Using yEd Software to Visualize and Analyze Project Management Knowledge Systems Data

Dmytro Lukianov[a], Victor Gogunskii[b] , Oleksii Kolesnikov[c] and Kateryna Kolesnikova[c]

[a] Interdisciplinary Institute for Advanced Studies and Retraining, Belarusian National Technical University, 77, Partyzansky ave., Minsk, 220107, Belarus
[b] Odessa National Polytechnic University, 1, Shevchenko ave., Odessa, 65044, Ukraine
[c] Taras Shevchenko National University of Kyiv, 60, Volodymyrska Street, Kyiv, 01033, Ukraine

Abstract

The article proposes to consider some conclusions about the significance of a number of elements of the model of individual competencies of project managers proposed by the International Project Management Association (IPMA ICB 4.0) when presented as a directed graph. It is proposed to consider elements of the competency model (a set of 28 elements for the ICB model for project management) as the vertices of such a graph. It is proposed to carry out a structural analysis of such a graph using various combinations of representations that combine the "centrality" parameter and "weight characteristics" for the vertices of such a graph based on information about the number of edges adjacent to the vertices. The article demonstrates the approach proposed by the authors to the analysis of a directed graph using software such as the openly distributed product yEd, which has sufficiently wide capabilities for visualizing various systems modeled with its help, including graphs. It is also proposed to consider, as an example of using such a representation, a variant of transforming the existing IPMA ICB 4.0 model based on the representations for this structure obtained during the visual analysis using the yEd service. The structure of the general communication system IPMA ICB 4.0 is clearly demonstrated, and the presentation of each of the blocks of elements of this model is also visualized. Shows the role of the element "Leadership" as an "integral element", directly through which communication is carried out between all blocks of the model of elements. The role of such an element as "Power and Interest" in the analysis of a directed graph using a set of representations is also highlighted, which demonstrates the structural relationships of the entire system of elements of the system under consideration using the "centrality" property.

Keywords [1]

Project management, competences model, International Project Management Association, Individual Competence Baseline, adjacency matrix, directed graph, theory of graphs, centrality, visual analyses, modeling

1. Introduction

Almost all of the world's leading professional organizations that offer their views on the systems of necessary knowledge for project management today offer their presentation of the necessary "sets of competencies" required by managers of projects, programs and project portfolios for successful management. Such models are offered by such two most authoritative organizations in the world of project management as the International Project Management Association (IPMA) [1], and the American Institute for Project Management (PMI) [2].

IT&I-2020 Information Technology and Interactions, December 02–03, 2020, KNU Taras Shevchenko, Kyiv, Ukraine
EMAIL: dlukiano@gmail.com (D. Lukianov); vd.gogunsky@gmail.com (V. Gogunskii); akoles78@gmail.com (O. Kolesnikov); amberk4@gmail.com (K. Kolesnikova)
ORCID: 0000-0001-8305-2217 (D. Lukianov); 0000-0002-9115-2346 (V. Gogunskii); 0000-0003-2366-1920 (O. Kolesnikov); 0000-0002-9160-5982 (K. Kolesnikova)

2. Problem

Despite the attempts made by a number of authors to describe the interaction of elements of knowledge systems in various fields of human activity [3-7], unfortunately, there is still no established approach to formalizing such complex structures as a model of the competence of specialists, which makes it possible to apply analytical methods to their analysis& At the same time, attempts are being made to use rather complex analytical approaches to the description and analysis of such design systems [8, 9]. Despite the tendency that has emerged in recent years towards a similar representation of the competence structure in IPMA and PMI [10, 11], which happened, possibly due to ISO, and also despite the existing standards for assessing competencies, there is no unified approach to representing elements of such systems as systems (or models) of competencies. The lack of a unified, and, preferably, understandable and accessible, approach to the representation of systems does not allow, from our point of view, also to compare and evaluate them. Also, the lack of such a unified approach makes it difficult to apply an analytical approach to solving the problem of choosing an appropriate project management methodology for the project (including a possible justification for choosing a "mixed" approach [12]). It seems useful to create a general approach to describing such models, incl. to adjust existing approaches to project management [14].

3. Methods

As a possible approach to the construction of models of complex organizational, technical, socio-economic and other systems, it is proposed to use the graph theory toolkit, which is a constituent element of the general theory of systems in the representation of L. Bertalanffy [13].

An adjacency matrix can serve as a basis for constructing a directed graph for subsequent analysis.

As known, a system that combines sets of some entities, for example (1):

$$S\{s_1, s_2, \ldots, s_m\}, \tag{1}$$

which are vertices of an oriented graph connected by oriented arcs (2)

$$G\{g_1, g_2, \ldots, g_r\}, \tag{2}$$

can be displayed using the adjacency matrix (3)

$$[c_{ij}]_S = [i, j], \tag{3}$$

each line of which shows the connections of one vertex with other vertices of the graph. The element $c_{ij} = 1$, then it reflects the arc between the vertices S_i and S_j. If $c_{ij} = 0$, then the arc directly between the vertices of the graph i and j is absent.

