*Sigma J Eng Nat Sci, Vol. 40, No. 1, pp. 196–207, March, 2022*

**Sigma Journal of Engineering and Natural Sciences**
Web page info: https://sigma.yildiz.edu.tr
DOI: 10.14744/sigma.2022.00016

**Research Article**

# Modeling and analysis of effective factors in the outsourcing of R&D projects by SEM and ISM approaches: A case study of "Iranian aviation industries organization"

**Ghasem TAGHIZADEH[1,*], Hassan TORABI[1], Morteza RAJABZADEH[2]**

*[1]Faculty of Management and Industrial Engineering, MalekAshtar University of Technology, Tehran, Iran*
*[2]Faculty of Industrial Engineering, Mahallat Institute of Higher Education, Markazi, Iran*

## ARTICLE INFO

*Article history*
Received: 19 August 2020
Accepted: 22 June 2021

**Key words:**
CoPS; Development, ISM; Outsourcing; SEM

## ABSTRACT

Given that CoPS development projects are costly, failing to conduct them will ruin the organization. Therefore, the decision to out/in source them, is important. In this paper, the factors influencing this decision are discussed. Employing the Fuzzy Delphi method, the indices are utilized to develop the SEM model. The results s how three dimensions of t he "projects characteristics", "requirements" and "competency". Hypothese surge that projects characteristics have a significant effect on the requirements, which in turn have a similar effect on the competency. To compare, the ISM method was used. The results are quite similar to those of the SEM model. No sooner could organizations outsource such projects than they gain the technological, contractual, project control, integration, soft technologies, financial and communications strategies capability. The managers of organizations and companies developing CoPS such as airplanes power plants, express trains and ships can use the results and implications of this model.

**Cite this article as:** Taghizadeh G, Torabi H, Rajabzadeh R. Modeling and analysis of effective factors in the outsourcing of R&D projects by sem and ism approaches: A case study of "Iranian aviation industries organization". Sigma J Eng Nat Sci 2022;40(1):196–207.

## INTRODUCTION

CoPS (Complex Product Systems) are a certain body of products that mark a major difference with mass ones. These products are characterized by the need for special knowledge of constructing components, diversified and interconnected customized components [1–4], and highly-integrated legislative system [5]. Included in these systems are airplanes, flight simulators, high-speed trains, weapon systems, and cargo handling equipment.

***Corresponding author.**
*E-mail address: tzadeh@mut.ac.ir

*This paper was recommended for publication in revised form by Regional Editor Vildan Çetkin*

Published by Yıldız Technical University Press, İstanbul, Turkey

Outsourcing is generally defined as the transfer of activities and processes previously being completed internally to an external organization[6]. In the early 1990s, a very important paper "The core competence of the corporation" by Prahalad & Hamel,[7] introduced a new approach in management and therefore the firms outsourced the activities outside of their competency. Gaining the cost efficiency was no longer the sole driver of the outsourcing. To provide the strategically important and complex organizational processes with value, the firms started to seek external skill, capability, and knowledge. The strange, and new phrase of "strategic outsourcing" emerged[8].In contrary to conventional outsourcing, more strategic activities were now being outsourced rendering arms-length relations management as such insufficient[9]. As a result, firms started building closer relationships with their suppliers. Cooperation, and mutual development have been known as key issues in managing the outsourcing relationships. Outsourcing is not anymore the sole assignment of the work and receiving the deliverable, but a ray of the organizational integration spectrum whichreaches the acquisition and merger through the strategic alliance and joint venture. It is obvious that the development of CoPS can't be deprived of strategic outsourcing advantages. A lot has been urged about the outsourcing of commodity goods, but there is a gap about the CoPS[10]. This paper firstly seeks to answer the research question1: what are the influence factors in outsourcing of CoPS, and consequently research question 2: can these factors be modelled and what are the relationships among the model dimensions. The paper is structured as follows: First, the research background on outsourcing and CoPS is discussed. Second, the research methodology will be urged. Data analysis incorporating Fuzzy Delphi for selecting the factors, conceptual model and related hypothesis, and the results will be addressed in the third part. The paper closes with some discussion and conclusions.

**Literature review**

CoPS are capital goods with high degrees of technology and value. These products are supplied to certain commercial users as one-off or small-batch products, and are presented to customized business-specific consumers [1, 11]. CoPS play key roles in the promotion of modern technologies and the empowerment aimed at industrial, and economic developments in developed and developing countries. Particular capabilities are needed for development and innovation of CoPS, including technological ones, testing, system integration, management of large-scale projects, and, finally, the customer relationship management. These products can involve a significant percentage of industrial investment of a country. For example, Moody & Dodgson.,[12] state that 11% of a country's gross domestic product (GDP) belongs to CoPS. But more importantly, CoPS have a significant effect on other product categories. For example, the devices used for mass production processes are often categorized as CoPS, and so, they are the pillar bases of a lot of commodity goods [12]. Poudeh et al.,[10], identified and prioritized the effective factors on the supplier selection for CoPS R&D projects.

The application of outsourcing is rooted in TCE(Transaction Cost Economics). According toCoase, [13],companies raison d'ẽtre is the ability to organize some activities at a lower cost than market prices. Later, Oliver, [14] urged that if using the markets resulted in lower transaction costs than internally making a product, it should be bought from the markets. In addition, the new concept of transformational outsourcing does not directly and basically allude to the reduction of costs or acquisition of resources that are internally unavailable, as intended by TCE and RBV. Rather, new organizational structures are focused, and thus these theories appear to be as such inadequate in terms of capturing this concurrent strategy. As transformational outsourcing wishes to create an adaptive, and modular organization, scholars have considered modular systems theory as a possible theoretical base.Lee et al.,[15] urged that outsourcing affects perceived performance through its influence on job satisfaction.

