A Machine Learning Proposal for Predicting the Success Rate of IT-Projects Based on Project Metrics Before Initiation

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ABSTRACT
Thus far, the influence of information technology (IT) has grown tremendously with regards to all different aspects of today's society. As a result, many IT-projects have been initiated however the success rates are rather limited. As a matter of fact, research has shown that approximately 1 out of 3 IT-projects fail. Over the years, a number of researchers started to examine predictive techniques to see to what extent it is possible to predict success. Various models are proposed, however until now, none of them is focused on predicting success before initiation. With the use of extensive literature research to critical success factors and project metrics, a new set of variables is given that is fully focused on IT-projects. Moreover, this set was validated through interviews with experts and a survey after which average importance scores were given to each critical success factor and metric. Lastly, general measurements are provided for each project metric that has a significant influence on the success of a project. This way, the conducted study provided a solid base for the development of a prediction model that will validate the results of this thesis once an appropriate dataset has been found. Therefore, this thesis serves as a guideline for future research on how to predict the success of IT-projects based on project metrics before initiation.

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Keywords
Project Success, Critical Success Factors, Project Management, Success Rate Prediction, Prediction Instrument

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1. INTRODUCTION

Achieving 'project success' is the ultimate goal for every project practitioner. Despite all different ways of reaching project success, one thing is for sure: a project manager is crucial for the entire process of reaching this goal (Radujković & Sjekavica, 2017) Unfortunately when looking at the implementation of software projects it appears to be very difficult to reach project success. **Table 1** provides the results of a survey conducted by The Standish Group in the US. Given the results, it can be concluded that approximately 1 out of 3 projects fail and many researchers are intrigued to examine the possible causes of these failures.

In order to understand the context of software project failures, two concepts need to be elaborated on. One of which is project management. Multiple definitions have been formed, though the commonly used one states that project management includes the planning, organizing, directing and controlling of company resources that are put in place in order to achieve specific goals and relatively short-term objectives (Kerzner, 2017). Each of the mentioned processes includes multiple actions that should be performed in order to effectively manage a project. The other concept is project success. It seems that there is no uniform answer to the question 'when is a project a success?'. As a result, numerous researchers have found multiple critical success factors to assess the success of a project. On top of that, there is also a distinction being made between project success and project management success. Though unfortunately, due to the high levels of complexity and uncertainties project managers do not (yet) have the ability to guarantee success when starting the implementation process of a software project.

Given this complication, the search for alternative tools to help predict whether a project will be successful or not; to help identify critical factors of success; and to help foresee all possible risks has fascinated researchers. A few of these alternative tools are based on artificial intelligence (Magaña Martínez & Fernandez-Rodriguez, 2015). The term, artificial intelligence, was first used by John McCarthy 1956 who defines it as "the science and engineering of making intelligent machines". Over the years, multiple definitions were formed. For the sake of this paper, the definition of Nilsson (1981) is chosen which defines AI as "[…] a subpart of computer science, concerned with how to give computers the sophistication to act intelligently, and to do so in increasingly wider and independently realms". Martínez et al. (2015) performed a literature review in which 16 references were used where AI has been used as a tool to estimate project success or to identify critical success factors. The first reference dated from 1997 and the last reference dated from 2014. The purpose of this literature review was to compare and evaluate the proposals on how AI could be used in project management. One of the main conclusions that was derived from the research, was that the AI tools were suited for supporting project managers with controlling and monitoring the project, though it was not suited yet to make relevant predictions that are useful for decision-making.

Thus, it has been proven that the current project management approaches have endured challenges and complications for a long time. Therefore, the development of a tool that is able to predict the success rate of a project will be a valuable addition to the existing literature.

The current state of and research agenda on AI in project management is still in its early stage of providing solid solutions to enhance project management. Accordingly, one of the contributions of this paper is that it will reassess the level of importance of all identified critical success factors and project metrics and select the most essential metrics that influence the success rate of medium to large IT projects. Additionally, the influence a critical success factor has on the selected metric is examined. Lastly, specific input is provided for future research to develop an actual prediction instrument which should be validated when an appropriate dataset is obtained.

Next, to contributing to the existing literature, this research delivers a valuable contribution to businesses and their stakeholders. The reason being that it gives insights for improving the way an IT project is managed. This is done by the provision of a set of variables for medium to large sized IT projects. This set provides insights on which critical success factors are related to which project metric, the relative level of importance for each critical success factor is provided, and the most essential project metrics are given also with an average importance score. This enables project managers to give extra and better attention to the metrics (a measurable dependent variable) that have a higher influence on whether the project will succeed or fail. Moreover, the result of this research are propositions for future research on how to predict the success rate before the initiation stage of a project which will eventually be beneficial for practitioners.

For this research, a literature review has been carried out to derive a list of critical success factors. This list was validated by experts and used as the basis for the process of identifying essential project management metrics. Indicators were linked to each metric and after conducting interviews with experts, average weights were established for each metric. As a result, a set of variables with metrics and CSFs is proposed as input for a prediction model.

The guiding research question was:

Which project metrics have a significant influence on the success rate of an IT-project and to what extent are they predictable before initiation?

In this paper, chapter two will provide an overview of current scientific work related to the topics, project success, critical success factors, and success prediction. In chapter three the method used for this thesis will be discussed. Chapter four will provide all the results that were generated. In chapter five the results will be further discussed, the limitations will be identified, and recommendations for future research are given. Finally, in chapter six a conclusion will be drawn.

2. THEORETICAL FRAMEWORK

2.1 Literature Search Strategy

The literature search strategy included systematic and non-systematic approaches. The search has been conducted with the use of the databases Google Scholar, Scopus and the University of Twente library. Given the research question, documents that were searched for related to the topics: critical success factors, (IT) project success, (IT) project management success, prediction

Benchmark/year	1994	1996	1998	2000	2004	2006	2008
Succeeded (%)	16	27	26	28	29	35	32
Challenged (%)	53	33	46	49	53	46	44
Failed (%)	31	40	28	23	18	19	24

Table 1: Software project performance over a decade

techniques for the prediction of project success rates and prediction of project success rates. In order to effectively scan the mentioned databases, several search queries were used. A search query is a set of keywords that are used as input for a search engine that hopefully delivers specific information that is relevant for answering questions and building up the theory body. Queries that were used for this research are (*Identify* Or *Predict*) AND (*IT project* Or *Project* Or *Project management*) AND (*Success* Or *Failure* Or *Critical success factors*). This research included the search for papers focused on projects in general and projects focused on IT. The reason for this is to detect whether there is a significant difference between critical success factors for projects in general and IT projects since every project is unique. Since the researched topic is quite specific, a lot of literature was taken from backward citations found in analysed articles that were relevant for this research. Additionally, this ensured that all relevant papers were found also the ones that were not provided with the specific search queries.

