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Task Allocation in Software Engineering Based on Performance Patterns

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Abstract

Task allocation decisions are critical to the success of software projects. Task allocation is an NP problem, due to a variety of factors that affects it, and because the size of the software project grows. Managers also need to measure their team performance, weakness, and strength. It's been proven that personality is one of the most important criteria used in tasks allocation. In this thesis, a Personality Model for Task Allocation (PMTA) is presented. Data from previous projects are analyzed to identify tasks characteristics and the capability of each person to perform each type of task. This work is based on the principle that there are certain criteria that can be measured which allows drawing clear conclusions about the results of different task allocations. Then, performance patterns are defined to assess the productivity of the team members. Therefore we are aiming at identifying correlations with performance on certain criteria and the ideal or proffered task allocation. In this thesis, a case study has been conducted in a Palestinian software development company to investigate the relationships between task characteristics and developers' personalities which are identified using Belbin and MBTI indicators. The tasks have been decomposed based on six criteria which are task's difficulty, urgency, creativity, social, analysis, and design. Correlations are built based on productivity of personalities to perform each task type. An experiment also has been conducted to validate the proposed model. The proposed model has helped to improve the productivity of developers.

الملخص

يعد قرار توزيع المهام مؤثر جدا في نجاح مشاريع البرمجيات. توزيع المهام مشكلة صعبة الحل نتيجة لوجود عدة عوامل تؤثر عليها بالإضافة إلى ذلك حجم مشاريع البرمجيات يكبر بشكل يجعل هذه المشكلة معقد أكثر. مدراء مشاريع البرمجيات أيضا بحاجة إلى قياس أداء الفرق ونقاط ضعفهم وقوتهم. في هذه الرسالة, نموذج يستغل الشخوص لتوزيع المهام تم بنائه أطلق عليه (PMTA). الفكرة تنص على استخدام بيانات من مشاريع سابقة للمبرمجين تم تحليلها لتحديد صفات المهام التي عمل عملوا عليها وبعدها تم حساب التوافق بين كل صفة للمهام وقدرة الشخصية لتنفيذ هذه المهمة.

هذه الدراسة تم بناؤها اعتمادا على المبدأ الذي ينص أن هناك معايير معينة يمكن قياسها لرسم استنتاجات واضحة لنتائج مختلفة لتوزيع المهام. لاحقا, أنماط اداء تم تعريفها لقياس الإنتاجية لافراد الفريق. لهذا, نحن نهدف لتحديد العلاقات أداء المبرمجين بناءا على معايير معينة.

في هذه الرسالة, دراسة حالة تم دراستها في شركة فلسطينية متخصصة في بناء البرمجيات. الغرض من هذه دراسة الحالة هو تحديد العلاقات بين صفات المهام و صفات الشخصية للمبرمجين التي تم تحديدها بناء على مقاسي MBT و Belbin. هذه العلاقات تم استخدامها لبناء نموذج توزيع المهام الذي يستغل هذه العلاقات لتوزيع المهام. أخيرا, تجربة علمية تم تنفيذها لقياس كفاءة النموذج المقترح لتوزيع المهام.

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Chapter 1

Introduction

This research investigates the relationship between human factors and software development team performance. In this research, the human-factors are identified using Belbin Team Roles (BTRs) [1] and Myers-Briggs Type Indicator (MBTI) [2], which have been proven to be significantly influence team productivity in software development [3, 4]. A case study has been conducted, in a Palestinian software development company, to study the relationship between the personality of the software engineer and the task types, to investigate its effects on the productivity. This research aims to use these relationships to build a task allocation model called Personality Model for Task Allocation (PMTA). This research also includes an experiment designed to validate the PMTA model which is proven to be significantly better. The results of this research would help project mangers and team leaders to allocate projects tasks, based the optimal match between the personality and the task.

1.1 Introduction and Motivation

Task allocation is consider a critical decision to the success of software development projects. Moreover, it has been considered one of the risk factors for the

failure of software projects [5]. In addition to that, it has been proven that allocating the right people to the tasks has a significant impact on team effectiveness [6, 7].

