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CRITICAL SUCCESS FACTORS FOR PROJECTS IN THE SPACE SECTOR

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ABSTRACT

The paper identifies the critical success factors for space projects. A list of factors was synthesized from existing literature, and risk management and requirements management were added as the authors felt that these had particular significance in the space sector. The paper identifies 58 success factors that were then classified into 11 groups. These factors were then tested within the space industry using an elicitation technique, the data obtained was then analysed to test a number of research hypotheses. It is concluded that both requirements management and project risk management should be considered as critical success factors. The paper also uses the relative importance index approach to rank the classified categories based on their perceived importance.

1. Introduction

It has been more than 70 years since the beginning of space flight and a variety of satellites, probes, manned spacecraft and semi-permanent space stations have been launched to explore and exploit space. Space research has led to a better understating of the natural world, and to the creation of new technologies and capabilities that have transformed our lives such as telecommunications, satellite navigation, weather forecasting and climate monitoring *(United Nations Office for Outer Space Affairs , 2011)*.

According to a space industry report *(Space Foundation, 2014)*, the estimated size of the global space industry was $314.17 billion in 2014, which showed a growth of 4% from the previous year. The majority of the growth in this industry is derived from commercial activity, which contributes nearly three-quarters of the space economy. The key players in this industry are Russia, United States, China and Europe. Projects in the sector are classified into five areas namely orbital human space flight, launch vehicles, space stations, satellites, and ground stations *(Space Foundation, 2014)*.

To ensure the continuity of the positive growth in the industry, new and bigger projects have to be undertaken *(Kerzner, 2002)*. These projects generally come with a sense of complexity; this is due to the aim of developing projects in areas that have not been done before. An example is the Rosetta project undertaken by the European Space Agency aimed at landing a robot space probe on a comet *(Ferri, 2006)*.

Project success is the ultimate goal for every project *(Chan & Chan, 2004)* and so has been a subject of much consideration *(Alexandrova & Ivanova, 2012)*. In the space sector there is currently no formal definition of success for projects except for established generic definitions from project management bodies such as the Project Management Institute and the Association for Project Management. Different participants and stakeholders will have different views of success. Since Critical Success Factors enable success, different perspectives of success will involve different Critical Success Factors.

2. Background

Project Success

Early works on project success focus on the achievement of time, cost and quality objectives. More recently greater appreciation of the issues, including the diversity of stakeholder perspectives, has led to the recognition that a broader set of measures is needed *(Atkinson, 1999; Wateridge, 1998)*. De Wit *(1988)* explains that a project is considered successful overall if it meets the technical performance specification, and if there is a high level of satisfaction concerning the project's outcome among key people in the parent organization, key people in the project team and key users or clients of the project workforce. Projects differ in size, uniqueness and complexity *(Müller, 2007)*. Therefore, the criteria for measuring success vary from project to project and industry to industry, making it difficult to establish a unique set of criteria for all projects *(Westerveld, 2003)*.

Critical Success Factors

Critical Success Factors *(CSFs)* can help provide a better understanding of best practices to improve the success rate of projects. Smaller organizations that do not have the manpower or capabilities to invest heavily in all aspects of the project can focus their limited resources on the factors that will make the biggest difference *(Bullen & Rockart, 1981)*. Rockart *(1982)* defines critical success factors as: "Those key areas of activity in which favorable results are absolutely necessary for a manager to reach his/her goals." Futrell et al. *(2001)* define CSFs as those factors in which success is necessary in order that each of the major project participants in a project has the maximum chance of achieving their goals. The implementation of CSFs in project key areas ensures success is made explicit *(Boynton & Zmud, 1984)*. CSFs can be used by a project manager as a description, as a predictor, and as a guide to achieve success *(Vedder, 1992)*.

CSFs have been used as a means to identify characteristics of achieving project success since the 1970s in a variety of disciplines such as project management in general *(Muller & Jugdev, 2012)*, construction *(Gudiene N. , Banaitis, Podvezko, & Banaitiene, 2014; Berssaneti & Carvalho, 2015; Yong & Mustaffa, 2013; Omran, Abdulbagei, & Gebril, 2012)*, information technology *(Almajed & Mayhew, 2014)*, and enterprise solutions *(Finney & Corbett, 2007; Umble, Haft, & Umble, 2003)* . This paper identifies the CSFs for the space industry.