2.2 Project Success and Project Management Success

When talking about project success in literature, one thing is certain, there is no universal agreement on a standard or even a universally accepted operative framework to assess project success (Shenhar, Dvir, Levy, & Maltz, 2001). This is due to the fact that "success means different things to different people" (Beale & Freeman, 1991). Therefore, the following distinction can be made project management success versus project success. Project management success is achieved by managing the project on time, staying within budget, and meeting the quality/performance specifications. According to the traditional project management methodologies, this is how a project was perceived as a success (Wit, 1988). However, it might be the case that success has been achieved by being on time, staying in budget, and meeting performance specifications. Though, it is not necessarily guaranteed that the key stakeholders are satisfied with the product outcome. The vice versa situation might also occur which implies that the key stakeholders are satisfied with the project outcome. However, it has been delivered later than planned or more expensive than planned. (Birchall, Arne Jessen, Money, & Andersen, 2006). Baker, Murphy, and Fisher (1983,1988) argue that the definition of project success is much more complex than the traditional view. In fact, they conclude that the thing that really matters is that the parties associated with and affected by the project are satisfied. This enlightens the counter-concept which is project success. According to this concept, a project is considered successful if it meets all requirements and objectives, and if there is a high level of satisfaction concerning the project outcome among all stakeholders such as key users, key people in the project team, and key people in the organization (Wit, 1988).

Based on the aforementioned theories, a project can be classified as four different classes. First of all, a project can be classified as a complete failure when the objectives have not been met nor are the stakeholders satisfied with the outcome of the project. Secondly, given the definition of project management success, a semi-failure can be achieved when the project team achieved its objectives regarding time, budget and scope. However, the stakeholders are not satisfied with the project outcome and will most likely not use the end product. Thirdly, a project can be classified as a semi-success when the project manager and team did not meet all objectives, though the customer is satisfied with the outcome and is likely to use the end product. Finally, a project can be considered to be a success as a whole when both objectives are met by the project manager and team, and the stakeholders are satisfied with the end product. However, project success appears to remain a rather elusive concept since both academicians and practitioners do not seem to agree on one universally accepted definition of project success or framework to assess project success.

2.3 Critical Success Factors

In order to determine the success of a project and project management, objectives or success criteria can be used for evaluation. However, the identification of measurable objectives or success criteria appears to be troublesome. Because how can the required level of performance be specified to achieve success (Wit, 1988)? In literature, various techniques are proposed for the identification of measurable objectives (Might & Fischer, 1985; P. Morris & Hough, 1987; P. W. G. Morris & Hugh, 1987; Sapolsky, 1972). One of which, the critical success factor approach, is the focus of this thesis.

The concept 'success factors' was introduced by Daniel, (1961) which he later, in 1979, specified to as critical success factors' (CSFs). He defined CSFs as the number of areas in which the activities should be constantly monitored and evaluated, and these activities should provide satisfactory results. In this way, the CSFs enhance the attainment of the objectives or success criteria. (Rockart, 1979) Usually, when a software project fails it is not because of just one reason but it is often a combination of technical, project management and business decisions (Cerpa & Verner, 2009) Therefore, it is essential to identify and define the CSFs. However, in addition to the debate on the definition of project success, there also seems to be a lack of agreement in regards to what extent CSFs have an influence on project success (Fortune & White, 2006).

From the moment this concept was introduced in 1960, the search for CSFs began. For instance, Reel (1999) identified five essential factors to manage a software project successfully and they were based on ten identified signs of IT project failure. The five critical success factors he mentioned are 1) start on the right foot; 2) maintain momentum; 2) track progress; 4) make smart decisions; 5) institutionalize post-mortem analysis. Abe et al., (2006) identified 29 metrics that enable software measurement and quantification in order to control and reflect upon a project. The metrics were classified into five categories which were 1) development process; 2) project management; 3) company organization; 4) human factor and; 5) external factor. Belassi and Tukel (1996) also grouped their identified CSFs into different areas which were 1) factors related to the project; 2) factors related to the project managers; 3) factors related to the organization; 4) factors related to the external environment. Mohd and Shamsul (2016) derived a list of 26 CSFs from extensive literature research that included 43 publications. They did not group their factors but have put an emphasis on the top 5 critical factors since the percentage of frequency of occurrences for each factor was more than 50%. The critical factors identified were 1) clear requirements and specifications; 2) clear objectives and goals; 3) realistic schedule; 4) effective project management skills/ methodologies; 5) support from top management; and 6) user/client involvement. In addition to the aforementioned researches, many more have researched the topic critical success factors. (Al Neimat, 2005; Cerpa & Verner, 2009; Chow & Cao, 2008; Fortune & White, 2006; Jones, 2004; Verner, Sampson, & Cerpa, 2008). The reason why the identification of the CSFs is essential is because they are the key drivers of project success. Therefore, selecting the right key drivers will result in a better success prediction outcome.

In order to create more value, several authors developed a model, with different purposes, based on the identified critical success factors. De Wit (1988) developed a project success framework that tried to clarify the relationship and interdependencies of project objectives. The model takes on the perspective of a client for a commercial oil-field development project. The identified limitation admits that this framework is not yet an operational framework that can be used for different projects. Additionally, this research concludes that an objective measurement of success of a project is an illusion due to the uniqueness of all projects and due to all different perceptions on success from different stakeholders. In contrary to these conclusions, Fortune and White (2006) argue that they are able to capture different stakeholder viewpoints and use critical success factors in order to state whether a project is a success or a failure at a certain moment in time. 63 publications were reviewed which led to the identification of 27 CSFs. Based on all the identified factors, they developed a formal system model (FSM). This model is used to conceptualize a moment in time as a system, followed by a comparison of this outcome to the FSM. Thereafter the extent to which the components are successfully working without failure will be evaluated. Additionally, it shows to a certain extent how factors are related to one another. Cerpa and Verner (2009) also developed a map in which relationships between the most important failure factors were depicted, however it did not show whether a causal relationship was present. To the contrary, Rodriguez-Repiso et al., (2007) introduced the approach of using Fuzzy Cognitive Maps (FCM) for modelling critical success factors and defining the relationships among them. An FCM combines fuzzy logic and neural networks and is able to indicate whether a relationship between factors is either positive or negative. In order to make this model even more valuable, fuzzy weights are a valuable addition. With these weights, not only the direction of the relationships is shown but also the magnitude of the change.

2.4 Prediction of Project Success

Due to the high complexity and uncertainties, the development and implementation process of an IT project has a high failure rate. Even though software programs are being developed since the 1960s, the ability to substantially increase the success rate of IT projects is still not fully developed (Cerpa, Bardeen, Kitchenham, & Verner, 2010). The aforementioned approach to mitigate the high risk of failure was to identify and focus on the critical success factors. Additionally, researchers started to build models that are able to predict the success probability of a(n) (IT) project (Reyes, Cerpa, Candia-Véjar, & Bardeen, 2011). In order to capture all papers in which an AI-tool has been proposed for success prediction or critical success factor identification, Martínez and Rodriguez (2015) performed a literature review and a structured analysis. Sixteen publications were found from which several algorithms were proposed for the prediction project success which will be explained in the following sections.

2.4.1 Bayesian Classifier

Abe et al., (2006) predicted the final status of a software development project with the use of the Bayesian Classifier. After the selection and validation process of metrics, the Bayesian classifier was applied to classify the project as either successful or unsuccessful. The results, however, are limited to only three viewpoints with regard to success which are focused on 1) the quality of the product, 2) the cost of development and 3) the duration of the project. The prediction is based on a set of metrics of which some of them are strongly related to one of the viewpoints. However, for some of the metrics, there is not a direct relation to one of the viewpoints which were then left out of the prediction model. As a result, a metric that could potentially have an impact on success, in general, is excluded which may lead to an incomplete prediction outcome. Also, it is unclear whether a project was seen as a success in general when the prediction for one of the success viewpoints was unsuccessful. Lastly, in order to build the Bayesian model, the assumption of independence among the predictors is taken. Even though it is hardly possible to have a dataset with independent predictors the results generated by this classifier is surprisingly well.