For the analysis of such structures use the adjacency matrix, which has specific properties. In the case of successive reduction of the adjacency matrix in the degree $n = 2, 3$ ... the elements of the n-th degree $(c_{ij})^n$ show the path containing n arcs between the i-th and j-th vertices of the graph.

To formalize the adjacency matrix obtained by the method described above, it is proposed to use the Microsoft Excel [15] software, in particular, so that other actions can be performed in the same computing environment to simulate the behavior of the system under study. In particular, due to the fact that this software in its basic functionality supports the necessary set of operations with matrices. For further visualization and presentation in the form of a graph, it is proposed to use the yEd [16] software.

4. Results

An adjacency matrix can serve as the basis for constructing a directed graph for subsequent analysis. In this case, such a matrix can be easily obtained for the considered IPMA ICB 4.0 system [17] due to the fact that in the text of this standard there are explicit references to the relationships of each of the elements with other elements of the system. The logic of its construction corresponds to that which was applied when describing the structure of the previous version of the IPMA ICB 3.0 model [14] (Fig. 1).

For further visual analysis of the resulting graph, it is proposed to use such well-known and open-source software as yEd, which allows modeling various kinds of complex structures, in particular, using a wide range of different graph representations. Fig. 2 shows the structure of a graph created in the yEd environment using the standard Shape Nodes template of structural elements.

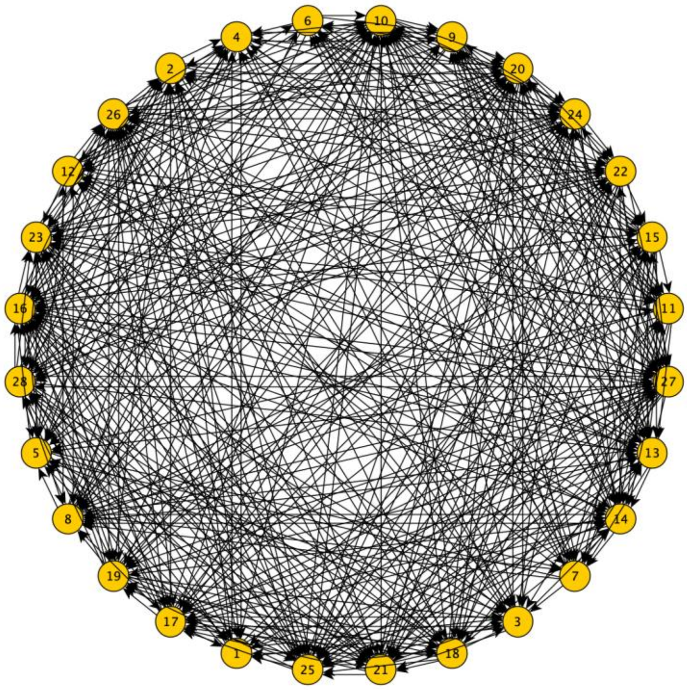

Figure 1: Formation of a first-order adjacency matrix for ICB 4.0 (screenshot fragment) [18]

Factor name	Elements that are affected (columns)	Strategy	Governance, structure and processes	Compliance, standards and regulations	Power and interests	Culture and values	Self-reflection and self-management	Personal integrity and reliability	Personal communication	Relations and engagement	Leadership	Teamwork	Conflict and crisis	Resourcefulness	Negotiation	Results orientation	Project design	Requirements and objectives	Scope	Time	Organisation and information	Quality	Finance	Resources	Procurement	Plan and control	Risk and opportunities	Stakeholder	Change and transformation
Influencing Elements (Rows)	FID	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
Strategy	1	0	1	1	1	1	0	0	0	0	1	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	1	1	0
Governance, structure and processes	2	1	0	1	1	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	1	1	1	1	0	0	1
Compliance, standards and regulations	3	1	1	0	1	1	0	0	0	0	1	0	0	0	1	0	1	1	0	0	1	1	0	0	0	0	1	0	0
Power and interests	4	1	1	1	0	1	0	1	1	1	0	0	0	0	0	0	1	0	0	0	1	0	0	0	1	0	0	1	0
Culture and values	5	1	1	1	1	0	0	1	1	1	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0
Self-reflection and self-management	6	0	0	0	1	1	0	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Personal integrity and reliability	7	0	0	1	1	1	1	0	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Personal communication	8	0	0	0	1	1	1	1	0	1	1	1	1	1	1	1	0	0	0	0	1	0	0	0	0	0	0	1	0
Relations and engagement	9	0	0	0	1	1	1	1	1	0	1	1	1	1	1	1	0	0	0	0	1	0	0	0	0	0	0	1	0
Leadership	10	0	0	0	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Teamwork	11	0	0	0	1	1	1	1	1	1	1	0	1	1	1	1	0	0	0	0	1	0	0	1	0	1	0	0	0
Conflict and crisis	12	0	0	0	1	1	1	1	1	1	1	1	0	1	1	1	0	0	0	0	0	0	0	1	0	1	1	0	0
Resourcefulness	13	0	0	0	0	0	1	1	1	1	1	1	1	0	1	1	1	1	0	0	0	0	0	0	0	1	1	0	0
Negotiation	14	0	0	0	0	0	1	1	1	1	1	1	1	1	0	1	1	1	0	0	0	0	0	0	1	1	0	0	0
Results orientation	15	1	0	0	0	0	1	1	1	1	1	1	1	1	1	0	1	1	0	0	0	1	0	0	0	1	1	1	0
Project design	16	1	1	1	1	1	0	0	0	0	1	0	0	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1
Requirements and objectives	17	1	1	1	0	0	0	0	1	0	1	0	0	1	1	0	1	0	1	1	1	1	1	1	1	1	1	1	1
Scope	18	1	1	1	0	0	0	0	0	0	1	0	0	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1
Time	19	0	1	1	0	0	0	0	1	0	1	0	0	1	1	0	1	1	1	0	1	1	1	1	1	1	1	1	1
Organisation and information	20	0	1	1	0	0	0	0	1	0	1	1	0	1	1	0	1	1	1	1	0	1	1	1	1	1	1	1	1
Quality	21	0	1	1	0	1	0	0	0	0	0	1	0	1	0	1	1	1	1	1	1	0	1	1	1	1	1	1	1
Finance	22	0	1	1	0	0	0	0	0	0	1	0	0	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1
Resources	23	0	1	1	0	1	0	0	0	0	1	1	0	1	1	0	1	1	1	1	1	1	1	0	1	1	1	1	1
Procurement	24	0	1	1	0	1	0	0	0	1	1	0	0	1	1	0	1	1	1	1	1	1	1	1	0	1	1	1	1
Plan and control	25	1	1	1	0	0	0	0	0	0	1	0	1	1	1	0	1	1	1	1	1	1	1	1	1	0	1	1	1
Risk and opportunities	26	1	1	1	1	0	0	0	0	0	1	0	1	1	0	0	1	1	1	1	1	1	1	1	1	1	0	1	1
Stakeholder	27	1	1	1	1	1	0	0	1	1	1	0	0	1	0	0	1	1	1	1	1	1	1	1	1	1	1	0	1
Change and transformation	28	1	1	0	1	1	0	0	1	0	1	0	0	1	0	0	1	1	1	1	1	1	1	1	1	1	1	1	0

