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Paweł Wyrozębski

5

RISK AND UNCERTAINTY IN PROJECT PLANNING PROCESS

5.1. Introduction

Projects are present in almost every field of human activity, and for decades have remained one of the most dynamically developing fields of knowledge[1]. This knowledge applies to functional, organizational, and personal problems and solutions of project management[2].

Functional problems, associated with the course of the projects are reflected in the stages of the project management cycle[3]. In the literature they are present in a variety of models[4], but usually they include activities related to the initiation, planning, implementation, monitoring and control, and closing projects[5].

Projects are complex, temporary, unique undertakings. Like all human activities, for right execution they require preparation before the action – i.e. planning. Planning is considered one of the most important management functions[6]. Problems and solutions associated with project planning are widely discussed in the literature,

[1] J.M. Nickolas, H. Steyn, *Project Management for Business, Engineering and Technology*, Butterworth-Heinemann/Elsevier, UK 2008, p. 17.

[2] L. Crawford, *Global Body of Project Management Knowledge and Standards*, in: *The Wiley Guide to Managing Projects*, eds. P.W.G. Morris, J.K. Pinto, John Wiley and Sons, Hoboken, New Jersey 2004, p. 1153, doi: 10.1002/9780470172391.ch46; P. Wyrozębski, E. Pączek, *Empirical Study On Knowledge Sources In Project-Intensive Organisations*, in: *Within And Beyond Boundaries Of Management*, eds. Z. Dworzecki, M. Jarosiński, Warsaw School Of Economics Press, Warsaw 2014, pp. 211–226.

[3] *Nowoczesne zarządzanie projektami*, ed. M. Trocki, PWE, Warsaw 2012.

[4] R.M. Wideman, *The Role of the Project Life Cycle (Life Span) in Project Management*, "Max's Project Management Wisdom" 2004; R.G. Cooper, *Winning at new products: pathways to profitable innovation*, Proceedings Project Management Research Conference, Montreal 2006.

[5] *A Guide to the Project Management Body of Knowledge*, 5th edition, Project Management Institute, USA 2013.

[6] H. Kerzner, *Project Management. A Systems Approach to Planning, Scheduling and Controlling*, 9th ed., John Wiley and Sons, USA 2006, p. 396.

textbooks and standards of project management[7]. Proper planning of projects is also a factor of success and failure of project execution[8].

Given the complexity of the project objectives and results, planning processes are also accompanied by considerable difficulty and complexity, resulting from, among others, domains subject to planning, quality and reliability of available information and the predictability and volatility of future conditions of the project[9]. The difficulty to simulate future states of the project in its complex and variable environment justifies the need to consider the impact of risk and uncertainty in the planning processes[10].

The aim of the chapter is to present the progress and results of the study on the level of risk and uncertainty in project planning with the recognition of the diversity of their occurrence in relation to selected industries and the characteristics of the projects. Based on the analysis of the literature and foreign research, presentation of which is beyond the scope of this chapter, three research questions have been formulated:

- RQ1. What is the level of risk and uncertainty of project planning?
- RQ2. In what areas of planning is the level of risk and uncertainty the greatest?
- RQ3. Is there a relationship between the level of risk and uncertainty of the project, and the type and context of project implementation?

The next section of the chapter presents the course of the research process, the obtained results and conclusions.

7 *Project Cycle Management Guidelines*, European Commission, Brussels 2004; *A Guide to the Project Management…*, op.cit.; *Managing Successful Projects with PRINCE2. TSO*, OGC, London 2009; ISO 21500:2012, *Guidance on project management*, 2012.

8 D. Murphy, N. Baker, D. Fisher, *Determinants of Project Success*, National Aeronautics and Space Administration Boston College, Boston 1974; J.K. Pinto, *Project Implementation: A determination of its critical success factors, moderators and their relative importance across the project life cycle*, University of Pittsburg, Pittsburg 1986, p. 20; D.J. Cleland, *Field guide to project management – second edition*, Wiley, New York 2004, pp. 24–25; D. Dvir, T. Raz, A. Shenhar, *An empirical analysis of the relationship between project planning and project success*, "International Journal of Project Management" 2003, vol. 21, no. 1, pp. 89–95.

9 A. Clarke, *A practical use of key success factors to improve the effectiveness of project management*, "International Journal of Project Management" 1999, vol. 17, no. 3, pp. 139–145; O. Zwikael, R.D. Pathak, G. Singh, S. Ahmed, *The moderating effect of risk on the relationship between planning and success*, "International Journal of Project Management" 2014, vol. 32, pp. 435–441; J.C. Taylor, *Project Scheduling and Cost Control. Planning, Monitoring and Controlling the Baseline*, J. Ross Publishing, New York 2008, p. 120; P. Wyrozębski, S. Spałek, *An Investigation of Planning Practices in Select Companies*, "Management and Production Engineering Review" 2014, vol. 5, no. 2.

10 J.R. Meredith, S.J. Mantel, *Project Management. A Managerial Approach*, 6th ed., John Wiley and Sons, New York 2006, p. 64; O. Zwikael, R.D. Pathak, G. Singh, S. Ahmed, *The moderating effect…*, op.cit., pp. 435–441.

5.2. Strategy and Research Model

Risk and uncertainty manifest themselves in many areas of project planning[11]. They have an impact on defined requirements, assumptions and limitations of projects, the scope, cost, time, quality and results[12]. The risk of the project is defined as the cumulative effect of uncertainty impacting the project as a whole[13]. According to the PMBoK authors, "the level of risk of the project is more than just a simple sum of the individual risks, because it takes into account all sources of uncertainty in the projects" [14].

The importance of risk and uncertainty in project planning is emphasized by Prof.M. Trocki. According to his proposed approach, in the case of projects one deals with three planning situations: planning under conditions of certainty, planning under conditions of risk and planning under conditions of uncertainty[15].

Planning under conditions of certainty (planning under conditions of full information) occurs when information on all the major issues of planning is complete and reliable. In this situation, one can explicitly specify the implementation conditions of future activities and states subject to planning, and the probability of deviation from the plan is low. With **planning under conditions of risk** "information on major issues of planning is not complete and reliable"[16]. In this case, planners face the need to identify different variants of the project and analyze them from the point of view of the likelihood of materializing. The last situation described by M. Trocki occurs when one is **planning under conditions of uncertainty**. According to the definition, "it occurs when the information on the main issues of planning, as in the second case, is incomplete and unreliable, various action options and their effects exist there, but one cannot determine – either objectively or subjectively – probability of their occurrence" [17].

This definition became a starting point to undertake this study and to make an attempt to answer the research questions posed at the beginning. On the basis of the works of M. Trocki, proposed by him aspects of risk and uncertainty of project planning were extended to the list of 25 statements listed in Table 5.1.

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[11] J. Schuyler, *Risk and Decision Analysis in Projects*, 2nd ed., Project Management Institute, USA 2001.

[12] E.W. Larson, C.F. Gray, *Project Management. The Managerial Process*, McGraw-Hill International, USA 2011, p. 211.

[13] *A Guide to the Project Management…*, op.cit.

[14] Ibidem, p. 30.

[15] *Planowanie przebiegu projektu*, ed. M. Trocki, P. Wyrozębski, Warsaw School of Economics Press, Warsaw 2015.

