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A decision-making model to outsource complex product systems research and development projects

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Abstract

Purpose: Complex product systems are goods with high technology. Research and development on their production requires resources beyond the capability of an organization. This study aimed to propose a decision-making model to outsource CoPS R&D projects.

Research methodology: The decision-making criteria were identified using the literature review and the Fuzzy Delphi method. Two conceptual models were developed using structural equation modeling. The pattern of relationships among criteria were determined by employing the DEMATEL technique. Then to prioritize the criteria and select between alternatives, the analytical network process was utilized.

Results: In the intra-organizational model, "project characteristics" has a positive effect on "requirements" and the latter has a similar effect on "competency". In the extra-organizational model, the "competency" has a positive effect on the "task performing capability", and the latter has a similar effect on the "adaptability". A two-stage decision model was developed. In the first stage, the decision to in/outsource the project is taken. In the second one, the mechanism of outsourcing is determined.

Limitation: Due to the breadth of types of inter-organizational cooperation in the range of integration between the organization and the supplier, only one of these types, namely outsourcing, has been addressed.

Contribution: An organization cannot outsource the development of CoPS unless it enjoys the technological, contractual, project control, integration, and soft technologies competencies. Furthermore, appropriate communication strategies and adequate financial resources are required. The managers of organizations developing CoPS such as airplanes, missiles, and power plants and can utilize the implications of the model.

Keywords: *CoPS, R&D, Outsourcing, Decision making, SEM, ANP*

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1. Introduction

Today, because of the constant changes in technology and the emergence of complex and new products, intense competition to access the opportunities is formed. Therefore, being prepared to take swift actions aimed at obtaining the best of opportunities is among the fundamental challenges confronted by

firms (Cuervo-Cazurrra et al., 2017; Smith, 2017; Warner, 2017). Moving from an industrial society to an information one, from a national economy to a global one, from centralization to decentralization, and finally from hierarchical to network-based structures are clear indices signifying basic development in the present-day environment (Smith, 2017). R&D units, therefore, have no other choice but to build flexible structures and effectively utilize extra-organizational resources (Barge-Gil & López, 2014).

Undoubtedly, responding to these changes requires novel solutions (Warner, 2017), one of which being outsourcing which increasingly takes a broader range and to which many organizations have recently been enticed (Hsu & Liou, 2013). Reviewing the theoretical and practical background of the outsourcing, and interviewing 18 experts of the Iranian Aviation Industries Organization, this paperaims at developing a model to outsource the defensive R&D projects of complex product systems.

2. Literature Review

2.1. Complex Product Systems

Complex Product Systems (CoPS) are capital goods with a high degree of technology and value. Incorporated in these systems are airplanes, telecommunications systems, flight simulators, high-speed trains, air traffic control systems, and weapon systems. These products are supplied to certain commercial users as one-off or small-batch products (Naghizadeh et al., 2016; Safdari Ranjbar et al., 2016b).CoPS play a key role in the promotion of modern technologies, and empowerment aimed at technological, industrial, and economic developments in developed and developing countries (Safdari Ranjbar et al., 2016a). Particular capabilities are needed for the development and innovation of CoPS, including technological capabilities, testing, system integration, networking, interaction and collaboration, planning and management of large-scale projects, intra-organizational and extra-organizational knowledge management, and, finally, market and customer relationship management. These capabilities were investigated in a separate study as critical success factors of innovation in CoPS with the national helicopter project carried out by the Iranian Aviation Industries Organization constituting its case study. Researchers developing the literature consider these products as certain categories of industrial ones that are distinct from commodity goods such as automobiles, semi-conductors, and ordinary electrical appliances (Dedehayir et al., 2014). CoPS may allocate a significant percentage of industrial investment to themselves. For instance, Moody and Dodgs (2006) state that %11of the GDP of a country belongs to CoPS. Moreover, the important issue is that mass products are significantly affected by CoPS. For instance, devices used for mass-production processes are often categorized as CoPS hence, rendering them the base pillar of many commodity goods. Safdari Ranjbar et.al illustrate a macro view of the development in the field and explore common themes by connecting research findings in this area. The utilization of CoPS is manifested in the context of the systems integration, an atmosphere as two sides of the same coin, including activities within and outside the organization. The research illustrates that both sides of the systems integration have found more strategic status, and the integration above is supposed as the core competency for competitive advantage of well-known firms such as General Electric, ABB ,Dell ,Ford ,IBM ,Siemens ,Rolls-Royce and McDonell. Gholz et al. examine the “second face” of systems integration related to the organization and management of supplier networks and illustrate the importance of the supply chain as a source of commercial-military integration, linking defense production to the wider economy (Gholz et al., 2018). Yassine presents an integrative literature review that includes theories, models, and tools that can be used to manage complex product development (Yassine, 2019). In a study, seven institutional and infrastructure factors affecting knowledge management processes were identified (Beigi, 2020). Zhou et al. develop strategic cooperation models under downstream competition and bargaining in a supply chain of CoPS and propose a revenue-sharing contract based on a specific investment relationship to coordinate the supply chain (Zhou et al., 2020). Ghorbani and Naghdi Khanachah presented 149 factors affecting the failure and delay of R&D projects (Ghorbani & Khanachah, 2020a). Safdari Ranjabr et al. contribute to sectoral innovation systems and CoPS literature by shedding light on the evolution of the

gas turbine industry as CoPS in the context of Iran as a developing country with some restrictions in global technology collaborations (Safdari Ranjbar et al., 2021).

2.2. Outsourcing

The recent body of business literature defines outsourcing as a phenomenon that involves using the extra-organizational resources to perform tasks and processes or produce goods or services which were already done within the organization (Espino-Rodríguez et al., 2017).

There is a broad stream of research behind the notion of outsourcing. Due to this scientific diversity, this concept is very extensive. Outsourcing, and specifically offshore outsourcing, can be used to refer to very distinct strategies. The conceptual legacy of outsourcing causes divergence among academic researchers and exponents. Elites like Kern interpret outsourcing as evolution and natural continuity to the views of Williamson and other studies on contracting and TCE1 . Simply put, Williamson states that if using the market led to transaction costs lower than the hierarchies, it should be purchased from the market-in other words, contracted out. These opinions antedate to Coase, who recommended internal organization of activities when the cost of doing this is less than using the market (Tadelis & Williamson, 2012).

Hymer discusses externalization vs internalization. Similarly, Richardson urged that “cooperation " and "coordination "in using the market mechanisms are in contrast to the duality of the market and the hierarchy of the transaction cost approach .Furthermore, in the garment industry, the transferring of the production activities to other companies has so long been recognized as pulling-out. Although the terms “externalization, coordination, and pulling-out” present a slightly different view to the idea of contracting out, all of these approaches point to the same managerial decision–making duality-to make or to buy (Cheng & Johansen, 2014). In a study, the challenges of SCM for research-development projects in Iran were divided into six categories: cultural, motivational, contextual, process, infrastructural, and capabilities (Forozandeh, 2021).