Task allocation is also a NP (nondeterministic polynomial time) problem [8, 9], due to varieties of factors that could affect task allocation. These factors are classified based on individuals' personalities, their competences, and team balance [10]. Additionally, software development process encompasses various aspects which require different abilities and skills [11–13]. Moreover, these abilities are not binary, since every developer shows different performances for each competence [10, 14]. Previous studies showed that team member personality is one of the most important criteria that is used in tasks allocation [15]. Also, it has been shown that 42% of software project failures are caused by human-related factors [16]. As it has been reported that there is a significant relationship between personality and team performance [7, 17–19]. Although, there is a lack of studies focusing on task characteristics [3, 4, 20], which is very important in tasks allocation decision. Andrejczuk et al[4] concluded that there is a need to consider the task types and their influence on teams' performance. The tasks are classified based on the following four criteria: difficulty, urgency, creativity and the type of the software development activities, such communication, analysis, and design.

Managers and team leaders face difficulties in allocating tasks to the right developers, because of the complexity of identifying the correlation between developers' performance and the tasks [21]. The task allocation also requires to consider the individuals' personalities and behaviors, in addition to their technical skills [8, 22]. There are studies that proposed solutions to this problem [3, 8, 10, 16, 23, 24]. Unfortunately, these studies are context related and the threats

to external validity were not very well addressed [24, 25]. For instance, organizational contexts should be considered, since human capabilities are dynamic in a variety of contexts [24–30].

Based on the above, this research has two goals, first, to analyze the correlations between personalities and task types. Secondly, to propose a task allocation model that is based on personality-task relationship to maintain the balance within the team and improves its performance. Team productively is used to measure its performance.

1.1.1 Research Objectives and Problem Statement

An efficient task allocation should be based on the individuals' personalities, behaviors, skills, and task type. Therefore, the propose model addresses the following issues:

- Myers-Briggs Type Indicator (MBTI) [2] is used to identify the personality of software engineers. MBTI is a psychological test, that is used to identify the personality of individual, it indicates to different psychological preferences: how people perceive the world around them and make decisions.
- Belbin Team Roles (BTRs) is a behavioral test that is used to assess how an individual behaves in a team environment team [1]. BTRs is used to assess how the software engineers behaves within the software development environment.
- Investigate the relationship between software engineer personality and the types of software engineering tasks.
- Develop a task allocation model that is based on personality-task relationship, and apply it on software development project.

- Analyzing the software development team performance for each task types.
- Conducting an experiment to validate the proposed model.

1.1.2 Summary of progress and contribution

This study analyzes the relationship between individuals' personalities and team performance. This relationship is used to build task allocation recommendations based on performance patterns that aim to compose the best team depending on the type of each particular task. This study also consists of an experiment that aims to validate the proposed model.

In this study, the current problem is discussed and analyzed in details. In order to put the reader in the context of the topic studied, a brief conceptual background about personality theories are presented. The literature was reviewed to ensure the topic is fully understood, to identify potential areas for research, and most importantly, to identify ideas suggested by previous studies. In this study, the research methodology shows the theories and assumptions made to classify the tasks and how productivity is measured.

1.1.3 Overview of this report

This thesis is organized as follows. The following chapter reviews the literature about the relationship between personality and team performance, and team formation. It also gives an overview about personality theories. Chapter 3 and 5 introduce the research methodology, which shows the theories and assumptions that are made, and how the data is analyzed. In chapter 6, the results and discussion are presented in Sections followed by an experiment to validate the proposed model. Chapter 7 is a conclusion. Finally, chapter 8 shows the limitations of this study and recommendations for future research.

Chapter 2

Related Work

2.1 Characteristics of individual in software development team

This section reviews number of methodologies and criteria, which were used to classify individual in software engineering teams. The main purpose of this review is to show the importance of the individual characteristics, mainly personality and behavior, on software development team performance.

The previous studies showed the importance of the human aspects on performance in software development [7, 17, 18, 31–34]. For example, Rasch and Tosi [18] found that the individual characteristics affect the perceived performance of software development professionals.

Silva et al.[15] analyzed criteria used in team composition, and how these criteria could affect project success. They used semi-structured interviews with project managers and team members from various software companies to understand which criteria were used. Table 2.1 shows the result of these interviews. It also shows that the most used criteria, which are shown in column 4, are Technical Profile and Personality.

TABLE 2.1: Team building criteria[15]

Groups	Sub-groups	Criteria	Importance
Individual Factors	Innate	Personality	6
		Behavior	5
	Technical	Technical Profile	6
		Productivity	4
Organizational Factors	Internal	Individual Cost	3
		Availability	4
	External	Project Importance	3
		Customer Importance	5

Their results show a significant correlation between the team building criteria and project success. The results also show that criteria related to human factor, such as personality and behavior, have a strong correlation. However, they don't address the problem how to use these criteria to build good team as well as how to measure individual personality and behavior.