[16] Ibidem.

[17] Ibidem.

Table 5.1. Project Planning Level of Risk and Uncertainty Measures

q04.1	When planning the project, the team had access to all the necessary information
q04.2	The information, based on which the project was planned, was complete
q04.3	The information, based on which the project was planned, was considered certain
q04.4	The plan was supposed to present one, best variant of the project implementation
q04.5	Environment of the project had a stable and predictable character
q04.6	The overall level of project risk was low
q04.7	Key stakeholders were in agreement as to the course of the project
q04.8	The team knew exactly the expectations towards the project
q04.9	Goals of the project could be clearly and precisely identified
q04.10	The end result could be accurately described
q04.11	Way to obtain the final result was previously known in the organization
q04.13	There was no need to consider different variants of the project
q04.14	List of project tasks was determined and permanent
q04.15	Relationships between the project tasks were understood by everyone in the team
q04.17	Each task could be clearly described to contractors
q04.18	The project did not anticipate the possibility of returning to the already completed tasks
q04.19	The duration of each task could be precisely determined
q04.20	The team was certain of task duration estimates
q04.21	The estimation of project duration was not difficult
q04.22	There was no need to use large reserves of time
q04.23	Determination of needed resources didn't cause difficulties
q04.24	The number of needed resources could be determined with high precision
q04.25	The cost of individual tasks could be precisely determined
q04.1	There was no need to reserve substantial funds for unforeseen events
q04.2	Cost estimates of the project were certain

Source: own study.

In order to prepare a research tool, the above statements were supplemented by the scale of measurement, which is based on a five-point Likert scale.

Research tool supplemented by descriptive variables has been distributed among project management specialists. As a result of the collecting of empirical material, the efforts made it possible to reach the group numbering a total of 185 respondents.

The acquired sample is of nonprobability character. Due to the specifics of project activities, limited scale and scope of professional organizations and the lack of frame as a basis for sampling it was not possible to meet the conditions for its representativeness. One should therefore bear in mind the formal lack of sample's representativeness. Nevertheless, according to the author, one can, based on the obtained sample, observe the phenomena and put forward cautious conclusions regarding the whole population.

5.3. Characteristics of the Research Sample

The obtained structure of the research sample is quite diverse. About a quarter of the surveyed projects are construction ones (24.3% of the sample), every sixth project is an information technology project (16.8%), while one in ten – organizational (10.8%) and associated with the development of products and services (9.7%). Along with the scientific-research projects (7.0%) they constitute more than two-thirds of cases involved.

Table 5.2. Distribution of Project Types Represented by the Study Participants

Type of project		Frequency	Percent	Valid percent	Cumulative percent
Important	construction	45	24.3	24.5	24.5
	information technology	31	16.8	16.8	41.3
	organizational	20	10.8	10.9	52.2
	products and services development	18	9.7	9.8	62.0
	scientific-research	13	7.0	7.1	69.0
	industrial/production	13	7.0	7.1	76.1
	infrastructure	10	5.4	5.4	81.5
	marketing	8	4.3	4.3	85.9
	sales	7	3.8	3.8	89.7
	social	6	3.2	3.3	92.9
	educational/training	5	2.7	2.7	95.7
	other	8	4.3	4.3	100.0
	total	184	99.5	100.0	
Lack of data		1	0.5		
Total		185	100.0		

Source: own study.

The research survey was addressed to members of project personnel in Polish organizations participating in the projects. Among the respondents most numerous (70 people / 40%) were specialists – project team members and members of the project management team (27.4%). Slightly more than one in five respondents (22.3%) was a project manager performing managerial functions in relation to subordinate employees. Together these three groups accounted for almost 90% of the obtained sample.

Table 5.3. Most Often Occupied Positions in Projects

Occupied position		Frequency	Percent	Valid percent	Cumulative percent
Important	specialist/project team member	70	37.8	40.0	40.0
	project management team member	48	25.9	27.4	67.4
	Project manager	39	21.1	22.3	89.7
	informal cooperation within projects	12	6.5	6.9	96.6
	Project management office employee	3	1.6	1.7	98.3
	passive observer	1	0.5	0.6	98.9
	project board member	1	0.5	0.6	99.4
	member of the organization's senior management	1	0.5	0.6	100.0
	total	175	94.6	100.0	
Lack of data		10	5.4		
Total		185	100.0		

Source: own study.

Table 5.4. The Division of the Organization due to the Scale of Support from the Head Office/Parent Organization

Scale of support		Frequency	Percent	Valid percent	Cumulative perent
Important	no, full independence	43	23.2	24.9	24.9
	minimal support	56	30.3	32.4	57.2
	medium support	53	28.6	30.6	87.9
	intensive support	21	11.4	12.1	100.0
	total	173	93.5	100.0	
Lack of data		12	6.5		
Total		185	100.0		

Source: own study.

From the point of view of the role of project management in enterprises two-thirds of respondents work in organizations where it is high (33.1%) or very high (33.7%). One in thirteen respondents indicated the intensity level of projects in the organization as small. Among the organizations represented by respondents dominated the ones with a minimum or medium support from the head office or the parent organization. Only every twelfth respondent described the level of obtained support as intense. It can therefore be concluded that in the entire further tested sample management practices have individual character and are relatively independent of other organizations.

5.4. Scale Reliability Analysis

The obtained research material allowed the accession to the analytical work on the verification of data quality and the development of a synthetic indicator of risk and uncertainty of project planning. This index will be used in further steps to verify research hypotheses.

Due to the fact that the research questions were supposed to measure the analyzed phenomenon in order to verify the quality of data, one used scale reliability analysis of the reliability scale using Cronbach's alpha index and the procedure for the design of a reliable scale described in the literature on the methodology of scientific research[18].

The scale reliability analysis was conducted using Cronbach's alpha coefficient. For the full list of 25 partial measures the coefficient amounted to 0.879.

Table 5.5. Cronbach's Alfa Reliability Analysis – the First Iteration

Reliability statistics	
Cronbach's alfa	Number of positions
0.879	25

Total statistics of positions				
	scale average after removal of positions	scale variation after removal of positions	Total correlation of positions	Cronbach's alfa after removal of positions
q04.16	79.2749	187.353	0.107	0.883

Source: own study.

In the light of the methodological recommendations presented in the literature, the level of reliability of the obtained scale can be considered sufficient.

The analysis showed that it is possible to improve the reliability and quality of the scale by excluding from it the q04.16 statement: "The project did not anticipate having to return to the already completed tasks". This statement in the least way correlated with the scale. Apparently, the respondents felt the difficulty of understanding it and granting to it the right answers. On this basis, it was decided to exclude this measure from the scale.

Repeated analysis of the reliability of the 24 partial indicators showed a value of Cronbach's alpha of 0.883. At the same time again it was possible to improve the

18 *Electronic Statistics Textbook*, StatSoft, 2015, www.statsoft.com/textbook (23.11.2015).

scale's quality by the exclusion of the statement q04.12: "There was no need to consider different variants of the project". Alfa in this case increases to 0.884. Just as in the previous case, it was decided to exclude this statement from further analysis.