While the transaction cost approach supposes purchasing to be an approximately arms-length transaction, outsourcing involves different even closer inter-organization relationships. However, it has been urged that in ‘early phases’ the outsourcing strategy mainly incorporated contracting out upon cost-based incentives. As the applications have expanded and increasingly strategic activities are being outsourced, the relations have progressed beyond arms-length arrangements. Therefore, it is not that the theory is obsolete, it is perhaps the evolution of application that has caused the theory base to be complicated. Hence, although the theory of transaction cost can be considered as the basis of out-sourcing, it is insufficient in explaining the current complete scale of the outsourcing (Yuan et al., 2020). In a similar study, effective factors of knowledge success in construction projects include human resource development, knowledge-based orientation, knowledge evaluation, and transfer, information systems infrastructure, business culture, and modeling (Ghorbani & Khanachah, 2020b).

But how is outsourcing defined today? It may be viewed from two perspectives: production or process. From the process perspective, as defined by Barthelemy, outsourcing can be seen as transferring all or part of the organizational activities and processes to a supplier outside the organization. In terms of production, Ellram & Tate, 2015 for instance define outsourcing as “turning over the production of the merchandise or services previously done internally to an external organization. Not only the production of goods and services are outsourced to outside organizations, but also the responsibilities of the management, development, and continuous improvement of the activities. These approaches, with slightly different views to this phenomenon, define outsourcing with just slightly different characteristics. The common denominator as the main theme of outsourcing is the fact that outsourcing entails the transfer of the ownership of an activity. But the extent to which the ownership is transferred

[1]Transaction Cost Economics

is different and this is the main reason which leads the researchers to review and expand the concept of outsourcing (i.e. strategic and transformational outsourcing) (Mazumder & Garg, 2021).

In a study by (TAGHIZADEH et al., 2022) the intra-organizational factors affecting the CoPS R&D projects outsourcing have been stated (See Table1).

Table1. Intra-organizational factors affecting the CoPS R&D projects outsourcing (by the author)

Row	Factors	**Symbol**	Reference
1	Asset Specificity	C_1	(Beaugency et al., 2015)
2	The flexible structure of the organization	C_2	The experts
3	The technological uncertainty	C_3	(Gelderman et al., 2016)
4	High modularity and low batches of the CoPS	C_4	(TAGHIZADEH et al., 2022)
5	The quality improvement	C_5	(Zhou et al., 2019)
6	Strategic alliance with the suppliers to proliferate the product	C_6	(Lin & Darnall, 2015)
7	The risk of regular financial resources	C_7	The experts
8	Resource heterogeneity	C_8	(Munjal et al., 2019)
9	Reducing the time to development	C_9	(Li et al., 2017)
10	Vital information leakage	C_{10}	The experts
11	Market uncertainty	C_{11}	(Choi et al., 2018)
12	Cost reduction	C_{12}	
13	Behavioral uncertainty	C_{13}	(Yeo & Saboori-Deilami, 2017)
14	Belief in open innovation	C_{14}	The experts
15	Cognition	C_{15}	The experts
16	Intellectual property right	C_{16}	(Buss & Peukert, 2015)
17	Competence in supplier relationship management and being the employer	C_{17}	The experts
18	Learning by doing	C_{18}	(Lambrechts & Van Petegem, 2016)
19	Competence in integration	C_{19}	

In another study by (Poudeh et al., 2019) the extra-organizational factors affecting the CoPS R&D projects outsourcing have been stated (See Table 2).

Table 2. Extra-organizational factors affecting the CoPS R&D projects outsourcing (Poudeh et al., 2019)

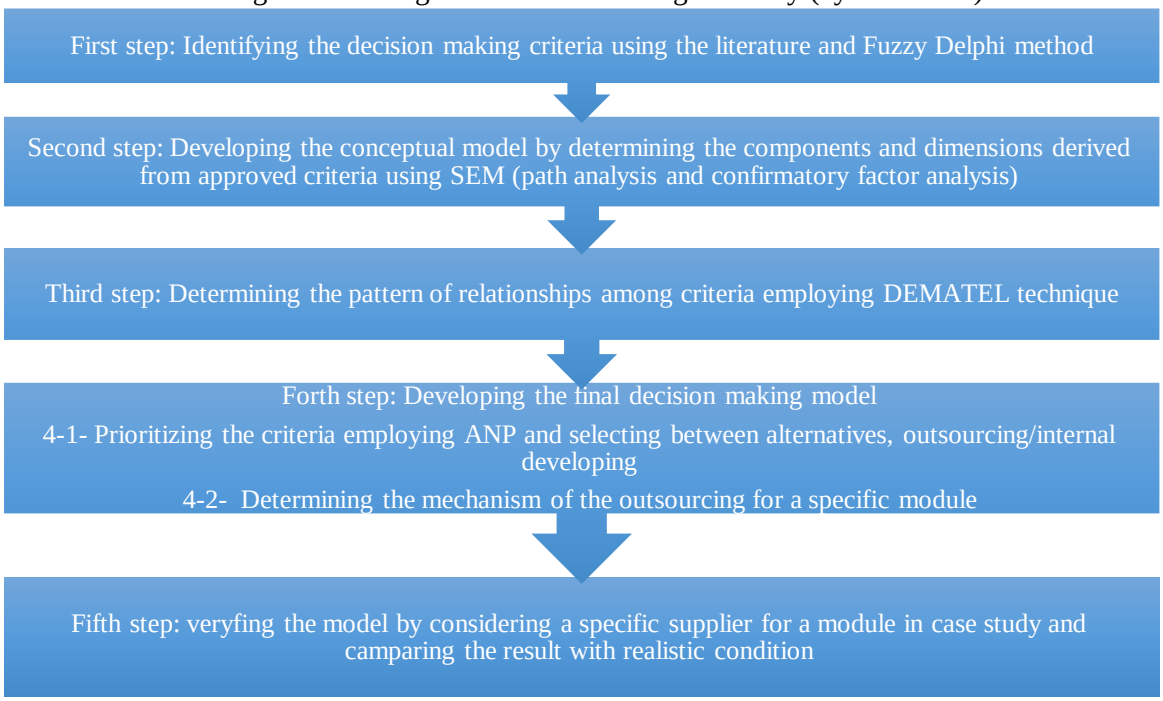
No.	Factor (regarding the supplier)	References	symbol
1	The familiarity with the latest methods in the world in delivering intended project-related services	(Poudeh et al., 2019)	D_1
2	Having standards including all kinds of ISOs	Babin & Quayle,) (2016	D_2
3	The flexibility in the way of delivering services according to the employer and collaborators' opinions	(Aguezzoul, 2014)	D_3
4	The software mastery in the area related to the project	(Cunningham & James, 2017)	D_4
5	The quality of service providing	(Feng et al., 2019)	D_5
6	Good record of doing the project with former employers	(Poudeh et al., 2019)	D_6
7	The financial sustainability during the project completion period	(Tirkolaee et al., 2020)	D_7
8	The extent of experience and expertise in the area related to the project		D_8
9	The time commitment to complete the job	(Aguezzoul, 2014)	D_9
10	The ability to attach importance to do even small and partial project-related orders	(Poudeh et al., 2019)	D_{10}
11	Timely delivery of the project	(Cheng et al., 2021)	D_{11}
12	The amount of working capital in a fiscal year	Cunningham &) (James, 2017	D_{12}
13	The level of the senior decision-makers' knowledge in the area related to the project	(Killen et al., 2020)	D_{13}
14	The responsibility for the provided offers and services	Gelderman et al.,) (2016	D_{14}
15	Adapting to values, beliefs, and organizational culture	Ertosun & Adiguzel,) (2018	D_{15}

