The impact of management method on IT projects success

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Abstract: The current study examined the relationship between the extent to which project management is carried out according to the Project Management Body of Knowledge (PMBOK) and project success in 70 IT projects. The study presented prediction tools that assisted in predicting project success. The results exhibit a positive, strong, and significant relationship between managing projects based on the PMBOK and project success. In addition, a significant difference in the success score measure was found between projects managed using the Waterfall and Scrum methods. The current study's implications may be useful for technological organisations that utilise the PMBOK for their project management needs. The study presents insights that may benefit project managers dealing with IT defence projects, by helping them find optimal management methods that will lead to successfully meeting the complex targets of these types of projects.

Keywords: project management; critical success factors; linear methodology; iterative methodology; agile methodology; Waterfall model; innovativeness.

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1 Introduction

The project management field contains a diverse range of approaches focusing on different project management levels. Research on the subject is broad and comprehensive; however, a gap exists between theoretical project management compared to its practical application. According to recent studies, the percentage of successful projects is relatively low and the reasons for this are varied. For instance: The Standish Group's 2012 Chaos Report presented a global perspective on statistical project data, reporting that 18% of all projects suffer from failure, while 43% deviate from their original course, with only 39% ending in success (CHAOS MANIFESTO, 2013).

The project management arena contains several important terms:

1 A successful project is defined as a project that is delivered to the client on time, regarding all components and as defined by the client. This means that the project in its entirety has been fully implemented, all worker instructions have been carried out, and the client is already using the new system with all budgetary conditions having been met.

2 On the other hand, a failed project is defined as a project that has failed to meet one or more of the above conditions and have not been completed.

3 Finally, a challenged project is a project that has been completed and handed over to the customer – it may or may not already have been implemented or the customer may already be using a different system.

Either way, any project may have one or more problems such as: deviating from the planned budget, failure to adhere to the time schedule, failure to submit work contents (failure to submit the systems contents in their entirety, as per the project's defined conditions), failure to complete worker instructions regarding project implementation, failure to implement the new system into the client's existing systems, and in the worst case scenario – a project where the new system has been abandoned and the client has gone back to working with the old one (Standish Group, 2003; Kerzner, 2006).

Many industries currently utilise several different project management methods, with the most important being the Project Management Body of Knowledge (PMBOK). The current study evaluated project management methodology conducted in the IT section of a military unit, which provides services in the fields of information storage, connectivity/media and communications. The study examined the management methods of IT projects in a military unit, and examined the extent to which the PMBOK contributes to project success and meeting project targets. PMBOK concentrates on the best practices and guidelines for managing the project from initiation to closing. It includes processes, tools, techniques, inputs/outputs, and roles/responsibilities, for handling the project tasks. Defence projects in a military IT unit must be managed effectively and efficiently, enabling the project manager to resolve problems quickly and precisely. The reasons for choosing the PMBOK in the current study are based on the assumption that PMBOK will help project managers to make better decisions, particularly in situations of uncertainty in the battlefield arena. Regarding defence projects, which deal with battlefield challenged and the development of IT advanced systems, it is necessary to cope with a dynamic and rapidly changing reality.

The study implications are important for the improvement of complex military defence project management methods, in general, and their ability to meet project targets, in particular (scheduling, budget and scope) because of their need and urgency.

1.1 Study innovation

The study innovation is expressed by two means:

1 It is the first to evaluate the project management process conducted on military projects according to the PMBOK, since most often the information is limited for accessibility because of its confidentiality issues and field of security.

2 It shows how different machine learning techniques can support and improve the statistical findings obtained on the collected data. In most cases, the learning models can outperform over common statistical methods such as linear regression.

   With that approach we show that machine learning methods should be considered as a useful tool for project management evaluation over inferred statistics. To demonstrate our claim, we provide the comparison between random forest vs. linear regression analysis, which is known as being non-accurate in cases where the data is messy or dirty (as in our military case). In such cases it is better to be handled with random forest over regression models. In addition, random forest uses a sum of piecewise function, where linear regression is linear. Least but not last, linear regression needs regularisation to avoid overfitting, where random forest has a regularisation already inbuilt.

The study presents insights that may benefit project managers dealing with IT defence projects, by helping them to find optimal management methods that will lead to successfully meeting the complex targets of such types of projects.

2 Research goals

- To examine the project management methods used in the IT unit of a military technology division, and the characteristics of the management process.
- To examine the correlation between project success and project management based on the PMBOK.
- To examine the correlation between IT unit project manager seniority and project success.
- To examine the correlation between project management method (Scrum or Waterfall) and project success.
- To examine various methods used for prediction and data visualisation to support conventional statistical analysis.

3 Literature review

In general, the literature defines a 'project' as a temporary effort with a defined beginning, middle, and end. Carried out with the aim of producing a specific product or providing a service, it is usually executed under certain limitations such as time, costs, budget and other organisational, social or legal constraints (Globerzon et al., 2009). In most cases, the project must include the following criteria:

1 At the end of the project, a product or service has been created in response to a pre-determined need.

2 Effort must be fairly complex, in accordance with parameters of execution duration, total costs, technical complexity, etc.

3 A relatively high level of uncertainty exists.

4 Teamwork, which includes workers from different organisational fields is an important factor (Globerson et al., 2009).

These items are essentially subjective criteria, stemming from the attitudes of each organisation.

The extent of a project's success can be assessed using objective and quantitative performance measures. Their use clarifies whether it is worthwhile to invest in a project or not, producing insights for future projects. Most studies refer to the accepted measures for project success as 'the golden triangle' (triple constraint), which are termed as follows:

1 Adherence to the project's budget (cost) (compared to the planned budget).

2 Adherence to the project's scheduled completion deadlines (time) (compared to the planned date).

3 Compliance with project content (scope) or defined performance levels (compared to the planned performance envelope). A fourth dimension may also be added:

4 Satisfaction of the involved parties with the project's outcome, in particular, that of the client (Globerson et al., 2009).

Van der Westhuizen and Fitzgerald (2005) created a new project success schema, which distributes each of the areas into separate project success measures. In addition, they stressed the overlapping success measures between project management success and project product success such as: system quality, information quality and service quality. However, this schema together with the recognition of the conventional 'triple constraint' or 'golden triangle' project success criteria – of cost, time, and scope – is still incomplete (Atkinson, 1999; PMI, 2016). In other words, as the focus of projects shifts – from product creation to value creation (Winter et al., 2006), it is necessary to expand these criteria to include the full range of value delivered by the project. The 'full range' covers not only project outputs and outcomes, but also project benefits (PMI, 2016). Additionally, the concept of project success is still perceived as more complex than a binary outcome between success and failure. Cases such as the 'Sydney Opera House' and 'the Hubble Telescope' indicate that while a project may be a failure in terms of output efficiency, it may still be considered a success in terms of investment effectiveness (Shenhar and Dvir, 2007). Likewise, a project that delivers the required outputs within its budget, schedule, and quality constraints is not necessarily considered a successful investment if it does not produce the necessary target benefits (PMI, 2016). Furthermore, notions about a project's 'success' and 'failure' may be contestable depending on the context. For example, the cancellation of a project due to changing business conditions may not necessarily indicate a failure (Jenner, 2015).

