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Risk management in industrial projects using structural equation modeling

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A B S T R A C T

This paper presents an empirical investigation to study the effects of different factors influencing on accomplishment of projects in Iranian oil industry. The proposed study designs a questionnaire consists of 50 questions in Likert scale with seven factors including sanctions, economy, scheduling, contractor management weaknesses, cultural/social, force majeure and contractee. The study considers the effects of these factors in three categories; namely risk of project scheduling, risk in project cost and risk in management weakness. Using structural equation modeling, the study confirms that all three factors influence on the success of oil projects. In other words, The results have indicated that budgeting as well as cost accounting is the most important factor in accomplishment of oil projects followed by weakness in management and having an appropriate scheduling.

1. Introduction

During the past few years, there have been tremendous efforts on detecting important risks involved in executing big industrial projects (Craighead et al., 2007; Olson & Dash Wu, 2010). Risk identification often generates nothing more than a long list of risks, which can be difficult to manage. The list is normally prioritized to detect, which risks should be considered first, but this does not give any insight into the structure of risk on the project (Hillson, 2003). Tang and Musa (2011) investigated the research development in supply chain risk management (SCRM). The study identified and classified the potential risk related to various flows, namely material, cash and information flows. Thun and Hoenig (2011) performed an empirical analysis of supply chain risk management practices based on a survey with 67 manufacturing firms conducted in the German automotive industry and identified supply chain risks by analyzing their likelihood to happen and their potential effects on the supply chain. According to Qazi et al. (2016) "Project complexity has been extensively explored in the literature because of its contribution towards the failure of major projects in terms of cost and time overruns". Qazi et al. (2016)

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proposed a method, which helps capturing interdependency among project complexity, complexity induced risks and project objectives.

Cervone (2006) shed light on the issues associated with risk management in digital library projects as well as techniques for mitigating risk in these projects. ALNabhani et al. (2016) discussed the relative importance of public participation in legislation of TENORM risk management in the oil and gas industry. Salazar-Aramayo et al. (2013) shed light on factors, which influence Exploration and Production (E&P) project management success and corporate financial performance using structural equation modeling (SEM) methodology for a case study in a large Brazilian oil company. Marcella and Rowley (2015) presented an exploration of the extent to which project management tools and techniques could be implemented across creative industries through a comprehensive investigation of their application in the fashion industry in the North East of Scotland. Bjerga and Aven (2015) discussed management of risk for a case of large uncertainties and the adaptation of risk management in such circumstances. They used a case from the oil and gas industry to gain insights into how adaptive risk management could be used when giving due attention to the knowledge and uncertainty aspects of risk.

2. The proposed study

This paper presents an empirical investigation to study the effects of different factors influencing on accomplishment of projects in oil industry. The proposed study designs a questionnaire consists of 50 questions in Likert scale with seven factors including sanctions, economy, scheduling, contractor management weaknesses, cultural/social, force majeure and contractee. Details of the questionnaire is given in Table 8 in Appendix. The study considers the effects of these factors in three categories; namely risk of project scheduling, risk in project cost and risk in management weakness. Fig. 1 demonstrates the structure of the proposed study,