3. Research Methodology

The research is categorized from four perspectives: purpose, usage, time, and approach (Bryman, 2016). As the purpose of this paper is to explore a novel issue and to determine the affecting factors in CoPS R&D projects outsourcing, how to make the decision on the outsourcing, and to describe an organizational phenomenon, it is classified under exploratory- descriptive one. On the other hand, as the result of this research can be immediately used by the case study, namely IAIO[2]and other CoPS manufacturing organizations, and help solve their related problems, it is applied in terms of usage. From the time perspective, because data gathering in this paper has taken place in one section of time, it is cross-sectional. Finally, in terms of approach, the present study is inductive because a new theoretical framework appears, and, by gathering data from experts and studying the literature, a model is developed and the moving direction is from component to the whole.

The executive algorithm of this paper is designed based on systematic steps according to the scientific research method. Steps taken to achieve the goal of the research are illustrated in Fig.1.

Figure 1. The algorithm for conducting the study (by the author)



[2]Iranian Aviation Industries Organization

In the present study, the unit of analysis encompasses the R&D projects of IAIO. The framework of the sampling includes all the experts dominating in doing the relevant projects of IAIO, they are 38 people in total. So, the number of the population is equal to 38. Using the Cochran's Sample Size Formula, the number of samples equals 35. Randomly sampling in an "appropriate category" way (Newman, 1991), so that the sample number of every category (equivalent to the industry in this study) is proportional to the whole number of category members, the questionnaires were presented to the members of the sample.

4. Data collection and analysis

4.1. Implementing the Fuzzy Delphi method in determining the factors affecting the decision-making

To determine and finalize factors influencing the decision making in this area, using the Delphi Fuzzy method, the following steps were taken:

In the first step, using the Fuzzy Delphi method, intra-organizational factors (see Table 1) found from the literature review were exposed to expert judgment, and the average of the experts' opinions (see Table 3) and its defuzzified equivalent (see Table 4) in two steps were obtained for each factor (see Table 5).

Table 3. The method to calculate the fuzzy average (Bojadziev & Bojadziev, 1995)

Fuzzy number	*Fuzzy average*
$(m_a^1, m_m^1, m_\beta^1)$ $(m_{a1}, m_{m1}, m_{\beta 1})$. $(m_{an}, m_{mn}, m_{\beta n})$	Fuzzy average= $\left(\frac{m_{a1}+m_{a2}+\cdots+m_{an}}{n}, \frac{m_{m1}+m_{m2}+\cdots+m_{mn}}{n}, \frac{m_{\beta 1}+m_{\beta 2}+\cdots+m_{\beta n}}{n}\right)=(m_a, m_m, m_\beta)$

Table 4 Defuzzification method(Bojadziev & Bojadziev, 1995)

$Xmax_3=\frac{m_a+4m_m+m_\beta}{6}$ $Xmax_2=\frac{m_a+2m_m+m_\beta}{4}$ $Xmax_1=\frac{m_a+m_m+m_\beta}{3}$	Crisp number = Z^* = max($Xmax_1$, $Xmax_2$, $Xmax_3$)

According to the Fuzzy Delphi method and Cheng and Lane's view (Cheng & Lin, 2002), we excluded the factors that their defuzzified deviations (according to equation 1 in which the Ami refers to the fuzzy number in ith step, and the am_{ij} refers to the jth element of the triangular fuzzy number in ith step) exceeded the threshold (0.1) in the first and second steps, and the rest of the factors were approved as the final ones (indicated by green stars in Table 5).

$$S(Am_2,Am_1) = [\frac{1}{3}[(am_{21}+am_{22}+am_{23})-(am_{11}+am_{12}+am_{13})] \quad (1)$$

Table 5. Intra-organizational factors with deviated defuzzified means based on the experts' view (by the author)

Row	Factors	symbol	Defuzzified average based on Fuzzy Delphi questionnaire		The abstract of deviation between 1st and 2nd steps	Experts' view	
			First step	Second step		accepted	rejected
1	Asset Specificity	C_1	0/65	0/71	0.06	*	
2	The flexible structure of the organization	C_2	0/73	0/72	0.01	*	
3	The technological uncertainty	C_3	0/65	0/74	0.09	*	
4	High modularity and low batches of the CoPS	C_4	0/3	0/35	0.05	*	
5	The quality improvement	C_5	0/72	0/8	0.08	*	
6	Strategic alliance with the suppliers to proliferate the product	C_6	0/69	0/70	0.01	*	
7	The risk of regular financial resources	C_7	0/46	0/46	0	*	
8	Resource heterogeneity	C_8	0/47	0/53	0.06	*	
9	Reduction of the time to development	C_9	0/52	0/57	0.05	*	
10	Vital information leakage	C_{10}	0/63	0/64	0.01	*	
11	Market uncertainty	C_{11}	0/78	0/91	0.13		*
12	Cost reduction	C_{12}	0/6	0/61	0.01	*	
13	Behavioral uncertainty	C_{13}	0/74	0/79	0.05	*	
14	Belief in open innovation	C_{14}	0/42	0/41	0.01	*	
15	Political risk	C_{15}	0/67	0/67	0	*	
16	Intellectual property right	C_{16}	0/53	0/59	0.06	*	
17	Competence in supplier relationship management and being the employer	C_{17}	0/53	0/5	0.03	*	
18	Learning by doing	C_{18}	0/32	0/44	0.12		*
19	Competence in integration	C_{19}	0/65	0/65	0	*	

On the other side, the final extra-organizational factors are stated in a study by the author (Poudeh et al., 2019) (refer to table 2).

4.2. Conceptual model and hypotheses

4.2.2. Intra- organizational model

According to a survey of experts (246 people), the accepted indices in Table 5 were placed in the clustering of Table 6 to be used in structural equation modeling. As the subject of the study belongs to R&D in a specific type of product, and there is no model including its components and dimensions, they were constructed employing the experts' views.

This part of the research expanded qualitatively with an inductive approach from the indices to the dimensions. Of these experts, 34 were willing to be interviewed and comment on the construction of components and dimensions, with due observance of security considerations. From experts' point of view, and after the clustering of indices in components of "resources", "communication strategy", "soft technology", "integration", "uncertainty", "hardware", "time", "quality", "Technical Characteristics" and " appropriability ", experts evaluated the components with a more in-depth view. Playing an essential role in giving it an outstanding status, four items of these components are related to the capabilities and characteristics of the outsourcing organization. These components including resources, communication strategy, soft technology, and integration are considered to be the competencies of the organization in R&D projects of CoPs and are encompassed in the "competency" dimension. The lack of "competency" will excessively endanger the organization's position in the effective and successful outsourcing of the projects. On the one hand, it is expected that the organization will have requirements along with these capabilities. Second and in terms of hardware, certain equipment would be needed. Third, the desirable time and quality of delivering the project would be among the successful requirements of the outsourcing. Therefore, the components of certainty, hardware, time, and quality are clustered at the dimension of the organization's "requirements". The technical characteristics and appropriability of a project related to CoPs have an outstanding status among the indices, and the outsourcing process is based on these characteristics. As a result, the "Project characteristics" was bunched as the third dimension along with the "Competency" and "Requirement" (see Table 6).