2.4.2 Super Vector Machine and Fast-Messy Genetic Algorithm

Cheng, Wu, & Wu, (2010) Proposes an evolutionary support vector machine inference model (ESIM) which is a hybrid that integrates a support vector machine (SVM) with a fast-messy genetic algorithm (fmGA). The SVM is a learning machine for two-group classification problems, which was first suggested by Cortes and Vapnik (1995). The data is separated by a decision boundary and the data points that are closest to this boundary are the so-called support vectors. The aim is to maximize the margin between the support vectors and the decision boundary because this will lead to a lower generalization error. If it is minimised, the SVM will be susceptible to overfitting which will lead to poor performance. The fmGA was introduced by Goldberg et al., (1993) which can identify optimal solutions efficiently for large-scale permutation problems. Therefore, this method was added to the ESIM for optimization purposes. Furthermore, to improve the accuracy, K-means clustering was used to aggregate similar data and identify discrepancies between clustered categories. The generated results show that the combination of these AI tools is a feasible and effective approach. However, the dataset used for this research contains typical construction projects, therefore, it would be interesting to evaluate the performance with medium to large IT-projects data.

2.4.3 Logistic Regression

Cerpa et al., (2010) proposed a logistic regression (LR) model for a set of variables to predict project success. LR is another technique for classification problems of which the outcome is measured with a dichotomous variable. The utilized dataset contained heterogeneous data which was collected from multiple companies and was tested against a homogenous dataset that contained data from only one company. The focus of this research was to identify the right cut-off point in order to optimize the accuracy rate and the authors stressed the importance of taking into account the context of the project for doing so. The question raised is: "Is it more desirable to accurately predict a failure, or to accurately predict a success?". For software projects the cost of failure and the cost of success appear to be relatively equal, so the cut-off that gave the best overall accuracy might be more important than the accuracy of only one classification.

Despite the positive results and findings, this model excluded variables when values were missing which results in a less accurate prediction outcome. Therefore, other analysis methods should be employed to validate the results generated from the standard logistic regression model.

3. METHODOLOGY

3.1 Prediction Instrument Development for Complex Domains

In order to develop a predictive model, the *Prediction instrument development for complex domains* (Spoel, 2016) has been utilized as an inspiration. This prediction instrument development for complex domains is based on intelligence meta-synthesis and consists of a preparation stage and three stages. Due to the scope limitations of this thesis, the focus is only laying on the preparation stage and stage one. Within the preparation stage, the research domain and goal variable are defined. In stage one, assumptions and hypotheses on factors that are influencing what is predicted are gathered based on literature research and experts' views through qualitative methods.

Given the research question, the research domain is IT-projects and the goal variable can be defined as predicting the success rates of IT-projects. Given this, stage one was initiated which consisted out of two parts. The first part included an extensive and critical literature review. As mentioned in section 2.1., specific search queries have been used in order to perform efficient literature research. Before full papers were analysed, their abstracts were read and based on that it was chosen to analyse the full paper or not. As a result, 58 papers were chosen to be relevant and valuable for this thesis. From this literature review, a list was derived that consisted of 59 critical success factors that have a potential influence on the success of an IT-project.

From literature, it was assumed that the stakeholders with the highest influence on project success were the client, project manager, project team and organization. The organization as a stakeholder was included due to the impact of the project on its revenue, reputation and their impact on the project with regards to providing a satisfying working environment, having adequate resources in place and providing support from senior management. Thus, in order to structure the factors that were found, they were grouped into categories that related to one of the four important stakeholders.

Moreover, while observing and classifying the factors to a category, a few factors were removed. This was due to irrelevance or because they were merged into one factor due to the fact that different authors meant the same but used a slightly different formulation. Eventually, a list of 39 critical success factors remained of which 17 factors were related to the project manager, 8 factors related to the project team, 5 factors related to the client and 9 factors related to the organization.

Lastly, when the factors were classified according to important stakeholders, the CSFs were again put in classes according to which KPI they were related. Within the category 'project manager related factors' the five classes that appeared were 1) project manager capabilities, 2) scope and goal of the project, 3) planning, 4) quality, and 5) project management methodology. Within the 'project team related factors' three classes were formulated, 1) working environment, 2) method for way of working, and 3) team member capabilities. For the 'client-related factors' two classes arose which were 1) budget, and 2) client involvement. Finally, three classes appeared for the 'organizational related factors' which were 1) support and involvement of the organization, 2) working environment, and 3) availability of resources.

The objective for these classifications was to eventually formulate the most important metrics that will be included in the predictive model. The essence of defining metrics is because project management metrics are being used to estimate or gauge how well the performance of a component is, in contrast to the critical success factors that only evaluate the state the project is in. Therefore, the use of project management metrics is a way to measure the success of a project. (Whiting, 2002).

The second part of stage one was to find the right experts to conduct a semi-structured interview. First of all, research regarding which companies are engaged in IT-projects in the region of Twente was conducted. Next to this, only companies engaged in larger projects were chosen since the scope of this thesis considers medium to high complex IT-projects that entail high and many risks. Eventually, four experts were found that agreed on participating in an interview and fill out a questionnaire. All these experts were male between the age of 25 and 45 and had significant experience in the field of this research. The reason why a semi-structured interview was conducted, was due to the fact that it was desired to have an additional open discussion that could possibly give more insights. In addition to the interview, a questionnaire was created with a 7-point Likert scale in which the experts had to assess the importance of each CSF and metric that was formulated. These scores were evaluated and eventually, weights were calculated for every CSF and metric by looking at the average scores.

4. RESULTS

4.1 Observations Related to CSFs

The results presented in **Table 2** were generated based on stage one of the prediction instrument development. All critical success factors that were identified during the literature research were noted down and were validated with four experts through a survey and an interview. The average scores can be found in **Appendix** A. Some factors were excluded from the final list as they were not crucial for the initiation of a project due to the following observations.

First of all, number 12 was considered to be relatively less important. The reason being that project quality control, a continuous activity, takes place when the project is initiated. Even then, this factor is perceived to be quite stable by the experts, and it is even self-evident that quality control takes part throughout the whole project. The fact remains that project quality control is of less importance compared to the other CSFs when it comes to deciding whether to initiate a project or not.

Secondly, number 9 was not included in the final list. The literature stated that there is a higher chance of success with a contingency plan in place. However, in practice it is not necessary to have a contingency plan developed when the actual project has not been initiated yet. By all means, it is important to take into account possible risks and how they should be mitigated. Though these are considered in the risk analysis which is part of the project plan. Developing a full contingency plan is of more relevance when the project has been running for a while and some major complications are coming up. For initiation, an extensive and critical risk analysis is sufficient enough.