The third iteration and analysis of the reliability of the scale for 23 partial measures showed that further exclusions of statements do not improve the quality of projection of the examined phenomenon in the research tool. The final layout of measures thus consisted of 23 statements, with a high value of the alpha coefficient of 0.884.

Table 5.6. Analysis of Cronbach's Alfa Reliability – the Third Iteration

Reliability statistics	
Cronbach's alfa	Number of positions
0.884	23

Total position statistics				
	scale average after the removal of position	scale variation after the removal of position	Total position correlation	Cronbach's alfa after the removal of position
q04.1	73.6316	158.940	0.511	0.878
q04.2	73.5263	159.710	0.549	0.877
q04.3	73.0468	167.245	0.330	0.883
q04.4	72.6667	168.188	0.284	0.884
q04.5	73.5673	157.365	0.582	0.876
q04.6	73.7018	161.799	0.413	0.882
q04.7	73.1871	157.659	0.628	0.875
q04.8	72.7310	162.598	0.517	0.879
q04.9	72.4854	167.122	0.395	0.882
q04.10	72.3626	167.597	0.350	0.883
q04.11	72.9883	161.635	0.468	0.880
q04.13	73.2105	158.814	0.548	0.877
q04.14	73.1053	161.577	0.494	0.879
q04.15	72.8655	165.917	0.415	0.881
q04.17	73.2105	165.555	0.360	0.883
q04.18	73.3158	162.264	0.498	0.879
q04.19	73.4737	160.168	0.545	0.878
q04.20	73.5965	163.807	0.389	0.882
q04.21	73.2222	162.986	0.447	0.880
q04.22	73.0409	161.981	0.549	0.878
q04.23	73.0702	163.924	0.471	0.880
q04.24	73.2982	162.752	0.435	0.881
q04.25	73.2456	160.033	0.605	0.876

Source: own study.

5.5. Development of Risk and Uncertainty Index, RUI

Having partial measures one started to develop a summary scale.

The aim of summary scale was to obtain the synthetic indicator which reflects the overall level of uncertainty and risk in the planning of projects. This indicator has been in further stages used to verify the hypotheses placed in the beginning. The procedure adopted methodological recommendations for the design of composite indicators developed by the OECD and others[19].

The adopted method of creating RUI (risk and uncertainty index) included the following procedure[20]:

- determining the scope of the measurement and the appropriateness of the use for this purpose of composite index,
- choice of the partial indicators, designed to create a composite index,
- assessment of the quality of the data used,
- assessment of the relationship between partial indicators,
- weighting the partial indicators and their aggregation into a composite index.

The results of the first three steps associated with defining the scope, the selection of partial measures and the evaluation of the quality of the collected material were presented in earlier parts of this chapter.

In the assessment of the relationship between indicators and their aggregation into a composite index it was possible to use a few, described in the literature, alternative methods. According to the recommendations they can be determined arbitrarily, according to expert judgment or by using multiple regression, method of principal components, factor analysis, the Cronbach's alpha coefficient (Cronbach alpha), neutralization of correlation effects, efficiency frontier, the distance to the target and the analytic hierarchy process[21].

In the further described study the method of factor analysis using principal component analysis, PCA was used. Description of the method can be found in many

[19] *Handbook on Constructing Composite Indicators. Methodology and user guide*, OECD, Paris 2008; W. Florczak, *Pomiar gospodarki opartej na wiedzy w badaniach międzynarodowych*, "Wiadomości Statystyczne" 2010, no. 2; M. Nardo, M. Saisana, A. Saltelli, S. Tarantola, *Tools for Composite Indicators*, Brussels 2005; L. Hudrliková, *Composite indicators as a useful tool for international comparison: The Europe 2020 example*, "Prague Economic Papers" 2013, no. 4.

[20] W. Florczak, *Pomiar gospodarki*…, op.cit.

[21] *Handbook on Constructing*…, op.cit.; W. Florczak, *Pomiar gospodarki*…, op.cit.; M. Nardo, M. Saisana, A. Saltelli, S. Tarantola, *Tools for Composite Indicators*…, op.cit.; L. Hudrliková, *Composite indicators*…, op.cit.

sources, including the work of Lenka Hudrlikova[22], Bryan Manly[23], Donald Morrison[24], in StatSoft[25] statistical textbooks, and in the OECD's elaboration[26].

In order to verify the correctness of the analysis of the use of PCA, a Kaiser-Mayer-Olkin coefficient and Bartlett's test of sphericity were used in the study. KMO coefficient's threshold value reflecting the adequacy of the correlation matrix is determined by researchers at 0.5[27] to 0.7[28]. In the analyzed case, it amounts to 0.821. Barlett's test of sphericity showed that the hypothesis of uncorrelated factors may be rejected. The test statistic is 1,568.687 at the significance level of less than 0.001. According to the obtained results, further PCA analysis is justified and correct methodically.

Table 5.7. Kaiser-Mayer-Olkin and Bartlett's Tests

Tests of Kaiser-Mayer-Olkin and Bartlett		
KMO measure of sampling adequacy		0.821
Bartlett's test of sphericity	approximate chi-square	1,568.687
	df	253
	significance	0.000

Source: own study.

In the further analysis a method of extracting the factors of principal components with Varimax rotation was used. The selection of components was based on the Kaiser criterion, which assumes that eigenvalues of the separated factors will be greater than one.

Factor analysis helped to qualify 23 measures to six groups of factors, whose sum of the squares of the components after rotation was 63%. Cronbach's alfa that conveys the reliability of the whole amounted to 0.884.

The exact verification of the assignment of measures to components allowed to identify and name the individual components. Their configuration corresponds to the problem areas of project planning. Easy identification and uniformity of issues creating them seem to confirm the correctness of the preparation of a research tool.

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22 L. Hudrliková, *Composite indicators…*, op.cit.
23 B. Manly, *Multivariate Statistical Methods: A Primer*, Chapman and Hall, Londyn 2004.
24 D.F. Morrison, *Multivariate Statistical Methods*, Thompson Brooks, California 2005.
25 *Electronic Statistics Textbook…*, op.cit.
26 *Handbook on Constructing…*, op.cit.
27 A. Field, *Discovering Statistics using SPSS for Windows*, Sage publications, London–Thousand Oaks–New Delhi 2000; B. Williams, T. Brown, A. Onsman, *Exploratory factor analysis: A five-step guide for novices*, "Australasian Journal of Paramedicine" 2012, vol. 8, no. 3.
28 G. Wieczorkowska, J. Wierzbiński, *Statystyka. Analiza badań społecznych*, Wydawnictwo Naukowe Scholar, 2007.

Table 5.8. Factor Analysis – Results

The total explained variance									
Component	initial eigenvalues			sums of squares of components after extraction			sums of squares of components after rotation		
	total	% of variance	cumulative %	total	% of variance	cumulative %	total	% of variance	cumulative %
1	6.656	28.940	28.940	6.656	28.940	28.940	3.034	13.191	13.191
2	2.464	10.711	39.651	2.464	10.711	39.651	2.547	11.074	24.265
3	1.760	7.653	47.304	1.760	7.653	47.304	2.327	10.116	34.381
4	1.463	6.360	53.664	1.463	6.360	53.664	2.266	9.852	44.233
5	1.156	5.025	58.690	1.156	5.025	58.690	2.245	9.759	53.992
6	1.092	4.747	63.437	1.092	4.747	63.437	2.172	9.445	63.437
The method of extracting factors – the Principle components. The method of rotation – Varimax with Kaiser normalization.									