Figure 2: Directed graph for IPMA ICB 4.0 model implemented in yEd (screenshot fragment)

As you can see from the fig. 2, yEd allows you to visualize the links (edges) between the elements of the model (the vertices of the graph), including the direction of these links.

Unfortunately, such a basic view does not allow making any analytical conclusions. It is worth using other representations to analyze the graph. In particular, the simplest next step can also be a "circular representation", but with the visualization of the weights of the vertices based on the number of their connections with other vertices of the graph, as shown in Fig. 3 (normalized with respect to the element 10 with the maximum number of connections) for Centrality Measuring settings based on "Number of Connected Edges".

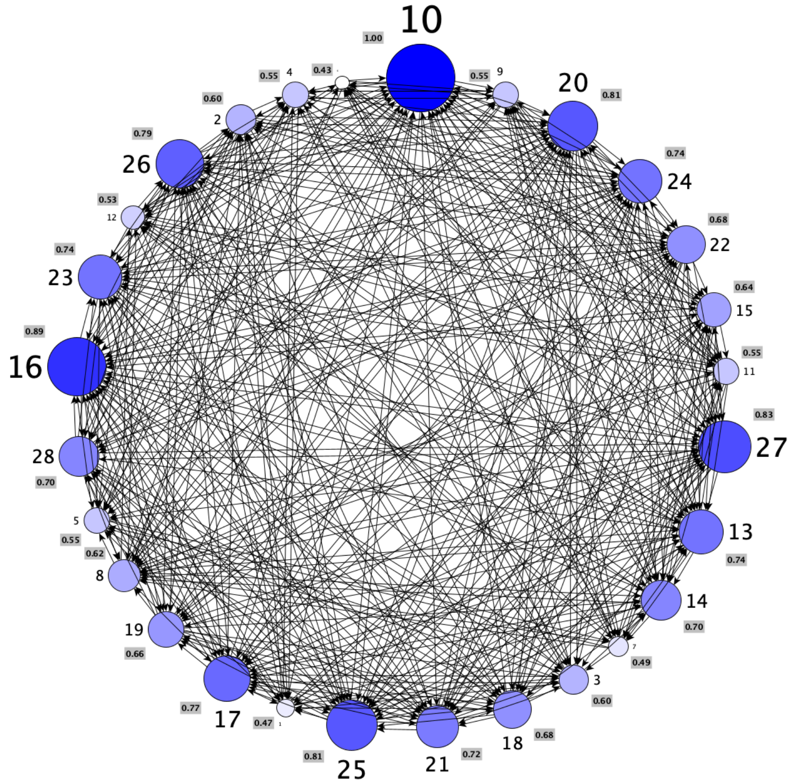

Figure 3: Directed graph for IPMA ICB 4.0 model, implemented in yEd (Circular Layout - Single Cycle representation) with routing style set as "Arc"