Then, number 17 was rejected due to the availability of many technological solutions. In literature, this factor was perceived as important since the higher the technological uncertainty, the lesser the chance the project will be a success due to all the risks and uncertainties that come along with high technological uncertainty. However, nowadays there are e.g. multiple Saas-solutions and licenses to receive access to the most advanced technologies. Unless the project is concerned with innovation, technological uncertainty is not really an issue anymore since most technologies are already on the market. This insight was given by an expert and has been validated by Choudhary (2007). Therefore, this CSF is not perceived as an important factor for the decision to start a project.

Another observation that was made, is that number 20 and 37 are closely related and are therefore excluded. The reason why this factor was included was because in literature it is stated that the behaviour of people can positively change in terms of motivation when incentives are in place. According to Skinners' Operant Conditioning theory, behaviour that is followed by pleasant consequences (incentives) is likely to be repeated (Skinner, 1963). However, in practice, the incentive strategy does not work in the long term. Since, medium to large IT-projects take on six months at a minimum, having an incentive strategy in place is not attainable. Given this time span, it's hard to say when an incentive would have been given if this was in place. On top of that, if the motivation is driven by only incentives it should be questioned whether the project manager or team member, whomever it may concern, should be involved in the project.

	Project manager related CSFs	Metric
1	Competent project manager	1. Project manager capabilities
2	Leadership skills of the project manager in terms of vision	
3	Leadership skills of the project manager in terms of communication	
4	Leadership skills of the project manager in terms of motivators	
5	Formulation of objectives	2. Clarity of scope and goal of the project
6	Formulation of requirements	
7	Scope complexity	
8	Planning of implementation process	3. Realistic planning
9	Employment of contingency plan	
10	Flexibility of planning	
11	Project milestone tracking	
12	Project quality control	4. Degree of quality assurance
13	Quality assurance plan	
14	Risks addressed/assessed/managed	5. Project management methodology
15	Monitoring and control	
16	The project plan is kept up to date	
17	Technological uncertainty	
	Project team related CSFs	Metric
18	The working environment in terms of the personal relationship among team members	6. Satisfying working environment
19	The working environment in terms of the level of autonomy	
20	The working environment in terms of incentives present	
21	Communication among team members	7. Method for a way of working
22	Method of the way of working	
23	Level of documentation	
24	Competent team member	8. Team member capabilities
25	Availability of resources in terms of the right people in place	
	Client-related CSFs	Metric
26	Adequate budget	9. Adequate budget
27	Degree of involvement of the client	10. Degree of client involvement
28	Level of participation in requirements definition	
29	Level of participation in the testing phase	
30	Way of communication with PM and project team	
	Organization related CSFs	Metric
31	Support from senior management	11. Support and involvement of other levels within the organization
32	Project sponsor/champion	
33	Degree of political stability	12. Employee-friendly working environment
34	Environmental influences (Level of competition)	
35	Environmental influences (Static or dynamic environment)	
36	Provision of training/guidance/support	
37	Incentives strategy	
38	Availability of adequate resources	13. Availability of resources
39	Adequate project funding	

Table 2: Classifications Overview

Lastly, number 33 and 35 were excluded. Both are related to environmental factors outside the project team that, according to the literature, have a potential effect on the success of a project. However, this was proven to the contrary by experts. It was stated that political stability within the organization and the environment the organization is operating in, is desirable. Though, if this is not stable to the fullest extent it might have an impact on the organization in general but not on the project itself. It will not exercise that big of an impact on the success of a project that is going to be initiated or currently running. As for number 35, a dynamic environment in the context of this thesis implies the fast-changing needs and wants (related to IT) of the client. Whereas a static environment is the opposite of a dynamic environment. This factor was perceived as relatively not relevant for the initiation and success of a project. The reason being that this factor is more of relevance for the business context, with regards to revenue and reputation, and not project context.

To summarize, seven out of thirty-nine critical success factors have been excluded due to the relatively low importance score and the reasoning behind the scores.

4.2 Observations Related to Project Metrics

All project metrics that were generated from literature research were also validated by experts. Again, a few were excluded from the final list as they were not crucial for the initiation of a project and the following observations were made.

Figure 1 shows the average score of each metric that was derived from the survey. The nominal scores can be found in **Appendix B.** In order to make a real distinction between very important metrics and relatively less important metrics, a benchmark of an average score of higher than five was taken. As an initial result, this meant that metric 1, 2, 5, 6, 8, 10, 11 and 13 were included. However, in order to be able to predict it is essential that the metric is measurable. Metric number six, 'satisfying working environment', is hardly possible to measure which is the reason why it has been excluded despite its high score of importance. There are so many different factors that can influence the perception of a satisfying working environment. Moreover, every individual perceives the level of satisfaction in a different way which makes it impossible to provide a general measure. This also explains why metric number twelve, 'employee-friendly working environment', has been excluded since it is impossible to generalise a measurement for this metric.

Certainly, having realistic planning contributes to the success of a project. It entails the creation of work breakdown structures and apportioning tasks to team members over time. So, with a realistic planning a place the right tasks are carried out at the right point in time. And apparently, all delayed or cancelled projects endured failure in planning. Nevertheless, there are at least fifty commercial project-planning tools and every large software project uses at least one. Even when any sort of disruption occurs during the project, the tool will update the plan to match the new objectives. (Jones, 2004) This suggests that there is enough support to be found to develop realistic planning which makes it relatively less important to focus on this metric for a successful prediction. Also, the average score given to this metric was a 4,75 which indicates that it is more or less important to have realistic planning but compared to the other metrics their importance score remains low. Therefore, it is assumed that this metric is not of high relevance for the prediction model and thus excluded.

It is for certain that having a quality assurance plan and control strategy in place will foster the success of a project. Especially when high customization is involved, the more complex the scope is likely to be, which will increase the need for a quality assurance plan. Nevertheless, the average score for this metric is 3.75 which is relatively very low, and it is also below the benchmark of five. The main reason given was basically: 'we do not know exactly what quality is'. Quality is a vague concept and takes on different definitions. The Project Management Institute defines quality as "a degree or grade of excellence" (Patterson, 1983). Since this is very vague and subjective it is a challenge, if not impossible, to make quantitative measurements especially if you want to give a prediction rate before the initiation of a project. Given the fact that quality could be measured by comparing reality against KPI's. Therefore, it has been suggested to exclude this metric.

It is not out ruled that the metric 'method for way of working' has an influence on the success of a project. However, when it comes to predicting the influence of this metric before the initiation stage of a project, the metric has a relatively low influence on the success. The main reason is that for every project a different method is taken due to many factors such as another business case, another project manager, another client or other team members. This implies that there is no universal method that can be used by every project team, assures success and applies for every IT-project (Shenhar, 2003). If this metric was to be included and a general measurement would have been given, the prediction rate will be flawed to a certain extent. Therefore, it is suggested to exclude this metric from the input for the prediction model.

Having an adequate budget is crucial for the initiation and continuity of a project. However, it is debatable whether this has a direct influence on the success of a project. Without an adequate budget, probably lesser resources can be deployed, or there will be time constraints that affect the success of a project, or the scope has to be limited to a certain extent. These are some examples of consequences when there is not an adequate budget. However, this also suggests that an adequate budget has an indirect influence on the success of a project. This is probably also the reason why this metric gained an average score of 3,75 by the experts since it is an indirect indicator of success. It is definitely important that there is an adequate budget in place, however, compared to the other metrics it relatively has a lower impact on the success rate. Therefore, it is suggested to exclude this project metric.

