y_4, y_5),$$

$$y_1 = f_{y_1}(x_1, x_2, x_3);\ y_2 = f_{y_2}(x_4, x_5, x_6);$$
$$y_3 = f_{y_3}(x_7, x_8, x_9);\ y_4 = f_{y_4}(x_{10}, x_{11}, x_{12}).$$

$$z_2 = f_{z_2}(y_6, y_7, y_8, y_9, y_{10}, y_{11}, y_{12}, y_{13}, y_{14}, y_{15}, y_{16}),$$

$$y_7 = f_{y_7}(x_{13}, x_{14}, x_{15});\; y_8 = f_{y_8}(x_{16}, x_{17}, x_{18});$$
$$y_9 = f_{y_9}(x_{19}, x_{20}, x_{21});\; y_{15} = f_{y_9}(x_{22}, x_{23}, x_{24}).$$

$$z_3 = f_{z_3}(y_{17}, y_{18}, y_{19}, y_{20}, y_{21}, y_{22}, y_{23}, y_{24}),$$

$$y_{18} = f_{y_{18}}(x_{25}, x_{26}, x_{27});\; y_{21} = f_{y_{21}}(x_{28}, x_{29}, x_{30});$$
$$y_{23} = f_{y_{23}}(x_{31}, x_{32}, x_{33}).$$

The quantitative value of the aggregate factor is determined by formula (3).

To describe the vagueness of a linguistic variable, it is best to specify its membership function, which is the degree of truth in fuzzy logic. Note that the rules for determining vagueness are also vague.

Membership functions can be represented by graphical forms: triangular, trapezoidal and normal. The type of membership functions is determined on the basis of various additional assumptions about their properties (symmetry, monotony, continuity, etc.) taking into account the specifics of the existing uncertainty, the real situation with the object of study and the number of degrees of freedom in functional dependence.

The set of model criteria with ranking is presented in Table 1.

Table 1. Criteria ranking with Saaty method

Criterion	Var	Weight
Convergence of project factors	z_1	0.5
PM standardization	y_1	0.3
Complete coverage of procedures by standardization processes	x_1	0.5
Project quality management functions distribution	x_2	0.2
Quality management methods	x_3	0.3
The level of subject area standardization	y_2	0.2
Complete coverage of project product standards	x_4	0.3
Product development processes standardization	x_5	0.2
Development process management standardization	x_6	0.5
Level of implementation of PM methodologies	y_3	0.3
Agile	x_7	0.4
Waterfall	x_8	0.2
Mixed methodologies	x_9	0.4
The level of implementation of PM ITs	y_4	0.1
Completeness of information technology project management functions	x_{10}	0.5
Degree of security of systems	x_{11}	0.2
Scalability of information systems	x_{12}	0.3
The level of development of PM terminology	y_5	0.1
Convergence of contextual factors (internal)	z_2	*0.2*
Language barrier	y_6	0.2
The level of ensuring culture and values	y_7	0.2
Religion	x_{13}	0.2
Cultural values	x_{14}	0.5
Family values	x_{15}	0.3
The level of trust of the project team	y_8	0.05
Existence of joint projects that were implemented earlier	x_{16}	0.4
Teamwork skills	x_{17}	0.2
Ability to communicate	x_{18}	0.3
The level of interaction in the team	y_9	0,2
Feedback	x_{19}	0.6
Proactivity	x_{20}	0.3
Team development stage	x_{21}	0.1
The level of worldview formation and personality development of project team members	y_{10}	0.05
The level of flexibility and ability of the participating organization to change	y_{11}	0.05
Compliance of the draft development strategy of the participating organization	y_{12}	0.05
Sustainability of participating organizations	y_{13}	0.05
Personnel potential of the participating organization	y_{14}	0.05
Technical and technological development of the participating organization	y_{15}	0.05
Technical support of the participating organization	x_{22}	0.3
Technological support of the participant's organization	x_{23}	0.3
Scientific and technical development of the participant's organization	x_{24}	0.4
The level of maturity of the participating organization	y_{16}	0.05
Convergence of geographical factors	z_3	*0.3*
State and international programs support	y_{17}	0.3
The level of economic development of the participating countries	y_{18}	0.2
Investment climate	x_{25}	0.5
Corruption level	x_{26}	0.3
Tax burden level	x_{27}	0.2
Political stability of the participating countries	y_{19}	0.05
Legislative support of the project area of the participating countries	y_{20}	0.05
The level of infrastructure development in the participating countries for the project implementation	y_{21}	0.1
Transport connection	x_{28}	0.2
Communication networks	x_{29}	0.3
Logistics	x_{30}	0.5
The level of scientific and technological development of the participating countries	y_{22}	0.1
Influence of social factors of the participating countries on the project	y_{23}	0.1
Working conditions	x_{31}	0.3
Conditions of rest	x_{32}	0.2
Wage level	x_{33}	0.5
Impact on the project of natural and environmental factors of the participating countries	y_{24}	0.1