Source: own study.

Table 5.9. The Configuration of Components and Their Measures in the Study

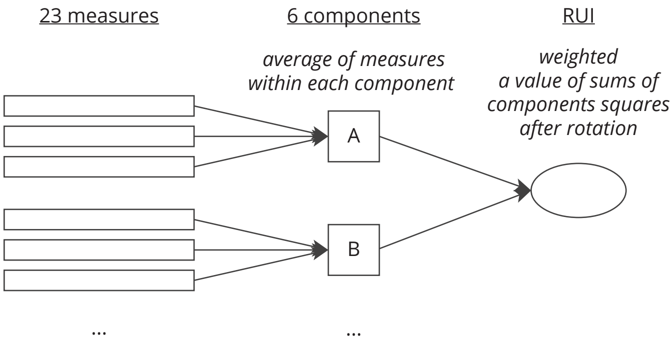
	Name of a component	The scope of measures/ questions	Translated % of the variance after rotation	Weigh
A	Risk and uncertainty of project resources	4.21–4.25	13.191	0.2079
B	Risk and uncertainty of project assumptions	4.1–4.4	11.074	0.1746
C	Risk and uncertainty of project time	4.17–4.20	10.116	0.1595
D	Risk and uncertainty of project scope	4.13–4.15	9.852	0.1553
E	Risk and uncertainty of project environment	4.5–4.7	9.759	0.1538
F	Risk and uncertainty of project result	4.8–4.11	9.445	0.1489
			Sum: 63.437	Sum: 1.000

Source: own study.

In order to aggregate 23 partial indicators to six components, and then one index which reflects a sum of risks and uncertainties of project planning (RUI), a procedure for weighting was adopted and averaging measures were presented in the diagram shown in Figure 5.1. Weighs have been standardized by the sum of the squares of components, which correspond to the part of the variance translated by the component.

As a result of the described procedure the desired composite index – RUI – reflecting a level of risks and uncertainties of project planning was obtained. The use of the indicator in the study will be presented later in this chapter.

Figure 5.1. The Procedure for Creating RUI Index



Source: own study.

5.6. Results and Discussion

End of works at the pre-treatment of data enabled the transition to the next stage of works and reference to the questions set at the beginning of research.

The answer to the first question **RQ1 on the level of risk and uncertainty** of project planning is possible on the basis of the distribution analysis of previously developed RUI indicator. Hypothetical RUI values may range from 1 to 5, since the linear indicator averaging process does not alter the border value of distribution. Because of the way of the partial measures structure and the adopted scale with an increase in value of the index, increases the level of risk and uncertainty of project planning. Properties of index for the researched project sample are shown in Table 5.10

The median of the distribution is 2.68, while half of the sample was located between the values of the first and third quartile respectively of 2.24 and 3.09. According to the respondents, projects represented by them were characterized by medium or even medium-low level of risk and uncertainty in planning. A detailed distribution of level of risk and uncertainty of the analyzed projects is shown in Figure 5.2.

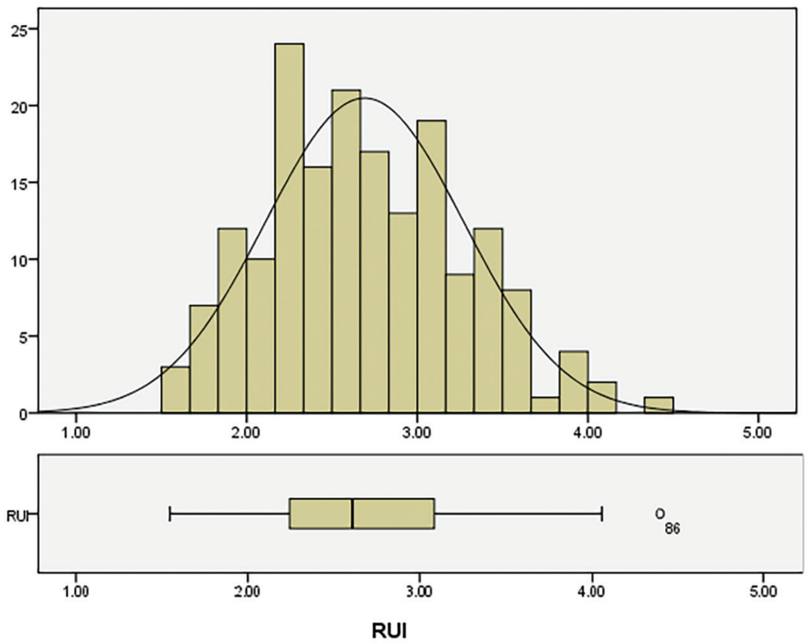
The researched sample is a nonprobability sample, so one needs to keep in mind the restrictions of drawing conclusions about the entire population. Therefore, two additional research questions involve a greater cognitive load than the first one.

Table 5.10. RUI Indicator – Descriptive Statistics

descriptive statistics (DESCRIPTIVES)				
			statistics	Standard error
RUI	Average		2.69055	0.043430
	95 percent confidence interval for the average	lower limit	2.60484	
		higher limit	2.77625	
	5 percent truncated mean		2.67668	
	Median		2.60620	
	Variance		0.338	
	standard deviation		0.581048	
	Minimum		1.540	
	Maximum		4.390	
	Range		2.850	
	interquartile range		0.846	
	Skewness		0.347	0.182
	Kurtosis		–0.432	0.361

Source: own study.

Figure 5.2. RUI Indicator – Histogram



Source: own study.

The second question **(RQ2)** applies to in-depth analysis of the level of risk and uncertainty from the perspective of the individual domains of project planning. For this purpose, the results of the factor analysis carried out earlier were used. This analysis made it possible to group the individual measures into six components (Tab. 5.11).

Table 5.11. Components of RUI Index – Descriptive Statistics

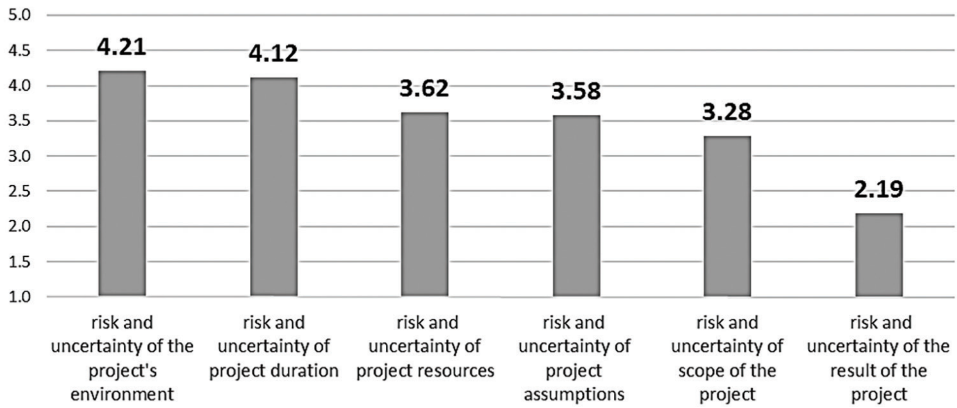
Statistics							
		risk and uncertainty of project resources	risk and uncertainty of project assumptions	risk and uncertainty of project duration	risk and uncertainty of scope of the project	risk and uncertainty of the project's environment	risk and uncertainty of the result of the project
N	important	179	180	179	179	180	180
	lack of data	6	5	6	6	5	5
Average		2.7089	2.7222	2.9404	2.5680	3.0000	2.1708
Standard error of average		0.06012	0.06253	0.06258	0.06429	0.07259	0.05492
Median		2.6000	2.7500	3.0000	2.3333	3.0000	2.0000
Standard deviation		0.80429	0.83895	0.83722	0.86017	0.97390	0.73684
Sum		484.90	490.00	526.33	459.67	540.00	390.75

Source: own study.