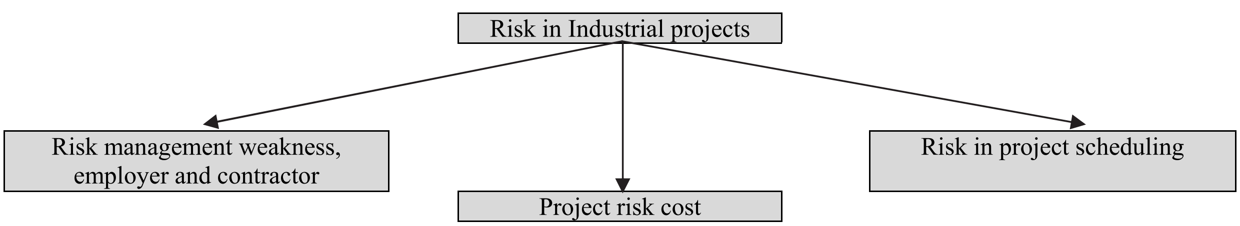

Fig. 1. The structure of the proposed study

The current research is a practical and applicable type of research and it is descriptive and inferential in terms of collecting data which explains the features of the sample and then generalizes these features to the statistical population. In this study, the descriptive research has been applied in survey type, because the means of collecting data (questionnaires) has been distributed and then collected in the samples of statistical population. The methods of collecting data in this research is of library and field operation kind. Thus, it can be generally said that this study is a practical descriptive survey research of correlation type analyzed by using exploratory function analysis for the first and second time and by the helping of SPSS and factor analysis together with Amos application and afterwards, by utilizing the factor analysis, the structural model was presented. Due to the fact that this is a case study and related to Derik energy company, the statistical population of this study is of accessible type in sampling method including the present managers, experts and employees and the volume of the samples (X) for explorative function analysis ($5\times q<x<15\times q$) and "q" stands for the number of questions in questionnaires Kline, Paul. (1994). First, the effective variables of the structures in the first step of Delfi were identified by the experts and then the effective variables were added from the sources including articles and the books after being collected. The common items of sources and elites were omitted and in the second step of Delfi elites, 38 effective variables of structures were ranked between the scales of

1 and 10 and 80 percent of the variables with high ranking were kept and the others were deleted and ultimately, “q” as the number of questions in questionnaires was designed equal to 31 effective variables in Likert scale between 1 and 5 and its content validity was confirmed the experts and the thesis supervisors and thesis advisors. The sample volume n=172 is considered between the minimum of 150 and maximum of 453. The questionnaires are distributed among the experts and managers and employees and in the final step, the questionnaires were collected and the entering of information and reforming the lost data by means of the median method were carried out (Draycott, & Kline, 1994). Fig. 2 demonstrates personal characteristics of the participants.

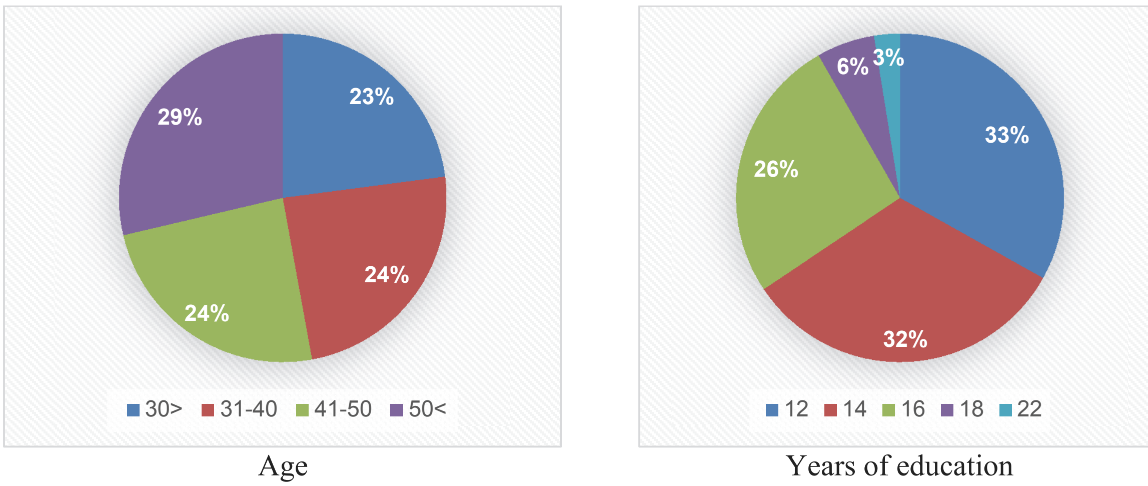

Fig. 2. Personal characteristics of the participants

As we can observe from the results of Fig. 2, most participants in our survey are middle aged with good university educations. The proposed study of this paper uses structural equation modeling (SEM) to measure the effects of three mentioned risk factors on accomplishment of industrial projects. Fig. 3 demonstrates the preliminary results of the implementation of the proposed study. The SEM has been extensively used for accomplishing different projects (Seyedaliakbar et al., 2016; Seyedaliakbar & Zaripour, 2017).