B. FUZZY MODEL FOR DETERMINING THE KNOWLEDGE CONVERGENCE LEVEL IN THE PROJECT

The Knowledge Management domain is confidently classified as weakly formalized. The task of formalization is not facilitated by the practical impossibility of obtaining an indicators quantitative assessment of existing knowledge management systems convergence in multinational project. Taking into account the absolute dependence of the KM systems convergence assessment on the expert, the use of linguistic variables and the conclusions derivation similar to human judgments are justified.

This approach ensures the transparency of obtaining conclusions based on the expert`s experience involved in the process of a fuzzy inference system creation at the stages of forming an individual set of terms and membership functions for each linguistic variable, and a rule based compilation. The type of membership functions is determined on the basis of various additional assumptions about their properties (symmetry, monotony, continuity, etc.) considering the specifics of the existing uncertainty, the real situation with the object of study and the number of freedom degrees in functional dependence.

For the convergence assessment, each criterion is characterized by triple-term linguistic variable, which offers "Low" (L), "Average" (A) and "High" (H) level designations. The Table 2 demonstrates a fragment of defining terms for a parameter y_1 "PM standardization", where $y_1 = (x_1, x_2, x_3)$.

The terms of linguistic variable determine the system`s ability to converge. The greater the degree of standardization is, the higher the convergence rate.

The number of input parameters can be very high, which will greatly complicate the fuzzy model construction. As the number of parameters increases, the accuracy of the model may also decreases due to “Dimension Calamity”. To increase the validity of the decisions made by the expert (qualitative assessments) on priorities, the criterion`s weight w_i is obtained with the method of hierarchy analysis [23].

Table 2. PM standardization” linguistic variable description (fragment)

Criterion	Var	Terms
PM standardization	y_1	Low (L); Average (A); High (H)
Complete coverage of procedures by standardization processes	x_1	Standardized separate project management processes (L); All project management processes are standardized (A); Developed a procedure for continuous improvement of project management processes (H)
Project quality management functions distribution	x_2	Quality management functions are distributed among project participants (L); Quality management functions are assigned to an individual project participant (A); Developed for the implemented project quality management plan (H)
Quality management methods	x_3	The quality of the project is determined by deviations from the planned (L); Project quality is planned and formalized (A); In addition to qualityplanning, its constant assessment and forecasting is carried out (methods of mastered volume, etc.) (H)

The processing of the system with the Saaty method allows ranking the criteria and filter out the least significant ones for recent case (see Table 1). Note that the relationship between input and output indicators determining the convergence level of the project is represented with the following functional dependency:

$$Q_{int} = \\ = w_1 \cdot f_{Z_1}\left(f_{y_1}(x_1, x_2, x_3), f_{y_2}(x_4, x_5, x_6), f_{y_3}(x_7, x_8, x_9)\right) + \\ + w_2 \cdot f_{Z_2}\left(y_6, f_{y_7}(x_{13}, x_{14}, x_{15}), f_{y_9}(x_{19}, x_{20}, x_{21})\right) + \\ + w_3 \cdot f_{Z_3}(y_{17}, f_{y_{18}}(x_{25}, x_{26}, x_{27})),$$

where w_i – convergence factor`s weight; fZ_1 – aggregated fuzzy value of a multidimensional function from fuzzy arguments presented as the value of relevant factors fuzzy functions.

According to the evaluation model, a set of hierarchically connected fuzzy inference systems (FIS) is implemented. The output of the lower-level FIS acts as one of inputs for the higher-level subsystems. This approach reduces the cognitive load on the expert conducting the FIS filling and avoids mistakes in rule bases creation, as well as significantly reduces the rules number. Based on the domain specifics, a bunch of factors and the lack of the ability to establish strict mathematical relationships between inputs and outputs, FISs process the results using the Mamdani algorithm.

The output is a fuzzy convergence of multinational projects knowledge systems.

According to the result, one of the recommended strategies (see Table 3) will be applied.