The measurement of individual variables and six components was made on an ordinal scale. Therefore, Friedman test has been used in order to assess the degree of risk and uncertainty of project planning areas and the development of a single component ranking. The results are shown in Figure 5.3.

The lowest level of risk and uncertainty accompanied the examined projects in the area of planning their results. The result of Friedman's test with an average rank of 2.19 and a large (1.09 points) distance to the second area in the ranking allow to regard it as an area with relatively lowest probability of deviations during the project. Respondents knew the expectations towards their projects and in their opinion possessed enough defined objectives. Both the end result and how it was delivered were largely known in advance in the organization. Relatively high confidence about the results of the projects corresponds to another area, i.e. the scope of the project (average rank of 3.28). A small uncertainty accompanying the results facilitates defining and planning the scope, identification of partial tasks and working out the cooperative structure of a project. The obtained results indicate that the highest levels of risk and uncertainty concerned the project's environment (average rank of 4.21). In particular, this uncertainty was related to the predictability of changes in the environment of the project, the overall risk assessment and actions of project stakeholders. Interestingly, while planning the results and scope of projects were characterized by a relatively low level of risk and uncertainty, duration planning was ranked second (average rank of 4.12), just behind the area of the project's environment, and therefore as an area significantly more difficult in planning.

Figure 5.3. Friedman's Test Statistics for Components – Average Ranks



Statistics of the test[a]	
N	179
Chi-square	142.722
df	5
The asymptotic significance	0.000
[a] Friedman's test	

Source: own study.

A detailed list of variables adopted in the study which underwent Friedman's test is presented in Table 5.12. The respondents relatively often opposed recognition of their projects as low-risk ones. Relatively most their problems were caused by the access to the necessary information needed in planning. They recognized the need for having reserves in order to protect the milestones and the deadline of the project. Environment of projects planned by them was more dynamic than stable. At the same time, according to the earlier analysis, among the factors characterized by a low level of risk they pointed planning objectives and results of the projects and their scope.

Table 5.12. Statistics of Friedman's Test for Individual Measures

Ranks			
		Average rank	Arithmetic mean
q04.6	The level of project risk was low	15.19	3.2278
q04.1	When planning the project, the team had access to all the necessary information	14.81	3.1222
q04.20	There was no need to use large reserves of time	14.44	3.1285
q04.5	Environment of the project had a stable and predictable character	14.37	3.0944
q04.2	The information, based on which the project was planned, was complete	14.31	3.0222
q04.19	The estimation of project duration was not difficult	14.21	3.0000
q04.18	The team was certain of task duration estimates	13.09	2.8547
q04.25	Cost estimates of the project were certain	12.96	2.7753
q04.24	There was no need to reserve substantial funds for unforeseen events	12.71	2.8258
q04.21	Determination of needed resources didn't cause difficulties	12.42	2.7584
q04.17	The duration of each task could be precisely determined	12.35	2.7709
q04.7	Key stakeholders were in agreement as to the course of the project	12.22	2.6816
q04.13	List of project tasks was determined and permanent	12.13	2.7095
q04.14	Relationships between the project tasks were understood by everyone in the team	11.82	2.6236
q04.22	The number of needed resources could be determined with high precision	11.58	2.5866
q04.23	The cost of individual tasks could be precisely determined	11.51	2.5819
q04.3	The information, based on which the project was planned, was considered certain	11.49	2.5698
q04.11	Way to obtain the final result was previously known in the organization	10.68	2.5222
q04.15	Each task could be clearly described to contractors	10.50	2.3743
q04.8	The team knew exactly the expectations towards the project	9.37	2.2611
q04.4	The plan was supposed to present one, best variant of the project implementation	9.01	2.1778
q04.9	Goals of the project could be clearly and precisely identified	7.82	2.0000
q04.10	The end result could be accurately described	7.02	1.9000

Test statistics[a]	
N	171
Chi-square	486.721
Df	22
The asymptotic significance	0.000
[a] Friedman's test	

Source: own study.

The third question adopted in the study (**RQ3) was associated with the search for the relationship between risk and uncertainty of the project, and the type and context of project implementation.** In order to answer it, three hypotheses were erected:

- H1. The respective domains of projects differ substantially in terms of the level of risk and uncertainty of planning,
- H2. "Hard" projects are characterized by a lower degree of risk and uncertainty than the "soft" ones,
- H3. With the increasing complexity of the project increases the degree of risk and uncertainty of planning.

These hypotheses were afterwards subject to verification using appropriate statistical tools and methods. Distribution normality research with Shapiro-Wilk test showed that none of the measures describing the level of risk and uncertainty of project planning (RUI, components, individual measures within the components) meets the conditions for having its distribution in line with the normal distribution. Normality tests statistics indicate that one must reject the null hypothesis talking about its normality. Therefore, the nonparametric tests were used for the study of the relationship between the variables.

Table 5.13. Distribution Normality Test Results of RUI Index and Components

Normal distribution tests						
Elements of analysis	Kołmogorow-Smirnow[a]			Shapiro-Wilk		
	statistics	df	significance	statistics	df	significance
RUI	0.069	179	0.037	0.983	179	0.029
Risk and uncertainty of project resources	0.096	179	0.000	0.970	179	0.001
Risk and uncertainty of project assumptions	0.087	179	0.002	0.978	179	0.007
Risk and uncertainty of project time	0.087	179	0.002	0.975	179	0.003
Risk and uncertainty of project scope	0.161	179	0.000	0.947	179	0.000
Risk and uncertainty of project environment	0.115	179	0.000	0.965	179	0.000
Risk and uncertainty of project result	0.144	179	0.000	0.956	179	0.000
[a] With a Lilliefors significance correction						

Source: own study.

H1. The respective domains of projects differ substantially in terms of the level of risk and uncertainty of planning

According to the state of scientific and practical knowledge, type of project, understood as the area of its implementation, affects its specificity. Therefore, hypothesis binding domain of the project with the level of risk was justified.

Groups having less than 13 cases were excluded from the analysis, obtaining as a result six domains in the comparisons. In the first step of the analysis the differences of the RUI composite index reflecting the overall level of risk and uncertainty of projects were examined. The analysis conducted with Kruskal-Wallis test did not show the significant differences in the sample (chi-square = 3.512, p = 0.622).