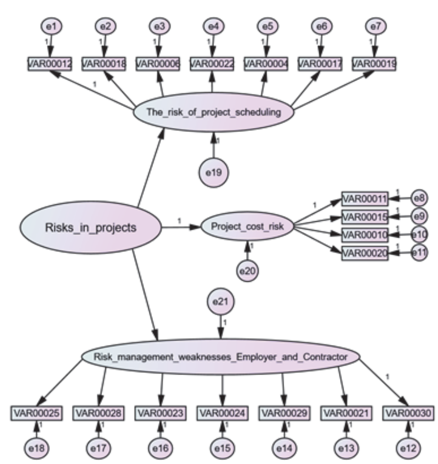

Fig. 3. The results of the implementation of structural equation modeling

As we can observe from the results of Fig. 3 and Table 1, most statistics are not within desirable values and we have to make some changes to make the model more appropriate by considering the relationships among internal variables. Fig. 4 demonstrates the revised model after the changes have been made (See Appendix for more details of the method used). As we can observe from the results of Table 2, all statistics are within desirable limits. Chi-Square value is more than the desirable value, and root mean square error of approximation (RMSEA) is less than 10%. Other statistics such as Goodness of fit index (GFI), Adjusted goodness of fit index (AGFI), Non-normed fit (NFI) index, etc. have maintained values of greater than 0.9, which confirm the overall model. Therefore, We can examine the hypotheses of the survey based on the results.

Table 1
The results of statistical observations

	Attribute	Symbol	Value	Desired value
	Chi-Square	χ^2	0.000	>0.05
Absolute fit attributes	Goodness of fit index	GFI	0.885	>0.90
	Adjusted goodness of fit index	AGFI	0.858	>0.90
	Non-normed fit index	NNFI	0.786	>0.90
	Normed Fit Index	NFI	0.662	>0.90
Comparative fit index	Comparative Fit Index	CFI	0.809	>0.90
	Bollen's Incremental Fit Index	IFI	0.815	>0.90
	Parsimonious normed fit index	PNFI	0.589	>0.5
Economic fitness	Root mean square error of approximation	RMSEA	0.055	<0.05
	Relative chi-square	CMIN/df	1.802	<2
Sample adequacy	Sample adequacy	Hotrel	120	>200

Table 2
The results of statistical observations

	Attribute	Symbol	Value	Desired value
	Chi-Square	χ^2	0.06	>0.05
Absolute fit attributes	Goodness of fit index	GFI	0.928	>0.90
	Adjusted goodness of fit index	AGFI	0.906	>0.90
	Non-normed fit index	NNFI	0.958	>0.90
	Normed Fit Index	NFI	0.798	>0.90
Comparative fit index	Comparative Fit Index	CFI	0.965	>0.90
	Bollen's Incremental Fit Index	IFI	0.966	>0.90
	Parsimonious normed fit index	PNFI	0.669	>0.5
Economic fitness	Root mean square error of approximation	RMSEA	0.024	<0.05
	Relative chi-square	CMIN/df	1.55	<2
Sample adequacy	Sample adequacy	Hotrel	220	>200