Following an in-depth review of past work on CSFs outside the space industry, 46 CSFs were identified and grouped under 9 main categories as in **Table 1**: *(1)* external challenge; *(2)* client knowledge and experience; *(3)* top management support; *(4)* institutional factors; *(5)* project characteristics; *(6)* project manager competence; *(7)* project organization; *(8)* contractual aspects; and *(9)* project team competence. These 9 categories cover all the elements that have an impact on space sector projects and exclude the areas that the authors are testing to see where they stand on the relative importance index. The two additional areas are *(10)* project risk management; and *(11)* requirements management which have 12 CSFs associated with them making the total number of CFSs 58. The authors then classified the 11 categories into 2 different sets, which are those that are under the control and influence of the project manager, and those that are not. This paper compares the two classes to see which factors have higher influence on project success and highlights the importance of project risk management and requirements management in project success. **Table 1** gives a summary of the CSFs and their categories.

Studies have focused on the implementation of risk management on project success *(Zwikael & Ahn, 2011)*. Bakker et al. *(2012)* emphasize the need to identify risk, its effects on project success and suggest that risk management activities contribute to project success. However studies have linked risk management to project outcomes *(Almajed & Mayhew, 2014; Rabechini Junior & Monteiro de Carvalho, 2013; Didraga, 2013; Kutsch & Hall, 2010)* but not to CSFs. The factors under project risk management are sub divided into two which are firstly hard aspects with initiation, identification, assessment, response planning, response implementation and secondly, soft aspects of risk, which are risk communication and attitude, monitoring and review *(David, 2009)*.This suggest the following Hypothesis

H1: Project Risk Management has a positive impact on Project Success.

Studies have highlighted the importance of requirements management and project success *(Mirza, Pourzolfaghar, & Shahnazari, 2013; Varajao, Dominguez, Ribeiro, & Paiva, 2014; The Standish Group, 2013)* but there has not been a direct connection with CSFs. The factors under requirements management are elicitation technique, identification, analysis and negotiation, modelling, validation and scope management *(Nuseibeh & Easterbrook, 2000)*. This has also led to the following hypothesis.

H2: Requirements Management has a positive impact on Project Success.

3. Methods

Since there has been little or no previous research on CSFs in the space industry, a study of CSFs in other related disciplines was first performed to provide insight. CSFs have been applied extensively to other disciplines such as enterprise resource planning and construction, and the literature in those areas with respect to project success were studied and the CSFs that may be important to the space industry extracted. The second strategy was to develop a questionnaire with the key areas and ask experts in the space industry to give their view and opinion as to how to improve the questionnaire organization before distributing it to project managers and participants for feedback.

The questionnaire is of key importance, as it was used to test the importance of the factors and test our hypotheses. Relative importance index was included to aid analysis and facilitate a ranking of factors. In previous studies the factors are regarded as critical but few actually rank them based on importance from the respondents' viewpoint. Ultimately this will help target resources.

To analyze the data Statistical Package for Social Sciences *(SPSS)* software was used, in the application the answers of the respondents were subject to various statistical analysis such as regression and reliability tests to give further insight into the data.

Questionnaire Design

An online approach was selected to assess the relationships between the CSFs found in the literature review and project success. The variables used to measure the CSFs were adapted from past publications. The questionnaire was divided into 5 sections with 37 questions. The first section obtained general background information of the respondents with 11 questions. The second section contains 11 questions asking respondents to weigh each CSF based on a 10 point scale. The third and fourth sections looks into a specific CSFs which are project risk management and requirements management, these two sections are also based on the Likert scale. The Likert scales are all uniform in the questionnaire using a scale of 1 to 10 which signifies a range from weak impact to strong impact. The final section is optional because it asks respondents to provide their names and email if they are interested to discuss their responses in more detail or to be contacted for further research.

As selection of the initial measurements items was derived from the existing literature, it is important to assess its validity. A pilot questionnaire test was give to 3 potential participants to complete and critique the questions. The recommendations they made were considered and incorporated into the final draft of the questionnaire.

Study Sample

The questionnaire was distributed online via email to project managers and project participants in the following agencies, the European Space Agency *(ESA)*; Surrey Space Technology *(SSTL)*; Mullard Space Science Laboratory *(MSSL)*; the National Space Research and Development Agency *(NASRDA)*. The total number of emails sent was 213, which led to 57 responses of which 49 were valid and completed. This means we had a return rate of 23% for valid and complete responses.