Andrejczuk et al.[4] also analyzed the relationship between team composition and team performance. Thus, they reviewed literatures dealing with team composition and team performance. They classified team members according to two dimensions:

- Capacity: Particular skill required to perform an action [35, 36]
- Personality: How individuals behave and what makes them behave differently, such as how individuals perceive the world, make decisions, and communicate. For example, MBTI and Belbin are used to measure the individual personality[1, 37]

They concluded that the majority of previous works do not correlate team type with a task type. Indeed, they showed need to further explore task types and their influence on teams' performance.

Andrejczuk and Rodríguez-Aguilar[10], and Andrejczuk et al. [38] used personality in team composition. They refered to the possible approaches to determine personality, such as the Five Factor Model (aka FFM or "Big Five"), Belbin theory, and the Myers-Briggs Type Indicator (MBTI).

Farhangian et al[8, 24] suggested a model to be used in resource allocation based on personality and skills. They used Belbin and MBTI [1, 37] to measure personalities of developers. They allocated tasks by taking into consideration the required levels of creativity, urgency, social interaction and complexity of a tasks, using known correlations between these skills and the personality.

Gulati et al.[39] analyzed the relationship between performance and personality of a software programmer, and how personality could influence the performance of software programmer. Goldberg's IPIP (International Personality Item Pool)[40] was used in their study to identify the personality. However, the relationship was not significant using Goldberg's IPIP.

Cruz et al.[3] presented a systematic mapping study of research on personality in software engineering. They reviewed more than 90 articles published between 1970 and 2010. The research results showed that MBTI was the most used test, which was used by 48% of reviewed articles. They also showed that contradictory evidence was found due to differences in context. Finally, MBTI was applied in different topic such as, team effectiveness, software process allocation, and individual performance.

Ayoubi and Ustwani[19] proposed a methodology to find the correlation between students' natural preferences and students' grade point average (GPA). 89 students participated on their study. The MBTI result and GPA for each student were measured, analyzed to find the correlations.

The previous studies showed it's important to take into consideration the individuals' personalities as well as their performance. It also showed possible

indicators that could be used to measure the individuals' personalities such as Myers-Briggs Type Indicator (MBTI)[2, 3, 41], the big five personality dimensions (aka FFM or "Big Five") [42], and Belbin Team Roles (BTRs) [1].

2.2 Background

This section provides an overview for the major tests of personality that are used to assess personality and individual behaviors. Belbin [1, 43] and MBTI[37] are the most popular tests used to assess individual personality. These tests are also able to identify and measure the qualities of personalities.

2.2.1 Belbin Team Roles

Belbin's team role theory was published in 1981 by Raymond Meredith Belbin which is a British researcher and management theorist, best known for his work on management teams. Individuals can play nine different roles in a team based on their personalities. So, a team must consist of different roles to achieve maximum performance[1, 43]. The roles are classified based on four dimensions: feeling, will power, thinking, and decisiveness.

The Belbin test is a questionnaire composite of a set of questions for personalities preferences.The best role of the team member within the team is determined by analyzing its answers. Table 2.2 identifies the nine Belbin's team role. The table also describes the strengths and weaknesses for each role.

The Belbin test gives a percentage score for each role. The highest scoring role of the participant is considered as the primary role, the next one as secondary .. etc. Roles with 70% scoring or higher are called "naturally" present, these roles are authentic for the participant.

TABLE 2.2: Characteristics of the Belbin team roles [1, 43].