Table 6. Clustering of intra-organizational indices to be used in path analysis (by the author)

Dimension	Component	Index
Competency	Resources(E_1)	The risk of regular financial resources (C_9)
		Resource Heterogeneity (C_{10})
	Communication strategy(E_2)	Strategic alliance with the suppliers to proliferate the product (C_7)
		Competence in supplier relationship management and being the employer (C_{20})
	Soft Technology(E_3)	The flexible structure of the organization (C_3)
		Belief in open innovation(C_{16})
	Integration(E_4)	Competence in integration (C_{22})
Requirement	Certainty(E_5)	The technological uncertainty (C_4)
		Vital information leakage (C_{12})
		Behavioral uncertainty (C_{15})
		Political risk (C_{18})
	Hardware(E_6)	Asset Specificity (C_1)
	Time(E_7)	Reduction of the time to development (C_{11})
	Cost(E_8)	Cost reduction C_{14})
	Quality(E_9)	The quality improvement (C_6)
Project Characteristics	Technical(E_{10})	High modularity (C_5)
	Appropriability(E_{11})	Intellectual property right (C_{19})

As indicated in Table 7, all the figures illustrating the reliability of the research dimensions are higher than 0.7. Thus, the reliability is confirmed.

Table 7. Reliability of the intra-organizational dimensions of the research (by the author)

Cronbach's alpha coefficient	**Dimension**
% 83	Competency
% 85	Requirement
% 76	Project Characteristics
% 80	*overall*

The confirmatory and conceptual model of the research will be under Figure 2.

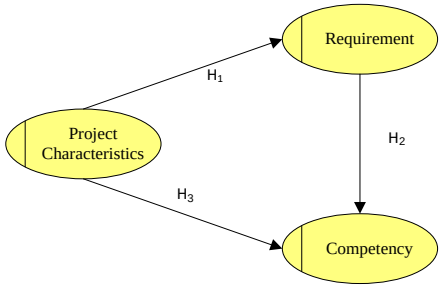


Figure 2 – Intra- organizational conceptual model (by the author)

Taking into account the experts' arguments and guidance in clustering the components and dimensions as well as studying the literature and the researcher's inference from them, the research hypotheses were extracted as a clever statement of the relationships among the dimensions of the proposed model (See Table 2). The first assumption is that the requirements of the organization are derived from the characteristics of the project. Therefore, the projects determine what gaps and shortcomings the organization faces. Once the requirements have been determined, according to the famous proverb "Necessity is the mother of the invention" the organization will seek to acquire the competency to meet the requirements. The second hypothesis is the significant effect of the requirements on competency determination. However, perhaps it is not too far-fetched that project characteristics directly determine an organization's competence. As a result, and with weaker probability than the former two hypotheses, this matter can be considered as the third one. Therefore, according to Fig. 2 and relationships among the dimensions, the hypotheses for measuring in the organization are as follows:

1- The "Project characteristics" have a positive and significant effect on the "Requirement".
2- The "Requirement" has a positive and significant effect on the "Competency".
3- The "Project characteristics" have a positive and significant effect on "Competency".

4.2.2.1. Testing the proposed intra-organizational hypotheses by path analysis approach

In this section, the structural equation modeling is applied to test causal relationships among dimensions of "competency, requirement and project characteristics". By path analysis approach, the proposed hypotheses are shown in Fig. 3 in the form of the intra-organizational conceptual model. Moreover, in figure 3, the intra-organizational conceptual and confirmatory model including the factor loadings written on each relationship can be seen.

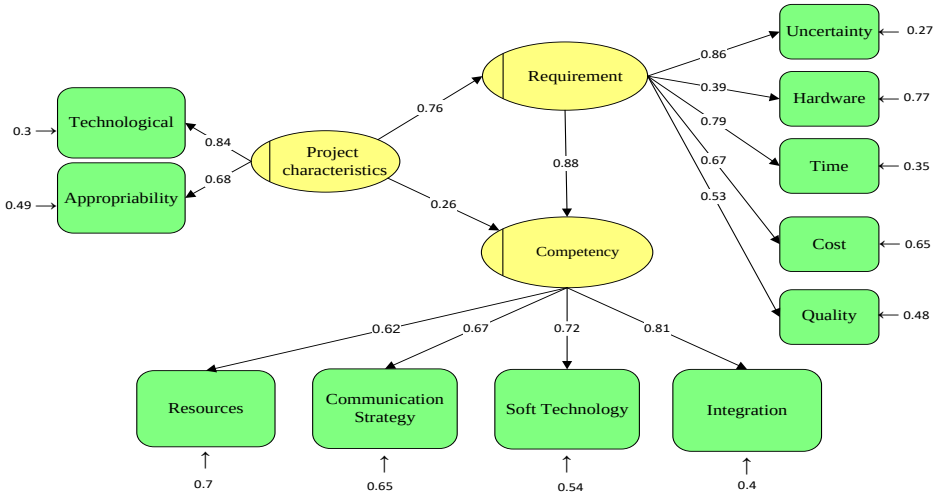


Figure 3. Estimating the intra- organizational model and coefficients of the existing paths among the variables (by the author)

To test the research hypotheses and to make sure about the correctness of obtained coefficients regarding the effectiveness of the dimensions on each other, one should also refer to the statistically significant levels of relationships among them (see Fig. 4).

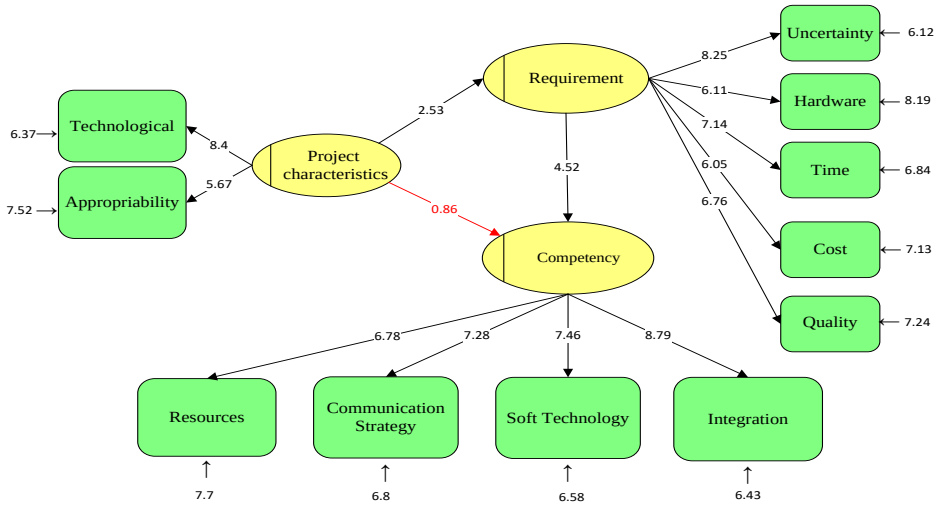


Figure 4. Intra- organizational model significance test and determining the verifiable paths based on confirmatory factor analysis (by the author)

On the other side, in Table 8, the research hypotheses are evaluated in proportion to the standard estimation of the relation and its related significant levels.