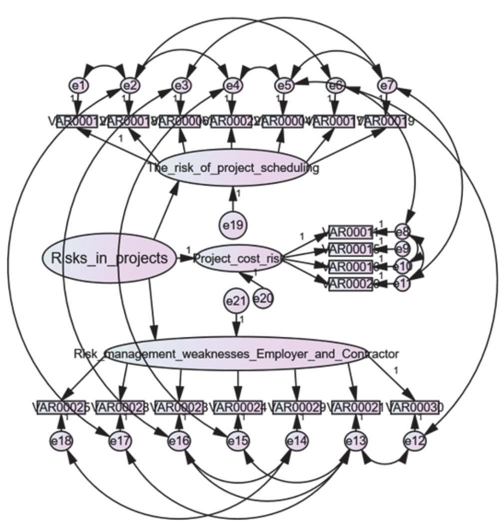

Fig. 4. The revised model

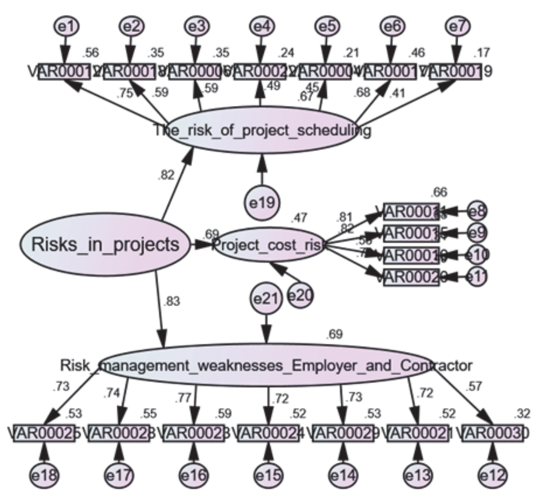

Fig. 5. The results of standard coefficients

Fig. 5 shows the results of standard coefficients on different factors. Moreover, Table 3 shows the results of our survey.

Table 3
The results of comparison of details of the fitting model

Variable			Estimate	S.E.	C.R.	P	Label
The_risk_of_project_scheduling	→	VAR00012	1				
The_risk_of_project_scheduling	→	VAR00018	0.478	0.088	5.421	***	par_1
The_risk_of_project_scheduling	→	VAR00006	1.035	0.152	6.809	***	par_2
The_risk_of_project_scheduling	→	VAR00022	0.666	0.139	4.8	***	par_3
The_risk_of_project_scheduling	→	VAR00004	0.659	0.128	5.151	***	par_4
The_risk_of_project_scheduling	→	VAR00017	0.988	0.135	7.292	***	par_5
The_risk_of_project_scheduling	→	VAR00019	0.56	0.111	5.052	***	par_6
Project_cost_risk	→	VAR00011	1				
Project_cost_risk	→	VAR00015	0.946	0.115	8.206	***	par_7
Project_cost_risk	→	VAR00010	0.437	0.074	5.922	***	par_8
Project_cost_risk	→	VAR00020	0.897	0.107	8.412	***	par_9
Risk_management_weaknesses_Employer_and_Contractor	→	VAR00030	1				
Risk_management_weaknesses_Employer_and_Contractor	→	VAR00021	1.21	0.18	6.734	***	par_10
Risk_management_weaknesses_Employer_and_Contractor	→	VAR00029	1.066	0.15	7.084	***	par_11
Risk_management_weaknesses_Employer_and_Contractor	→	VAR00024	1.213	0.159	7.634	***	par_12
Risk_management_weaknesses_Employer_and_Contractor	→	VAR00023	1.366	0.183	7.474	***	par_13
Risk_management_weaknesses_Employer_and_Contractor	→	VAR00028	1.126	0.148	7.615	***	par_14
Risk_management_weaknesses_Employer_and_Contractor	→	VAR00025	1.113	0.163	6.831	***	par_15

3. Conclusion and discussion

Based on the results of the survey, we are now ready to discuss of testing different hypotheses of the survey. The first hypothesis of the survey investigates the relationship between the risk in industrial projects and an appropriate scheduling of the projects. Table 4 shows the results.

Table 4
The results of testing the relationship between risk in industrial projects and an appropriate scheduling of the projects

	Correlation	Sig.	Result
Appropriate scheduling → Risk in project	0.755	0.000	Confirmed

According to the results of Table 4, we observe a positive and significant correlation between having an appropriate scheduling and risk in project. In other words, when there is an appropriate scheduling for accomplishment of a project, one may expect a reduction on risk involved in industrial projects. Table 5 demonstrates the results of testing the effect of cost involved in accomplishment of a project and the cost and budget.

Table 5
The results of testing the relationship between risk in industrial projects and cost of the projects

	Correlation	Sig.	Result
Budgeting the project → Risk in project	0.75	0.000	Confirmed

The results also confirm that there was a positive and meaningful relationship between these two variables and we can confirm the second hypothesis of the survey. Thus, we may expect to reduce the risk involved in project by appropriately assigning cost and budget. Finally, the last hypothesis of the survey studies the relationship between weakness in management and risk involved in accomplishment of projects, which are summarized in Table 6 as follows,

Table 6

The results of testing the relationship between risk in industrial projects and weakness in management

	Correlation	Sig.	Result
Weakness in management → Risk in project	0.14	0.023	Confirmed

The results of the survey have confirmed the relationship between these two variables and confirm the last hypotheses. Finally, Table 7 shows the results of standard coefficients.