As can be seen from fig. 3, yEd allows visualizing the weights of vertices (model elements) based on information about the number of edges (links), which makes such a representation much more information-rich than the primary representation of the model in the form of a graph which presented in Fig. 2. Nevertheless, such a representation, although it already allows you to form some hypothesis based on the visualization of the parameters of the system of links, in particular, to allow ranking the vertices by the number of links, but any spreadsheet editor in which you can sum up values in rows and columns of the original adjacency matrix (Fig. 1). In graph analysis, one of the key concepts is centrality. Accordingly, visualization of representations of such a parameter as "centrality" will be of undoubted interest. At the same time, "centrality" can be considered both "structural" and "weighted". In particular, thanks to such a representation as "Weighted Centrality" (Fig. 4), it is possible to assess the importance for the entire structure as a whole, not only of element 10 (as follows from the representation in Fig. 3), but also 16: This representation allows one to form a number of hypotheses regarding the role of elements 6, 7, 8, 9, 11 and 12 presented in the "far orbit" in the system under consideration, in addition to other assumptions that can be formed on the basis of the visualization presented in Fig. 3. In any case, it is obvious that the information content of such a representation is much higher than that in Fig. 2 or Fig. 3. The visualization capabilities allow you to assess "centrality" directly from a structural point of view as shown in Fig. 5: In particular, Fig. 5 shows the importance of element 17, which was not at all visible based on the analysis of weights (Fig. 4), nor, even more so, such "simple representations" that were presented in Fig. 2 and Fig. 3, and were not at all obvious in any attempt to "visualize" the matrix representation of the system (Figure 1). Thus, in

Fig. 3-5, visualization options are presented, perhaps the most important topological representations of structural links existing in the IPMA ICB 4.0 model

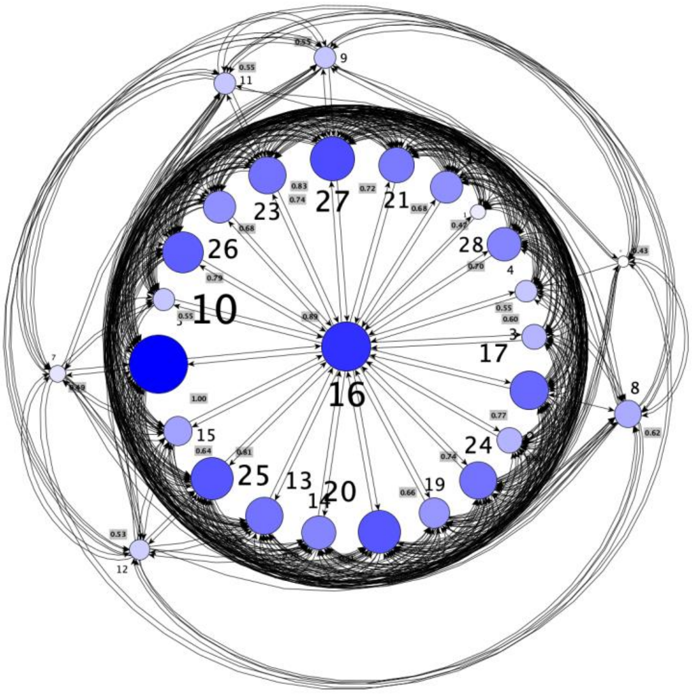

Figure 4: Visualization of some structural indicators (fragment) for a directed graph for the IPMA ICB 4.0 model in the yEd environment in the Radial Layout view for Weighted Centrality (distance from center)

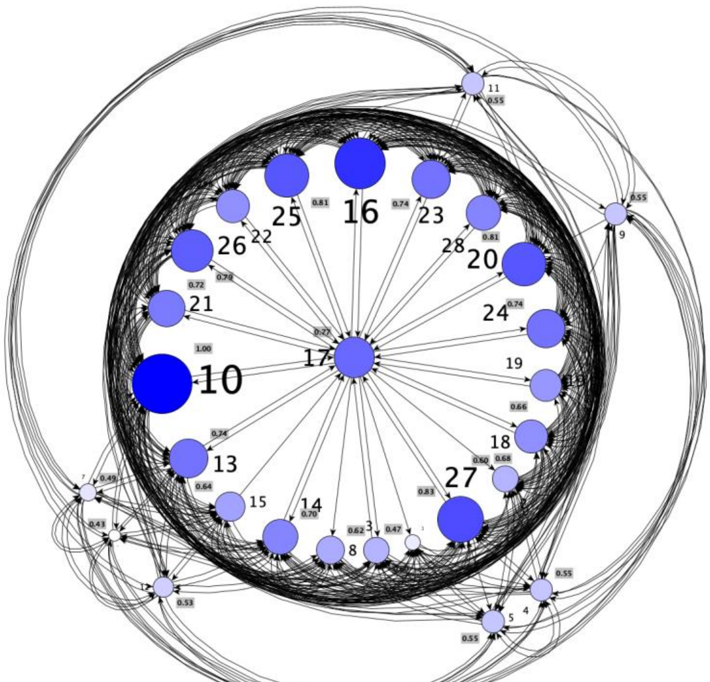

Figure 5: Visualization of some structural indicators (fragment) for a directed graph for the IPMA ICB 4.0 model in the yEd environment in the Radial Layout view for Centrality (distance from center)