For successful project completion, both planning and execution must be properly implemented. Improving quality planning processes requires the development of new tools in areas such as communications, as well as organisational training programs designed especially for functional managers. Atkinson (1999) claimed that the golden triangle measures are no longer adequate and that it is necessary to add other measures to ensure project success for the following reasons:

1 Insufficient number of measures – even if all three conditions are achieved, this may largely occur through approximations and guessing.

2 A scenario in which the three measures have been achieved, but the project cannot be considered a success – for instance, the financers are not satisfied, the users are not using the new product or service, and the new product or service has not managed to help make organisation more efficient.

3 Post-implementation criteria – a group of criteria that is not sufficiently related to the project delivery stage to be taken into account.

4 Additional criteria which includes six measures, referred to as the hexagon constraint model: adherence to time, scope, costs, customer satisfaction, quality, and risk level.

From an extensive list of possible project success factors, ten are found in the literature and referred to as 'critical success factors' (CSF) (Pinto and Slevin, 1986). These factors are affiliated with the following issues:

1 *Clear project goals and how to achieve them:* Initial clarity of the project's general goals and guidelines.

2 *Support of senior management:* Senior management's willingness to provide the required resources and authorisation or the support necessary for project success.

3 *Project schedule or planning:* Accurate detailing of necessary individual operational steps which are required to implement the project.

4 *Customer involvement:* Communication, consultation, and active attentiveness to all involved teams of influence.

5 *Manpower:* Recruitment, selection, and training of essential manpower needed for the project.

6 *Establishing and executing required technological tasks:* Availability of necessary technology and expertise to perform defined technological operational steps.

7 *Customer perception of the project:* 'Selling' of the final project to designated end users or customers.

8 *Follow-up and feedback:* Providing comprehensive critical information at the right time, at every stage of the implementation process.

9 *Communication:* Securing a network and necessary information required by all key entities involved in the project's implementation.

10 *Identifying problems and risk management:* Ability to cope with sudden and unplanned crises and unidentified problems.

According to Baccarini and Collins (1999), a project's success is comprised of two separate components:

a project management success

b project product success.

The authors differentiate between the two in the following manner: 'Successful project management' focuses on the project management process, especially on project success as it relates to cost, time, and quality. These three measures reflect the project's level of performance efficiency. However, 'project product success' focuses on the effects of the project's final product.

The results of many studies on factors leading to project success show that project manager seniority and/or experience is not an influencing factor. Moreover, prior studies also reveal that a significant positive relationship, characterised by a weak to medium level of intensity, exists between project manager's years of seniority in the organisation and management ability average (Turner and Muller, 2005; Sadeh et al., 2005).

Many studies have explored the reasons for project failure. These studies mainly focused on the reasons or factors that influenced the project's failure. There is no unanimous consensus on the defined parameters responsible for project failure. However, there is a common understanding that it is both necessary and important to study the subject in depth, and to develop the ability to evaluate and minimise such failures. Recent studies indicate three central aspects for evaluating project failure or success:

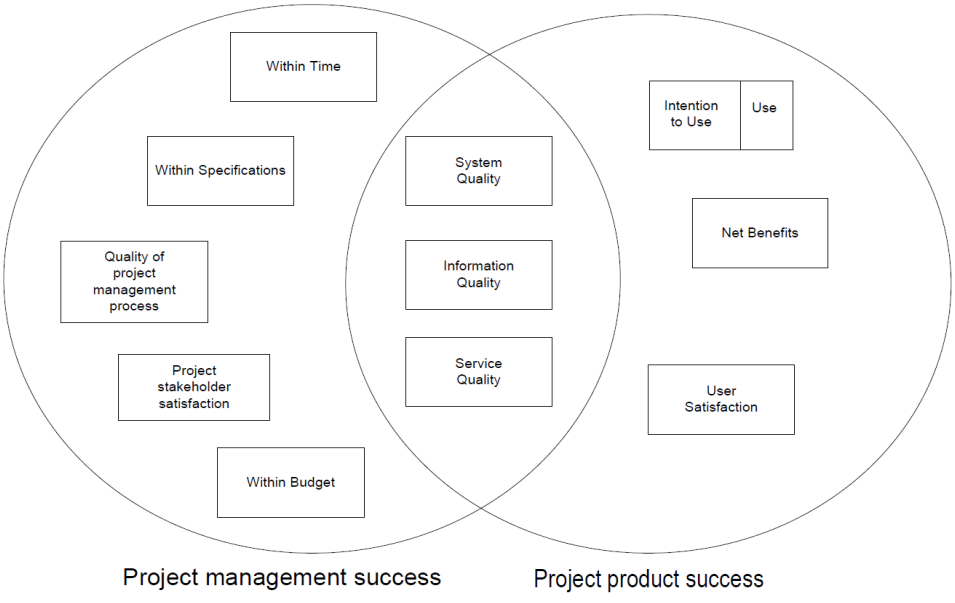
1 The golden triangle measure: Adherence to schedule, budget, and technical targets.

2 The subjective evaluation of involved parties: Added value, project efficiency, personal assessment of the project team regarding project success.

3 Customer satisfaction upon project completion: Estimated solely by the client (Pinto and Mantel, 1990).

A 'failed project' is a project that either fails to comply with one or more of the golden triangle success criteria or is abandoned before completion. In light of the current low project success rate, it is of great importance to analyse the key factors behind these failures. These key factors include: lack of customer involvement, faulty definition of requirements, sudden changes in project specifications and low levels of management support (Globerson et al., 2009). In fact, a marked inter-dependency exists among these factors. Therefore, any analysis of project failure should encompass these groups of factors, with the assumption that the main factor is: 'lack of time'.

Figure 1 Van der Westhuizen and Fitzgerald model for project success



Source: Van der Westhuizen and Fitzgerald (2005).

The current study evaluated the success of IT projects based on two different methodologies: linear methodology and agile methodology in a military unit and examined the linkage between the project success and the project management methods according to the PMBOK.

PMBOK is a thorough guide of project management knowledge, written by the Project Management Institute (PMI), enabling organisations to implement knowledge, expertise, tools and techniques for carrying out projects to meet all organisational demands and targets (Globerson et al., 2009; PMI Standards Committee, 2017). The PMBOK describes the nature of project management processes in terms of integration and inter-relationships as well as the goals they serve. These processes are grouped into five categories:

1 initiating

2 planning

3 executing

4 monitoring and controlling

5 closing.

The linear methodology provides the ability to import engineering product quality control to software development processes. In other words, software development processes, just like a product engineering processes, must conform to strict criteria related to efficiency, resiliency, and accuracy. The most distinguished linear type is known as the Waterfall method in which a software development process is conceptualised as a linear and unidirectional process, similar to an engineering product assembly line. The Waterfall method includes the following stages: idea, definition of requirements, basic planning, specified planning, coding and revisions, and testing, in which the management process is supported by large amounts of documentation and tight supervision over the project's progress. The model is, in particular, affiliated with specific stages; each stage ends with a report, documenting the actions that have been carried out. After being validated and authorised by the management staff, the project advances to the next stage, until it has been implemented or completed (Turner and Muller, 2005).

On the contrary, the agile methodology is considered an iterative type, adapted to small teams in which efficiency, agility, and quality are emphasised. The method is receptive to changes in software specifications, and can be conceptualised as game-like, based on goal-oriented cooperation. The agile methodology stresses the need for a proper infrastructure that encourages communication among teams, learning through action and experience, close cooperation with the client, and the importance of flexibility when developing software. The agile model is implemented by the scrum model. In a Scrum project, the development process is executed in iterations ranging from two weeks to one month. The model focuses on self-directed teams that navigate the development process independently (Leffingwell, 2007).