Table 3. A set of recommended strategies

The convergence indicator`s value	Sources of efficiency	Characteristics of potential (controlled factors)	Recommended development strategy
High	Staff training, introduction of flexible management methodologies, development of team trust	High level of interaction in the project team, comprehensive standardization, lack of communication barriers	*Optimistic strategy.* Introduction and standardization of innovative PM methods and models
Average	Standardization of project management procedures, development of communications, overcoming communication barriers	Stable development of the project team, use of a common methodology, overcoming institutional barriers	*Support strategy.* Project and product quality management at all stages of project implementation
Low	Forming a team of professionals. Working with a team, ensuring project proactivity. Implementing a project and product quality system	Promoting the understanding of the values of the project participants and the formation of common values of the project. Rapid development of the project team,strict control	*Integration and development strategy.* Definition and formalization of common approaches to project management

After the expert ranking evaluation, the factors with the probability measure less than or equal to 0.05, were excluded. The project convergence level $Qint$ takes the form of the following functional dependency:

$$Qint = \\ = w_1 \\ \cdot fZ_1(fy_1(x1, x2, x3), fy_2(x4, x5, x6), fy_3\,(x7, x8, x9)) + \\ + w_2 \cdot fZ_2\,(y6, fy_7(x13, x14, x15), fy_9(x19, x20, x21)) + \\ + w_3 \cdot fZ_3(y17, fy_{18}\,(x25, x26, x27)).$$

The set of strategies is recommended and may be adapted to the project`s specifics.

C. THE MODEL IMPLEMENTATION

The study of the knowledge convergence level was conducted on the example of three multinational projects implemented within IPMA’s international activities. Input data are collected in Table 4.

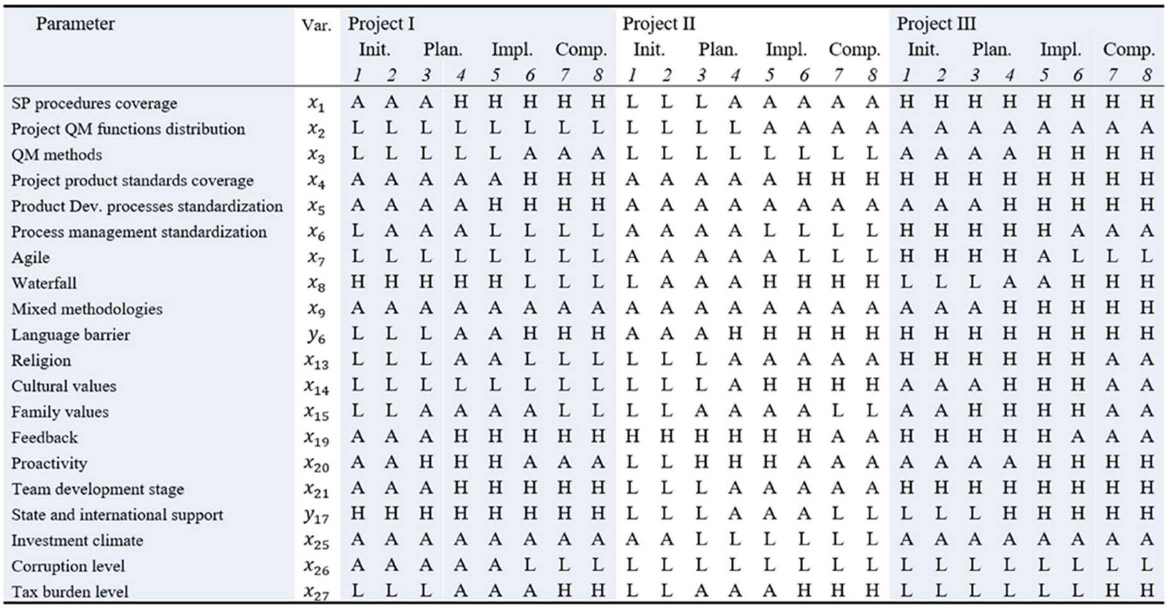
A regression models of the knowledge convergence in dynamics (β-convergence) for each multinational project were obtained. The quality of regression models is being tested confirmed with the mean absolute percentage error (MAPE < 10%) and the coefficient of approximation (R Squared approx. 1). The reliability of the convergence regression model is checked with the F-test (Fisher’s criterion) [24]. The models are considered as adequate if $F_{fact} > F_{tabl}$, where $F_{tabl}(0.05, 1, 5) = 6.6079$.

The obtained model provides an opportunity to predict the convergence level for subsequent projects and to form warning recommendations during the knowledge management system development.

To obtain the convergence level for the New Project, it is necessary to determine the baseline project by comparing the initial conditions within the similar projects in the cluster using different measures of similarity. In our case the Euclidean distance is chosen: the shorter the distance between projects the more similar they are.

The speed of knowledge convergence (β-convergence) for the New Project is forecasted based on the selected basic project.