Table 5.14. The Results of Kruskal-Wallis Test for RUI

Ranks			
	type of project	N	average rank
RUI	construction	43	64.21
	information technology	31	78.65
	scientific-research	13	73.62
	organizational	19	61.42
	industrial/production	13	67.92
	products and services development	17	65.29
	Total	136	

Source: own study.

Table 5.15. The Results of the Kruskal-Wallis Test of Components

Test statistics[a,b]						
	risk and uncertainty of project resources	risk and uncertainty of project assumptions	risk and uncertainty of project time	risk and uncertainty of project scope	risk and uncertainty of project environment	risk and uncertainty of project result
Chi-kwadrat	1.960	2.094	7.676	1.621	3.011	14.829
df	5	5	5	5	5	5
The asymptotic significance	0.855	0.836	0.175	0.899	0.698	0.011
[a] Kruskal-Wallis test						
[b] Grouping variable: Type of project						

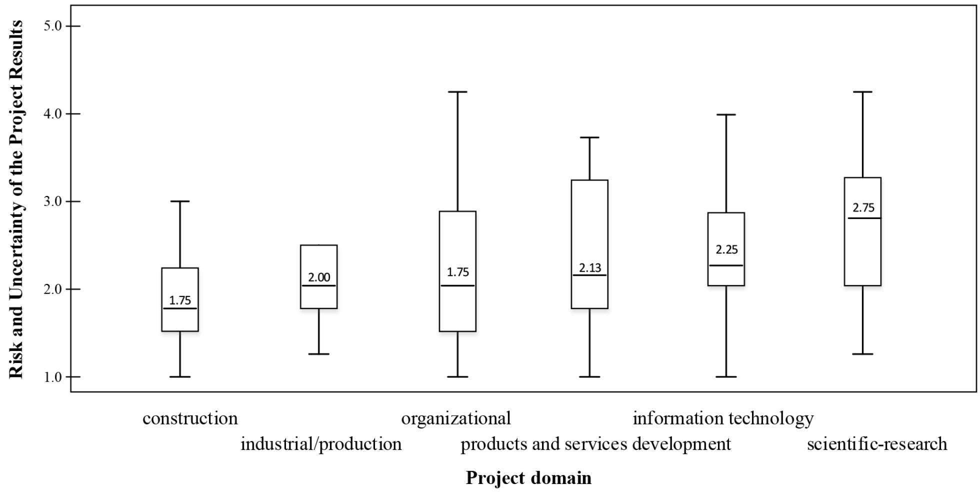
Source: own study.

In the next step the different levels of risk and uncertainty from the perspective of six areas of the components forming together a composite indicator were examined.

Kruskal-Wallis analysis, which showed in this respect one significant differentiation, was used again. It concerned the component – the risk and uncertainty of the project.

Participants of the study representing different domains of projects significantly differ in assessing the degree of risk and uncertainty associated with the planning of the project results. Further information is provided by the analysis of the box-plot shown in Figure 5.4. Component's distributions are characterized by a considerable dispersion between their minimum and maximum values. However, one can see a relatively high certainty of the final result and a focus of values around the median for the construction and industrial-production projects.

Figure 5.4. Quartile Distribution of Risk and Uncertainty of the Project Results by Project Domains



Source: own study.

These observations are confirmed by complementary post-hoc analysis. Conducting pairwise comparisons showed that with the level of $p < 0.05$ the level of risk and uncertainty of project results planning differs significantly between construction projects, and in turn: information technology, scientific-research and products and services development. In each case, the construction projects were accompanied by greater certainty and stability of assumptions on the results. The other three types of projects are characterized by a relatively high level of risk and uncertainty.

Table 5.16. The Results of Post-Hoc Tests

Sample 1 – Sample 2	Statistics of test	Standard error	Standardized statistics of test	Significance
Construction vs. information technology	–28.735	9.299	–3.090	0.002
Construction vs. scientific-research	–35.592	12.491	–2.849	0.004
Construction vs. products and services development	–23.727	11.079	–2.142	0.032

Source: own study.

H2. "Hard" projects are characterized by a lower degree of risk and uncertainty than the "soft" ones

Among the various types of projects one of the dimensions of their classification is a division into the so-called "hard" and "soft" projects. The nature of the end result is a reference point. "Hard" projects are the projects whose end result has a form of a physical effect – the object, structure, investment asset, element of infrastructure, or product. Such results, though often very complex, are easily identifiable, tangible and thus potentially easier to imagine, define and plan. "Soft" projects – through the opposition – are the projects, whose end results are of intangible nature. They will include events, modifications and improvements of processes, implementation of changes, training or organizational projects. In literature they are also defined as "product oriented", i.e. "hard" and "process-oriented", i.e. "soft". A different specificity of two categories of projects affected hypotheses investigating the level of risk and uncertainty in their planning.

Due to the division of the survey sample into two independent groups according to the criterion discussed above, Mann-Whitney's test to verify the hypothesis was used. As a result of the test procedure in relation to the RUI index, one failed to find significant differentiation of this feature because of the nature of the final result (U = 3221.0, P = 0.671).

Table 5.17. The Mann-Whitney Test Results for RUI Index

Statistics of test[a]	
	RUI
Manna-Whitney	3221.000
Wilcoxona	4761.000
Z	–0.425
The asymptotic significance (double-sided)	0.671
[a] Grouping variable: Type of result	

Ranks				
	Type of result	N	Average rank	Sum of ranks
RUI	soft	55	86.56	4761.00
	hard	122	90.10	10992.00
	total	177		

Source: own study.

In-depth analysis from the perspective of each of six components showed statistically significant differentiation in the case of two of them.

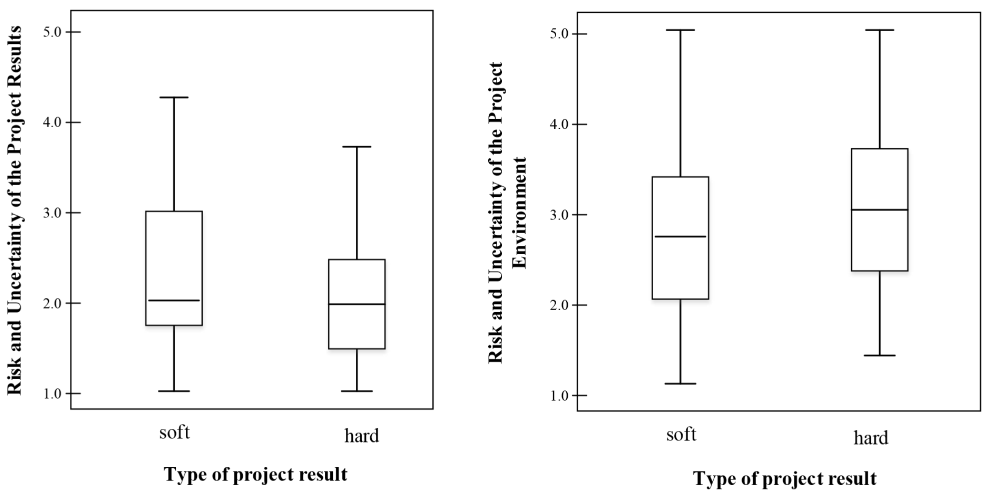
Table 5.18. Mann-Whitney Test Results for the Individual Components

Statistics of test[a]						
	risk and uncertainty of project resources	risk and uncertainty of project assumptions	risk and uncertainty of project time	risk and uncertainty of project scope	risk and uncertainty of project environment	risk and uncertainty of project result
Manna-Whitney	3104.000	3356.500	3068.500	3197.000	2733.500	2696.000
Wilcoxon	4644.000	10982.500	4608.500	10700.000	4273.500	10322.000
Z	–0.798	–0.082	–0.912	–0.506	–2.054	–2.174
The asymptotic significance (double-sided)	0.425	0.935	0.362	0.613	0.040	0.030
[a] Grouping variable: Type of result						

Source: own study.