4 Methodology

4.1 The study stages and tools

The IT unit affiliated with this organisation is characterised by a hierarchical structure and comprised of 95 individuals. The unit focuses on on-going operational research and development-related tasks. In the current study, the evaluated projects by the authors included two types of managed projects:

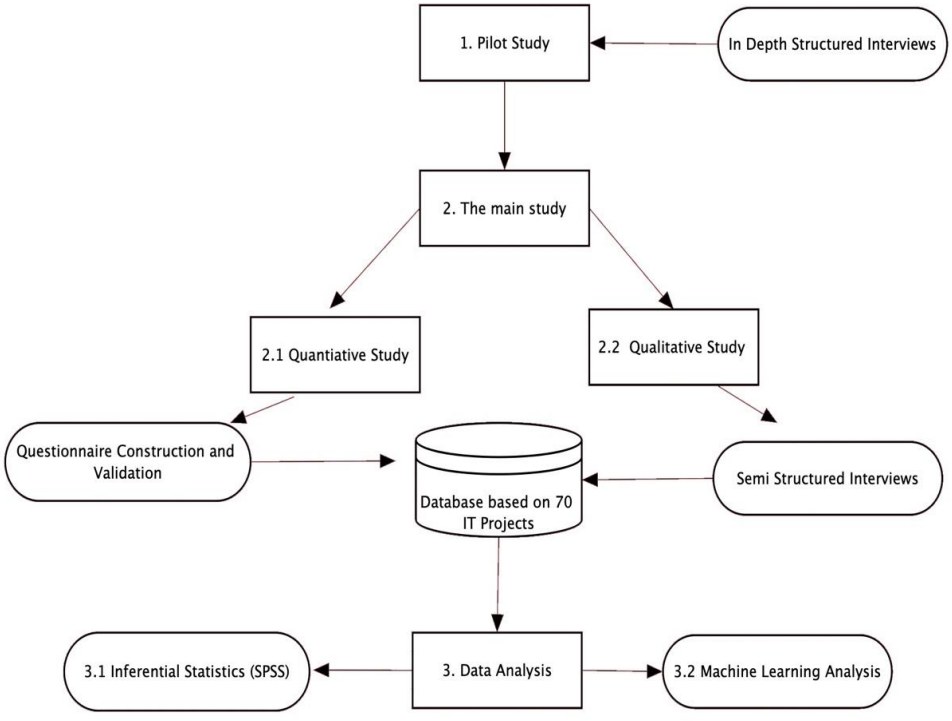
1 projects that involve developing new systems and new infrastructures

2 projects that involve existing systems improvements.

The study was comprised from three stages as described in Figure 2. In Stage 1, a pilot study was used to identify project management success and failure factors. The pilot was conducted by in-depth structured interviews. The interviews were conducted with senior IT project managers and department heads in a military unit. All of the interviewees had a rich background and broad experience in IT advanced systems. The goals of the pilot study were to examine the percentage of successful projects, identify project success measures, and to understand how they are measured. Additional aim was to map the

factors leading to project failure. The main results of the pilot study are presented in the finding section.

Figure 2 The study stages



Followed the pilot study, we conducted in Stage 2 (the main study) two types of studies: quantitative (Stage 2.1) and qualitative (Stage 2.2) and, in which we collected data through questionnaires. The validated quantitative questionnaire was built from 30 closed questions on a 5 Likert scale (1 = very low level of agreement, 5 = very high level of agreement). 25 questions were used for the analysis of how the knowledge is managed by the managers according to the PMBOK and additional five questions were used to estimate the level of project success according to these guidelines. The qualitative questionnaire was constructed by a semi-structured interview, in which we asked the managers to provide general information about the project and about them. We used both types of questionnaires to collect data on 70 different IT projects. The data was coded into an Excel and SPSS file. Next, we performed two types of analysis on the collected data (Stage 3):

1 On the SPSS file we performed inferred statistics analysis (Stage 3.1).

2 On the Excel file, we performed machine learning analysis (Stage 3.2).

For the machine learning analysis (Mitchell, 1997; Maaten and Hinton, 2008) we used three types of tools:

1 A scatter plot which is also termed as correlation plot to identify correlations between two different quantitative variables. The independent variables were plotted along the horizontal (X) axis, where the dependent variables were plotted along the vertical (Y) axis. This type of plot, assisted not only in analysing patterns of relationships between different set of continues data variables, but also by showing whether the data pattern is linear (straight) or nonlinear (curved); and whether unusual features such as outliers, clusters and gaps exist in the data sets.

2 A Mosaic plot, to examine the relationship among two or more categorical variables by an n-way contingency table.

3 A random forest algorithm, which is recognised as a very popular classification algorithm, that in most cases outperform over linear regression.

For the random forest model construction (Hassoun, 1995), we divided the excel data set into two parts: 70% of the records were used as a training set and 30% as a test set. We also performed ten-fold cross-validation to test the accuracy of the obtained model. The analysis with machine learning techniques, assisted in supporting the results obtained by conventional statistics methods.

4.2 The study sample

The study was carried out at an IT branch in a technology division of a military unit. The IT branch routinely carries out 8–10 projects of different types and different degrees of importance at any given time. The study's sample included 107 projects carried out during the years 2014 to 2017 in this IT branch. We examined a sample of 70 out of a total of 107 different projects, according to the following categories: 35 projects managed according to the Waterfall method, and 35 projects managed according to the Scrum method.

4.3 Study variables

Dependent variables: *project success* – this variable includes success measures, as discussed in the literature review, comprising traditional measures (cost, time, and scope); as well as non-traditional ones: satisfaction and quality measures.

Independent variables: *project management according to PMBOK* – this variable includes nine management areas of project execution, in accordance with the PMBOK, comprising: project integration, project scope, schedules and deadlines, costs, quality, human resources, knowledge, information communications, risk, and purchasing management. In addition, we also included additional independent variables: project manager seniority, project management method (Waterfall or Scrum), project size, and the project's importance to the organisation.

4.4 Study tools

The study tool we used included a questionnaire validated by three IT project management experts. Exclusion and inclusion of questions was carried out and the questionnaire's final version was formulated.

The questionnaire was comprised of three parts:

Part 1 Background questions about the project type and the respondents.

Part 2 25 questions anchored in eight areas of knowledge management; each area represents a specific PMBOK subject.

Part 3 Five questions, aimed at estimating project success.

Parts 2 and 3 of the questionnaire present closed questions; responses were requested to answer them on a Likert scale (1 = very low level of agreement, 5 = very high level of agreement).

4.5 Data analysis

Inferred statistics and machine learning analysis was conducted on the 70 IT project based database (Figure 2, Stages 3.1 and 3.2). Machine learning has become an important tool for a multitude of scientific disciplines. Any formal machine-learning task could be described as follows.

Given: Formal machine learning task

- a space of possible instances denoted by X
- an unknown target function $f: X \to Y$
- a hypothesis space L containing functions $X \to Y$
- a set of examples $E = \{\{(x, f(x)) \mid x \in X\}$
- a loss function loss $(h, E) \to \mathbb{R}$

The main objective in utilising machine learning is to find a model $h \in L$ that minimises the loss (h, E).