The definition of outsourcing can be viewed from two perspectives: product or process. From the process view, as suggested by Barthelemy[16], outsourcing can be viewed as giving up the entire or part of organizational activities and processes to an external vendor. From the production view, Ellram&Billington [6] for instance define outsourcing as "the transfer of the production of goods or services that have been performed internally to an external party". Wibisono, et al., [17] indicate that interaction capability consisting of communication and coordination has a positive impact on outsourcing success, and that this capability is in turn influenced by management capability. A performance model developed by Singgih et al.,[18] can be used to assess the performance of maintenance outsourcing providers. Bruccoleri et al.,[19] suggest that offshore outsourcing and captive offshoring have opposite effects in terms of their influence on the magnitude of product recall. Damanpour et al.[20] indicate that the outsourcing process mechanisms, especially the mechanisms associated with implementing the outsourcing decision, predict insourcing.Thakur-Wernz&Wernz[21]provide evidence that knowledge spillovers do happen, and R&D offshore outsourcing can turn vendors into potential competitors.HA et al.,'[22] findingis that outsourcing innovation is risk-taking behavior, but outsourcing product innovation strategy is a less risky option as compared to the outsourcing process innovation.Yamaguchi et al.,[23] state that firms employing more doctorate holders and diversifying in knowledge spaces tend to make more use of R&D outsourcing.

Several studies have covered mass–products outsourcing, but there is a gap concerning CoPS. The variables involved in this decision have been identified for commodity goods but little research has been done on CoPS. That

is, both the variables related to the outsourcing of CoPS are still unclear, and how to achieve a model that categorizes these variables and determines the relationships between its dimensions. So the first Gap is related to the research question 1 and the second one to the other.

## RESEARCH METHODS

Regarding purpose, usage, time, and approach, this study is respectively a descriptive, applied, cross-sectional case study, and deductive one, rendering it as a quantitative research with survey method of gathering data altogether.

The steps of conducting the research are illustrated in Fig. 1. First, initial indices were identified through the literature review and exploratory interviews. Second, the Fuzzy Delphi method in the form of a questionnaire (Appendix 1) was employed to verify indices relevant to the case studied. The validity and reliability of the questionnaire were checked before distributing them among the experts. The approved indices were used in SEM (Structural equations modeling) and LISREL softwareto represent the exploratory model. To compare the results and to study the relationship between components, the ISM method was used.

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 population is equal to 38. Using the Cochran's Sample Size Formula, the number of samples equals to 35. Randomly sampling in an "appropriate category"(Brannen, J.,[24]) way, so that 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.

On account of uncertainties in practical concepts and given the fact that replies were presented based on lingual variables in a qualitative and indefinite atmosphere, the questionnaires were analysed using Fuzzy Delphi Method (see Table 1 for related triangular fuzzy numbers). In order to examine the content value of the questionnaire, 10 professors dominating the subject and research method were surveyed and therefore irrelevant and vague indices were eliminated. To examine the reliability of the questionnaire, Cronbach's alpha was calculated. The result equals to 0.86 rendering the questionnaire so as to be reliable. Out of 35 distributed questionnaires, 24 items were completed and gathered. Expert surveys were completed in two steps and data saturation was reached. The realm of this study is the ongoing R&D projects of IAIO, and in terms of time, the information in the time horizon of June-August 2018 has been gathered. The fitting criteria of the model were also examined and validated using the output of the LISREL software.

In order to obtain the fuzzy average and defuzzification ensuing therefrom, the approach introduced by Bojadziev & Bojadziev, [25])was applied as shown in equations cited in Tables 2 and Table 3.

## THE CASE STUDY

The case study of this paper is the projects of the Iranian Aviation Industries Organization. Even though

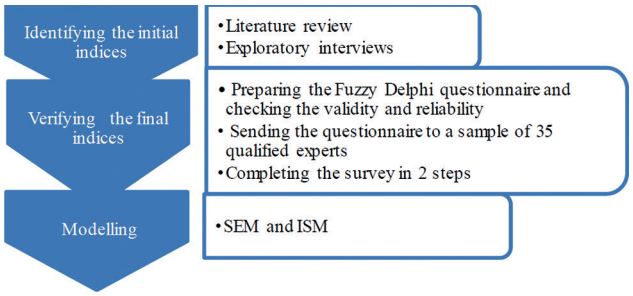


**Figure 1.**The algorithm of conducting the study.

**Table 1.** Triangular fuzzy numbers (TFN) equivalent to the verbal variable

| Verbal variables on the impact of indices | TFN |
|---|---|
| Very high | (0.75, 1, 1) |
| High | (0.5, 0.75, 1) |
| Average | (0.25, 0.5, 0.75) |
| Low | (0, 0.25, 0.5) |
| Very low | (0, 0, 0.25) |

**Table 2.** The method to calculate the fuzzy average [25]

| Fuzzy number | Fuzzy average |
|---|---|
| $(m_a^l, m_m^l, m_\beta^l)$<br>$(m_{a1}, m_{m1}, m_{\beta 1})$<br>$(m_{an}, m_{mn}, m_{\beta n})$ | $\text{Fuzzy average} = \left(\frac{m_{a1}+m_{a2}+\cdots+m_{an}}{n}, \frac{m_{m1}+m_{m2}+\cdots+m_{mn}}{n}, \frac{m_{\beta 1}+m_{\beta 2}+\cdots+m_{\beta n}}{n}\right) = (m_a, m_m, m_\beta)$ |

**Table 3.** Defuzzification method

| | |
|---|---|
| $X\max_3 = \frac{m_a + 4m_m + m_\beta}{6}$<br>$X\max_2 = \frac{m_a + 2m_m + m_\beta}{4}$<br>$X\max_1 = \frac{m_a + m_m + m_\beta}{3}$ | Crisp number $= Z^* = \max)$<br>$Xmax_1, Xmax_2, Xmax_3$ |

the details of these projects are subject to confidentiality, but in general, this organization can be considered as one of the most advanced organizations in the country that deals with research and development, production and maintenance of complex products such as aircraft and helicopters. IAIO incorporates 5 divisions including Iran Aviation Industries which acts on the overhaul of more than 19 types of aircraft, 18 types of aircraft engines and 9 types of helicopters, construction of jet engines, various spare parts, large Hangar, and turbine engines). The second one is Iranian Helicopter Support and Renovation Company which acts on the heavy repairs of the helicopter fleet. This company known as the PANHA has various branches for the construction of helicopter, black boxes, and floating systems. The third one is the Iranian Aircraft Manufacturing Company which is the manufacturer of Iran 140 jet aircraft with a capacity of 52 people. The fourth one is the Quds Industries which acts on the designing, manufacturing and providing various types of drones with extensive after-sales services. The last one is the Research Institute of the Aviation Industries Organization. The researchers in this institute work on the aviation product technology, and the design and construction of the manned and unmanned aerial vehicles.