Table 4. Convergence management model inputs



Parameter	Var.	Project I								Project II								Project III							
		Init.		Plan.		Impl.		Comp.		Init.		Plan.		Impl.		Comp.		Init.		Plan.		Impl.		Comp.	
		1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*
SP procedures coverage	x_1	A	A	A	H	H	H	H	H	L	L	L	A	A	A	A	A	H	H	H	H	H	H	H	H
Project QM functions distribution	x_2	L	L	L	L	L	L	L	L	L	L	L	L	A	A	A	A	A	A	A	A	A	A	A	A
QM methods	x_3	L	L	L	L	L	A	A	A	L	L	L	L	L	L	L	L	A	A	A	A	H	H	H	H
Project product standards coverage	x_4	A	A	A	A	A	H	H	H	A	A	A	A	A	H	H	H	H	H	H	H	H	H	H	H
Product Dev. processes standardization	x_5	A	A	A	A	H	H	H	H	A	A	A	A	A	A	A	A	A	A	A	H	H	H	H	H
Process management standardization	x_6	L	A	A	A	L	L	L	L	A	A	A	A	L	L	L	L	H	H	H	H	H	A	A	A
Agile	x_7	L	L	L	L	L	L	L	L	A	A	A	A	A	L	L	L	H	H	H	H	A	L	L	L
Waterfall	x_8	H	H	H	H	H	L	L	L	L	A	A	A	H	H	H	H	L	L	L	A	A	H	H	H
Mixed methodologies	x_9	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	H	H	H	H	H
Language barrier	y_6	L	L	L	A	A	H	H	H	A	A	A	H	H	H	H	H	H	H	H	H	H	H	H	H
Religion	x_{13}	L	L	L	A	A	L	L	L	L	L	L	A	A	A	A	A	H	H	H	H	H	H	A	A
Cultural values	x_{14}	L	L	L	L	L	L	L	L	L	L	L	A	H	H	H	H	A	A	A	H	H	H	A	A
Family values	x_{15}	L	L	A	A	A	A	L	L	L	L	A	A	A	A	L	L	A	A	H	H	H	H	A	A
Feedback	x_{19}	A	A	A	H	H	H	H	H	H	H	H	H	H	H	A	A	H	H	H	H	H	A	A	A
Proactivity	x_{20}	A	A	H	H	H	A	A	A	L	L	H	H	H	A	A	A	A	A	A	A	H	H	H	H
Team development stage	x_{21}	A	A	A	H	H	H	H	H	L	L	L	A	A	A	A	A	H	H	H	H	H	H	H	H
State and international support	y_{17}	H	H	H	H	H	H	H	H	L	L	L	A	A	A	L	L	L	L	L	H	H	H	H	H
Investment climate	x_{25}	A	A	A	A	A	A	A	A	A	A	L	L	L	L	L	L	A	A	A	A	A	A	A	A
Corruption level	x_{26}	A	A	A	A	A	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L
Tax burden level	x_{27}	L	L	L	A	A	A	H	H	L	L	A	A	A	H	H	H	L	L	L	L	L	L	H	H

IV. RESULTS

As a result, the system for determining a fuzzy indicators of knowledge convergence in multinational projects is built, and indicators for the above three projects are defined. The calculations were conducted using Mathlab Fuzzy Logic Designer. The results are summarized in Table 5. Also, a fuzzy forecast of the convergence level for a New Project was conducted, which is on the Initiation stage and based on the similar projects experience.

A regression knowledge convergence model for each multinational project is presented in Table 6.

The forecast results for New Project are located in Table 7.

Table 5. Convergence by Projects stages

Stage		Project I	Project II	Project III	New Project
Initiation	1	0,6186	0,4522	0,6373	0,4378
	2	0,6186	0,4522	0,6373	0,4778
Planning	3	0,6186	0,4965	0,6373	0,6018
	4	0,6075	0,5055	0,6803	0,6872
Implementation	5	0,6496	0,6040	0,7315	0,7080
	6	0,6990	0,6599	0,7703	0,7561
Completion	7	0,7411	0,6850	0,7683	0,7058
	8	0,7411	0,6850	0,7483	0,6795

V. DISCUSSION

Table 5 results show that the Project I had standardized, unified planning processes and a fairly high level of similarity in geographical indicators, but during implementation showed significant differences in the perception of the project results by different participants, which significantly reduced the convergence level.

The Project II is the most capable of convergence. On the Initiation and Planning stages, the project lagged behind, but then, due to the implementation of a common project management standard (PMBoK) by all participants it improved significantly the project internal interaction and led to its successful implementation.