The data is mostly represented by a matrix X, where the samples are denoted as follows [equation (1) – general machine learning data representation]:

$$\mathrm{X} \in \mathbb{R}^{n \times m} = \begin{bmatrix} x_{1,1} & x_{1,2} & x_{1,3} & \cdots & x_{1,m} \\ x_{2,1} & x_{2,2} & x_{2,3} & \cdots & x_{2,m} \\ x_{3,1} & x_{3,2} & x_{3,3} & \cdots & x_{3,m} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ x_{n,1} & x_{n,2} & x_{n,3} & \cdots & x_{n,m} \end{bmatrix} \tag{1}$$

where the targeted labels are stored in a vector denoted as follows [equation (2) – class attribute (target labels) representation]:

$$y \in \mathbb{R}^{n \times 1} = \begin{bmatrix} y_1 \\ y_2 \\ y_3 \\ \vdots \\ y_n \end{bmatrix} \tag{2}$$

For the machine-learning process (Breiman, 2001), we used the ‘OrangeTM’ Tool (https://orange.biolab.si): “An open source machine learning and data visualisation for

novice and experts that includes interactive data analysis workflows with a large toolbox:", as reported by the tool creators.

The construction of the models used for predicting project success or failure was performed according to the following steps:

1 We visualised the features and their importance as part of the 'Feature Selection' process (Figure 3).

2 We trained a model on 70% of the Data Table records (Training Set).

3 We tested the model on the rest 30% of the Data Table records (Testing Set).

The whole process is depicted in Figure 4.

The dependent variable, known as the label, was marked as the 'project outcome': It had two values: project success or project failure. The outcome was evaluated according to the following features (independent variables): type of project management method, project risk, and the nature and quality of the IT project manager's unit. The model tree appears in Figure 7. Based on the process depicted in Figure 4, we also constructed a scatter plot and a Mosaic visualisation display [Figure 5(a)–5(c), Figure 6(a)–6(c)]. We also analysed the data by using the following statistics methods:

1 correlation analysis

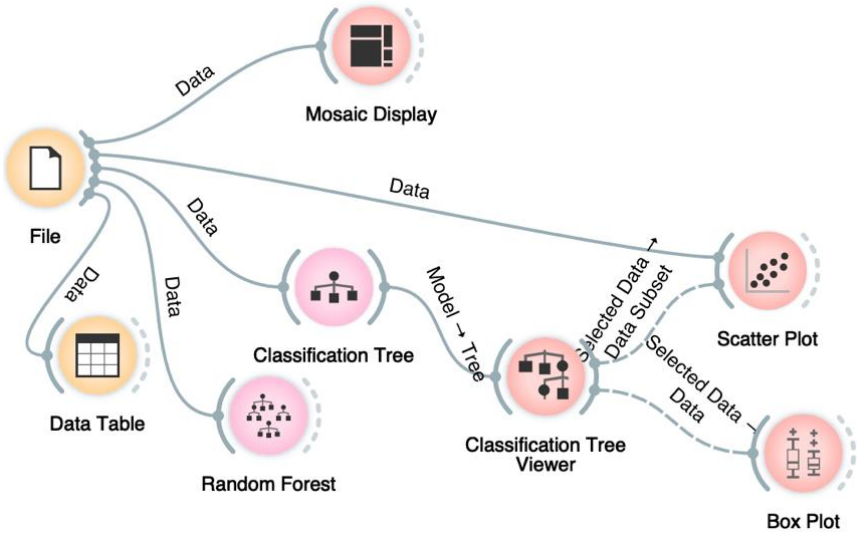
2 multiple regression analysis

3 multiple regression with dummy variables.

Figure 3 Features values as part of the 'Feature Selection Process' (see online version for colours)

	#	Jnivar. reg ▼	RReliefF
N PMBOK		25.345	0.257
N Risks		18.239	0.236
N Content		15.436	0.204
N Quality		15.322	0.256
N Importance		13.195	0.305
N Integration		9.724	0.176
N Project Type		9.677	0.307
N Time		7.295	0.231
N Yar of project		4.521	0.200
N Methodology		3.956	0.317
N Communication		3.729	0.235
N Age		2.048	0.225
N Project Seniority		1.917	0.282
N Project Manager		1.071	0.224
N Seniority		0.727	0.212
N Project Manager Role		0.659	0.246
N Project Area		0.591	0.301
N HR		0.181	0.154

Figure 4 The model used to classify project success according to the random forest decision tree algorithm (see online version for colours)



5 Results

5.1 The pilot study findings

The interviewees described the way project success was measured: With the completion of each cycle (sprint), a discussion takes place together with the customer's participation; the project is reviewed in relation to the project plan. One month after the project's completion, a similar discussion takes place, wherein quality data is presented, along with any gaps that appeared over the course of the month (since project completion). This discussion represents the project's real completion and final conclusion.

Transparency measures: Project success measures (demands, schedules, deadlines, etc.) are transparent to all project participants, hence once a week, a project status report meeting is held between the unit head and all project managers. All of the projects currently being executed are reviewed (goals, status, progress).

The discussion between the participants takes place on the macro level. Its goal is not to focus on any one project, but rather to share information about the status of the projects currently in progress.

The reported project success percentage: We found that the project success rate was 75% (the interviewee average).

According to the unit head, there was a higher chance of success in relation to projects that take place within a single department, and a lower chance of success regarding projects that take place in multiple departments, as these projects demand higher levels of synchronisation among the involved parties.

Factors that improve project success: Harnessing of the involved parties (especially for multiple-departmental projects); assigning a project manager (whose only role is to manage the project); customer professionalism in understanding the project's demands (technology professionals may know more than the customer); good customer relations, clarity about the project's relevancy and need (the project must be meaningful and of value to the organisation and or customers, with some projects becoming irrelevant after a short period of time); and quality assurance (often due to time constraints and tasks which not executed properly).

According to the interviewees, project success measures included: meeting demands, meeting time schedules and deadlines (even at the cost of lowering standards). Results show no increase in resources or damage to other projects, meeting the required quality levels (quality assurance includes all activities to produce a product at the required quality level based on availability, number of problems, etc.), as well as customer satisfaction. Answers related to defining project success measures clearly reflected the golden triangle and the constraint hexagon, currently accepted as defining project success. The branch head explained that each measure has a different weight, depending on the project type. For example, for an operational project, more weight would be assigned to the quality measure. That is, the main aspect examined as a success measure would be the number of problems or availability of the service for a defined time period upon project completion.

A positive relationship: Was found between project management methods according to the PMBOK measures and project success measures. In other words, the more a project is managed according to the PMBOK, the more the company's project success measures increase. The rationale behind this hypothesis is that the more a project is managed according to organised processes, the higher the chances that it will consider as succeed. This hypothesis is in line with the professional literature as well as the PMBOK. The importance of the PMBOK variable in predicting project success was also found during the feature selection process (RReliefF score = 0.257); the PMBOK was also found to be the most influential variable in the decision tree predictions.

Three significant differences were found:

1 Between project size and project success average. The rationale behind this hypothesis is that the larger a project is, the more supervision and management are required during its execution. As a result, there is a higher chance of project success. This hypothesis was supported by the interviews conducted as part of the pilot study.