## DATA ANALYSIS AND RESULTS

The effective factors on outsourcing the CoPS R&D projects are shown in Table 4, based on reviewing the literature and after the experts' survey in two steps. In the first step using the Fuzzy Delphi method and according to the questionnaire, factors found from the literature review were exposed to expert judgment, and the average of the experts' opinions and its defuzzified equivalent (using Table2 and Table 3) were obtained for each factor. In the second step, another questionnaire was prepared. In this questionnaire, the mentioned factors were again sent to the members of the expert group along with the previous point of view of each individual, as well as the average of the experts' opinions in the first step, to apply probable changes in their opinions by comparing these two values. According to the Fuzzy Delphi method and Cheng and Lane's view[26], we excluded the factors that their defuzzified deviations (according to equation 1 in which the Ami refers to the fuzzy number in $i^{th}$ step, and the $am_{ij}$ refers to the $j^{th}$ element of the triangular fuzzy number in $i^{th}$ step ) exceeded the threshold (0.1) in the first and second steps (rejection (8th) column in Table 4), and the rest of the factors were accepted as the final ones (acceptance (7th) column of Table 4). For example regarding the first factor, Asset Specificity, the defuzzified deviation is equal to $\frac{1}{3}(0.71 - 0.65) = 0.02$ which is smaller than the threshold value (0.1), so renders this factor to be acceptable .Also, for examining the questionnaire reliability, we calculated the Cronbach's alpha. Then, to determine the capabilities, the accepted factors were employed to develop the explorative model using the structural equation modelling in LISERL software (with a survey from 246experts in the organization).

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

**Conceptual model and hypotheses**

According to a survey of experts (246 people), the acceptedindices in Table 4 were placed in the clustering of Table 5 to be used in structural equationmodelling. The experts whose comments were used in this section of the study were among the aforementioned 246 experts who completed the questionnaire. Of these experts, 34were 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 ofCoPs and encompassedin the "competency" dimension. The lack of the "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. Regarding the other components, the first idea was that technological, market, and behavioural uncertainty would prompt the organization to take a precautionary measure. Second and in terms of hardware, certain equipment would be needed. Third, desirable time and quality of delivering the project would be amongst the successful requirements of the outsourcing. Therefore, the components of certainty, hardware, time and quality are clustered at the level of the organization's requirements. The technical characteristics and appropriability of a project related to CoPshave evidently 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 5).

The confirmatory and conceptual model of the research will be in accordance with Figure 2.

Taking into account the experts' arguments and guidance in clustering the components and dimensions as well

**Table 4.** Effective indices in outsourcing of CoPS R&D projects

| Row | Factors | References | symbol | Defuzzified average based on Fuzzy Delphi questionnaire | | Experts' view |
|---|---|---|---|---|---|---|
| | | | | First step | Second step | |
| 1 | Asset Specificity | [27] | $C_1$ | 65/0 | 71/0 | * |
| 2 | The flexible structure of the organization | The experts | $C_2$ | 73/0 | 72/0 | * |
| 3 | The technological uncertainty | [3, 5] | $C_3$ | 65/0 | 74/0 | * |
| 4 | High modularity and low batches of the CoPS | [3, 5] [28] | $C_4$ | 3/0 | 35/0 | * |
| 5 | The quality improvement | [29, 30] | $C_5$ | 72/0 | 8/0 | * |
| 6 | Strategic alliance with the suppliers to proliferate the product | [9] | $C_6$ | 69/0 | 70/0 | * |
| 7 | The risk of regular financial resources | The experts | $C_7$ | 46/0 | 46/0 | * |
| 8 | Resource heterogeneity | [31] | $C_8$ | 47/0 | 53/0 | * |
| 9 | Reduction of the time to development | [29, 30] [28] | $C_9$ | 52/0 | 57/0 | * |
| 10 | Vital information leakage | The experts | $C_{10}$ | 63/0 | 64/0 | * |
| 11 | Market uncertainty | [31] | $C_{11}$ | 78/0 | 91/0 | * |
| 12 | Cost reduction | [32] | $C_{12}$ | 6/0 | 61/0 | * |
| 13 | Behavioral uncertainty | [33] | $C_{13}$ | 74/0 | 79/0 | * |
| 14 | Belief in open innovation | The experts | $C_{14}$ | 42/0 | 41/0 | * |
| 15 | Political risk | The experts | $C_{15}$ | 67/0 | 0/67 | * |
| 16 | Intellectual property right | [34] | $C_{16}$ | 53/0 | 0/59 | * |
| 17 | Competence in supplier relationship management and being the employer | The experts | $C_{17}$ | 53/0 | 5/0 | * |
| 18 | Learning by doing | [28] | $C_{18}$ | 32/0 | 44/0 | * |
| 19 | Competence in integration | | $C_{19}$ | 65/0 | 65/0 | * |

**Table 5.** Clusters of the research factors

| Dimension | Component | Index |
|---|---|---|
| Competency | Resources($D_1$) | The risk of regular financial resources ($C_9$) |
| | | Specific, and superior resources ($C_{10}$) |
| | Communication strategy ($D_2$) | Strategic alliance with the suppliers to proliferate the product($C_7$) |
| | | Competence in supplier relationship management and being the employer ($C_{20}$) |
| | Soft Technology ($D_3$) | The flexible structure of the organization($C_3$) |
| | | Belief in open innovation($C_{16}$) |
| | Integration ($D_4$) | Competence in integration ($C_{22}$) |
| Requirement | Certainty ($D_5$) | The technological uncertainty($C_4$) |
| | | Vital information leakage ($C_{12}$) |
| | | Behavioral uncertainty ($C_{15}$) |
| | | Political risk ($C_{18}$) |
| | Hardware ($D_6$) | Asset Specificity($C_1$) |
| | Time ($D_7$) | Reduction of the time to development ($C_{11}$) |
| | Cost ($D_8$) | Cost reduction $C_{14}$) |
| | Quality ($D_9$) | The quality improvement ($C_6$) |
| Project Characteristics | Technical ($D_{10}$) | High modularity($C_5$) |
| | Appropriability ($D_{11}$) | Intellectual property right ($C_{19}$) |

as studying the literature and the researcher's inference from them, the research hypotheses were extracted as a clever statement of the relationships amongthe dimensions of the proposed model. Therefore, according to Fig. 2 and relationships between factors, the assumptions 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 the "Competency".