Team role	Characteristics	Allowable weaknesses
Plant (PL)	Creative, Innovative and original. Solves difficult problems	Forgetful, ignore the details and poor communicate skills
Monitor Evaluator (ME)	Seldom wrong, unemotional, strategic and analysis. Sees all options. Judges accurately.	Overly critical. Lacks drive, inspiration and ability to motivate others.
Coordinator (CO)	Leader, mature and confident. Clarifies goals, promotes decision making.	Can be seen as manipulative. Offloads personal work, intellect or creative ability
Resource Investigator (RI)	Extrovert enthusiastic, Inquisitive, communicative, outgoing. Explores opportunities.	Over-optimistic, weak respond to challenge. May forget to follow up on a lead
Implementer (IMP)	Disciplined, Organizing ability, conservative and efficient. Converts plans into practical workable activities	Somewhat inflexible, resistance to unproven ideas and non-enterprising.
Complete Finisher (CF)	Painstaking, orderly, conscientious. Searches out errors and omissions. Delivers on time. Pay attention to detail	A tendency to worry about small things. Reluctant to delegate. Reluctance to "let go".
Team Worker (TW)	Cooperative, mild, perceptive and diplomatic. Listens, builds, averts friction respond to people and situations.	Indecision at moments of crisis, avoid conflict, indecisive and over-sensitive
Shaper (SH)	Challenging, dynamic, thrives on pressure, ineffectiveness and complacency. The drive and courage to overcome obstacles	Impatient, prone to provocation, opinionated and offends people's feelings
Specialist (SP)	Single-minded, self-starting, dedicated. Provides knowledge and technical skills in rare supply and professional standards	Contributes on only a narrow front, dwells on technicalities and limited interest in others

2.2.2 Myers-Briggs Type Indicator (MBTI)

The Myers-Briggs Type Indicator (MBTI) has been considered one of the most trusted and widely used instruments in the field of personality psychology for determining personality types[44]. The MBTI personality indicator was developed by Katherine Briggs and Isabel Briggs Myers. The MBTI indicator classifies the individuals based on variety of permutations of mental functions, which are[2]:

- Focus of Attention (**E**xtrovert vs. **I**ntrovert): This refers to the scope of attention that is given by individuals. **E**xtrovert tends to breadth-of-knowledge approach, **E**xtrovert (**E**) people usually prefer to work with others. **I**ntrovert is oriented to a depth-of-knowledge approach, **I**ntrovert (**I**) people prefer to work quietly alone.

- Seeking Information (**S**ensing vs. i**N**tuitive): This refers to style of information gathering. **S**ensing (**S**) people rely on facts, reality and no nonsense, so they usually focus on the details. i**N**tuitive (**N**) people rely on their imagination and ability to see the big picture.

- Decision-Making (**T**hinking vs. **F**eeling): This refers to the way that people make decisions. **T**hinking (**T**)people make decision based on impersonal points of logic such as laws, policy and criteria. In other hand, **F**eeling (**F**) people take the emotions and opinions of others into consideration when making a decision.

- Relationships with the World (**J**udging vs. **P**erceiving): This refers to the way that people deal with the outer world. **J**udging (**J**) people make decisions quickly, they prefer to collect only enough data to make judgments.

Perceiving (**P**) people make decisions slowly. They collect additional data to consider all possibilities.

The MBTI classification results 16 personality types which are reported as a combination of the four dimensional pairs (**E** or **I**, **S** or **N**, **T** or **F** and **J** or **P**).

2.3 Relationship between human factor and team performance

In previous section, the studies showed capabilities to use MBTI[2], Big Five[42], and Belbin Team Roles [1] to measure human factors in software development team. Thus, in this section, a systematic literature review is presented for studies that correlate MBTI and Belbin Team Roles with team performance in software development. The big five personality dimensions measure only positive qualities of personality, so they are not used in this study.

2.3.1 Belbin Team Roles

Belbin Team Roles [1] is widely used in software management, such as team composition [45]. The review of Belbin literatures, showed that most of the studies correlate balance of Belbin team roles with team performance [46–49]. Other studies addressed the correlation between Belbin roles and individual performance [50–52]. In contrast to the expectations, there are some research papers showed that there is no significant relationship between team balance and team performance [53–56].

Senior [46] used Belbin to find the link between team role balance and team performance. He used real teams in real organizations in his study. He addressed the following issues:

- How to identify a person's 'natural' team role.

- How to measure whether a team is balanced or not.
- How to measure team performance.

In his study, for each team, he measured the team's average score for each Belbin role. The team performance was determined by a one-to-one interview with participators, where each participator was asked to choose if the team is a 'good' team, a 'bad' team ..etc. Senior [46] has proved what was claimed by Belbin that if all team roles are strongly represented across the employees, then the team is predicted to have high performance.

Prichard and Stanton [47] found that mixed teams performed better than teams consisting of shaper team roles alone. The main objective of their study was to determine if differences in team-role composition affected team performance. In their experiment, they had twelve teams of four people, the teams were classified into two categories. First, teams contain shaper role only, and the others contain mixed roles. The teams were asked to perform set of tasks. The result of the study proved that a statistical relationship between team performance and role balance hypothesis.