2 Between project importance level and project success average. This hypothesis was supported by the interviews conducted as part of the pilot study, according to which the higher a project's importance, the higher the need is to complete it successfully - even if this influences the success of a less important project.

3 Between projects managed according to the Waterfall method and those that were managed according to the Scrum method (the Scrum method was found to be more successful). The rationale behind this hypothesis is that the Scrum method is more suitable for software projects, in light of its advantage: Flexibility. This hypothesis is based on the literature review, according to which the Scrum methodologies are considered more suitable for projects characterised by a lack of clarity regarding requirements in the initial project stage, and those that have a high potential for

changes during execution. Projects such as these are common in the routine work of the IT branch.

5.2 The finding of the main study

The main findings resulting from the questionnaire are as follows:

5.2.1 Projects distribution

Projects distribution according to size: Project size is determined by project length and the human resources required for its execution, according to the following categorisation:

1 Large – over four months

2 Medium – up to four months

3 Small – up to two months.

A total of 24% of the projects were found as large-sized; 27% of the projects were found as small-sized; and 49% of the projects were found as medium-sized.

Projects distribution according to importance: In the branch, a project's importance is determined by the following three hierarchies:

1 Imperative – planned within the military unit's work plan framework.

2 High – planned within the division's work plan framework or a new, unplanned operational project.

3 Medium – project authorised at the branch head level.

A total of 24% of the projects were found as of imperative-importance; 33% of the projects were found as of medium-importance; and 43% of the projects were found as of high- importance.

5.2.2 Correlative analysis – examining the correlation between the PMBOK average and project success average

The PMBOK management average was determined by calculating the cumulative average of the results of items 1–25 in the questionnaire, which represent the PMBOK's eight knowledge areas. The project success average is as defined by items 26–30 in the questionnaire.

The study findings show a positive significant correlation between the project management average according to the PMBOK (the PMBOK average) and the project success average ($R = 0.521$, $Sig = 0.000$).

5.2.3 Simple linear regression examining whether the project success average can be predicted from the PMBOK average

According to the regression findings, it appears that the PMBOK average is a significant predictor to the project success average (Beta = 0.521, $p = 0.000$). Over-whole, a total of .27.2% of project success average variance can be explained by the PMBOK average.

Table 1 Linear regression

Variables entered/removed[a]			
Model	*Variables entered*	*Variables removed*	*Method*
1	PMBOK average[b]		Enter

Notes: [a]Dependent variable: project success average.
[b]All requested variables entered.

Model summary				
Model	*R*	*R square*	*Adjusted R square*	*Std. error of the estimate*
1	.521a	.272	.261	.3350

Note: [a]Predictors: (constant), PMBOK average.

ANOVA[a]						
Model		*Sum of squares*	*df*	*Mean square*	*F*	*Sig.*
1	Regression	2.845	1	2.845	25.345	.000b
	Residual	7.634	68	.112		
	Total	10.479	69			

Notes: [a]Dependent variable: project success average.
[b]Predictors: (constant), PMBOK average.

Coefficients[a]						
Model		*Unstandardised coefficients*		*Standardised coefficients*	*t*	*Sig.*
		B	*Std. error*	*Beta*		
1	(Constant)	.861	.630		1.368	.176
	PMBOK average	.787	.156	.521	5.034	.000

Note: [a]Dependent variable: project success average.

5.2.4 One-way ANOVA test – to examine the difference in project success average among projects of different sizes

A significant difference in the project success average was found among projects of different sizes, $F(2, 67) = 4.969$, sig = 0.010.

In Post Hoc tests (Tukey), a significant difference was found between small and large projects (sig = 0.009). According to LSD, a significant difference exists between small and medium-sized projects (sig = 0.025) and between small and large-sized projects (sig = 0.003).

Table 2 One–way ANOVA for projects of different sizes

	Sum of squares	*Df*	*Mean square*	*F*	*Sig.*
Between groups	1.353	2	.677	4.969	.010
Within groups	9.125	67	.136		
Total	10.479	69			

Multiple comparisons

According to a Bonferroni test, a significant difference exists between small and large-sized projects (sig = 0.009). A correlative analysis was also carried out to examine the correlation between the PMBOK average and the project success average for all project sizes. A strong positive correlation was found between both variables for all project sizes (small, medium, large).

5.2.5 One-way ANOVA test – to examine the difference in project success average among projects of varying importance levels (imperative importance, high importance and medium-level importance)

A significant difference in project success average was found among projects with different levels of importance, ($F(2, 67) = 6.592$, sig = 0.002).

According to a Tukey test, a difference exists between projects with imperative importance levels and projects of medium-level importance (sig = 0.002).

According to LSD, differences exist between projects with imperative importance levels and projects with high importance levels (sig = 0.029) and between projects with imperative importance levels and projects of medium-level importance (sig = 0.001).

According to a Bonferroni test, a difference exists between projects with imperative importance levels and projects of medium-level importance (sig = 0.002).

In addition, it is possible to see that the higher the project's importance level is, the higher its PMBOK average will be; therefore, the project success average increases.

5.2.6 Examining the correlation between project manager seniority and project success average

The study findings did not show a correlation between project manager seniority and project success average ($R = 0.318$, sig = 0.248).

5.2.7 Independent sample T-test to examine project success average differences among projects managed according to different methods (Scrum/Waterfall)

We found a significant difference in the project success average was found among projects managed according to different methods ($t = –1.989$, sig = 0.051), where 1 represents a project managed according to the Waterfall method and 2 represents a project managed according to the Scrum method.

5.2.8 Linear multiple regression analysis

According to the questionnaire's results, several clusters were defined comprising project management according to the PMBOK measure. Each cluster was comprised with a number of questions presenting the relevant measure in a quantitative manner.

The questionnaire clusters included the following: integration management, content or capacity management, time management, quality management, human resources management, communication management, risk management, and purchasing management.

Table 3 Linear multiple regression analysis

Model summary				
Model	*R*	*R square*	*Adjusted R square*	*Std. error of the estimate*
1	.579[a]	.336	.261	.3351

Notes: [a]Predictors: (constant), integration management, content/capacity management, time management, quality management, human resources management, communication management, risk management, and purchasing management.

ANOVA[a]						
Model		*Sum of squares*	*df*	*Mean Square*	*F*	*Sig.*
1	Regression	3.518	7	.503	4.476	.000b
	Residual	6.961	62	.112		
	Total	10.479	69			

Notes: [a]Dependent variable: project success average.
[b]Predictors: (constant) integration management, content/capacity management, time management, quality management, human resources management, communication management, risk management, and purchasing management.

According to the results of the ENTER method for multiple regression analysis, it was found that, at a 10% significance level, there are four main areas of knowledge that predict project success: integration (sig = 0.067), content/capacity (sig = 0.063), quality (sig = 0.074), and communication (sig = 0.055).

A positive correlation of R = 0.579 was obtained, with an explained variance of 33.6%.

5.2.9 Multiple regression with dummy variables

The following independent variables were defined: The PMBOK, project manager seniority, project importance, project size, and project management methodology.

The dependent variable was: project success average.

In contrast to all of the independent variables, the PMBOK average is not considered a background variable; therefore, two tests were performed: Test 1 did not include the PMBOK variable; Test 2 included the PMBOK variable.