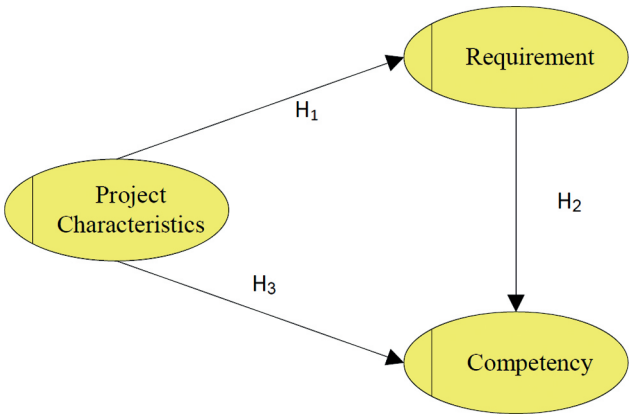


**Figure 2.** Research conceptual model.

**The proposed hypotheses analysis by the path analysis approach**

In this section, the structural equation modelling is used to test causal relationships amongdimensions of "competency, requirement and project characteristics". By path analysis approach, theproposed hypotheses are shown in Fig. 3 in the form of research conceptual model. In figure3, the conceptual and confirmatory model of the research, including the factor loadingswritten on each relationship can be seen.

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

On the other side, in Table 6, the research hypotheses are evaluated in proportion to the standard estimation of the relation and its related significant levels.

It is worth noting that if the significancelevels 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 Table6, hypotheses 1 and 2 are accepted, but hypothesis 3 is rejected. This conclusion is accompaniedby 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.