Table 7

The results of standard coefficients

	Standard coefficient	Sig.	Result
Appropriate scheduling → Risk in project	0.44	0.000	Confirmed
Budgeting the project → Risk in project	0.66	0.000	Confirmed
Weakness in management → Risk in project	0.62	0.000	Confirmed

The results of Table 7 have indicated that budgeting & cost accounting is the most important factor in accomplishment in projects involved in oil industry followed by weakness in management and having appropriate scheduling. The results of this survey are consistent with other findings reported earlier in the literature. Salazar-Aramayo et al. (2013), for instance, presented similar implementation by using a conceptual model for project management of exploration and production in the oil and gas industry in Brazil and reported that the model could contribute substantially to the firm because it was a global representation of the main factors for improving E&P project management. Capolei et al. (2015) reported that in oil production optimization, we normally plan to maximize a deterministic scalar performance index such as the profit over the expected reservoir lifespan. However, when there are some uncertainty in the existing parameters, the profit results in a random variable, which could assume a range of values depending on the value of the uncertain parameters. They considered the concept of risk and explored how to handle the risk by applying appropriate risk measures.

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Appendix

The questionnaire of the survey consists of 50 questions in different categories summarized in Table 8 as follows,

Table 8
The questionnaire of the survey

Variable			Description
Embargo	1	1	Commercial embargo
	2	2	Financial embargo
	3	3	Technological embargo
	4	4	Transportation embargo
	5	5	Limitation in the number of available suppliers
	6	6	Work with low quality suppliers
Economic	7	1	Lack of existence of necessary infrastructures for accomplishment of the industrial project
	8	2	Price fluctuation
	9	3	Inflation
	10	4	Changes in currency exchange rate
	11	5	Unsuitable estimate in cost of project
	12	6	Revenue reduction and lack of employment satisfaction
	13	7	Lack of customer satisfaction
	14	8	Inefficient contractors
Scheduling	15	1	Time limitation for supplement of goods and equipment
	16	2	Error in scheduling project
	17	3	Tight schedule for the accomplishment of the project
	18	4	Inefficient contractors
	19	5	Damage in transportation of equipment
	20	6	Delay in transportation of equipment
	21	7	Delay in production and construction of equipment
	22	8	The effects of contractors' insufficient cash in accomplishment of project
	23	9	The effects of contractee's insufficient cash in accomplishment of project
Weakness in management	24	1	Lack of knowledge of contractor about tools and techniques associated with project activities
	25	2	Lack of commitment on behalf of contractor for the implementation of project activities
	26	3	The lack of skilled manpower
	27	4	The lack of skilled employees
	28	5	Rework to fix mistakes, resulting in delays in business
	29	6	Delays in clearance forms in custom section
	30	7	Damage to goods in transit
	31	8	Damage in goods and equipment
	32	9	Poor labor productivity
	33	10	Weak mobilization
	34	11	Violating the scope and terms of the contract
	35	12	The misallocation of human resources and equipment
	36	13	Lack of supervision of installation and commissioning of machinery and project Management
Cultural/Social	37	1	Cultural conflict and sabotage residents
	38	2	Theft and theft of equipment installed
	39	3	Inappropriate industrial culture workforce
Force majeure	40	1	Natural disasters such as flood, earthquake, etc.
	41	2	Fire and theft
Contractee	42	1	Lack of knowledge and familiarity with application of modern administrative methods
	43	2	Lack of access to records of similar projects
	44	3	Lack of coordination and the necessary support staff of the project
	45	4	The lack of systematic approach between the sectors related to the project
	46	5	Improper or incomplete economic feasibility studies
	47	6	Delays in resolving cases of contract
	48	7	Posing tight schedule to contractor
	49	8	Intervene and breaking the law by the contractee
	50	9	Inefficient system of evaluation and selection of contractors

The assessment of normality test is executed in Table 9. According to the results of Table 9, some of the variables have maintained Kurtosis values of less than 2.58 and we can observe that 18 variables are not normally distributed. To handle this problem, we use maximum likelihood estimator and Bootstrap. Table 10 shows the Mahalanobis distance for observations farthest from the centroid.