Regarding the Project III, the convergence level on all stages remained stable. This indicates a high organization of the project, and a well-established knowledge management mechanism. However, this usually has a negative impact on its development and in the future implementation of such projects may be recommended using Agile methodologies and training to implement new knowledge within the project.

Table 6. Knowledge convergence regression model check

Criterion	Project I	Project II	Project III	New Project
β-convergence Regression model	$\hat{y} = 0{,}97 + 0{,}6982 \cdot \ln x$	$\hat{y} = 0{,}9063 + 0{,}5287 \cdot \ln x$	$\hat{y} = 0{,}930 + 0{,}5991 \cdot \ln x$	$\hat{y} = 0{,}8507 + 0{,}3914 \cdot \ln x$
R	0,9036	0,9421	0,9009	0,9032
$R\ Squared$	0,8165	0,8875	0,8116	0,8158
MAPE, %	3,3933	4,5319	3,1635	5,4715
F_{fact}	22,24	39,4472	21,5418	22,1504
F-test	✓	✓	✓	✓
Euclidean dist.	9,165151	7,745967	8,944272	–

Table 7. Fuzzy logic and Regression model comparison

β-convergence regression model	New Project, Fuzzy logic $\hat{y} = 0{,}8507 + 0{,}3914 \cdot \ln x$	New Project, Regression model $\hat{y} = 0{,}9063 + 0{,}5287 \cdot \ln x$	Absolute deviation $\lvert \hat{y} - y \rvert$
1	0,4378	0,4378	0
2	0,4778	0,4696	0,0082
3	0,6018	0,5067	0,0951
4	0,6872	0,5469	0,1403
5	0,7080	0,5872	0,1208
6	0,7561	0,6248	0,1313
7	0,7058	0,6576	0,0482
8	0,6795	0,6846	0,0051
MAPE, %	6,8637<10		

Based on the Project II, for the new one it may be predicted a decrease in convergence during the Initiation and Planning stages. According to the method of analogies, it may be recommended at the beginning of the project to clearly prescribe standards for project products and improve the Quality management methods; to introduce agile methodologies; to work on deepening the understanding of the values of all project participants.

The quality of regression models is confirmed with the MAPE and the R-Squared approximation [25]. The shortest Euclidean distance indicates the greatest similarity of the New Project to the Project II. Therefore, it can be recommended when choosing the reference value of convergence in the project.

Comparing the forecast values on the basis of fuzzy logic and the forecast values of β-convergence, MAPE = 6,8637, i.e., the difference between the forecast values of both proposed methods is minimal. Therefore, the Project II β-convergence model can be used to predict β-convergence in similar projects. The use of such a method of assessing the convergence of knowledge in the project can significantly reduce the time in the formation of a knowledge management system and interaction in the project. Obtained results are presented in Fig. 1.

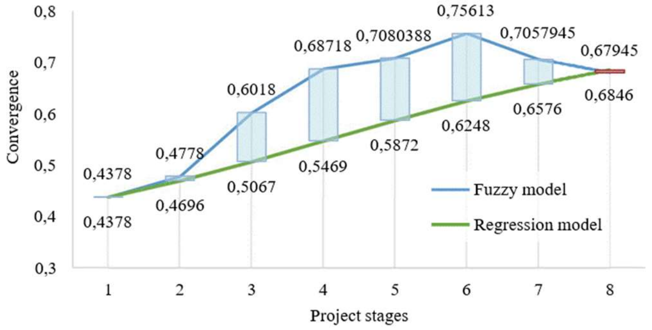


Figure 1. Comparison of predicted values of Fuzzy logic and Regression model β-convergence of the project management system by stages

The deviations presented in Fig. 1 show the practical coincidence of the predicted values by Fuzzy logic with the predicted values by the Regression model of the New Project based on the data of the similar project implementation.

Thus, determining the level of convergence by Fuzzy logic, and then assessing the rate of its development or decline provides a transition from fuzzy to well-defined indicators. It can significantly increase the accuracy of modeling, as well as significantly reduces time to search and predict the knowledge transfer processes in multinational projects.

VI. CONCLUSIONS

Thus, the proposed approaches to determining and forecasting the knowledge convergence level in projects allow us to identify “bottlenecks” in the interaction of multinational project participants at different project`s stages and to take corrective action from the beginning to ensure its successful implementation. It can also significantly reduce the time to adapt and form a knowledge management strategy in the project.

The further development of research may be carried out in information system construction to support the fuzzy knowledge convergence level assessment in projects, whereas numerous influencing factors require to form and process a large rulebase. Also, the consistent systematic project database formation with certain basic parameters will allow us to assess the project`s ability to transfer knowledge based on convergence value with sufficient accuracy and less time costs.

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