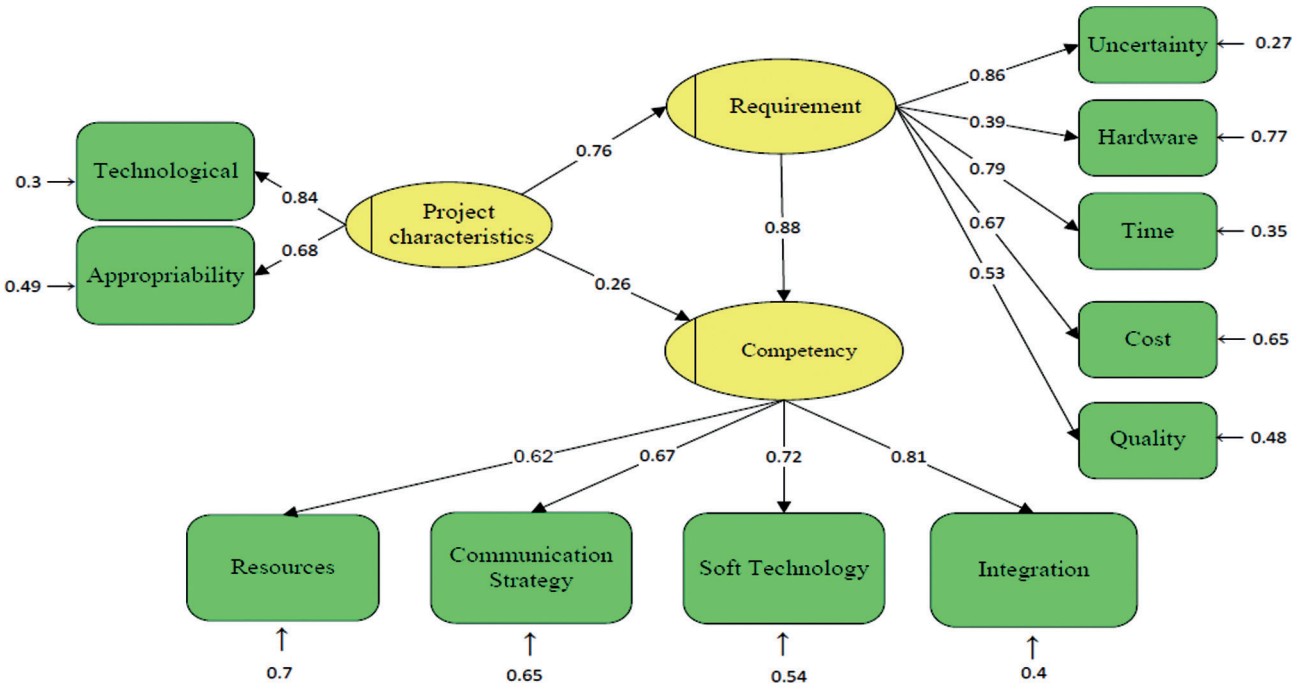


**Figure 3.** Estimating the model and coefficients of the existing paths among the components.

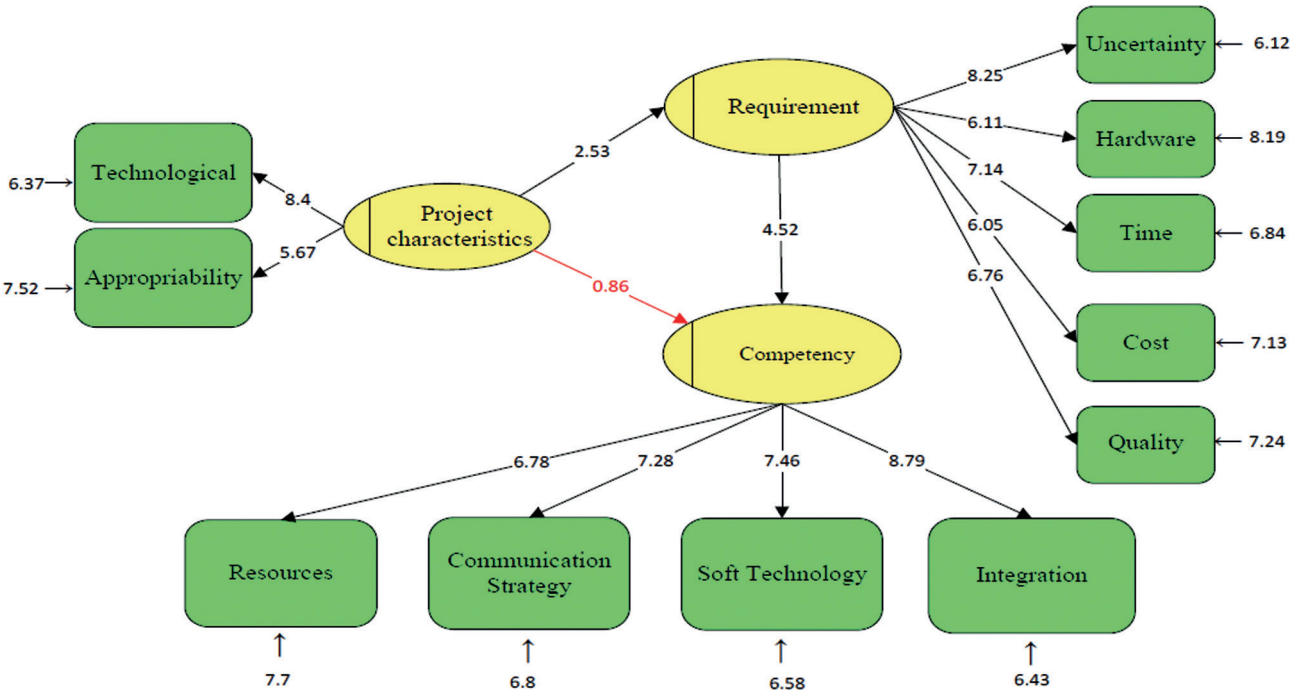


**Figure 4.** Testing the significance of the model and determining the verifiable paths based on the structural equation model.

**Table 6.** Test of research hypotheses

| 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 |

**Application of ISM (Interpretive Structural Modelling)**

In this research, the ISM method is used to study the relationship between components. In order to observe the limitation of the number of pages in this paper, the matrices areput aside and the final interpretive structural model is presented. In this method, using the views of 18 experts from IAIO, the following steps were taken (due to the limited pages of the paper the explanations of each steps are put aside while can be easily accessed in most of ISM guide references):

Step 1: DevelopanSSIM (Structural Self-interaction Matrix)

Step 2: Develop an initial reachability matrix

Step 3: Develop the final reachability matrix (See Table 7)

Step 4: Partition the reachability matrix obtained as above into different levels

In this model, the effect appears from the bottom to the top. The ISM model related to components of this paper can be seen in Fig. 5.

**ISM results**

As it is evidentbased on ISM partitioning (Fig. 5); at the sixth level, which has the most impact, the components of technological characteristics and appropriability in corporated in the project characteristics dimension are placed. Level 5 is exclusively dedicated to hardware component and Level 4 is allocated to components of reliability, cost, and quality, all encompassed in requirement dimension. The only remaining component of this dimension is the time that is positioned at Level 3. Another component at Level 3 is integration, which is related to competency, and other components of this dimension are at Level 2 and Level 1.

**Comparing ISM with SEM results**

In order to confirm the SEM results, the results of these two methods are compared. In SEM, the dimension of the project characteristics affects the requirement and the latter one affects the dimension of competency and therefore somehow the extent of the effect of dimensions, namely "project

**Table 7.** Final reachability matrix.

| | $D_1$ | $D_2$ | $D_3$ | $D_4$ | $D_5$ | $D_6$ | $D_7$ | $D_8$ | $D_9$ | $D_{10}$ | $D_{11}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $D_1$ | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 |
| $D_2$ | 1 | 1 | 1 | 0 | 1 | 0 | 1 | 1 | 1 | 0 | 0 |
| $D_3$ | 1 | 1 | 1 | 0 | 1 | 0 | 1 | 1 | 1 | 0 | 0 |
| $D_4$ | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 0 | 1 |
| $D_5$ | 1 | 1 | 1 | 0 | 1 | 0 | 1 | 1 | 1 | 0 | 0 |
| $D_6$ | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 0 |
| $D_7$ | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 |
| $D_8$ | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 |
| $D_9$ | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| $D_{10}$ | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| $D_{11}$ | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |

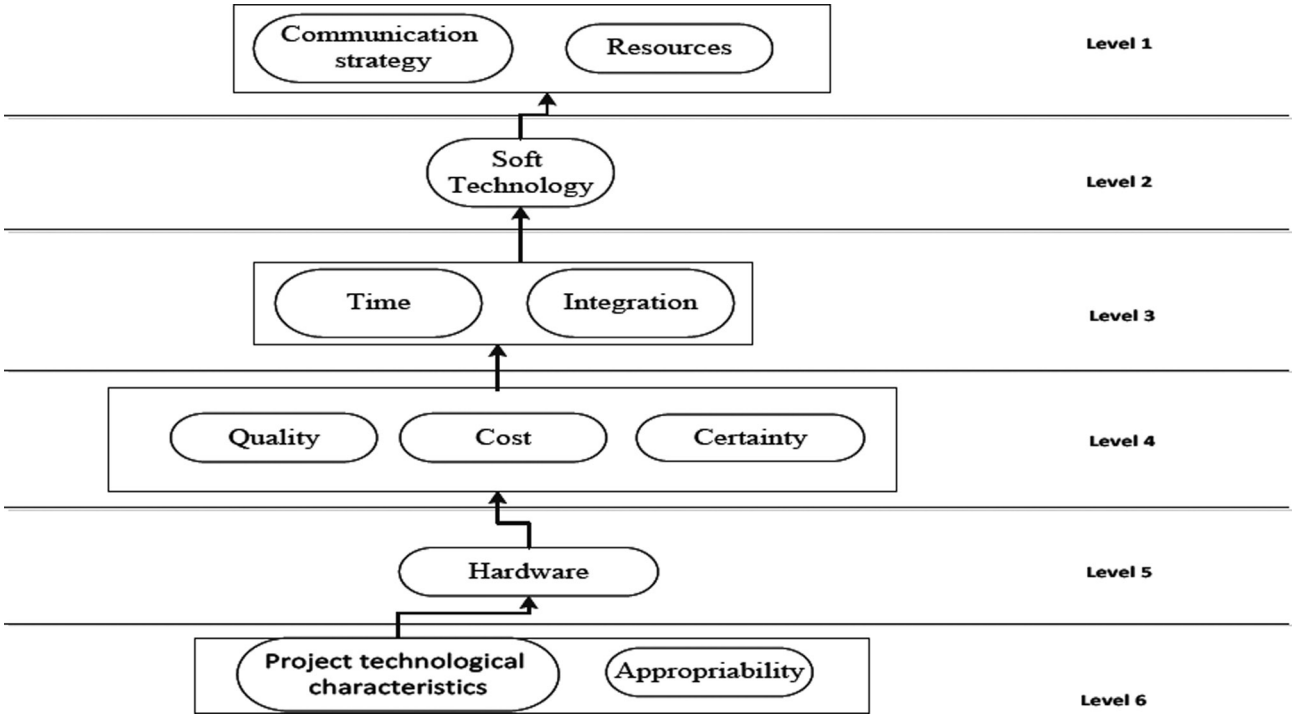


**Figure 5.** ISM Model.

characteristics", "requirement", and "competency"reduces one after another. If this is the case in ISM, then the components of these dimensions should be placed at lower levels, respectively, to indicate a decrease in effect. By examining the position of the components in Fig.5, it is clear that both results of the ISM and SEM are consistent. In the results of the ISM, the presence of the components related to"project characteristics" dimension at the highest (sixth) level represents their greatest effect. On the other hand, the presence of the components related to the"requirement"dimension (hardware, quality, cost, certainty, and time) at a level lower than the dimension of "project characteristics", represents the confirmation of the first hypothesis of the SEM model. Similarly, the components of the "competency" dimension are also at levels lower than those of the "requirement" dimension, thereby againrendering the second hypothesis of the SEM model as such confirmed.

## DISCUSSION

It was expected that the more relevant indices would be to CoPS and high-tech products development projects,

the experts would give more priority to them. According to Table 4, the results of the fuzzy Delphi method are fully consistent with this logic as follows:

- Given that CoPS are very costly, the high sensitivity to budgeting on a regular basis has a key impact on outsourcing success. If the funding is not provided in a timely manner, the project stops and the technologies planned to be used may be abandoned. Therefore, the restart of the project and the provision of new technologies will impose a much higher cost than the initial conduction of the project. On the other hand, given that CoPS have multiple and varied modules, the ability to integrate them into small-batch production is very important. As the organization's core competence, the integration cannot be outsourced. Regarding the fact that the development of CoPS usually takes more than a decade, the governments being in office for 4 or 8 years with a different approach to outsourcing decisions can delay the completion of projects, because some governments are in favor of developing and outsourcing these products and providing the necessary funding, while some others are opposed to this. Thus, the indices of "The risk of regular financial resources", "Competence in integration" and "political risk" have the first priority from the viewpoint of the experts with zero mean difference (see Table 4).
- The second priority indices with a mean difference of 0.01 include "The flexible structure of the organization", "Strategic alliance", "Vital information leakage", "Cost reduction" and "Belief in open innovation". Due to the high technologies used in CoPS, they cannot be developed within the predetermined organizational structure. Rather, this structure should be tailored to the type of technology, product lifecycle, research phases, time, and development requirements. Therefore, conducting CoPS development projects in a non-flexible organization risks a lot, so that the project stops in the initial phases and cannot be completed. It should be noted that the development of these products is time-consuming and generally lasts more than a decade and requires continuous research for development and updating. Therefore, it is necessary for the organization to collaborate strategically with superior organizations, and to consider future upgrades in the light of this long-term alliance. The index of "Cost reduction" is based on the TCE in outsourcing supporting theories. Given the high cost per unit of CoPS, their multiple customized components and also exchanges in small batches but high value, this index is of particular importance, especially since the R&D funding for CoPS is provided by the user. Taking the index of "Belief in open innovation" into account, since there are many systems and sub-systems in CoPS R&D projects; if the close innovation approach is adopted, the organization would become very large. Therefore, project-related funds are paid to employees who spend a small amount of their time on the projects and the remaining wasted time greatly increases organizational overhead costs.
- The index of "Competence in supplier relationship management and being the employer" was ranked third among the accepted indices with a mean difference of 0.03. The organization must be a professional employer and comply with technical, contractual, and project control requirements. Due to the numerous and varied modules of CoPS, the relationship with multiple suppliers in the development of the product is inevitable and the organization's ability in this index is of great importance.

## CONCLUSION

By testing the significance of the model and determining the verifiable paths based on the SEM in LISREL software, the first and second hypotheses were confirmed, but the third one was rejected. To confirm and compare the results of the SEM, the components were partitioned using ISM. The position of components related to "project characteristics" dimension at the highest level of the ISM model indicates the most effect of these components and is a sign of the first hypothesis confirmation. The position of the components related to the "requirement" dimension at the intermediate levels of the ISM model and above the components of the "competency" dimension indicates is a sign of the second hypothesis confirmation.

In sum and regarding the characteristics of the project, the IAIO should list the requirements for the development of CoPs projects, and, in order to meet these requirements, choose reliable and superior suppliers to obtain competencies. The study was confronted with a limitation in data collection from the organization. Building trust for gathering data and completing the questionnaires were very frustrating due to the difficulty of coordinating with the experts. Although the non-confidential data was sought, it was not easy to urge the authorities of the organization to approve that. The contribution of the present research incorporates finding the indices affecting the outsourcing of CoPS development projects, selecting the more relevant ones by Fuzzy Delphi method, determining their relationship with the survey of experts in IAIO as a case study using the SEM and ISM methods. No sooner could organizations outsource such projects, thaionsn they gain the technological, contractual, project control, integration, soft technologies, financial and communications strategies capability. The managers of organizations and companies developing CoPS such as airplanes power plants, express trains and ships can use the results of this model. Of course, determining the

characteristics of such projects suppliers is also of great significance, which can be considered as a future research.