In the study sample most respondents are currently project managers with doctoral degrees, and have an average of more than 15 years project experience and some project management experience. They have participated in more than 15 projects with an average value of order of magnitude 10 million $/€/£, delivering sub systems and hardware, and are geographically located in the United Kingdom, Netherlands, United States of America, Germany, China and Nigeria.

Category	Critical Success Factors	Sources
External Challenge	The external challenges are the factors that have influence on the project but are external to the project. The attributes under this factor are the economic environment, social environment, political environment, physical environment and regulatory/legal environment.	(Gudiene N. , Banaitis, Podvezko, & Banaitiene, 2014); (Omran, Abdulbagei, & Gebril, 2012); (Tan & Ghazali, 2011); (Toor & Ogunlana, 2009) (Fortune & White, 2006); (Iyer & Jha, 2005); (Jugdev & Muller, 2005); (Chan, Scott, & Chan, 2004); (Belassi & Tukel, 1996); (Morris & Hough, 1987).
Client knowledge and experience	The attributes concerned with the client's characteristics include nature of finance, experience, organization size, emphasis on cots quality and time, ability to brief, decision making, roles and contribution, expectations and commitment, involvement and influence. All the factors deal with the client's ability to contribute to the success of the project.	(Gudiene N. , Banaitis, Podvezko, & Banaitiene, 2014); (The Standish Group, 2013); (Omran, Abdulbagei, & Gebril, 2012); (Tan & Ghazali, 2011); (Turner, Zolin, & Remington, 2009); (Kulatunga, Amaratunga, & Haigh, 2009); (Bryde & Robinson, 2005); (Jugdev & Muller, 2005); (Iyer & Jha, 2005).
Top management support	The variables in this factor are support given to project head, support to critical activities, understanding of project difficulty and stakeholder influence. The factors look at the amount of time devoted by high-ranking executives to ensure project success.	(Ram & Corkindale, 2014); (Varajao, Dominguez, Ribeiro, & Paiva, 2014); (Almajed & Mayhew, 2014); (Berssaneti & Carvalho, 2015); (The Standish Group, 2013); (Toor & Ogunlana, 2009); (Fortune & White, 2006); (Iyer & Jha, 2005).
Institutional factors	The attributes under this factor are standards and permits. They deal with organizational processes and culture, which include how a business operates and its application of standards.	(Gudiene N. , Banaitis, Podvezko, & Banaitiene, 2014); (Gudiene, Banaitis, & Banaitiene, 2013)
Project characteristics	The attributes under this factor are project type, size, nature, complexity, design, resources allocation time and level of technology. These factors detail the general characteristics of the project.	(Yong & Mustaffa, 2013); (Omran, Abdulbagei, & Gebril, 2012); (Fortune & White, 2006); (Chan, Scott, & Chan, 2004); (Akinsola, Potts, Ndekugri, & Harris, 1997); (Belassi & Tukel, 1996).
Project manager competence	Variables under the umbrella of the project manager competence include experience, coordinating and motivating skills, leading skills, communication and feedback, management skills, conflict resolution skills and organizing skills.	(Toor & Ogunlana, 2009); (Malach-Pines, Dvir, & Sadeh, 2009); (Barclay & Osei-Bryson, 2009); (Turner, Zolin, & Remington, 2009); (Muller & Turner, 2007); (Wang & Huang, 2006); (Jugdev & Muller, 2005).
Project organization	A variety of attributes will affect this factor including planning and control effort, team structure and integration, safety and quality program, schedule and work definition, budgeting and control of subcontractors.	(Gudiene N. , Banaitis, Podvezko, & Banaitiene, 2014); (Varajao, Dominguez, Ribeiro, & Paiva, 2014); (Berssaneti & Carvalho, 2015); (Almajed & Mayhew, 2014); (The Standish Group, 2013) (Yong & Mustaffa, 2013); (Omran, Abdulbagei, & Gebril, 2012); (Tan & Ghazali, 2011); (Kulatunga, Amaratunga, & Haigh, 2009).
Contractual aspects	The factors under contractual aspects are contract type, tendering (procedures or steps for the selection of that service) and procurement (company selection to provide services) process.	(Yong & Mustaffa, 2013); (Omran, Abdulbagei, & Gebril, 2012); (Tan & Ghazali, 2011); (Chan, Scott, & Chan, 2004).
Project team competence	The composition of the project team is integral to the success of the project hence the attributes covered in this factor include the team experience, technical skills, planning and organizing skills, commitment and involvement, teams adaptability to changing requirements, working relationships, educational level, training availability and decision making effectiveness.	(Gudiene N. , Banaitis, Podvezko, & Banaitiene, 2014); (Varajao, Dominguez, Ribeiro, & Paiva, 2014); (Almajed & Mayhew, 2014); (Ram & Corkindale, 2014); (Tan & Ghazali, 2011); (Toor & Ogunlana, 2009); (Kulatunga, Amaratunga, & Haigh, 2009); (Turner, Zolin, & Remington, 2009); (Barclay & Osei-Bryson, 2009); (Shenhar & Dvir, 2007); (Fortune & White, 2006).