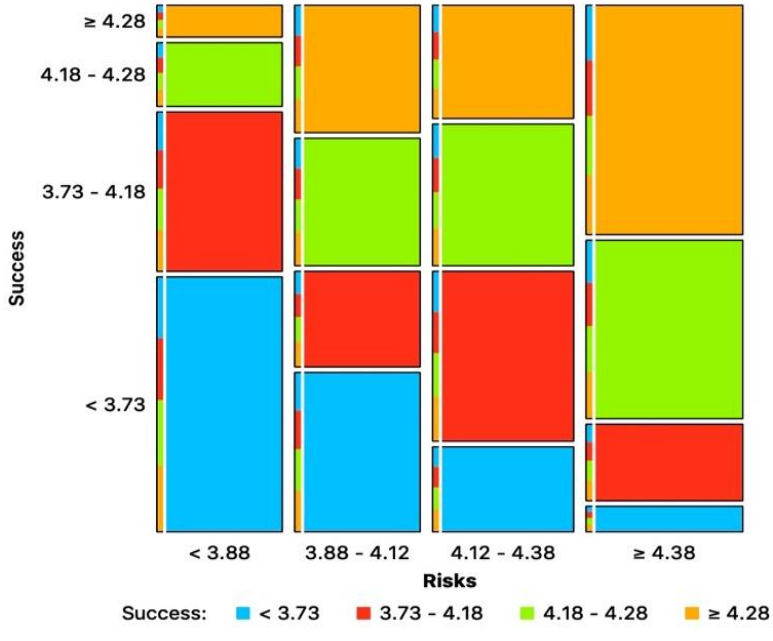
According to the results of Test 1 using the Stepwise method for multiple regression with dummy variables, a positive correlation of R = 0.515 was obtained; the explained variance was 26.6%.

It was found that project management methodology (sig = 0.000, $\beta = 0.319$) was the most important variable, followed by the project importance variable (imperative importance and high-level importance) (sig = 0.000, $\beta = 0.313$), and finally, the project size variable (medium-sized) (sig = 0.019, $\beta = -0.245$).

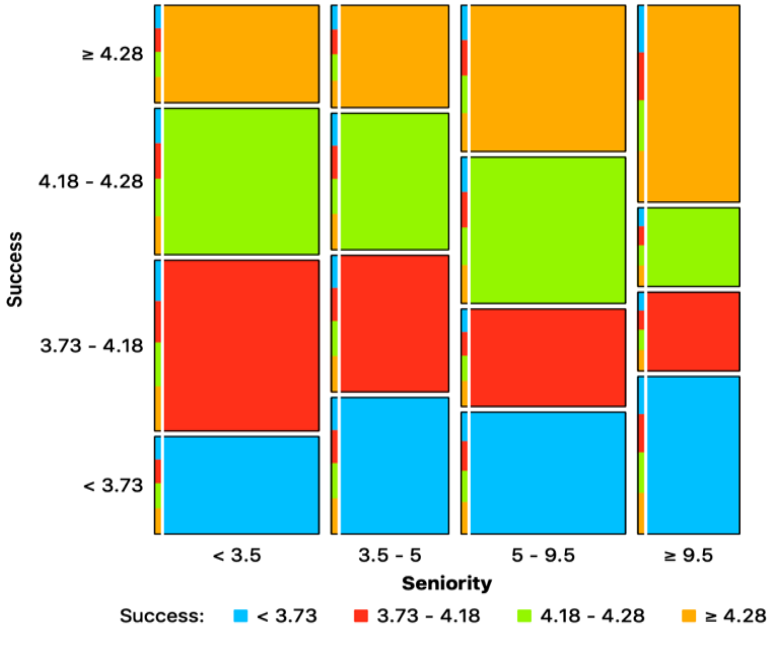
According to the results of Test 2, which included the PMBOK variable using the Stepwise method for the multiple regression analysis with dummy variables, a positive correlation of R = 0.655 was found; the explained variance was 43%.

The results showed that the most important variable was the PMBOK average (sig = 0.000, $\beta = 0.572$), followed by project management methodology (sig = 0.000, $\beta = 0.424$), and finally project size (small/medium-sized) (sig = 0.019, $\beta = -0.229$).

Figure 5 Mosaic display of, (a) risks vs. the success rate affiliated with projects (b) seniority vs. the success rate affiliated with projects (c) methodology vs. the success rate affiliated with projects (see online version for colours)

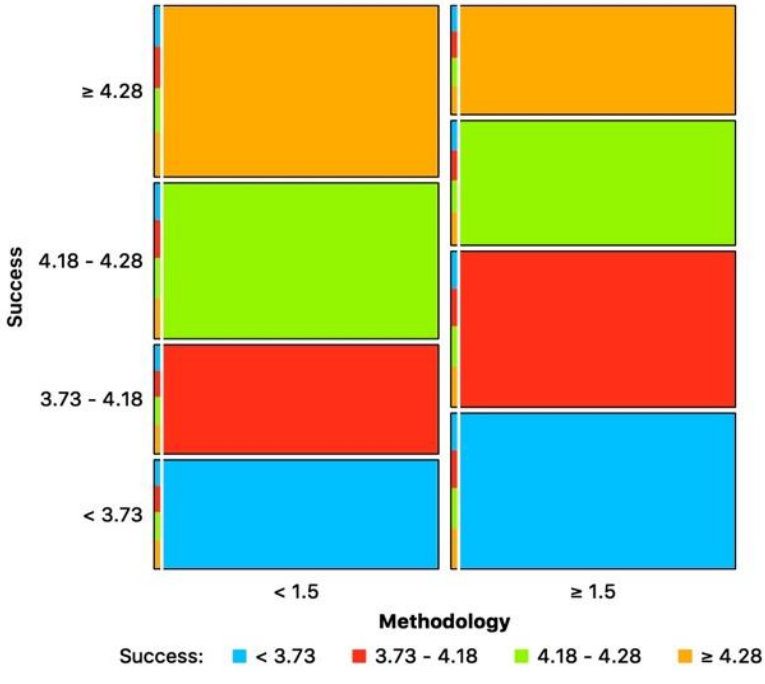


(a)



(b)

Figure 5 Mosaic display of, (a) risks vs. the success rate affiliated with projects (b) seniority vs. the success rate affiliated with projects (c) methodology vs. the success rate affiliated with projects (see online version for colours)



(c)