## MANAGERIAL IMPLICATIONS

Based on the intra-organizational model, the implications will be as follows:

Technical features of CoPS R&D projects, which include the development of modular products with specific standards at each stage of production, causes technological uncertainty for the organization. The complexity of these projects requires the organization to use special equipment. The organization alone cannot provide this equipment. Technological uncertainty and the need for special equipment jeopardize the time and quality of product availability. The risk of leaking the organization's core information and trying to maintain the intellectual property of the project exposes the organization to uncertainty about the supplier's behaviour. In other words, the organization is unsure whether the supplier is committed to the intellectual property ownership of the project.

Behavioural uncertainty leads the organization to acquire competencies in managing supplier relationships. Furthermore, it forces the organization to acquire integration capability. If the organization entrusts the development of product modules to different suppliers and is able to integrate the product by receiving each of the modules, the possibility of leaking information and product specifications outside the organization is minimized. Obviously, the breakdown of the project into separate parts so that the relationship of the components is not clear to different suppliers, is the prerequisite to the integration. Behavioural uncertainty also leads the organization to adopt a strategic alliance approach. Given that a long-term partnership will be established by sharing intellectual property, and technical, financial, and information risk, if this alliance is realized, the confidence in supplier behaviour in improving the quality and preserving the common intellectual property of the project increases significantly. Finally, behavioural uncertainty prompts the organization to gain the competence in being the employer in outsourcing and build trust in different stages of product development. This competence manifests itself in the ability to help the supplier which encounter problems, reviewing technical appendices, training the supplier, and finally the ability to collect the different modules of the project and ensure the correct operation of the product.

The need for hardware, forces the organization to prioritize payment to the supplier over the receipt of equipment by obtaining adequate financial resources. Failure to

## APPENDICES

Fuzzy Delphi questionnaire

| Row | Factors | symbol | Extent of effect | | | | |
|---|---|---|---|---|---|---|---|
| | | | Very low | low | medium | high | Very high |
| 1 | Asset Specificity | $C_1$ | | | | | |
| 2 | The flexible structure of the organization | $C_2$ | | | | | |
| 3 | The technological uncertainty | $C_3$ | | | | | |
| 4 | High modularity and low batches of the CoPS | $C_4$ | | | | | |
| 5 | The quality improvement | $C_5$ | | | | | |
| 6 | Strategic alliance with the suppliers to proliferate the product | $C_6$ | | | | | |
| 7 | The risk of regular financial resources | $C_7$ | | | | | |
| 8 | Resource heterogeneity | $C_8$ | | | | | |
| 9 | Reduction of the time to development | $C_9$ | | | | | |
| 10 | Vital information leakage | $C_{10}$ | | | | | |
| 11 | Market uncertainty | $C_{11}$ | | | | | |
| 12 | Cost reduction | $C_{12}$ | | | | | |
| 13 | Behavioral uncertainty | $C_{13}$ | | | | | |
| 14 | Belief in open innovation | $C_{14}$ | | | | | |
| 15 | Political risk | $C_{15}$ | | | | | |
| 16 | Intellectual property right | $C_{16}$ | | | | | |
| 17 | Competence in supplier relationship management and being the employer | $C_{17}$ | | | | | |
| 18 | Learning by doing | $C_{18}$ | | | | | |
| 19 | Competence in integration | $C_{19}$ | | | | | |

The questionnaire related to the classification of indexes and development of dimensions

| Index | Component | Dimension | Opinion | | | | |
|---|---|---|---|---|---|---|---|
| | | | Very low | low | medium | high | Very high |
| The risk of regular financial resources ($C_9$) | Resources ($D_1$) | Competency | | | | | |
| Specific, and superior resources ($C_{10}$) | | | | | | | |
| Strategic alliance with the suppliers to proliferate the product ($C_7$) | Communication strategy ($D_2$) | | | | | | |
| Competence in supplier relationship management and being the employer ($C_{20}$) | | | | | | | |
| The flexible structure of the organization ($C_3$) | Soft Technology ($D_3$) | | | | | | |
| Belief in open innovation($C_{16}$) | | | | | | | |
| Competence in integration ($C_{22}$) | Integration ($D_4$) | | | | | | |
| The technological uncertainty ($C_4$) | Certainty ($D_5$) | Requirement | | | | | |
| Vital information leakage ($C_{12}$) | | | | | | | |
| Behavioral uncertainty ($C_{15}$) | | | | | | | |
| Political risk ($C_{18}$) | | | | | | | |
| Asset Specificity ($C_1$) | Hardware ($D_6$) | | | | | | |
| Reduction of the time to development ($C_{11}$) | Time ($D_7$) | | | | | | |
| Cost reduction $C_{14}$) | Cost ($D_8$) | | | | | | |
| The quality improvement ($C_6$) | Quality ($D_9$) | | | | | | |
| High modularity ($C_5$) | Technical ($D_{10}$) | Project Characteristics | | | | | |
| Intellectual property right ($C_{19}$) | Appropriability ($D_{11}$) | | | | | | |

pay on time can lead to outsourcing failure. The organization's hardware requirements prioritize referring to a superior supplier in terms of equipment. It also makes creating a strategic alliance with a supplier owning superior resources to meet this long-term need, an attractive option for the organization. Technological uncertainty leads the IAIO to utilize the technological capability of the superior suppliers. It will justify the strategic alliance to improve the technological capability of the organization in the long run as well.

Frankly speaking, it should be noted that in order to carry out their complex product development projects, the industry managers should determine the mentioned requirements according to the characteristics of the projects, and to meet these needs, reliable and superior suppliers to obtain the required qualifications should be selected.

## AUTHORSHIP CONTRIBUTIONS

Authors equally contributed to this work.

## DATA AVAILABILITY STATEMENT

The authors confirm that the data that supports the findings of this study are available within the article. Raw data that support the finding of this study are available from the corresponding author, upon reasonable request.

## CONFLICT OF INTEREST

The author declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

## ETHICS

There are no ethical issues with the publication of this manuscript.