5. Discussion

The approach proposed in the article significantly expands the previously described [19] approach to the analysis of the properties of structural models. At the same time, the use of elements of such an approach has already been presented in relation to the analysis of communication processes in project management [20, 21], and in some cases it is explicitly applied to the analysis using the construction of graphs and the subsequent assessment of such parameters specific for the analysis of graphs as “degree centrality", "Betweenness centrality", "eigenvector centrality" [22]. Nevertheless, the visual representation of the "centrality" properties, from our point of view, significantly expands the possibilities of understanding the features of the systems under study. As can be seen from the views in Fig. 4 and 5, they are fundamentally different from the “descriptive” view in Fig. 2. Although they are still representations of the same system. In our opinion, the use of such powerful tools for versatile visualization of the graphs of the studied models allows us to look somewhat differently at the systems under study than only through the prism of analytical indicators presented in a matrix (tabular) form. Based on the information presented graphically, it becomes possible not only to propose new hypotheses regarding the structural relationships of the systems under study, but also to “quickly test” them by visual means. In particular, Fig. 6 shows the hierarchy of relations between the vertices of the graph (model elements).

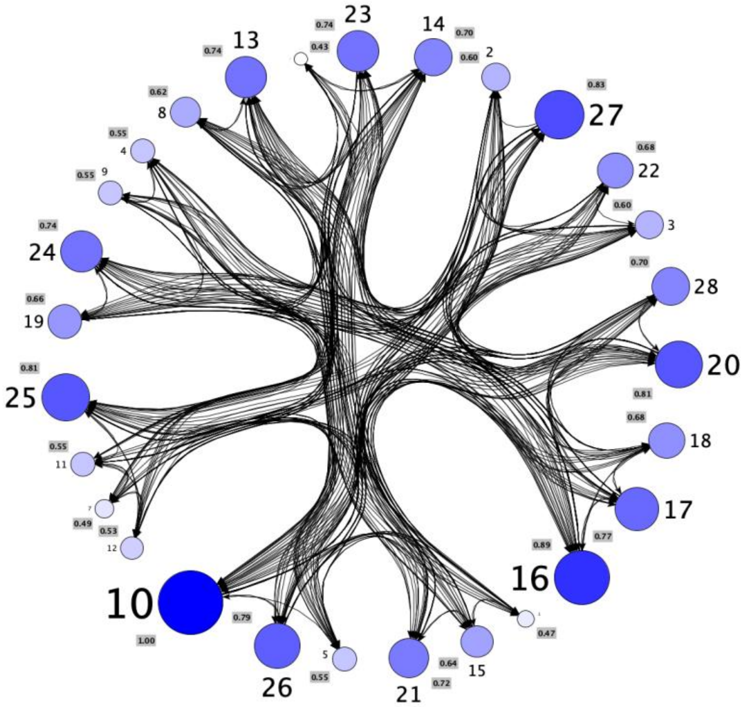

Figure 6: Visualization of some structure properties for a directed graph for the IPMA ICB 4.0 model in the yEd environment in the Circular Layout view with Enabled Edge Bundling setting on

On the other hand, visualization of structural connections in the form of trees allows you to look at the studied systems of connections "from a bird's eye view." For example, even if the creators of the IPMA ICB 4.0 standard had not proposed the grouping of elements of the ICB 4.0 competency model into three groups of competencies, as presented by its developers, but only information about the connections between the final elements of the entire model were given, this would be easy to do on based on the analysis of the graph of such a representation as shown in Fig. 7. Interesting, if the creators of the IPMA ICB 4.0 standard used similar types of representations of the models they develop, they might want to separately describe element 10 and describe its role as a connecting element between the three groups of competency elements, the need for which is clearly visible on the basis of the analysis of the representation models in fig. 7?

Of particular interest is the analysis of system connections when presented in the form of "Bus station", where you can also clearly see several clusters of "roads" that form three subsystems connected by only one "highway" with the main "station" – element number 10 (Leadership), as you can see on fig. 8. The presented toolkit is also of interest for structural modeling. For example, Fig. 9-11 show the results of modeling the system modification when the number of graph vertices decreases by “contracting” some edges to a vertex based on the analysis of the data in Fig. 4-6.