TABLE 1. *CSFs Identified in Literature.*

4. Data Analysis and Findings

Relative Importance Index

According to Tonidandel & LeBreton *(2011)*, the aim of the Relative Importance Index is to "partition explained variance among multiple predictors to better understand the role played by each predictor." The relative important index has been adopted by various project management research such as the works of *(Gudiene, Banaitis, & Banaitiene, 2013; Iyer & Jha, 2005; Assaf & Al-Hejji, 2006; Kumaraswamy & Chan, 1998)*. The formula is depicted below:

$$RII = \frac{\Sigma W}{X * Y} = (0 \leq RII \leq 1)$$

Where W is the weight given to one factor by each respondent, which ranges from 1 to 10, X is the highest score available *(10 in this case)* and Y is the total number of respondents that have answered the question. **Table 2**, 3 and 4 depict the results of the relative importance index.

Reliability of scale

To ensure reliability and consistency, the reliability of scale was implemented. According to Santos *(1999)*, it aims to "calculate the stability of a scale from the internal consistency of an item by measuring the construct". As discussed by Nunnally & Bernstein *(1994)*, in order to ensure high reliability and internal consistency the Cronbach's alpha value has to be higher than 0.7. This value has also been supported by Hair et al *(1998)* as anything above 0.7 is presumed to have a high internal consistency and highly reliable. **Table 5** depicts the results of the reliability of scale test.

Factor Analysis

Factor Analysis has been done with the aid of Bartlett's test of sphericity, here the constructs are considered acceptable only if their individual factor loading is above 0.5 *(Tabachnick & Fidell, 2001)*. In the case of the research only one question had a factor loading of below 0.5 which stood at 0.476, all other constructs have a factor loading of greater than 0.5. This is considered to be extremely good *(Field, 2005)*.

Regression Test

Linearity assumption

To measure the relationships between variables using regression analysis, both dependent and independent variables must be linear as suggested by Osborne & Waters *(2002)*, they also explain that to achieve linearity among the variables the residual values of the data has to be between the ranges of -3 to 3. As the minimum and maximum value fall between both ranges this means if there is a need to extrapolate from the data, there will be minimal risk of the data being prone to errors. **Table 6** depicts the results of the linearity assumption test.

Multicollinearity

Multicollinearity arises when high correlation exists between the variables of the study, which is not wanted because it can cause errors to arise. To avoid multicollinearity, the tolerance and variation inflation factor have to be greater than 0.1 and less than 10 respectively *(Garson, 2010)*. As the results in **Table 7** show, there is no issue of multicollinearity among the variables.

Hypothesis test.

For a hypothesis to be true and the null hypothesis rejected, the t-value and p-value have to be considered. The t-value should be >2.0 and p-value should be <0.05 respectively *(Berge & T, 1987)*. **Table 8** depicts the results of the hypothesis test.

5. Discussion

The first objective of the study is to gauge the importance of the CSFs as highlighted in past literature and also to gauge what people think of the importance of project risk management and requirements management. The ranking of the factors was performed using the relative importance index approach. From the results in **Table 2**, the authors found out that the most important success factor in projects is the Project Team Competence with an aggregated index of 0.859, followed by Project manager Competence *(RII = 0.831)*, and Requirements management *(RII = 0.816)*.

Consequently, from the results of the relative importance index, one can see that project risk management and requirements management are actually very important and should henceforth be always considered as a CSF. This can be derived from the basis that they both got very high index aggregates which led to requirements management coming in third place and project risk management in fifth. The results of the hypotheses test as seen in **Table 8** also support the positive relationship between both categories and project success. This is a very important finding and further research should be carried out to determine what makes project risk management and requirements management act as CSFs in the space sector. Does this apply for all complex projects, and why are they not listed as CSFs in previous research?