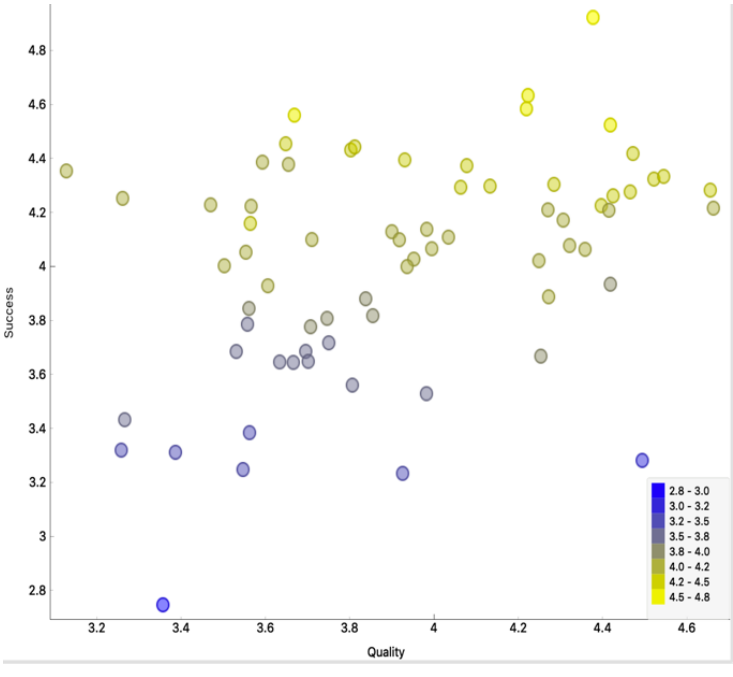
5.2.10 Scatter and Mosaic results

The Mosaic algorithm yielded the following: when the project's risks increase, the success decreases [Figure 5(a)]. We also found that seniority is distributed equally with success values, thus not significantly affecting the project's success [Figure 5(b)]. Scatter results evaluation also shows that only methodology values are classified into two groups (< 1.2 and > 2) according to the project success rate [Figure 6(b)], meaning that each methodology (Scrum or Waterfall) has a different impact on project success [this finding is supported also by Figure 5(c)].

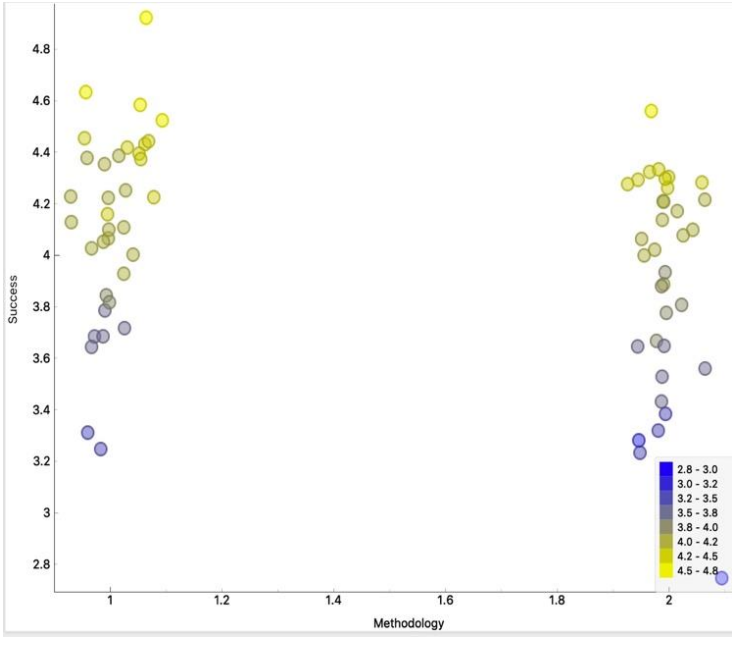
5.2.11 Random forest results

Results derived from the Random Forest classification model (Figure 7), show that the most important attributes that contribute to project success rate are: The PMBOK, methodology and time. In other words, results show that these attributes play an important part on the project success rate and impact the embedded risks. From the machine learning analysis, we can say that projects risks have a negative influence on project success, such as that projects managed by the PMBOK may yield higher success rates and low risk over those managed by different methodologies that embody high risks.

Figure 6 Scatter plot related to, (a) project quality according to the project's success rate (b) methodology (Scrum or Waterfall) according to the project's success rate (c) PMBOK according to the project's success rate (see online version for colours)

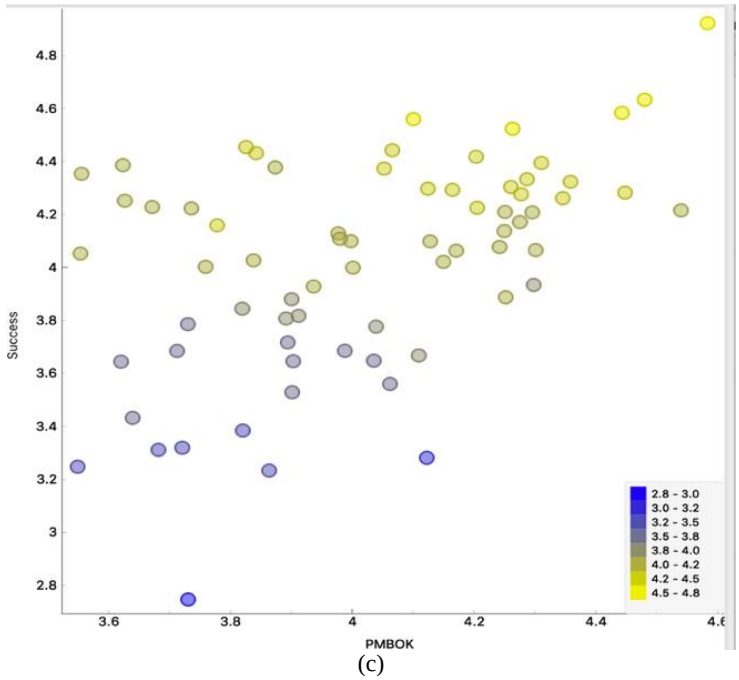


(a)



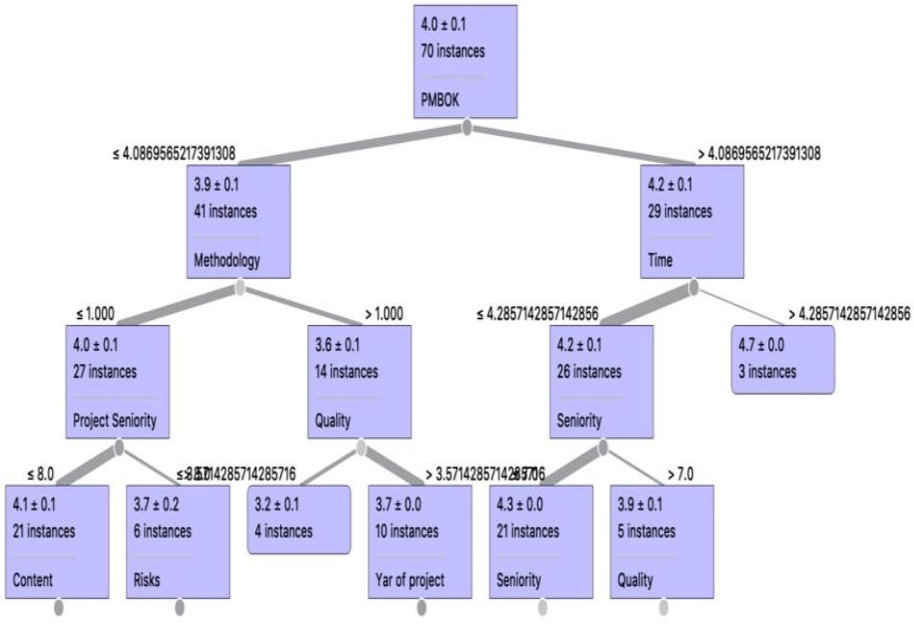
(b)

Figure 6 Scatter plot related to, (a) project quality according to the project's success rate (b) methodology (Scrum or Waterfall) according to the project's success rate (c) PMBOK according to the project's success rate (continued) (see online version for colours)



(c)

Figure 7 Classification tree constructed by the random forest algorithm (see online version for colours)