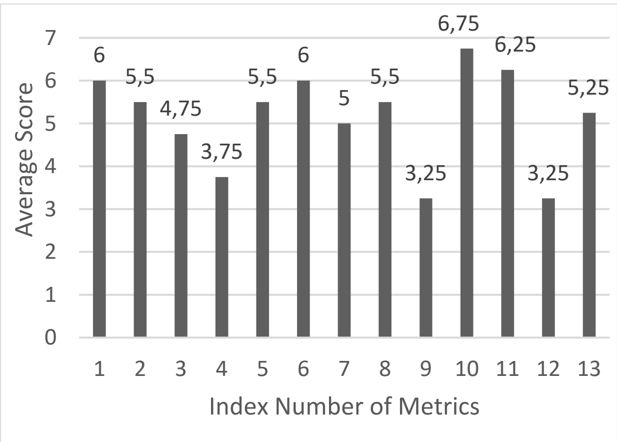

Figure 1: Display of Average Importance Score per Metric

4.3 General Measurements

In order to make the metrics measurable, both the measurements and scale to assess the metrics need to be defined. For this thesis, a binary scale has been chosen which means that the values the metrics can take are 0 and 1. The reason being that all metrics that are included in the instrument have a positive influence on the success of a project. Therefore, it would have been inappropriate to include a negative measure. Another reason why this scale has been chosen is due to the focus on the decision phase of initiating a project or not. When the project has not been started yet, it is impossible to evaluate how well the metric is performing.

To illustrate this with an example we will have a look at the metric 'degree of customer involvement'. The measure that has been given is illustrated in **Table 3** and will receive a score of 1 when it is in place, and a score of 0 when nothing alike is in place. Having a steering committee in place does not guarantee that they will have regular meetings or that communication flows are very well orchestrated. However, this cannot be measured when the project has not been initiated yet. Therefore, it is assumed that when some kind of steering committee is in place it will increase the success rate of a project.

4.4 Input for Prediction Instrument

First of all, the average was calculated for each critical success factor by adding all scores provided by the four experts after which the sum was divided by four. Then all these scores were taken into account for the calculations of the final score of the project metric. The average scores of the critical success factors that were classified under a specific metric were added up and divided by the number of critical success factors that were taken into account. Then, the average score of each project metric was generated by adding the scores given by the four experts divided by four. This score was added to the average score of the critical success factors related to this metric and finally divided by two. In this way, the average score of how important a metric is perceived by experts has taken into account all factors related to that metric. By only choosing the average score that was immediately generated by summing up the four scores and divide it by four, the critical success factors were not taken into account. Therefore, the calculation used provides a more precise score as an indication of how important the metric is. Then the final score has been calculated by multiplying the 'score from surveys' for a specific metric by 100%, after which this is divided by the sum of the 'score from surveys' which is 39,086.

Moreover, **Figure 2** is a display of the influence of each CSF on their related metric and how strong the influence of a metric is on the success of a project with respect to the weights generated from the surveys. This figure applies for every metric and in **Table 4** all scores can be found. The results for all identified metrics can be found in **Appendix C.**

To conclude, in the prediction instrument the selected project metrics will be used as "features" and will be presented in the columns. The average scores have been calculated to serve as insights that should be compared to the outcome of the regular machine learning technique. The insights given by the experts will then be enhanced through supervised learning. **Figure 3** is a visualization of how the metrics are used as features, and how the general measure is inserted.

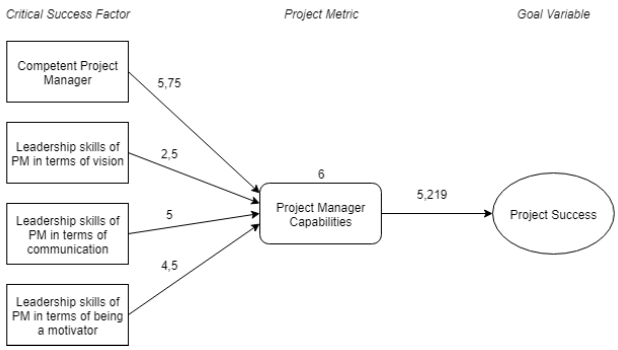

Figure 2: An Example of the Impact Flow with Respect to Average Weights

Project Metric	Way of Measurement	Score
Project manager capabilities	**Yes** = This can be measured by quantifying the rate of project success achievements. By multiplying the number of successful projects the project manager has been involved with by 100%, and then divide this by the total amount of projects the project manager has been involved with, a rate of success will be generated. With the use of a benchmark of 80%, the assurance can be given that the project manager has the right capabilities for managing a project based on his experience. **No** = The success rate that is generated and described above scores below 80%	Yes = 1 No = 0
Clarity of scope and goal of the project	**Yes** = Before the initiation phase of a project the clarity of the scope and goal of the project should be clear, and this can be tested through a survey and an interview to see whether the scope and goal of the project are clear to every stakeholder that is involved in the project. For this, some effort should be put in developing and conducting a survey and an interview **No** = No effort is put in conducting a survey, an interview, or some other form of research/ observation to find out whether everyone has a common thought on the scope and goal.	Yes = 1 No = 0
Project management methodology	**Yes** = The project manager has chosen an approach that is at least to some extent based on commonly used project management approaches. In this way, he can assure the client, project team and other stakeholders involved, that his approach is thought through. And he can justify certain decisions and actions. **No** = Management approach of the project manager cannot be reinforced by any project management approach that has been described in the literature. This could indicate that the project manager is just improvising.	Yes = 1 No = 0
Team member capabilities	**Yes** = This can be measured by quantifying the rate of project success achievements. By multiplying the number of successful projects the employee has been involved with by 100%, and then divide this by the total amount of projects the employee has been involved with, a rate of success will be generated. With the use of a benchmark of 80%, the assurance can be given that the employee has the right capabilities and is able to contribute to the project in a successful way. **No** = The success rate that is generated and described above scores below 80%	Yes = 1 No = 0
Degree of client involvement	**Yes** = There is some formation that takes the form of a steering group present. In this way, it is guaranteed that the client, project manager, team members, important people from the organization have the possibility to engage with each other as much as they desire. **No** = There is no form of steering committee in place	Yes = 1 No = 0
Support and involvement of other levels within organizations	**Yes** = When there is some form of a steering group present, and representatives of the organization participate in this group will assure that there is a clear and real possibility for the organization to be involved as much as they like. Moreover, when there is a project champion in place before the initiation of the project it shows that support from, for example, senior management can definitely be expected. **No** = Within the steering organization no representatives from other levels within the organization are present and/or no project champion is in place	Yes = 1 No = 0
Availability of resources	**Yes** = All necessary resources in order to fulfil the requirements and objectives that are mentioned in the scope are available. No = Not all necessary resources are in place in order to successfully fulfil the requirements and objectives mentioned in the scope	Yes = 1 No = 0