Omar et al.[50, 51] verified the importance of assigning correct role to correct team members by suggesting a technique that determines the balance of team roles. They used two roles from Belbin, which are Shaper and Plant. The result showed how their technique works successfully.

Marshall et al. [57] presented some observation from analysis of team compositions and team types. They analyzed participation of individuals during the teaching exercise. They established a team classification using Belbin Team Roles to model information about teams. They showed the importance of use personality in team compositions, and they also compared the result of their

model with teams were allocated randomly. Finally, they provided directions for future work such as using a new allocation strategies.

2.3.2 Myers-Briggs Type Indicator (MBTI)

Myers-Briggs Type Indicator (MBTI) [37], is one of most widely-used psychometric instruments for assessing personality characteristics[3, 41, 44]. The MBTI indicator proves that most effective software development will result from the combined efforts of a variety of mental processes and personalities [58].

The researchers used MBTI to highlight correlations between personality types and task types. Capretz [58] analyzed personality types of software developers, and its expected effect in team performance. They offered some insight to decision makers in guiding them to importance of using personality types to select software developers that are suitable into a specific task. They provided an abstract guiding as shown in table 2.3.

TABLE 2.3: Capretz [58] guideline

Task characteristics	**Suitable**	**Unsuitable**
Creative	NT's	ST's
Analysis	ESTJ and ENTJ	ESTP and ENTP
Communicate	ESTJ, ESTP, ENTJ and ENTP	INTJ
Designs	ESTJ and ENTJ	ESTP and ENTP
Problem solve	INTP and ISTP	-
Early phases	INTP	-
Planning	ISTJ and ESTJ	-
Management	ESTJ and ISTJ	-

Da Cunha and Greathead [59] discovered that people with a specific personality type perform better at one specific task. A Sixty-four university second year undergraduate students were participated in an experiment, they analyzed the students performance in a code-review task and their personality types. Each student was asked to review a given code which contains some bugs. Each bug

has a difficulty, which is used to measure the total score of each student. They concluded that students with 'NT' personality type, performed better at code review task than the others.

Omar et al.[22] compared personality type's preferences amongst agile and non-agile software developers.They surveyed 81 software developers that working in software industry. The result of their study showed that the software developers are mostly Introvert (I) personality types. It also showed that the dimensions of Intuitive (N), Thinking (T), and Judging (J) are dominant personality types among software developers regardless of software methodology used.

Barroso et al.[60] conducted an experiment to evaluate MBTI personality types' influences on developers professionals' work. Object Oriented Software Metrics were used to measure the developers professionals' work. They found that developers with "INTJ" type performed better than the others. However, an external validity is existed in their study, because only 6 developers participated in their experiment.

Another research papers used MBTI to build a successful team. Montequín et al. [44] studied how to build successful project team by learning more about team personalities which are measured using MBTI. They assessed more than 30 groups of students to find if there could be a correlation between MBTI types and quality of works. Different roles are assigned to the students: analysts, designers and programmers. For each role, they analyzed relationship between MBTI personality types and the role. Table 2.4 shows their result, which could be taken into consideration in task allocation.

Gilal et al.[16, 61, 62] proposed a solution to construct a balanced team for software development based on personality, which is identified by Myer Brig Type Indicator (MBTI) pairs. Their study focused on personality traits based

TABLE 2.4: Vicente Rodríguez Montequín et al.[44] Result

Role	**Preferred**
Analyst	N's
Designer	INTJs and ISTJs
Programmer	STJs type and INTJs

on gender classification for software programmers. 46 teams were participated. Each team was required to develop a web-based project with certain requirements. The performance of teams were assessed based on the given requirements. The result of their study showed the correlation between personality and gender with team effectiveness.

There are a lot of studies have correlated individual personality with academic performance using MBTI [63–65]. Kruck et al.[63] and Sendall et all[64] analyzed the correlation between student performance in a CIS courses and MBTI types. The student performance was measured using course grades. The result of their study showed correlations between student performance and MBTI types. Kruck et al's results are: **E**xtraverts performs better in coordination tasks. Programmer is an ISTJ type. **T**hinkers can make better decisions. **F**eeling and **J**udging tend to be organized, orderly and works according to a set schedule.