According to the outcomes of the test procedure, the nature of the result was important in the case of components that describe the level of risk and uncertainty concerning the outcome of the project itself and its environment.

Figure 5.5. Quartile Distribution of Risk and Uncertainty of the Project Result and Risk and Uncertainty of the Project Environment Components from the Perspective of Type of Result



Source: own study.

In the case of object-oriented projects level of uncertainty accompanying determining the expectations of the project, defining the objectives, specifics of effects and technology of their delivery was significantly lower than in the case of process-oriented projects. In this way an empirical confirmation that the specificity and the ability to visualize the effects of the end results affect the ability of project participants to more precise planning of the project's products was obtained. Soft projects are characterized in this area by much greater uncertainty, resulting from the difficulty of clearly identifying, describing and agreeing among project stakeholders their intangible effects.

Table 5.19. Types of the Results by Projects Domains – Frequency Statistics

Project domain		Type of result					
		soft			hard		
		size	% from N in a row	% from N in a column	size	% from N in a row	% from N in a column
Type of project	construction	0	0.0	0.0	44	100.0	35.2
	industrial/production	1	7.7	1.8	12	92.3	9.6
	infrastructural	1	10.0	1.8	9	90.0	7.2
	information technology	6	20.0	10.7	24	80.0	19.2
	products and services development	4	23.5	7.1	13	76.5	10.4
	scientific-research	5	38.5	8.9	8	61.5	6.4
	marketing	4	50.0	7.1	4	50.0	3.2
	sales	4	57.1	7.1	3	42.9	2.4
	other	5	62.5	8.9	3	37.5	2.4
	educational/training	4	80.0	7.1	1	20.0	0.8
	Social	5	83.3	8.9	1	16.7	0.8
	Organizational	17	85.0	30.4	3	15.0	2.4
	Total	56	30.9	100.0	125	69.1	100.0

Source: own study.

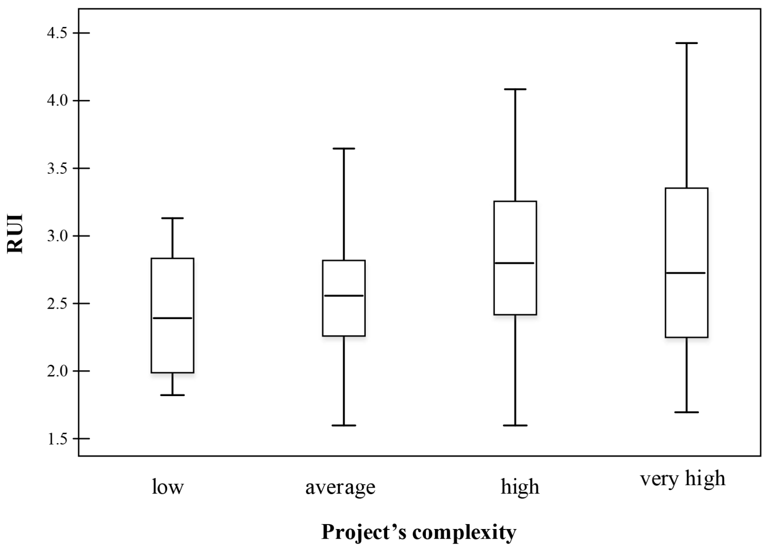
On the other hand, from the point of view of the risk and uncertainty of the project environment, their level was higher in hard projects. In particular, this applied to variable describing the overall level of risk (q4.06). In the case of soft projects the average value of the variable in the sample was 2.89 (median = 2.0) and, in the case of hard projects – 3.36 (median = 4). This observation can be explained by the complexity of projects, whose end result is a material object, consisting of many semi-products, subsystems, installations, etc. This situation occurs especially in the case of construction, industrial, infrastructure projects, and information projects related to building information infrastructure, which were strongly represented in the sample (see Table 5.19). The complexity of the results, and in consequence, of the problems of planning their implementation results in higher overall risk than in the case of soft projects.

H3. With the increasing complexity of the project increases the degree of risk and uncertainty of planning.

Third hypothesis related to the issues of project complexity, linking them to the level of risk and uncertainty of planning. Due to the measurement of all researched variables on an ordinal scale (in the case of project complexity it is increasing with the intensification of this phenomenon) in order to verify that hypothesis Spearman's rho correlation coefficient was used.

Conducted test procedure showed a statistically significant correlation between the RUI composite index, and the level of complexity of the project (rho = 0.173, p = 0.021). The strength of the correlation is moderate, but its direction remains in line with expectations – with increasing levels of complexity of the project there was an increase of the synthetic indicator of the level of risk and uncertainty of planning.

Figure 5.6. Quartile Distribution of RUI Index from the Perspective of the Level of Complexity of the Project



Source: own study.

In the next step, correlation analysis was performed with respect to the six components which constitute the RUI. The results are shown in Table 4.20.

Table 4.20. The Results of the Analysis of the Correlation Between the Variable Complexity of the Project and the Individual Components

Components	Complexity of the project		
	Spearman's rho correlation coefficient	significance (double-sided)	N
Risk and uncertainty of project resources	**0.265**[b]	**0.000**	**178**
Risk and uncertainty of project assumptions	0.019	0.805	179
Risk and uncertainty of project time	0.135	0.071	178
Risk and uncertainty of project scope	0.041	0.587	178
Risk and uncertainty of project environment	**0.301**[b]	**0.000**	**179**
Risk and uncertainty of project result	–0.022	0.768	179
[b] Correlation is significant at the 0.01 level (double-sided).			

Source: own study.

Of the six components, statistically significant correlations were found for the two of them. The greatest complexity of the project was related to the risk and uncertainty of the project environment. All three measures forming component also individually correlated with the level of complexity of the project. In the highest degree it concerned the variable describing the overall level of risk (q04.6), whose Spearman's rho coefficient was 0.35 at $p < 0.001$. Correlated variables associated with the variability and predictability of the project environment (q4.5) and the degree of compliance of the stakeholders towards the course of project (q04.7) were weaker, but still statistically significant ($p < 0.05$).

Table 5.21. The Results of Correlation Analysis Between the Measures Within the Component Risk and Uncertainty of the Project Environment and the Variable Complexity of the Project

Variables composing component "Risk and uncertainty of the project environment"		Complexity of the project		
		Spearman's rho correlation coefficient	significance (double-sided)	N
q04.5	**Project environment had stable and predictable character**	**0.174**[a]	**0.020**	**179**
q04.6	**Level of project risk was low**	**0.350**[b]	**0.000**	**179**
q04.7	Key stakeholders were in agreement as to the course of the project	0.180[a]	0.016	178
[a] Correlation is significant at the 0.05 level (double-sided).				
[b] Correlation is significant at the 0.01 level (double-sided).				