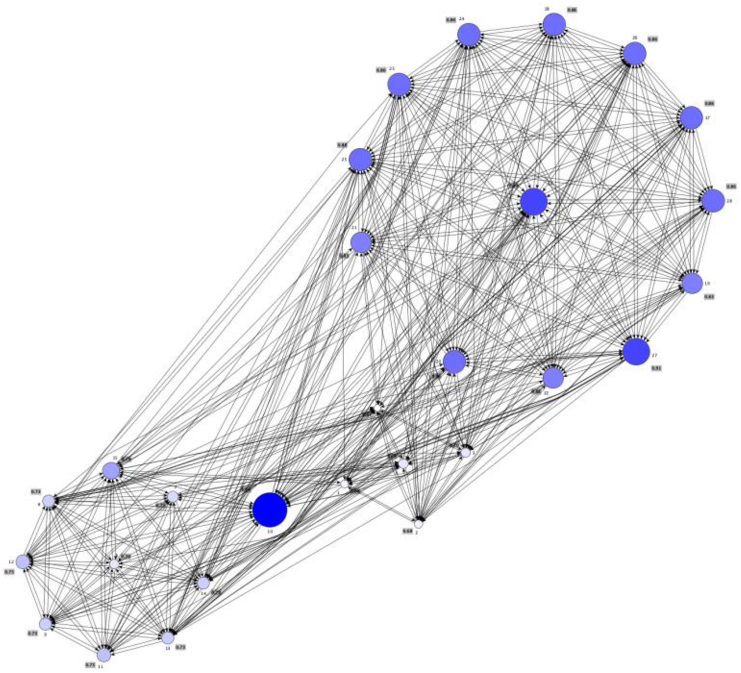

Figure 7: Visualization of some statistical indicators (fragment) for a directed graph for the IPMA ICB 4.0 model in the yEd environment in the Tree – Baloon Layout – Weighted Center Root – Organic view

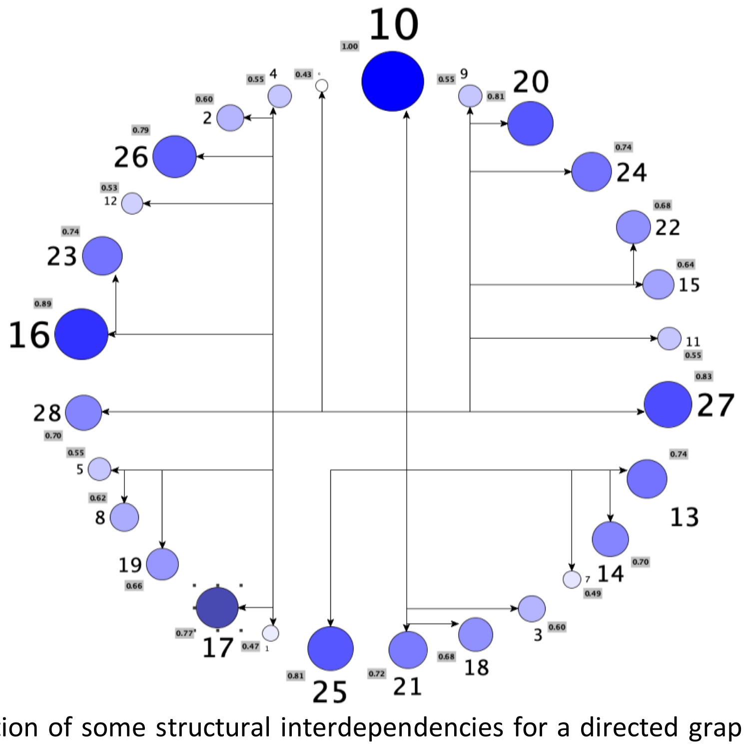

Figure 8: Visualization of some structural interdependencies for a directed graph for the IPMA ICB 4.0 model in the yEd environment in the Edge Routing - Orthogonal Bus-style view

As you can see from the visualizations presented in Fig. 9 and 10, the structural integrity of the system is preserved. In particular, the most significant elements of the system, namely "Power and interests" (4), "Leadership" (10) and "Project design" (16), continue to demonstrate their importance as truly backbone factors of the entire system as centers of their "planetary systems" corresponding in the logic of IPMA ICB 4.0 to each of the three blocks of competence. Further analysis can be carried out further, but the meaning of the given example is to show the possibility of using such structural analysis tools when carrying out work on both the creation and modification of systems, in particular, with the further development of competence systems in the field of professional project management.

The exclusion of the vertices 6, 7, 8, 9, 11, 12 from the model, which correspond to the elements of the "People" block of the original IPMA ICB 4.0 model, which is indicative, does not in any way diminish the structural role and influence of such an element as "Leadership". This, in turn, creates additional prerequisites (in particular, quite clearly visible in Fig. 7 and 8) to separate this single element into a separate subsystem, as an integral basis for the entire IPMA ICB model, for example, in the new version 5.0.

The presented visualizations certainly provide a lot of information, at least for the formation of hypotheses. it is obvious that some of these hypotheses, in principle, could not have appeared without visualization, similar to the one shown in the screenshots of the model views made in the eEd environment.