In the index figures of all the CSFs in **Table 2** and based on the respondents views, the project manager plays a very important role in ensuring project success since the top 6 ranking factors: the project team competence; project manager competence; requirements management; project organization; project risk management; and contractual aspects are all assumed to be under the control of the project manager. This means that the respondents believe that there are more factors under the control of the project manager that can lead to project success than factors that are not within their control. Factors that do not fall within the control of the project manager include institutional factors, top management support, external challenge and finally client knowledge and experience.

One of the important aspects of this research is highlighting the importance of project risk management and requirements management in project success. In this CSF *(requirements management)* the most important factors based on their individual relative importance index on **Table 4** is scope management with an RII of 0.808. Scope management oversees processes and manages other process involved in requirements management.

The ranking of the factors involved in project risk management can be seen in **Table 3** above. The most important factor is monitoring and review with an RII of 0.806. The process entails "monitoring and review of risk during the course of a project".

Finally, the results from the survey and the relative importance index analysis indicate that people find it easier to differentiate between the CSFs than the factors involved in project risk management and requirements management. This can be seen from the range of the relative importance factors of the three aspects in **Table 2**, 3 and 4.

Category	RII	Rank
Project Team Competence	0.859	1
Project Manager Competence	0.831	2
Requirements Management	0.816	3
Project Organization	0.812	4
Project Risk Management	0.8	5
Contractual Aspects	0.7	6
Institutional Factors	0.7	6
Project Characteristics	0.696	8
Top Management Support	0.692	9
External Challenge	0.667	10
Client Knowledge and Experience	0.659	11

TABLE 2. *RII of Critical Success Factors*

6. Conclusions

Project success has been a key topic of discussion in project management for decades, but there is still no accepted definition for it. This has led to the establishment of sector specific critical success factors. This paper has identified and prioritized a set of critical success factors that should be considered to improve the likelihood of success in space projects.

Based on the existing literature, a total of 58 factors were identified that could affect project success in the space industry. These factors were grouped and then ranked based on their relative importance index. The study established that people ranked requirements management and project risk management higher than many of the already established success factors as seen in **Table 2**. This alone should support the need for further study on requirements management and project risk management as this study shows how important both of them are and improving them can increase success rate of future projects.

It is interesting to note that the project managers surveyed in this research indicate that factors under the control of the project manager have a greater influence on project success than factors outside the project manager's control. Further research is needed to establish whether project managers' behaviour is consistent with this attitude.

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Project Risk Management	RII	Rank
Monitoring and Review	0.806	1
Implementation of Responses	0.802	2
Communication and Culture	0.8	3
Planning of Responses	0.765	4
Initiation	0.748	5
Identification	0.735	6
Assessment	0.721	7

TABLE 3. *RII of Project Risk Management Aspects*

Requirements Management	RII	Rank
Scope Management	0.808	1
Identification	0.8	2
Validation	0.771	3
Analysis and Negotiation	0.769	4
Modelling	0.721	5

TABLE 4. *RII of Requirements Management Aspects*

Constructs	No of Items	Cronbach's Alpha
Critical Success Factors	11	0.852
Project Risk Management	7	0.826
Requirements Management	5	0.822

TABLE 5. *Reliability of Scale*

	Minimum	Maximum	Mean	Std. Deviation	N
Predicted Value	5.4976	9.3511	7.4410	.86173	49
Residual	-1.03379	1.12110	.00000	.51544	49
Std. Predicted Value	-2.255	2.217	.000	1.000	49
Std. Residual	-1.962	2.127	.000	.978	49

TABLE 6. *Linearity Assumption*

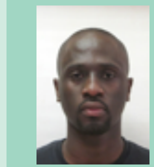
Predictor Variables	Tolerance	VIF
Critical Success Factors	.523	1.914
Project Risk Management	.404	2.472
Requirements Management	.353	2.836

TABLE 7. *Multicollinearity*

Hypotheses	Beta	t-value	p-value (Sig)	Outcome
H1: Project Risk Management	.519	4.852	.000	Accepted
H2: Requirements Management	.413	3.856	0.012	Accepted

TABLE 8. *Hypothesis Test*

authors



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