Source: own study.

The second component related monotonically with the level of complexity of the project was risk and uncertainty of project resources (rho = 0.265, p <0.001). An in-depth analysis of correlations within variables forming component highlighted the complexity of the relationship of the project with variables describing the risk and uncertainty of project costs. The increase in complexity of the project primarily affects the reduction of certainty of cost estimates (rho = 0.320, p <0.001), the need to secure substantial reserves for unforeseen events (rho = 0.273, p <0.001) and the ability to accurately determine the costs of the project tasks (rho = 0.199, p = 0.008).

Table 5.22. The Results of the Analysis of the Correlation Between Measures Within the Component Risk and Uncertainty of Project Resources with a Variable Complexity of the Project

Variables composing component **"Risk and uncertainty of project resources"**		Complexity of the project		
		Spearman's rho correlation coefficient	significance (double-sided)	N
q04.21	Determination of needed resources didn't cause difficulties	0.138	0.068	177
q04.22	The number of needed resources could be determined with high precision	0.124	0.099	178
q04.23	**The cost of individual tasks could be precisely determined**	**0.199** [b]	**0.008**	**176**
q04.24	**There was no need to reserve substantial funds for unforeseen events**	**0.273** [b]	**0.000**	**177**
q04.25	**Cost estimates of the project were certain**	**0.320** [b]	**0.000**	**177**
[a] Correlation is significant at the 0.05 level (double-sided).				
[b] Correlation is significant at the 0.01 level (double-sided).				

Source: own study.

5.7. Conclusions

Obtained results in the course of the research allow drawing findings and conclusions for the science and practice of project management in the organization.

First, these are the conclusions of a methodical nature. To measure the uncertainty accompanying project planning a set of measures was developed. Then, on their basis a composite index – RUI was prepared, consisting of six components separated during factor analysis (PCA). This process was based on best practices and methodological recommendations described in the sources indicated earlier in this chapter. Conducting research in the field of management, and project management in particular, often requires from researchers to measure the number of variables describing considered, most often a complex phenomenon. In particular, this problem affects researchers on the topic of project management maturity of organizations but also other complex areas such as project planning, risk management, or personal problems of project management. Composite indices are commonly used at the macro level to assess and compare the level of socio-economic development of countries. According to the author, knowledge and recommendations for the construction and interpretation can be successfully transferred to organizations management. As a result, it will be possible to improve research tools, and thus more accurate and reliable measurement and inference concerning researched objects and phenomena. Among the critical issues of project management, which longs for such solutions, there is a problem of assessing the success of the project. Despite years of effort, the environment of professionals of practice and science of project management has still not worked out a common, widely recognized methodology to evaluate the success of projects[29].

Among the other conclusions related to research on diversity of risk and uncertainty of project planning level, it is worth noting the following points.

First, the analysis demonstrated that with the project planning the lowest level of uncertainty accompanies the planning of results and scope of projects. The planned products and their specification are supposed to reflect the expectations of internal and external principals of the project. Their planning can be based on existing contracts, agreements, specifications and other project documents. In contrast, it is much harder when planning to obtain reliable information about the conditions of implementation and execution of these. It is relatively difficult to plan the time and resources, especially financial resources. In these areas, organizations should seek ways and solutions to improve the quality and reliability of planning.

Relative easiness of defining the objectives and results of the project and significantly higher uncertainty of time and resources justify directing project management attention to stochastic methods of project planning. Methods such as PERT, Critical Chain Project Management, Monte Carlo analysis allow to take into account the risk in the parameters of tasks falling within the scope of the project, and by so they facilitate determination of appropriate buffers of time and reserves of resources in projects[30]. In view of the obtained results using them in projects seems to be more

[29] A. Stretton, *Some deficiencies in data on project successes and failures. Series on Project Successes and Failures*, "PM World Journal" 2014, vol. 3, no. 7, www.pmworldjournal.net (23.11.2015).

[30] P. Wyrozębski, A. Wyrozębska, *Challenges of project planning in the probabilistic approach using PERT, GERT and Monte Carlo*, "Journal of Management and Marketing" 2013, vol. 1, no. 1; P. Wyrozębski, A. Wyrozębska, *Benefits of Monte Carlo simulation as the extension to the Program Evaluation and Review Technique*, in: *Proceedings in Electronic International Interdisciplinary Conference*, eds. M. Mokryš, Š. Badura, A. Lieskovský, Publishing Institution of the University of Žilina, Žilina 2013.

reasonable than the use of deterministic methods such as the critical path method (CPM), MPM methods or simple schedules.

In terms of industry comparisons (projects' domains) it should be distinguished construction projects, which were characterized by the lowest level of risk and uncertainty within planning results. In the light of the obtained data they were significantly lower than in the case of information technology, scientific-research and development of new products projects. This observation appears to be a consequence of the specific nature of this group of projects imposed by law, building standards and the long tradition of the construction industry. Objects erected as a result of construction projects are subject to detailed designing and documenting. In the case of Poland it includes Act of 7 July 1994 – Construction Law (Journal of Laws 2010 No. 243, item 1623, as amended) and accompanying regulations such as Regulation of the Minister of Transport, Construction and Maritime Economy of 25 April 2012 on the detailed scope and form of a construction project. Formal requirements towards construction undertakings oblige contractors to a detailed description of the results prior to the implementation of the project.

Practices and approach to the documentation of construction projects shape the specifics of the industry. On the other hand, it should be a source of inspiration and good practices that will support other industries during the planning of work.

In the case of information technology projects, R&D and NPD development of a detailed specification of the final result is often impossible. Then it is necessary to use methods that support exploration and design changes, allowing for an evolutionary move towards achieving that objective. One recommends greater flexibility of planning, decision-making freedom and delegating powers to low level and greater tolerance in the hands of the project manager on the range and quality of the results. Not only in IT but also in R&D and NPD it will be deliberate to use agile methods of project management, such as SCRUM, XP, DSDM and others.

The study showed differences in the risk and uncertainty of project planning results between the "hard" and "soft" projects. In the case of "process-oriented" projects efforts should be made in order to better identify and define the expected project results. In view of the accompanying significantly higher level of risk, management of projects must be certain that the offered products are described accurately, their composition, form, characteristics do not raise doubts, and all key stakeholders perceive them and understand the same. In another case there may be a risk of derogations and the poor quality of "soft / intangible" results – and therefore susceptible to individual interpretation.

As a result of the analysis one proved a correlation between the level of complexity of projects, and RUI index and the accompanying risk and uncertainty of project environment and resource planning. The complexity of the project as the only describing variable correlated in the study with the composite index. As in the case of geographical coverage, increase of the complexity of the project will require the use of stochastic methods of budget and resources planning and comprehensive analysis of the environment and the various risks during the stage of its preparation.

Moreover, the level of complexity of projects should be reflected in the internal regulations, e.g. project management methodology. In particular, its evaluation should affect the acceptable size of the buffers and financial reserves of projects. Based on the above it can be recommended for the management of complex projects to carefully analyze the quality of the estimates, made assumptions and effort put in planning, making sure that the work has been done to the best of their knowledge.

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