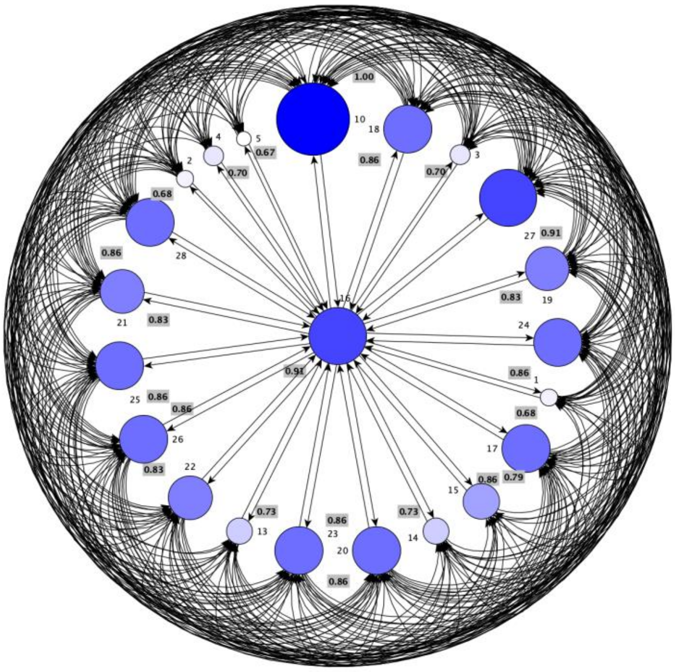

Figure 9: Visualization for a directed graph for the IPMA ICB 4.0 model in the yEd environment in the Radial Layout view for Weighted Centrality (Distance From Center) for structural model changes

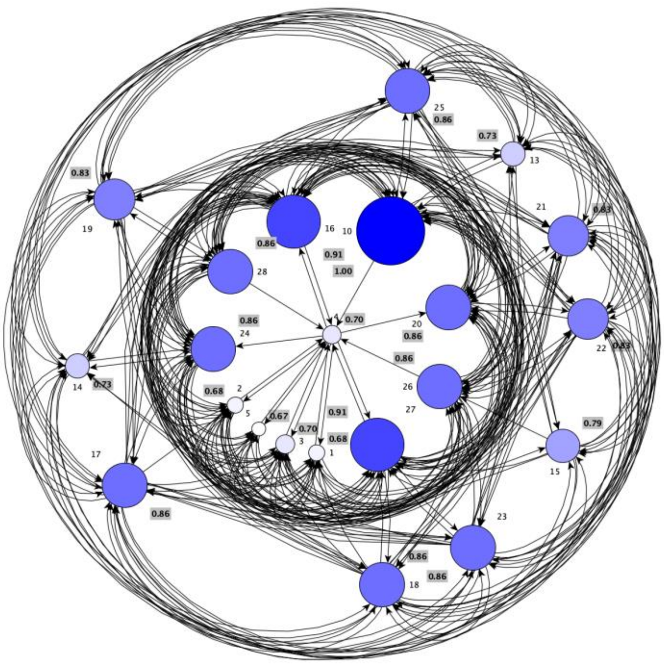

Figure 10: Visualization for a directed graph for the IPMA ICB 4.0 model in the yEd environment in the Radial Layout view for Centrality (Distance From Center) during structural model changes

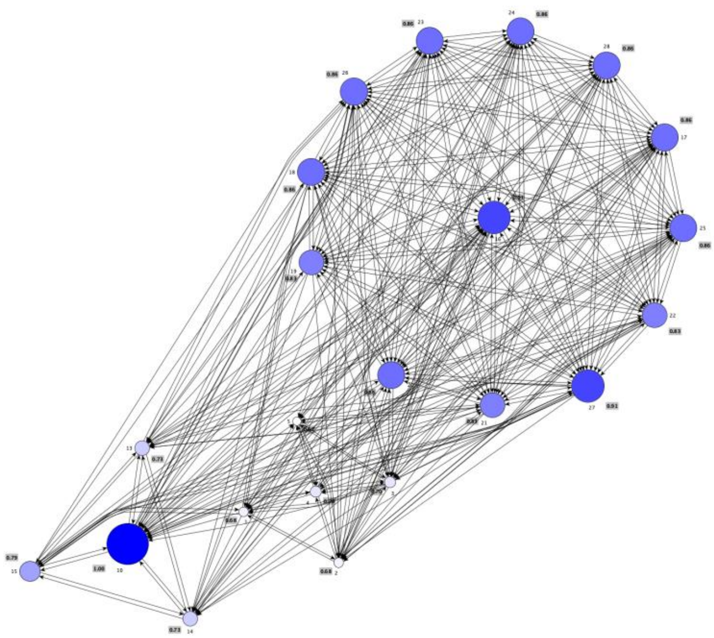

Figure 11: Visualization for a directed graph for the IPMA ICB 4.0 model in the yEd environment in the Tree - Baloon Layout - Weighted Center Root - Organic view during structural model changes

6. Conclusion

The presented approach to the use of graphical representations, according to the authors, can be used in the analysis of any other complex systems, where a sufficiently large number of mutually influencing elements can be identified. In order for the analysis of such systems to be as effective as possible, it is necessary to use the appropriate systems that automate the work on the primary processing and visual presentation of information. Such an effective tool for an analyst's work can be software with functionality similar to the example of using the yEd product presented in the article. Perhaps this approach will allow a more “instrumental” approach to assessing the importance of individual elements, incl. by modeling situations such as “excluding” a number of nodes or edges (elements of the studied systems or connections between them), and “adding” (predicting the need for a real but previously unidentified element or a connection between identified elements), which will allow a more professional and objectively approach the assessment of complex systems.