Table 9
The assessment of normality

Variable	Min	Max	Skew	C.R.	Kurtosis	C.R.
V19	1.000	5.000	-1.132	-5.790	2.469	6.315
V17	1.000	5.000	-.661	-3.383	-.025	-.064
V4	1.000	5.000	-.596	-3.047	.143	.365
V22	2.000	5.000	-.220	-1.124	-.977	-2.499
V6	1.000	5.000	-.497	-2.544	-.489	-1.250
V18	2.000	5.000	-1.109	-5.671	.480	1.227
V12	1.000	5.000	-1.012	-5.179	1.248	3.192
V20	1.000	5.000	-1.060	-5.423	1.693	4.330
V10	2.000	5.000	-.741	-3.793	.681	1.742
V15	1.000	5.000	-1.531	-7.831	2.773	7.093
V11	1.000	5.000	-1.608	-8.228	2.476	6.332
V30	1.000	5.000	-.747	-3.823	-.181	-.463
V28	2.000	5.000	-.180	-.919	-.968	-2.475
V21	2.000	5.000	-.204	-1.042	-.948	-2.426
V29	1.000	5.000	-.770	-3.940	-.151	-.387
V24	1.000	5.000	-.831	-4.251	.381	.974
V23	1.000	5.000	-.584	-2.988	-.612	-1.566
V25	1.000	5.000	-.371	-1.898	-.556	-1.421
Multivariate					43.473	10.150

Table 11
The summary of Mahalanobis distance for observations farthest from the centroid

Obs. number	Mahalanobis d-squared	p1	p2	Obs. number	Mahalanobis d-squared	p1	p2	Obs. number	Mahalanobis d-squared	p1	p2
48	52.814	0	0.004	126	23.748	0.163	0.032	105	17.598	0.482	0.876
122	52.814	0	0	39	22.82	0.198	0.184	150	17.598	0.482	0.841
64	39.806	0.002	0.005	113	22.82	0.198	0.137	25	17.103	0.516	0.953
60	37.099	0.005	0.009	29	22.312	0.218	0.264	144	17.103	0.516	0.936
78	37.099	0.005	0.001	148	22.312	0.218	0.207	46	17.064	0.519	0.923
54	32.69	0.018	0.068	15	22.303	0.219	0.16	120	17.064	0.519	0.898
72	32.69	0.018	0.026	90	22.303	0.219	0.119	36	16.904	0.53	0.917
18	32.525	0.019	0.011	134	22.303	0.219	0.086	110	16.904	0.53	0.89
93	32.525	0.019	0.003	8	21.791	0.241	0.194	155	16.904	0.53	0.857
137	32.525	0.019	0.001	127	21.791	0.241	0.148	40	16.82	0.535	0.853
26	32.276	0.02	0	9	21.277	0.266	0.304	114	16.82	0.535	0.814
145	32.276	0.02	0	84	21.277	0.266	0.245	49	16.792	0.537	0.783
63	30.515	0.033	0.002	128	21.277	0.266	0.193	123	16.792	0.537	0.733
81	30.515	0.033	0.001	19	21.15	0.272	0.193	68	16.662	0.546	0.755
59	30.204	0.036	0.001	99	21.15	0.272	0.149	62	16.615	0.55	0.729
77	30.204	0.036	0	138	21.15	0.272	0.112	80	16.615	0.55	0.674
37	29.626	0.041	0	55	20.814	0.289	0.182	43	16.497	0.558	0.691
111	29.626	0.041	0	73	20.814	0.289	0.14	117	16.497	0.558	0.633
156	29.626	0.041	0	82	20.814	0.289	0.105	67	15.801	0.606	0.922
58	27.757	0.066	0.004	17	20.717	0.294	0.1	38	15.744	0.61	0.913
76	27.757	0.066	0.002	92	20.717	0.294	0.073	112	15.744	0.61	0.885
27	27.264	0.074	0.003	136	20.717	0.294	0.053	157	15.744	0.61	0.85
146	27.264	0.074	0.001	20	20.52	0.304	0.067	21	15.503	0.627	0.905
33	25.535	0.111	0.066	100	20.52	0.304	0.048	101	15.503	0.627	0.875
107	25.535	0.111	0.041	139	20.52	0.304	0.033	140	15.503	0.627	0.838
152	25.535	0.111	0.024	5	20.184	0.323	0.067	66	15.42	0.633	0.835
22	24.985	0.125	0.055	96	20.184	0.323	0.048	45	15.261	0.644	0.864
102	24.985	0.125	0.034	51	19.449	0.365	0.239	119	15.261	0.644	0.825
141	24.985	0.125	0.021	125	19.449	0.365	0.192	53	14.993	0.662	0.896
14	23.947	0.157	0.142	6	18.985	0.393	0.38	71	14.993	0.662	0.863
89	23.947	0.157	0.101	97	18.985	0.393	0.32	34	14.988	0.663	0.826
133	23.947	0.157	0.069	42	18.81	0.404	0.363	108	14.988	0.663	0.78
52	23.748	0.163	0.073	116	18.81	0.404	0.304				
70	23.748	0.163	0.049	31	17.598	0.482	0.906				