## REFERENCES

[1] Miller R, Hobday M, Leroux-Demers T, Olleros X. Innovation in complex systems industries: the case of flight simulation. Ind Corp Chang 1995;4:363–400. [CrossRef]

[2] Hobday M, Davies A, Prencipe A. Systems integration: a core capability of the modern corporation. Ind Corp Chang 2005;14:1109–1143. [CrossRef]

[3] Dedehayir O, Nokelainen T, Mäkinen SJ. Disruptive innovations in complex product systems industries: A case study. J Eng Technol Manag 2014;33:174–192. [CrossRef]

[4] Hobday M. Product complexity, innovation and industrial organisation. Res Policy 1998;26:689–710.

[CrossRef]
[5] Naghizadeh M, Manteghi M, Ranga M, Naghizadeh R. Managing integration in complex product systems: The experience of the IR-150 aircraft design program. Technol Forecast Soc Change 2017;122:253–261. [CrossRef]
[6] Ellram L, Billington C. Purchasing leverage considerations in the outsourcing decision. Eur J Purch Supply Manag 2001;7:15–27. [CrossRef]
[7] Hamel G, Prahalad C. Strategic intent. Mckinsey Quarterly 1990:36–61.
[8] Alexander M, Young D. Strategic outsourcing. Long Range Plan 1996;29:116–119. [CrossRef]
[9] Hätönen J, Eriksson T. 30+ years of research and practice of outsourcing–Exploring the past and anticipating the future. J Int Manag 2009;15:142–155. [CrossRef]
[10] Poudeh HD, Cheshmberah M, Mohammad HT, Gavareshki HK, Hosnavi R. Determining and prioritizing the factors influencing the outsourcing of Complex Product Systems R&D projects employing ANP and grey-DEMATEL method (case study: Aviation Industries Organization, Iran). Technol Soc 2019;56:57–68. [CrossRef]
[11] Davies A, Brady T. Organisational capabilities and learning in complex product systems: towards repeatable solutions. Res Policy 2000;29:931–953. [CrossRef]
[12] Moody JB, Dodgson M. Managing complex collaborative projects: Lessons from the development of a new satellite. J Technol Transf 2006;31:568–588. [CrossRef]
[13] Coase RH. The nature of the firm. Economica 1937;4:386-405. [CrossRef]
[14] Oliver W. Markets and hierarchies: Analysis and antitrust implications. New York: Free Press, 1975.
[15] Lee GR, Lee S, Malatesta D, Fernandezet S. Outsourcing and organizational performance: The employee perspective. Am Rev Public Administr 2019;49:973–986. [CrossRef]
[16] Barthelemy J. The seven deadly sins of outsourcing. Acad Manag Perspect 2003;1787–1798.
[17] Wibisono YY, Govindaraju R, Irianto D, Sudirman I. Managing differences, interaction, and partnership quality in global inter-firm relationships: An empirical analysis on offshore IT outsourcing. Int J Manag Proj Bus 2018;12:730–754. [CrossRef]
[18] Singgih ML, Dalulia P, Suef M, Karningsih PD. Performance modelling for maintenance outsourcing providers based on the Kano model. Int J Technol 2018;9:797–808. [CrossRef]
[19] Bruccoleri M, Perrone G, Mazzola E, Handfield R. The magnitude of a product recall: offshore outsourcing vs. captive offshoring effects. Int J Prod Res 2019;57:4211–4227. [CrossRef]
[20] Damanpour F, Magelssen C, Walker RM. Outsourcing and insourcing of organizational activities: the role of outsourcing process mechanisms. Public Manag Rev 2019:767–790. [CrossRef]
[21] Thakur-Wernz P, Wernz C. Does R&D offshore outsourcing improve innovation in vendor firms from emerging economies? A study of biopharmaceutical industry in India. Int J Emerg Markets 2020 [Ahead of print] [CrossRef]
[22] HA LT, Thang DN, Dung HP, Thanh TT, Dung LD, Thanh Huyen NT. Determinants and risk-taking behaviour of outsourcing innovation decision and intensity in Vietnam: Make, pure or hybrid? Int J Innov Manag 2020:2040002. [CrossRef]
[23] Yamaguchi S, Nitta R, Hara Y, Shimizu H. Who explores further? Evidence on R&D outsourcing from the survey of research and development. R&D Management 2021;51:114–126. [CrossRef]
[24] Newman WL. Social research methods: Qualitative and quantitative approaches. Boston: Allyn and Bacon, 1991. [CrossRef]
[25] Bojadziev G, Bojadziev M. Fuzzy sets, fuzzy logic, applications. Singopare: World Scientific, 1995.
[26] Cheng C-H, Lin Y. Evaluating the best main battle tank using fuzzy decision theory with linguistic criteria evaluation. Eur J Operational Res 2002;142:174–186. [CrossRef]
[27] Beaugency A, Sakinç ME, Talbot D. Outsourcing of strategic resources and capabilities: opposing choices in the commercial aircraft manufacturing. Journal of Knowledge Management, 2015;19:912–931. [CrossRef]
[28] Becker MC, Zirpoli F. How to avoid innovation competence loss in R&D outsourcing. Calif Manag Rev 2017;59:24–44. [CrossRef]
[29] Zhu X. Managing the risks of outsourcing: Time, quality and correlated costs. Transp Res E: Logist Transp Rev 2016;90:121–133. [CrossRef]
[30] McIvor R. Outsourcing done right. Ind Eng 2011;43:30–35.
[31] Kim N, Shin S, Min S. Strategic marketing capability: Mobilizing technological resources for new product advantage. J Bus Res 2016;69:5644–5652. [CrossRef]
[32] Oshri I, Kotlarsky J, Gerbasi A. Strategic innovation through outsourcing: the role of relational and contractual governance. J Strateg Inf Syst 2015;24:203–216. [CrossRef]
[33] Yeo C, Saboori-Deilami V. Strategic challenges of outsourcing innovation in global market. Asia Pacific Journal of Innovation and Entrepreneurship, 2017;11:5–16. [CrossRef]
[34] Skowronski K, Benton Jr W. The influence of intellectual property rights on poaching in manufacturing outsourcing. Prod Oper Manag 2018;27:531–552. [CrossRef]