Table 8. Testing the intra- organizational research hypotheses (by the author)

Hypotheses	Path	Path coefficient	t statistic	Results of hypotheses
1	The effect of the project characteristics on the requirement	0.76	2.53	accepted
2	The effect of the requirement on the competency	0.88	4.52	accepted

3	The effect of the project characteristics on the competency	0.26	0.86	rejected

It is worth noting that if the significance levels are higher than 1.96, then the significance of the path between two variables can be accepted and the existence of this relationship can be confirmed. Hence, according to Table 6, hypotheses 1 and 2 are accepted, but hypothesis 3 is rejected. This conclusion is accompanied by this managerial inference that project characteristics cannot directly determine the competency of the organization, but rather firstly these characteristics lead to the requirements through which and to meet them, the related competencies are determined. For example, when the R&D project of CoPS determines that there are numerous modules (C5 in Table6) in the product, the organization encounters technological uncertainty(C4) and requires specific assets (C1) (first hypothesis) because complex products often require expertise and complex equipment which are beyond the abilities of a single organization. Therefore, and according to RBV, the organization looks for the required resources(C10) to acquire the necessary competency (second hypothesis) .This may also require the consolidation of the financial resources (C9) to establish a reliable relationship with the supplier.

On the other hand, based on the path analysis method of the conceptual model, a more detailed description of the statistical analysis related to hypotheses is presented in Table 9. As it is evident in Table 9, the indirect impact of the "project characteristics" on the "organization competency" is higher than the direct one rendering the "requirement" to mediate and empower this relationship so that the total impact of "project characteristics" on "competency" determination is higher than the direct impact of the "requirement".

Table 9. Direct and Indirect Impacts of Project characteristics and requirements on Organizational Competency(by the author)

Total effect on competency	Indirect effect on competency	Direct effect on competency	Variable
0.93	0.67 = 0.76 * 0.88	0.26	Project characteristics
0.88	-	0.88	requirements

4.2.3. Extra-organizational conceptual model

The indices in Table 2 are clustered in Table 10 to be employed in path analysis.

Table 10. Clustering of extra-organizational indices to be used in path analysis (by the author)

Dimension	Component	Index
Competency	Knowledge and skill (F_1)	The software mastery in the area related to the project(D_4)
		Good record of doing the project with former employers(D_6)
		The extent of the experience and expertise in the area related to the project(D_8)
		The level of the senior decision-makers' knowledge in the area related to the project (D_{13})
	Being up to date (F_2)	The familiarity with the latest methods in the world in delivering intended project-related Services (D_1)

	Compliance with standards(F_3)	Having standards including all kinds of ISOs(D_2)
	Financial ability(F_4)	The financial sustainability during the project completion period(D_7)
		The amount of working capital in a fiscal year(D_{12})
Adaptability	Adapting to values(F_5)	Adapting to values, beliefs, and organizational culture(D_{15})
	Flexibility in outputs(F_6)	The flexibility in the way of delivering services according to the employer and collaborators' opinions (D_3)
		The ability and to attach importance to do even small and partial project-related orders(D_{10})
	Adapting to time(F_7)	The time commitment to complete the job (D_9)
The capability of task performance	The quality of doing the project(F_8)	The quality of service provided (D_5)
	The time of doing the project(F_9)	Timely delivery of the project(D_{11})
	Responsibility during and after doing the project (F_{10})	The responsibility for the provided offers and services(D_{14})

Table 11 illustrates the reliability of the extra-organizational dimensions. As you can see, all digits are higher than 0.7, and thus the reliability is confirmed.

Table 11. The reliability of the extra-organizational dimensions (by the author)

Dimension	Cronbach's alpha coefficient
Competency	85%
Adaptability	87%
Task Performance	74%
Total variables	86%

Thus, the explorative and conceptual model related to extra-organizational dimensions is illustrated in Fig. 5.

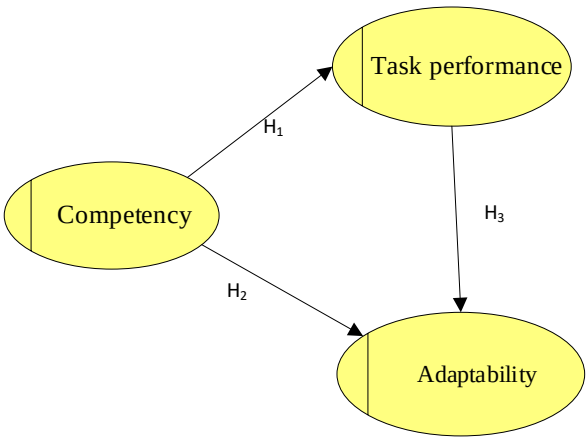


Figure. 5- Extra-organizational conceptual model (by the author)

According to Figure 5 and relationships among dimensions, the hypotheses for measuring in the organization are as follows:
1- Competency has a positive and significant effect on task performance.
2- Competency has a positive and significant effect on adaptability.
3- Task performance has a positive and significant effect on adaptability.

4.2.3.1. Analyzing the proposed hypotheses in the extra-organizational conceptual model with the path analysis approach

Similar to the intra-organizational conceptual model, the hypotheses in the form of the extra-organizational one based on the path analysis approach are illustrated in Fig.6.