6 Conclusions

The exploitation of machine-learning tools was shown as improving the quality of predicting project management success processes by the given set of independent attributes whose score is computed in parallel through the relief function. This feature provides a convenient way to calculate the scores for all attributes in a visual and textual mode. The tools enabled the authors to visualise and evaluate the importance of features that influence the success of project management processes over classical statistical methods, such as regression and correlation usage. We showed that the usage of machine learning prediction models such as random forest may be used to estimate project success rate without the need to specify the distribution of the dependent or independent variables in the inspected data. We also managed to evaluate the importance of project management methodology, risk levels and several of the manager's attributes (such as seniority) without making any pre-assumptions about the data, as is common in statistical methods, such as logistic or linear regression. In addition, we also managed to show that we received visualisation and prediction results simply from the learning process on the data without relying on rules-based programming This attitude differs from common statistical modelling, in which formalisation and relationships between the variables are conducted in the form of mathematical equations. To conclude, we found that machine-learning approaches can be utilised to predict and evaluate project success by means of different independent attributes. Moreover, we showed that the PMBOK significantly contributes to the ability to predict a project's success (Figure 7). Lastly, according to the Scatter and Mosaic plot analysis, we also showed that some attributes – such as project risks and manager seniority play some role but not solely in successful project management processes.

Concerning the inferential statistics findings, we conclude the following:

1 *A significant positive relationship* was found between project management average according to the PMBOK and the project success average variable. Simple linear regression analysis provided identical results to the Pearson correlation, regarding the nature and quality of the relationship between the two research variables.

2 *Significant differences* in project success average were found among projects of different sizes.

3 A significant and positive relationship was found between the two variables (the PMBOK and the project success) for all project sizes (small, medium, large). In addition, the larger a project's size, the more its PMBOK and success averages increase.

4 Significant differences in project success were found among projects with varying levels of importance. Therefore we may infer that the more important the project is, the more its PMBOK and success averages increase.

5 *No relationship* was found between project manager seniority and project success average.

6 *A significant difference* in the success measure was found between projects managed according to the Waterfall method and those managed according to the Scrum method. Therefore, we conclude that the Scrum method was more successful than the Waterfall one in the evaluated projects.

7 According to the linear multiple regression analysis, there were four main areas of knowledge that predict project success: integration, content or capacity, quality and communication, with an explained variance of 33.6%.

8 According to the decision tree method, there are three levels of importance regarding variables' predictors: The most important one is 'the PMBOK'. The second most important factors (on the same level) are 'project methodology' (Scrum vs. Waterfall) and time. On the third level, there are three more variables: 'project seniority, project quality and manager seniority'. These variables should be also taken into account during the project management process as part of the success or failure considerations. Our findings are further supported by the Mosaic and Scatter visualisation tools, which show how most of the projects in terms of quality and success are situated somewhere in the middle between success and failure. Therefore, we conclude that, in order to improve a project's success rate, its quality should be improved according to the affiliated risks.

7 Discussion

The current research focused on the relationship between the extent to which project management is carried out according to the PMBOK and project success. Our research data was elicited from a questionnaire distributed among project managers in the IT branch of a military technology unit, employing various project management methods in 70 different projects. Each project was ranked according to its estimated success and the extent to which it was managed based on the PMBOK.

According to the PMBOK, a project management method can be divided into defined knowledge areas: Integration management, content or capacity management, time management, project quality management, human resources management, communication management, risk management, and purchasing management.

It is important to mention that the cost management knowledge area was not included in our specific study, as there was no shortage of financial resources. Thus, the branch received whatever equipment it needed to carry out its projects. In addition, most required equipment was available from the unit's warehouse and was purchased in advance.

Our findings revealed a relationship between project management carried out according to the PMBOK and project success. In light of the rapidly changing threats in the military environment, and as a result of the existing competition in the defence industry, managing projects effectively becomes an issue of ever-increasing importance and relevance. The PMBOK is an essential tool, which defines and outlines managerial processes for all project stages. Its proper implementation and management of different areas of knowledge significantly improves a project's chances of success. The variance analysis results show that differences in project management success averages were found among projects with different importance levels. The higher a project's importance level is, the more the PMBOK is adhered to it and the more success levels increase. Possible explanations for this are as follows:

- The higher the project's importance level is, the higher its managerial focus will be.
- The higher a project's importance level is, the more the desire to complete it successfully increases. Thus, in the event that reinforcement or prioritising of resources becomes necessary, and in extreme situations in which another project is frozen as a result, these actions will come at the expense of less important projects, in order to advance more important projects.
- A project with a higher level of importance is more marketable and thus receives more exposure all of which provides it with a higher aura of success.

To conclude, our results are not consistent with the professional literature, which claims that the smaller a project's scope is, the more its chance of its success to increase. The reasons for this inconsistency may be explained by a clearer content or capacity or a smaller number of involved parties in the project.

In another variance analysis, differences in project success averages were found among projects of different sizes. We found that there is a positive correlation between the project's scope and the PMBOK adherence. In cases were the scope of the project is large, higher PMBOK adherences is needed in order to classify the project as successful.

This finding may be explained by project duration. The longer the project is, the more discussions related to control and supervision is needed. In addition, the longer the project duration, more time to fix problems and reduce risks is needed. Hence, differences in success measures are apparently a result of project size.

Another difference in project success was found between projects managed using the Waterfall and Scrum methods. The findings show that the PMBOK average obtained for projects managed by the Waterfall method was higher than those managed by the Scrum method. In contrast, the success average obtained for projects managed using the Scrum method was higher. Thus, each method has its advantages and disadvantages, as mentioned in the literature review.

The obvious advantage of Scrum is its flexibility and ability to adapt to environmental changes. In this context, it is important to stress that a large number of projects are accompanied by changing demands which occur over time, as a result of a dynamic operational environment and clients' desire to maximise costs. In addition, this methodology is well-suited to software projects. This may explain its high success averages relative to the Waterfall method.

As for the Waterfall model, its advantage lies in its organised programs for development, testing, schedules and deadlines, as well as content or capacity. This may account for its high PMBOK average value compared to the Scrum method.

Contrary to Turner and Muller (2005), the current study found no relationship between project manager seniority and success average variables. This may be attributed to project success dependence on many different variables. In addition, the number of projects a project manager manages simultaneously may also have an effect on the level of success.

Concerning machine-learning approaches, we managed to strengthen the findings found by conventional statistical methods: Pearson correlations, linear regression and ANOVA. Using the random forest algorithm, we also found that the PMBOK methodology plays an important role in a successful project management process. Although we found as opposed to the inferential statistics a weak correlation between the seniority affiliated with the manager as well as assimilated risks that impact project

success, the level of impact was found as low. This finding may be explained by the manager's level of experience as a high level of experience enables the manager to mitigate project risks, resulting in an increased probability of project success, but the success of the project is not totally dependent on this attribute alone.

To conclude, machine-learning approaches have been shown to be efficient in supporting consensual statistical methods. They can serve as predictive tools which assist project managers in decision-making processes, thus increasing their number of successfully managed projects.

One limitation of the current study is that it was only conducted in a single military IT branch; future research should include projects executed in other IT branches, other units and or other firms. Future research should also examine the extent of the combination of the two methods (Scrum vs. Waterfall), and their influence on project success. Likewise, it is recommended that future research will focus on additional factors that may have an impact on the success level of IT projects.

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