In particular, these are hypotheses about the special role of such elements of the model as 4 ("Power and interests"), 6 ("Self-reflection and self-management") and 16 ("Project design"), which are "centers" for their "subsystems", which are the corresponding blocks of the model under study, even if the initial model did not contain such a hierarchical representation. On the other hand, it may still be worthwhile to consider such an element as 10 ("Leadership") separately from any of any block of the model, and to single out its "integrating" and "connecting" role for the entire model. It is also worth taking more seriously an element such as 4, which, despite its "low weight", is still the "center" of the entire system, if we consider it from a topological point of view. In addition, the list of hypotheses can be supplemented with the possible need to revise the existing taxonomy when assessing competencies directly and when conducting certification according to this model — towards revising the "weights" of each of the blocks based on the analysis of the structure of links. Moreover, I would like to emphasize once again that all these hypotheses are not at all obvious and owe their emergence exclusively to the ability to conduct a visual analysis of the system under study using free software available today to any computer user.

7. Acknowledgment

Gratitude of the Ukrainian Project Management Association for the possibility of using in practice IPMA standards for assessing the competencies of project managers, as well as BNTU (Belarus) and

Project Management Bureau LLC (Ukraine) for using the competency models developed by the authors in the design and implementation of educational programs.

8. References

[1]. IPMA, 2019. URL: https://www.ipma.world/

[2]. PMI, 2020. URL: https://www.pmi.org/

[3]. Caupin, G., Knöpfel, H., Koch, G., Pannenbäcker, K., Pérez-Polo, F., & Seabury, C. Comparison between ICB and other project mangement standards. Bilbao: ICB Revision Project, (2004).

[4]. Yao, C. C., Siang L. F., Yih C. H. Comparing and Identifying the Similarities and Differences of Global Project Management Philosophies, Innovation and management, (2016): 1677.

[5]. Crawford, L. Competition, comparison, collaboration–mapping a pathway through project management standards. Procedia-Social and Behavioral Sciences, vol 74, (2013): 1-9.

[6]. Ghosh, S. et al. Enhance PMBOK® by comparing it with P2M, ICB, PRINCE2, APM and Scrum project management standards. PM World Today, vol. 14, issue – 1, (2012): 1 – 77.

[7]. Kössler, M. Project Management Standards and Approaches. A systematic Comparison. Manuel Kössler, (2013). URL: https://diglib.tugraz.at/download.php?id=576a76d6b24fa&location=browse

[8]. Qureshi, Sheheryar Mohsin, & Chang, Wook Kang. Analysing the organizational factors of project complexity usingstructural equation modelling. International Journal of Project Management, 33 (1), (2015):165-176. doi: http://doi.org/10.1016/j.ijproman.2014.04.006

[9]. Wen, Qi, & Maoshan, Qiang. Coordination and Knowledge Sharing in Construction Project-Based Organization: A Longitudinal Structural Equation Model Analysis. Automation in Construction, 72 (3), (2016): 309-320. doi: http://doi.org/10.1016/j.autcon.2016.06.002

[10]. A Guide to the Project Management Body of Knowledge. PMBOK® guide. Sixth Edition. (2016). Project Management Institute Inc.

[11]. PMCDF Project Manager Competency. Development Framework. Third edition. (2017). Project Management Institute.

[12]. S. D. Bushuyev, B. Yu. Kozyr. Hybridization of methodologies for managing infrastructure projects and programs. Bulletin of Odessa National Maritime University, vol. 61, (2020): 187-207.

[13]. Bertalanffy, L. Von. History and status of the general theory of systems. System researches: Yearbook, Moscow : Nauka, (1973): 20–37.

[14]. V. Morozov, O. Mezentseva and M. Proskurin. Trainable Neural Networks Modelling for a Forecasting of Start-Up Product Development. IEEE Third International Conference on Data Stream Mining & Processing, (2020): 55-60, doi: 10.1109/DSMP47368.2020.9204264.

[15]. Excel, (2020). URL: https://www.microsoft.com/en-us/microsoft-365/excel

[16]. yEd, (2020). URL: https://www.yworks.com/products/yed

[17]. IPMA standards – Individual Competence Baseline (ICB4), (2019). URL: https://www.ipma.world/individuals/standard/

[18]. Lukianov, D., Mazhei, K., Gogunskii, V. Transformation of the International Project Management Association Project Managers Individual Competencies Model. IEEE International Conference on Advanced Trends in Information Theory, (2019): 506-512

[19]. Lukianov D. et al. Analysis of the structural models of competencies in project management. Technology audit and production reserves, vol.2 (2), (2017): 4-11.

[20]. Lukianov, D., Bespanskaya-Paulenko, K., Gogunskii, V., Kolesnikov, O., Moskaliuk, A., & Dmitrenko, K. Development of the markov model of a project as a system of role communications in a team. Eastern-European journal of enterprise technologies, Vol. 3, Issue 3, (2017): 21-28.

[21]. Sherstiuk O., Kolesnikov O., Lukianov D. Team Behaviour Model as a Tool for Determining the Project Development Trajectory. IEEE International Conference on Advanced Trends in Information Theory, (2019): 496-500.

[22]. R. Trach, S. Bushuyev. Analysis communication network of construction project participants, Przegląd Naukowy Inżynieria i Kształtowanie Środowiska, (2020).