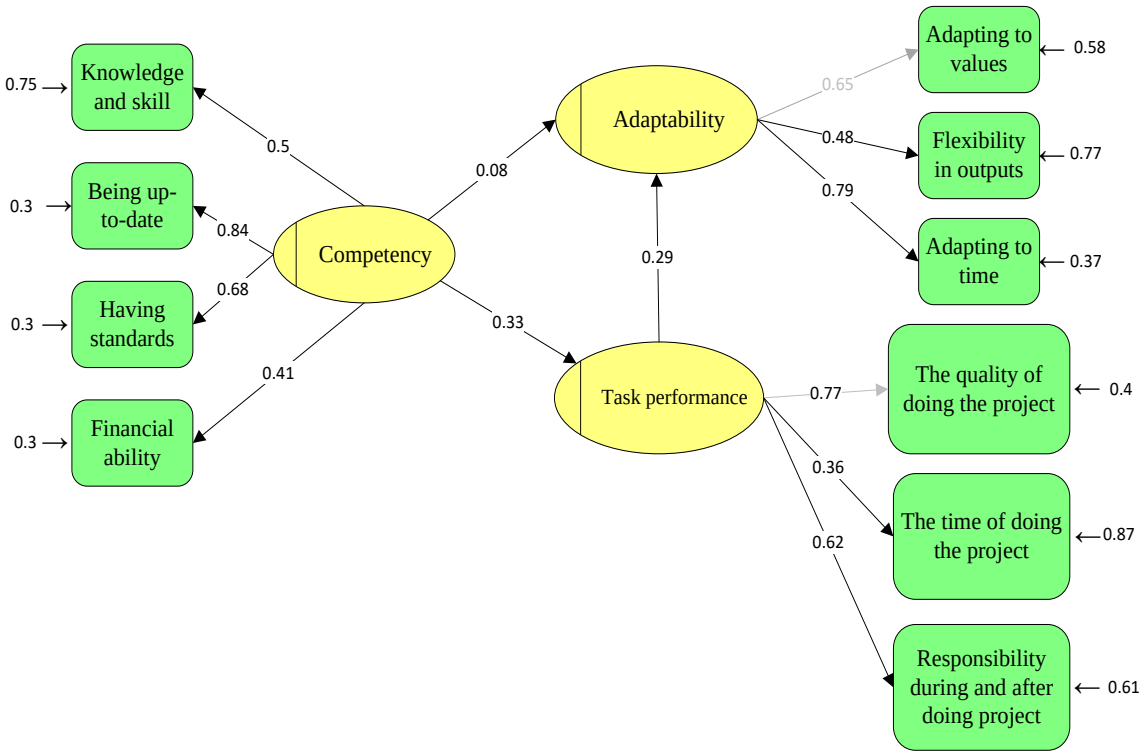


Figure 6. Estimation of the extra-organizational model and the coefficients of the paths among the variables (by the author)

To test the research hypotheses and to make sure about the correctness of obtained coefficients regarding the effectiveness of the dimensions on each other, one should also refer to the statistically significant levels of relationships among them (see Fig. 7).

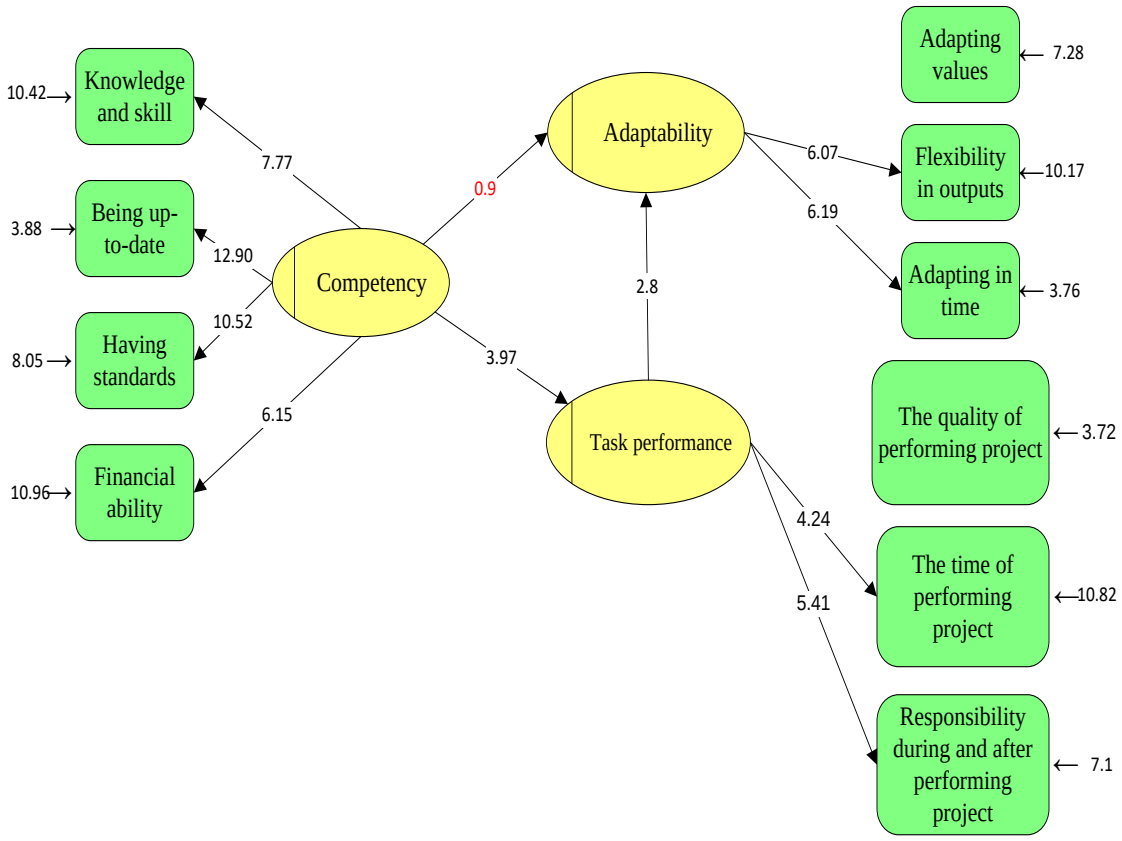


Figure 7. Testing the significance of the extra-organizational model and determining the verifiable paths based on the confirmatory factor analysis (by the author)

On the other side, in Table 12, the extra-organizational hypotheses are evaluated in proportion to the standard estimation of the relation and its related significant levels.

Table 12. Testing the extra-organizational hypotheses (by the author)

Hypotheses	Path	Path coefficient	t statistic	Results of hypotheses
1	The effect of the competency on the task performance	0.33	3.97	approved
2	The effect of the competency on the adaptability	0.08	0.90	rejected
3	The effect of the task performance on the adaptability	0.29	2.80	approved

It is worth noting that if the significance levels are higher than 1.96, then the significance of the path between two variables can be approved and the existence of this relationship confirmed. Hence, according to table 12, hypotheses 1 and 3 are accepted, but hypothesis 2 is rejected. This conclusion is accompanied by this managerial inference that competency cannot ensure adaptability by itself; because at first, competency must lead to task performance through which it can influence adaptability.

On the other hand, based on the path analysis method in analyzing the conceptual model, Table 13 provides a more detailed description of the statistical analyses related to the extra-organizational hypotheses. As it is clear in table 13, the indirect effect of competency on adaptability is greater than its direct effect, and as a result, the variable of task performance mediates this relationship.

Table 13. Investigating the direct and indirect effects of competency on adaptability (by the author)

Effect / Variable	Direct effect on adaptability	Indirect effects on adaptability	Total effect on adaptability
Competency	0.08	0.095 = 0.33 * 0.29	0.175
Task performance	0.29	-	0.29

4.2.3.2..Goodness of fit

As illustrated in Table 14, all fitting indicators of the model are within the standard limit, so the intra and extra-organizational models are very appropriate ones in this regard.

Table 14. The fitting indicators of the conceptual models (by the author)

Indicators	The standard limit based on studies [69][68]	Within extra-organizational model	Within intra-organizational model
x^2/df	Lower than 3	1.27	1.24
GFI	Higher than 90%	0.97	0.99
RMSEA	Lower than 0.05	0.032	0.027
IFI	Higher than 90%	0.98	0.99
CFI	Higher than 90%	0.98	0.99
AGFI	Higher than 90%	0.95	0.97
NFI	Higher than 90%	0.93	0.96
RFI	Higher than 90%	0.91	0.94

4.2.4. The pattern of relations among indices using DEMATEL

In this method, the arithmetic numbers 0 to 4 are applied to express the effect of the indices on each other, and in that regard 0 and 4mean no and the highest effect respectively. Numbers1,2, and 3 also mean the low, medium, and high effects.