Colvin-Sterling[65] examined the relationship between middle school students' personality type and their academic performance. The result of his study showed the ability to predict the skills of any students based on their personality. Their population included 647 eighth grade students. The personality of students, who participated in the study, were measured using the True Colors Splash Test (TCST) and MBTI. Table 2.5 shows the result of his study.

TABLE 2.5: Colvin-Sterling[65] result

Role	**Skills**
Blue (NFs)	Communicate and work with others . Dealing with creative tasks
Gold (SJs)	Identifying, analyzing, and implementing possible solutions
Green (NTs)	The ability to deal with open-ended problems. (Make a decision)
Orange (SPs)	Confidence in dealing with complexity, and difficult problems

2.4 Task allocation

In this section, critical review for previous task allocation studies are summarized. Only the studies that address human factors as well as task characteristics are covered. Thus, the following points are highlighted.

- How were individuals' personalities identified?
- How were task characteristics identified?
- How were tasks allocated among the team? (allocation metrics)

Acuña et al.[23] analyzed the relationships between personality, task characteristics, product quality and satisfaction in software development teams. A 35 teams of students were participated in this study. The big five personality dimensions [42] was used to identify personalities of participants. The result of big five is Neuroticism, Extraversion, Agreeableness, Openness or Conscientiousness. The tasks were classified into autonomy[66] and interdependency[67] tasks. The criteria were used to measure quality of teams' product are Decomposition and Modularization, Testability, Functionality, Re-usability, Programming style, and Participation. Finally, Gladstein's questionnaire was used to evaluate students' job satisfaction [68]. The results of their study show, first, a significant correlation between quality of product and personality factor extraversion. Secondly, the students with personality factors agreeableness and

conscientiousness tend to have a highest job satisfaction. Finlay, there are relationships between personality factors agreeableness and conscientiousness, and interdependency.

Farhangian et al.[8] compared two strategies in resource allocation. First, by minimizing team over-competency, secondly, by minimizing team under-competency. They mainly examined the relationship between these two strategies and dynamic nature of tasks, such as changes in task requirements or interdependency.

In order to measure competency, their model considered personalities of team members to measure goodness of team composition based on relevant literatures, such as influence of each personality role on other personalities. MBTI and Belbin Team roles were used to identify the team personalities. The tasks were classified based on (a) required creativity, (b) urgency, (c) required social interaction, and (d) complexity. This classification was used to find the best match between team members' personality and task. For example, the team members with personality of thinking types are the best to perform the complex tasks.

They conducted a simulation experiment using NetLogo platform. Their model was able to show the effect of the two strategies on changes in the task requirements. The most importantly, their model presented a capability to allocate tasks based on personality and skill.

In another study by Farhangian et al.[24], team-assemblage model was suggested for specific organizational contexts. This model was built based on a past performance of team members and their personalities. Their model primarily predicts team grouping formation and resulting team performances. Myer-Briggs Type Indicator (MBTI) was used to profile human personality. They measured influence of a particular personality on team performance as well as performance of team's mean level for each personality. The task were classified

based on degree of a task's being structured or open-ended. Finally, their model was constructed based on data were extracted from a project called Python Enhancement Proposal (PEP) process. They determined the relationships between personalities of software developers in (PEP) and probability of success in team composition. The result was used by NetLogo[69] to validate the model.

Andrejczuk et al.[10] also presented a computational model that performs task allocation. The main objective of their model was to create a balanced team based on competences, personality and gender. The Five Factor Model (FFM), Belbin, and the Myers-Briggs Type Indicator (MBTI) were used to determine personality of team members. The tasks were classified based on competence levels required for the tasks, such as level of required creativity, and degree of coordination. Their model took advantage of previous studies' result, which is an existence of a relationship between task types and personalities. For example, if the task requires a level of creativity, then team member with thinking personality is better to perform it. The result of their model is that the tasks are allocated with minimal cost measured by competence of team member to perform task.

The previous studies have shown the capability to use personality in task allocation. However, most of previous studies did not consider the task characteristics [3]. This observation was also noticed by Wiesche and Krcmar[3, 20], who did a study by conducting a structured literature review. Indeed, they suggested to consider task characteristics in software engineering, and correlate them to developer's personality to find the best in task allocation. Moreover, software engineering is becoming a very broad field of study; consequently, some tasks may not exist before. So, an up-to-date profile of software engineers is still needed.