Table 3: Way of Measurement Per Metric

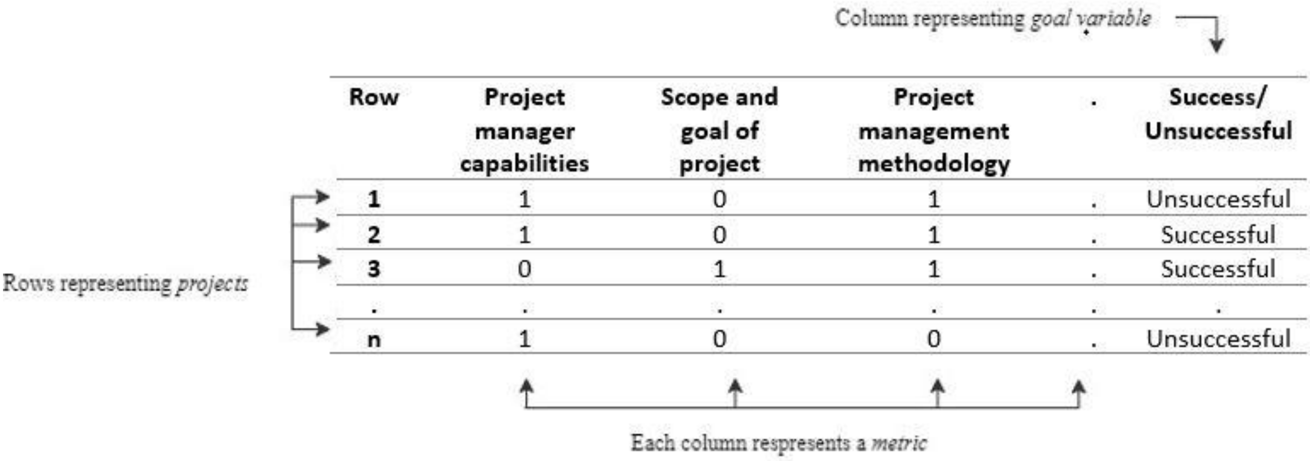

Figure 3: Representation of how the metrics and general measures are used as input for the prediction model

Variable	Project Metric	Score from Surveys	Final Score
A	Project manager capabilities	5,219	13,35
B	Clarity of scope and goal	5,167	13,22
C	Project management methodology	5,417	13,86
D	Team member capabilities	5,688	14,55
E	Degree of client involvement	5,969	15,28
F	Support and involvement of other levels within the organization	6,188	15,83
G	Availability of resources	5,438	13,91
		39,086	**100%**

Table 4: Scores per Metric

5. DISCUSSION

5.1 Set of Variables

This research intended to answer the research question '*Which project metrics have a significant influence on the success rate of an IT-project and to what extent are they predictable before initiation?*'. A survey has been conducted to measure the level of importance for every critical success factor (the predictor) and for every project metric (the dependent variable). Based on the scores, a discussion and literature research several factors and metrics have been excluded. This was done in order to create a base for a parsimonious prediction model which are simple models, that include just the right amount of predictors, with great explanatory predictive power (Stephanie, 2015). However, there is still a risk of not having included factors or metrics one perceives as very important due to the limited involvement of experts.

This risk could possibly be reduced by investigating the interrelationships between project metrics with the use of Structural Equation Modelling (SEM). The SEM is a multivariate technique that estimates the interrelated dependent relationships among a set of variables (Hair et al., 2006) and allows to investigate more complex structured models due to a high number of variables. The variables that are considered are measurement components and latent components (Byrne, 1994). In order to develop the SEM, the following steps have to be undertaken: 1) defining the latent and measurement components to create a hypothetical model; 2) validating the hypothetical model and develop it with modifications; 3) assess the validation of the final model and interpret it. (Chen, Zhang, Liu, & Mo, 2011) For this study, the project metrics will be taken as latent variables due to multiple indirect measures of this variable, namely the CSFs. By first including all identified project metrics it can be examined whether the effect of the excluded metrics is significantly low on the other variables, which indicates that it is acceptable to exclude them. Afterwards, the CSFs can be added to the model to investigate the interrelations among them which will possibly give the project manager more insights into what is driving the project metric, and where to focus on when a project metric has a strong impact on the success of a project. Concludingly to refine this model, both the causal relationships among the CSFs should be added with the use of the modification index provided by Amos in SPSS and additionally, the paths showing a significant low causal relationship should be deleted (Islam & Faniran, 2005; Wong & Cheung, 2005)

Since there is no dataset available, it cannot be concluded whether the relationships among project metrics are linear or nonlinear. Generally speaking, the SEM-method is utilized for data in which linear relationships are present, whereas a Fuzzy Cognitive Map (FCM) examines a set of variables in which nonlinear relationships are present. Therefore, as an alternative, it is suggested to employ the FCM as well. Also because it is able to deal properly with the high complexity and uncertainties of IT projects. (Rodriguez-Repiso et al., 2007) An FCM is a graphical representation of the most relevant factors and links between the factors that indicate their relationship. From an AI perspective, this method combines fuzzy logic (many-valued logic) with neural networks and describes the behaviour of a system in terms of concepts.

5.2 Way of Measurement

The measurements for 'project manager capabilities', 'clarity of scope and goal of the project', 'project management methodology', 'team member capabilities' and 'availability of resources' was relatively easily quantified since they can be considered to be hard factors to some extent. Those factors tend to be those elements that can somehow be formally defined or formalized which makes it possible to actually measure them. They can be measured through either the use of observations, calculations, or surveys and interviews. Given the uniqueness of every project and every organization, no guidelines are given for the exact way on how observations are made, or which questions to ask during the interviews.

For the degree of client involvement, the presence of some form of a steering group has been chosen as a measure. It is a challenge to define exactly how a client will be involved throughout the project before the initiation of a project. Several experts mentioned that before a project is initiated there is always a kick-off meeting in which the client, project manager, team members, and other relevant stakeholders are participating. The purpose of this meeting is to steer everyone involved in the project, in the same direction and make them agree on what is expected to be delivered. However, this kick-off meeting is just a one-time event at the start of a project and does not guarantee further in-depth discussions between the client and the stakeholders from the organization. In particular, this does not guarantee that throughout the project everyone is still steered in the same direction. Therefore, the presence of some form of a steering group is suggested as the right measurement for client involvement.

For the metric 'support and involvement of different levels within organizations,' the measurement is partly based on the same measurement as for the degree of client involvement. So, some form of a steering group should be present and other relevant levels/departments of the organization should participate in this committee. Moreover, a project champion should be present in order to assure that support is given by senior management. Especially in larger IT-projects, it is of high relevance that a project champion is present in order to advocate for the project and praise the benefits to the stakeholders. This will significantly keep up the motivation among all stakeholders who are involved. Because they are constantly reminded of why the effort that has been put in the project is of high relevance.

5.3 Limitations and Recommendations

Although this research has made multiple contributions, there are a few limitations. One of the main limitations of this research is that the input for a prediction instrument has not been validated with actual data. Despite the fact that the components have been validated by experts and an additional literature review, it remains uncertain whether this input is valuable and reliable for predicting the success rate of a project.

Given this limitation, it is recommended to employ the Evolutionary Support Vector Machine Inference Model proposed by Cheng et al., (2010), with the metrics provided in **Table 3**. Since the super vector machine is employed in this model, the generated weights from the questionnaires are of no use as input for this model. Though, it is interesting to examine the difference between the weights generated by the machine learning algorithm and the weights generated from the questionnaires. By doing this, the uncertainty of whether the input is valuable and reliable will be reduced.