4.2.4.1. Intra-organizational indices

It is noteworthy that due to the constraint on the number of paper pages, matrices are not presented.

Step One -Calculating the Direct Relation Matrix(M)

The initial matrix represented to each expert is as Eq. (1).

$$Z^k = \begin{matrix} C_1 \\ C_2 \\ \vdots \\ C_n \end{matrix} \begin{bmatrix} [0,0] & Z_{12}^k & \dots & Z_{1n}^k \\ Z_{21}^k & [0,0] & \dots & Z_{2n}^k \\ \vdots & \vdots & \ddots & \vdots \\ Z_{n1}^k & Z_{n2}^k & \dots & [0,0] \end{bmatrix} \quad (1)$$

In this matrix, Z_{ij}^k indicates the influence of element i on element j based on the opinion of the k_{th} expert. To obtain the final direct relation matrix, the average of experts' views on any elements of Z^k should be calculated according to Eq.2.

$$X_{ij} = \frac{\sum_1^k (Z_{ij}^k)}{k} \quad (2)$$

The direct relation matrix (M) is derived by calculating the average of experts' opinions (See Eq. 3).

$$X = \begin{bmatrix} 0 & x_{12} \dots & x_{1n} \\ x_{21} & 0 & x_{2n} \\ \vdots & \vdots & \vdots \\ x_{m1} & x_{m2} & 0 \end{bmatrix} \quad (3)$$

Step Two-Calculating the normal direct relation matrix (N = K*M)

To normalize the direct relation matrix, Eq. (4) – (5) are used.

$$S = \frac{1}{\max \sum_j^n X_{ij}} \quad (4)$$

$$N = S \times X \quad (5)$$

Step Three- Calculating the total relation matrix (T)

To calculate the total relation matrix (T), an identity matrix should first be established. Then T can be acquired by Eq. (8).

$$T = N \times (I - N)^{-1} \quad (8)$$

Step four- NRM

To establish the internal relations matrix and determine the network relations` map (NRM), the threshold value should be calculated. Simply put, the threshold value is acquired through calculating the average of all elements in T. Just relations with their value in the T matrix greater than the threshold value are illustrated in NRM, and the remaining values are considered zero. By so doing, minor relations can be discarded and the relevant NRM is drawn.

To determine the meaningful relationships, the following values are calculated:

The sum of the element values for each index in a relevant row (D) indicates the extent to which this index influences the others (effect given).

The sum of the element values for each index in the relevant column (R) indicates the extent to which this index is influenced by others (effect received).

Thus, the horizontal axis (D+R) indicates the overall influential directions of the index (degree of importance). In other words, the higher the value of D+R, the more the interaction of the factor with others.

Seemingly, the vertical axis (D-R) indicates the difference in the influences of the index (net effect). Generally, if the value of D-R is positive, then the index is a cause (net causer), and if the value is negative, the index is an effect (net receiver).

Finally, a Cartesian coordinate system is acquired. In this system, the horizontal and vertical axes illustrate the (D+R) and (D-R) values, respectively. The position of each index is determined by a point with a pair of numerical coordination, ((D+R), (D-R)). Therefore, a Grey-causal diagram is plotted.

The average of the matrix T elements and accordingly, the threshold intensity is equal to 0.0445. Therefore, based on the pattern of meaningful relations the causal relationship pattern of the intra-organizational indices is as illustrated in Table 15.

Table 15. Causal relationship Pattern of intra-organizational indices (by the author)

Index	D	R	D + R	D- R
C1	0.366	0.279	0.645	0.086
C3	0.888	0.444	1.331	0.444
.....	.....	.....	....	.....

C23	0.993	1.195	2.189	-0.202
C24	0.847	0.863	1.710	-0.016

According to Table 15, the 3 most influential indices are “Cognition”,” Resource heterogeneity", and " Behavioral uncertainty" respectively. Given that the indices of" Political risk "and "Behavioral uncertainty” are low effect receivers, they rank first and second in terms of net causing. The lowest causing belongs to the indices “quality improvement "and "technological uncertainty "respectively. The index "technological uncertainty "is a low effect, and thus rendering that to have the least interaction with other ones.

The indices “Resource heterogeneity”, “Belief in open innovation”, and “Strategic alliance with the suppliers to proliferate the product” have the highest effect receiving status respectively. Since these indices have a high effect giving, they are positioned higher than other ones in terms of the degree of importance. Tellingly they have the least net effect because of their high receiving

It was expected indices denoting fixed characteristics to have the lowest effect receiving. The DEMATEL results verify this expectation and the project characteristics entailing “High modularity and low batches of the CoPS” is so.

It is evident that project characteristics are intrinsic specifications, and regardless of outsourcing or internal development and without the intention of the designer, are not influenced by the other indices.

4.2.4.2. Extra-organizational indices

In a study by (Poudeh et al., 2019) the pattern illustrated in Table 16 was derived for extra-organizational indices.

Table 16. Causal relationship Pattern of extra-organizational indices (by the author)

D- R	D + R	R	D	Index
- 0.53	1.78	1.15	0.63	D1
1.09	1.50	0.21	1.29	D2
.....	.....	....	.....	.....
- 0.96	2.21	1.58	0.62	D14
-0.78	1.28	1.03	0.25	D15

According to Table 16, the index “Having standards including all kinds of ISOs” has the most effect given and the index “The responsibility for provided offers and services” has the most effect received and interaction among others.

4.3. The final decision-making model

Regarding the structural equations modeling of the intra and extra-organizational indices, components and dimensions, the final decision-making model is illustrated in Fig. 8.