Table 12 shows the results of Bootstrap selection procedure. Table 13 compares the results of Bootstrap with maximum likelihood estimator (MLE).

Table 12
The results of Bootstrap selection procedure

		proximity of covariance structures			
		GLS	ML	ADF	ULS
Parameter estimation	GLS	260.4	1015.82	_	563.71
	ML	539.335	311.77	_	**253.7**
	ADF	_	_	_	_
	ULS	_	_	_	_

Table 13
Comparison between MSL and Bootstrap

Parameter			ML			Bootstrap-ADF			
			Estimate	S.E.	C.R	mean	SE	L	U
z	→	Managementweaknesses	1	0	...	1	0	1	1
z	→	Riskofprojectcost	0.378	0.106	0.002	0.382	0.106	0.225	0.576
z	→	riskofprojectschedule	0.33	0.108	0.001	0.332	0.108	0.173	0.523
managementweaknesses	→	V25	1	0	...	1	0	1	1
managementweaknesses	→	V28	0.633	0.064	0.002	0.635	0.064	0.534	0.745
managementweaknesses	→	V23	0.855	0.074	0.003	0.859	0.074	0.732	0.981
managementweaknesses	→	V24	0.63	0.111	0.002	0.635	0.111	0.462	0.834
managementweaknesses	→	V29	0.703	0.069	0.003	0.707	0.069	0.588	0.814
managementweaknesses	→	V21	0.753	0.067	0.003	0.758	0.067	0.644	0.863
managementweaknesses	→	V30	0.462	0.111	0.002	0.464	0.111	0.298	0.66
riskofprojectcost	→	V11	1	0	...	1	0	1	1
riskofprojectcost	→	V15	1.36	0.238	0.002	1.405	0.238	1.14	1.834
riskofprojectcost	→	V10	0.686	0.202	0.003	0.721	0.202	0.422	1.007
riskofprojectcost	→	V20	1.57	0.46	0.002	1.663	0.46	1.136	2.437
riskofprojectschedule	→	V12	1	0	...	1	0	1	1
riskofprojectschedule	→	V18	0.275	0.185	0.118	0.267	0.185	-0.029	0.561
riskofprojectschedule	→	V6	0.975	0.262	0.004	1.015	0.262	0.619	1.312
riskofprojectschedule	→	V22	1.076	0.398	0.003	1.151	0.398	0.701	1.722
riskofprojectschedule	→	V4	0.931	0.501	0.003	1.026	0.501	0.524	1.705
riskofprojectschedule	→	V17	1.404	0.774	0.003	1.565	0.774	0.894	2.453
riskofprojectschedule	→	V19	0.893	0.397	0.002	0.972	0.397	0.602	1.579