Another reason why it is recommended to employ this model is that it has proven to be successful in the context of a construction project. However, not yet in the context of medium to large sized IT projects. These IT projects are relatively more complex and bring along more uncertainties, therefore, it is interesting to evaluate whether the model will also be successful with this type of data.

A second limitation of this research is that the interrelationships between the metrics have not been evaluated. Within the scope of this thesis, it was only limited to which CSFs influences a specific project metric, and which project metric have a significant impact on the success of a project. Though this does not capture the type of relationships and it did not take into account the interrelationships among all metrics. However, much more information was needed in order to determine this. And even then, it is still difficult to define the exact type of relationship due to the presence of multiple relationships and numerous factors that influence a relationship.

For this limitation, it is recommended to use the Structural Equation Modelling technique to estimate the interrelated relationships among the set of variables. Since this model is generally used for data in which linear relationships are present, an alternative would be to develop a Fuzzy Cognitive Map that also takes into account nonlinear relationships. This alternative is proposed since it cannot be said with certainty whether the relationship among the proposed set of variables is linear or nonlinear.

An additional limitation is that the results of this research are easily susceptible to bias due to the involvement of people in general. Every expert argues their opinion from his own experience and his experience is always unique. Even though this research put in maximum effort to avoid bias, it can never be completely avoided. By including more companies and also companies from other regions, the bias in this research could have been even more minimised.

Lastly, another limitation to this research is the role of subjectivity that plays in defining the measurements for the project metrics. First of all, because the measurements are based on the insights given by the experts and the literature research. On top of that, multiple metrics can be defined as soft factors and they tend to be intangible and very difficult, even hardly possible to capture, model, measure and control. (Sudhakar, Farooq, & Patnaik, 2011) This makes them very difficult to quantify and generalise. Therefore, the reliability and validity of the general way of measurement might not be as high as desired. Though, this should be figured out in a critical validation with the use of real-life projects.

For this very last limitation, it is recommended to use the provided measurements and evaluate the prediction outcome on numerous projects. This is the only way to see whether the measurements can be used in an appropriate way and whether it captures enough critical information that predicts success in an accurate way. If it does, the role of subjectivity is, to a large extent, reduced.

6. CONCLUSION

This thesis has answered the following research question: *Which project metrics have a significant influence on the success rate of an IT-project and to what extent are they predictable before initiation?* By conducting an extensive literature review a list of critical success factors and project metrics was created. Through interviews with experts and a questionnaire, the importance of each factor and metric was evaluated. In the end, seven metrics were selected as input for a future prediction instrument which resulted to the inclusions of 23 critical success factors. The metrics chosen are 1) project manager capabilities, 2) clarity of scope and goal, 3) project management methodology, 4) team member capabilities, 5) degree of involvement, 6) support and involvement of other levels within the organization, and 7) availability of resources.

The extent to which the project metrics are predictable is quite challenging to determine, considering the fact that multiple metrics can be defined as soft factors which are hard to quantify. Moreover, every project is unique which makes it difficult to create a general method for quantification. Despite these challenges, a general measure has been developed for every essential project metric based on discussions with the experts. The provided measures and metrics will serve as input for when the prediction instrument will be developed, and a dataset is obtained. Eventually, the outcome of the prediction instrument will be a classification which is either success or unsuccessful. Afterwards, it can be said with more certainty to what extent the selected metrics are predictable and if they were able to correctly predict whether the project was going to be a success or unsuccessful by evaluating this in a confusion matrix.

This study contributes to the ever-growing literature about the prediction of IT-project success. Numerous models and techniques have been employed in different contexts and different stages during a project. However, as of yet, no study was focused on the prediction of success before initiation. Thus, this study provided useful insights from existing techniques, a fresh set of variables that have a significant influence on success according to experts, and a general binary measurement scale for the project metrics that can be employed for the further development of a prediction instrument. All the provided insights can be seen as the first step towards the development of a prediction model that predicts the success rate of an IT-project before the project has been initiated.

The contribution to practice, as of now, is an updated set of variables for medium to large IT-project that includes project metrics, CSFs, and average importance scores. This will provide current project managers with insights on which CSFs are related to which project metric, which CSF tends to have a relatively higher impact on a metric, and which project metric has a relatively higher influence on project success. As a result, this set of variables can be used as a toolkit that provides guidance in focussing on the right aspects of a project and taking the bigger context into account when focussing on a specific metric or CSF.

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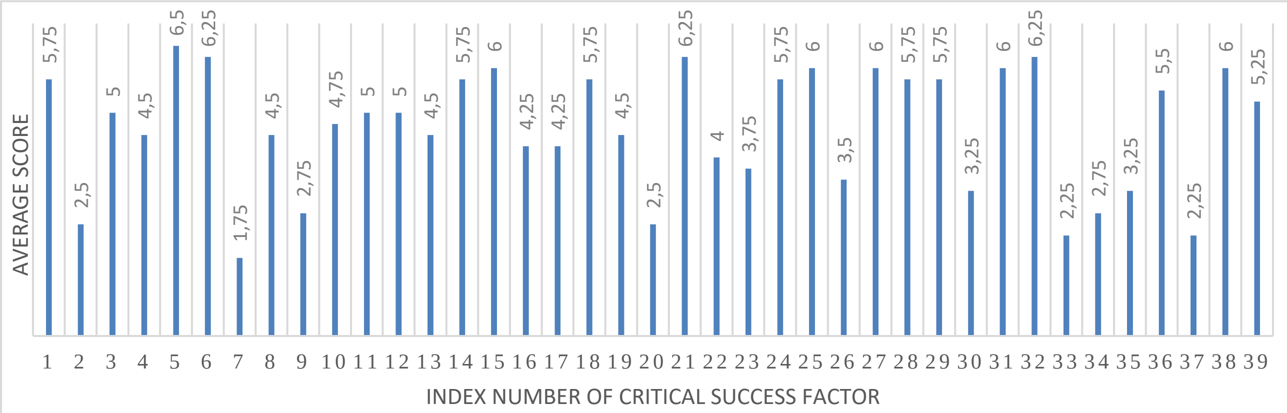
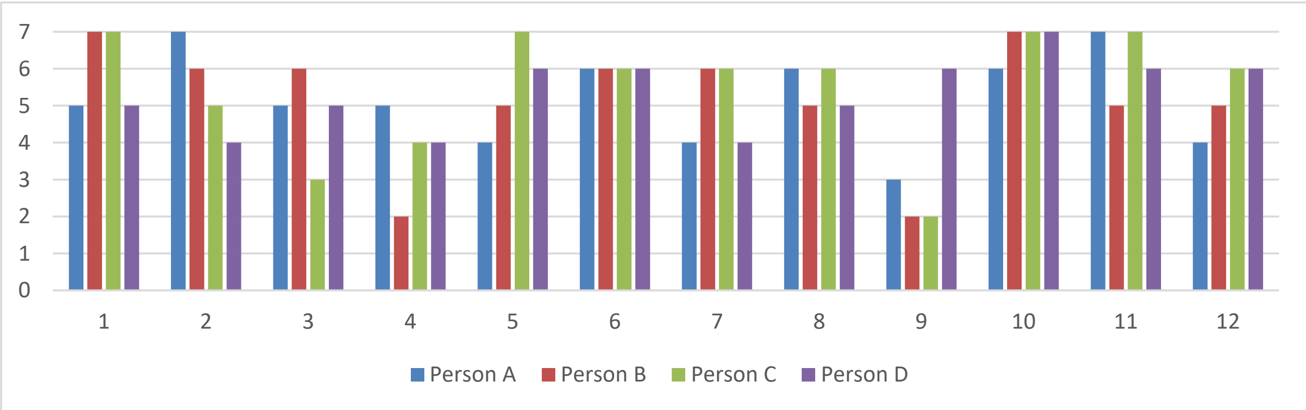
9. APPENDICES