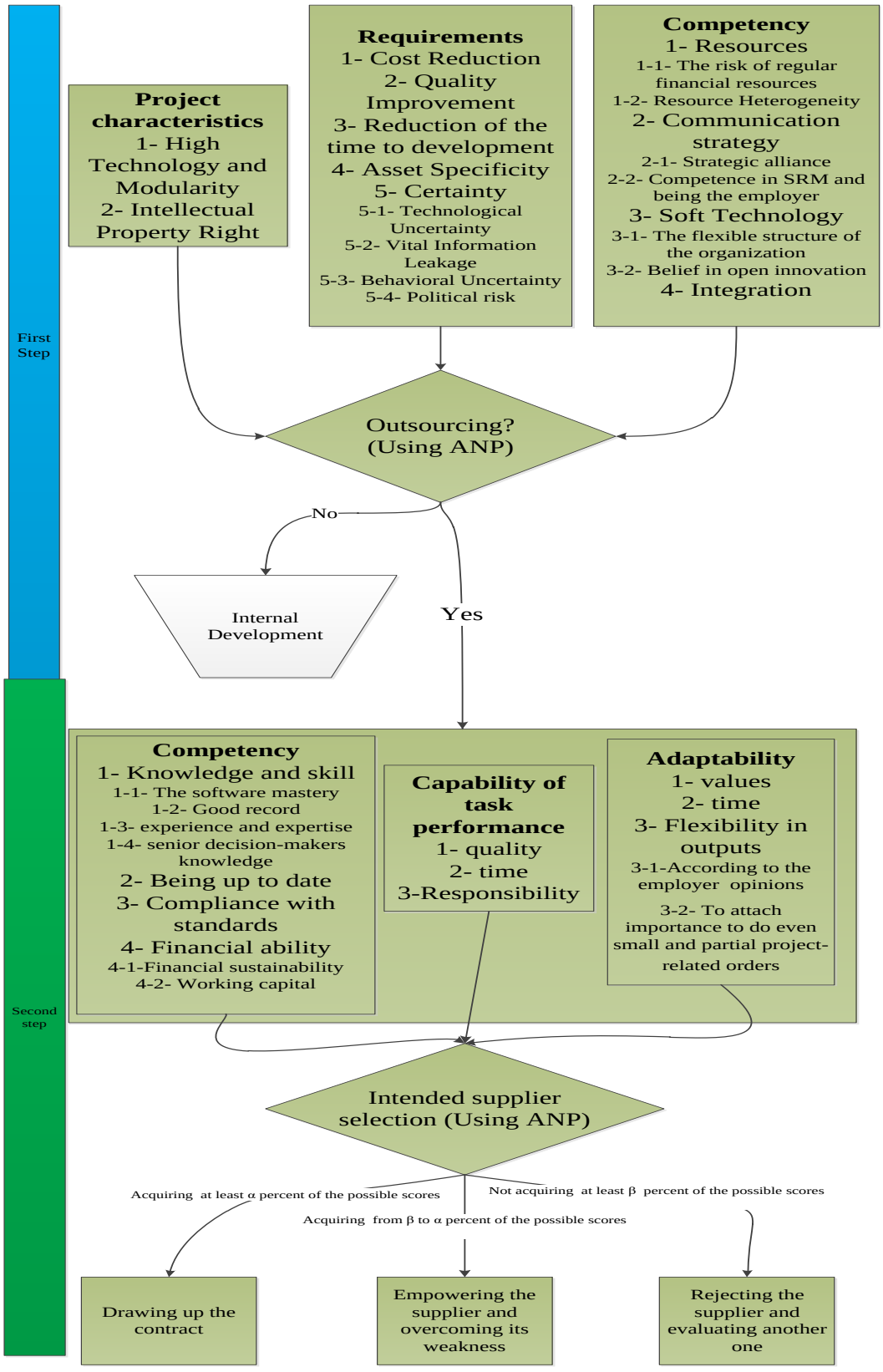


Figure 8. Research Final Model (by the author)

According to a literature review on decision models, the model illustrated in Fig. 8 is a combination of a decision tree model and a scoring one. In the first step, the dimensions, components, and indices derived from the intra-organizational conceptual model are used, and employing the ANP, the decision

to outsource/insource is made. If insourcing is selected, going further will be beyond the scope of this article .However, if the outsourcing option is chosen, the second step will start.

In the second step, using the previously developed extra-organizational conceptual model, the dimensions of supplier competency, task performance, and adaptability (which include their components and indices) are re-evaluated employing ANP. It is noteworthy that intra-network relationships have already been identified by structural equation modeling and DEMATEL. The result of the decision at this step is that, according to experts, if the supplier's scores gained are in the range of α up to%100 of the total possible ones, the supplier will be selected for the project, and the contract will be awarded. If the supplier's score is within β to α percent, the organization will empower the supplier and fix its weaknesses. If the supplier is unable to obtain at least β %of the scores, it is excluded and the organization considers another supplier from the list of approved ones (the values of α and β are up to the decision of the organization's experts, and $\beta<\alpha$).

4.4. Case study and verifying the model

Regarding the R&D project on the airplane fuel system which is considered to be out/insourced, the solution in the first step represents outsourcing as the chosen alternative. On the other hand, in the second step, Malek Ashtar University of Technology was evaluated as an alternative supplier for this project ,and the result of the model solution indicated the supplier appropriateness by gaining more than 60 % (determined as an α-cut by the experts of IAIO) of the possible scores. In a realistic situation, the mentioned project is successfully outsourced to the school of materials and construction technologies, composite research center, rendering the model to be efficient and credible.

If the supplier fails to obtain high scores, the organization must empower that financially, technologically, and also in human resources and knowledge areas.

5. Conclusion

In the literature, there are various decision-making models for commodity goods, but little research has been done on complex product systems. What exists is mainly about their outsourcing risk management, not the decision-making model. The contribution of the present article entails summarizing and screening the indices affecting the CoPs R&D projects outsourcing, developing the components and dimensions, and explaining the relationships among them using the survey of the experts and SEM. Moreover, the effect and cause relations among the indices are revealed by employing the DEMATEL method. The final two-step model specifies the decision to outsource or insource, and the mechanism of the outsourcing respectively. The result is that by employing the ANP, the decision on whether or not the organization outsources the CoPS R&D projects is made based on the project characteristics, the requirements of the organization, and the competencies required to meet the requirements . An organization can't outsource the development of CoPS unless it enjoys the technological, contractual, project control, integration, and soft technologies competencies. Furthermore, appropriate communication strategies and adequate financial resources are required. On the other hand, in the second step, regarding the alternative supplier and its obtained scores employing ANP, another decision is made. Based on this decision, the supplier is evaluated to be outsourced, empowered, or rejected . The managers of organizations and companies developing CoPS such as airplanes, missiles, power plants, high-speed trains, and ships can utilize the implications of the model. Outsourcing models in the literature are "at the embryonic stage and behind the practice". The present article is of high applicability because in-depth interaction with the case study organization is followed and several exploratory interviews and surveys have been done, among them are 18 expert interviews, 246 questionnaires completed by experts to develop conceptual models, and 35 ones to determine the relationships in DEMATEL and pair-wise comparisons in ANP. The model verification was tested against the realistic situation and approved through the airplane fuel system R&D project outsourced by IAIO to the Malek Ashtar University of Technology. The model presented in this paper resembles, in some indices, the decision-making models of the commodity goods outsourcing or manufacturing

field. However, the distinguishing point is related to the indices which imply the notion of CoPS (i.e. integration, strategic alliance, organizational flexible structure, high modularity and technology of the product, and accuracy of the standard scope), and R&D base (technological uncertainty for example). Finally, it should be noted that the present model not only provides a tool but also entails the process of the model application incorporating the selection of experts and surveys.

Further research

In the spectrum of the inter-organizational cooperation models integration and from an open innovation perspective, the scholars may investigate other forms like joint ventures, strategic alliance, joint R&D, research funding, and consortium as approaches to conducting CoPS R&D projects. Besides IAIO, other ones including aerospace and defense industries organizations can be studied as case studies, by doing so their related projects can be examined as successful or unsuccessful examples of outsourcing based R&D. The researchers may also concentrate on civil projects as interesting alternatives for future studies, e.g. R&D on ships, trains, and other CoPS. On the other hand, one can look at how outsourcing organizations can nurture their desired suppliers and achieve behavioral certainty from the outset. Offshore outsourcing is not highly welcome due to the appropriability of defensive projects. However, in future studies and regarding the characteristics of their business environment, foreign suppliers can be taken into account.

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