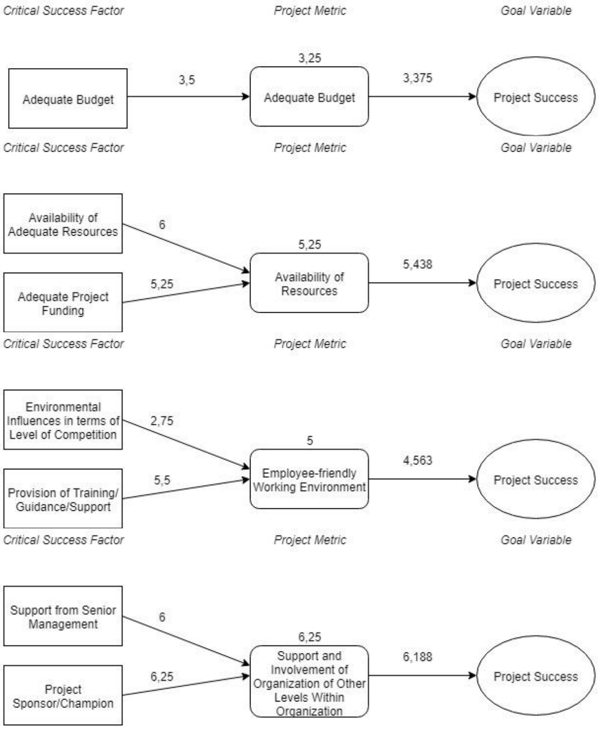


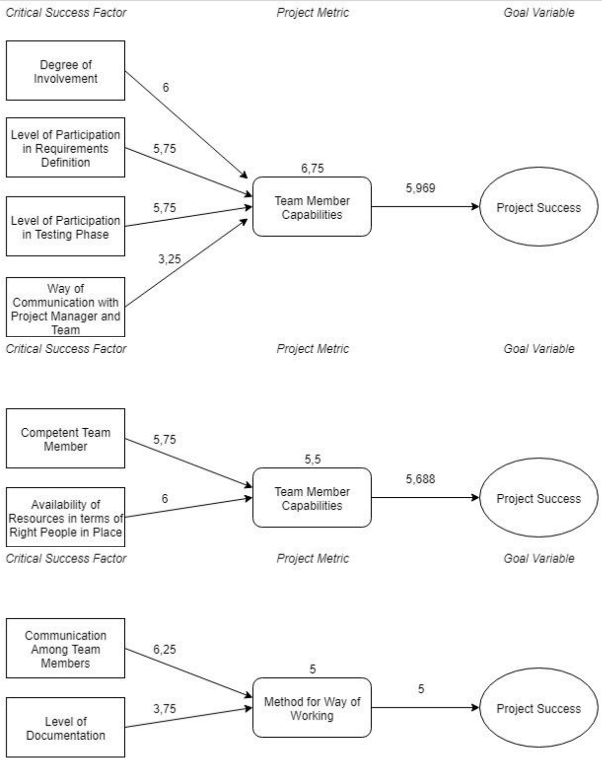
Appendix A: Average Scores Per Critical Success Factor

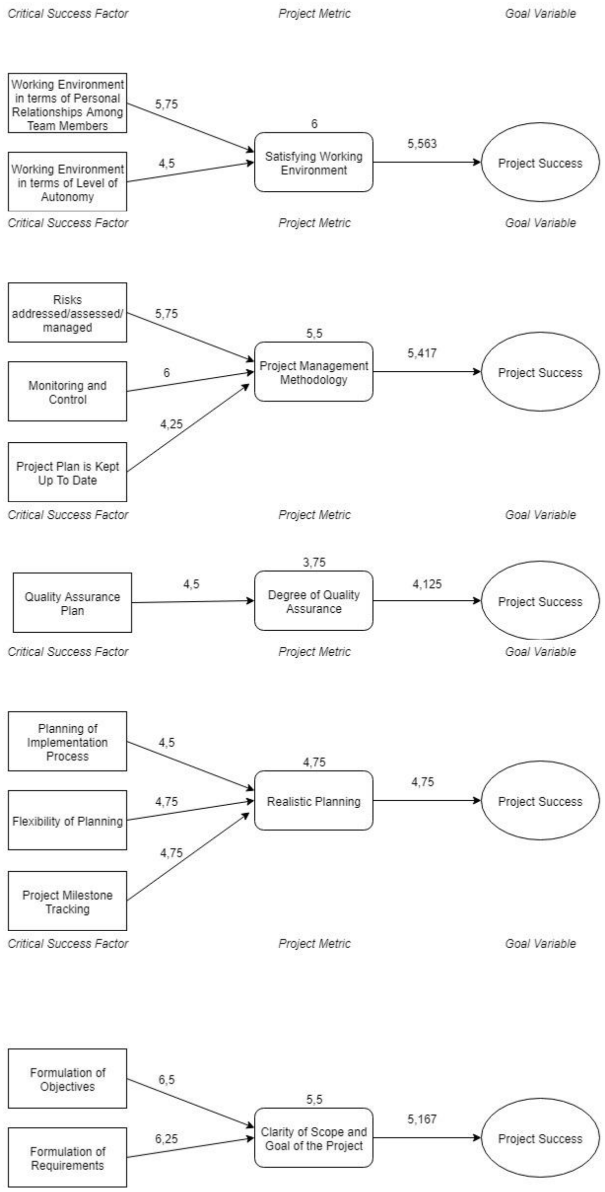


Appendix B: Nominal Metric scores given by four experts

Appendix C: All the Following Figures Depict the Impact Flow With Respect to Average Weights






Critical Success Factor
Project Metric
Goal Variable
Working Environment in terms of Personal Relationships Among Team Members
5,75
Working Environment in terms of Level of Autonomy
4,5
6
Satisfying Working Environment
5,563
Project Success
Critical Success Factor
Project Metric
Goal Variable
Risks addressed/assessed/managed
5,75
Monitoring and Control
6
Project Plan is Kept Up To Date
4,25
5,5
Project Management Methodology
5,417
Project Success
Critical Success Factor
Project Metric
Goal Variable
Quality Assurance Plan
4,5
3,75
Degree of Quality Assurance
4,125
Project Success
Critical Success Factor
Project Metric
Goal Variable
Planning of Implementation Process
4,5
Flexibility of Planning
4,75
Project Milestone Tracking
4,75
4,75
Realistic Planning
4,75
Project Success
Critical Success Factor
Project Metric
Goal Variable
Formulation of Objectives
6,5
Formulation of Requirements
6,25
5,5
Clarity of Scope and Goal of the Project
5,167
Project Success