Moreover, previous studies have typically disregarded significant organizational contexts [24, 25]. This is noticed in the result of some studies, that are mentioned in this section. For example, Colvin-Sterling [65] concluded that team member with NFs personality tends to be better to communicate with others. In other hand, Capretz [58] concluded that ET's personality is better to perform the tasks that require a communication.

2.5 Summary

The variances in the results of previous studies are due to the fact that the human capabilities are necessarily dynamic in a variety of contexts. The success and failure are often significantly related to contextual forces [24–30].

Therefore, this research investigates the correlations between team members and the task types. A case study is conducted to analyses the performance of a team which is working in an outsourcing software project. The case study takes palace in one of a Palestinian software development companies which is active in outsourcing. Also, in this research, an experiment is conducted to validate the proposed model.

Chapter 3

Personality Model for Task Allocation (PMTA)

In this chapter, a Personality Model for Task Allocation (PMTA) is presented. The PMTA is a mechanism that allocates tasks to team members based on compatibility between the tasks and team members. This capability is demonstrated through analysis of correlations between personalities and team performance in each type of task.

It has been proven that human factors have a significant impact on team productivity. The software development processes also encompass various aspects which require different abilities such as coordination, analysis, creativity ..etc. Moreover, review of the literature has shown the impact of task allocation decisions on team performance is significant. As a result of that, this study aims to build a PMTA model that could be used by managers and team leaders in task allocation decision making. This is achieved by providing the best possible corresponding between tasks and individuals. The best correspondence is reached based on performance of team member in previous tasks as well as team personalities.

PMTA model consists of three phases: In the first phase, personalities of individuals are identified using Belbin and MBTI indicators; in the second one,

tasks are classified based on four criteria, which are behavior requirements, urgency, creativity and difficulty of the tasks. Finally, the relationships between task types and personality are analyzed.

3.1 Identify personality and behavior of team members

As discussed in the literature review, there are different techniques used to identify personality of individuals. The most popular approach is to determine personality through a set of questions [1, 37, 42, 70]. In this study, Belbin Team Roles (BTRs)[1] is used to identify behavior, where Myers-Briggs Type Indicator (MBTI) [2] is used to identify personality.

The reason for selecting MBTI and Belbin indicators is due to the fact that they have significance relationship with team productivity in software development, as it is shown by literature survey in chapter 2. Belbin and MBTI also identify and measure both positive and negative qualities of personality. In contrast to other indicators, such as the big five personality dimensions (aka FFM or "Big Five") [42], which measures only positive qualities of personality. Also, MBTI and Belbin indicators have been used and tested by different researches. For example, MBTI has been used in almost more than 600 studies[71].

The Belbin and MBTI tests are a set of questionnaires of preferences that each participant has to answer. The result of Belbin test shows the best role that fits with in the team. MBTI test shows the participant personality types. There are 16 personality types.

3.2 Decompose the tasks

Software development processes encompass various tasks, which could be classified by various criteria. Each criteria uses various basis [8, 27, 72–79]. For

example, the tasks could be decompose based on group activities, complexity, behavior requirements ..etc. In this study, creativity, urgency, sociality, and difficulty are used to classified tasks. The reason behind choosing these criteria, is due to the relationship between these criteria and team productivity [8, 77, 78].

In the conducted case study, each task type is assigned a score ranging between 0 and 10 by manager of the team. The manager also scores the tasks based on the following criteria.

3.2.1 Task Difficulty

Task difficulty usually refers to the amount of effort required to complete the task. It has been proven an existence of relationship between task difficulty and performance [74, 76]. The required time to complete the task is used by MMTA as a metrics to measure task difficulty. Task difficulty has a score ranging between 0 and 10, where 0 means the task is easy and 10 corresponded to the very difficult task.

3.2.2 Urgency

The previous studies have proven the influence of urgency on human behavior[80, 81]. Urgency refers to the time sensitivity of a task in a particular situation as well as the importance of the task[82]. Task Urgency has a scale ranging between 0 and 10, where 0 means the task is unimportant and 10 means task is very urgent.

3.2.3 Creativity

Creative task refers to novelty of the task for the team member rather than one already known to him/her[72, 83]. Task creativity varies across the team, so in

the score range, 0 corresponded to the novelty in the field (not at all familiar) and 10 means the team member is extremely familiar with the task.

3.2.4 Software development activities

This classification is based on category of development activities required by the task[84]. In this research, three activities are identified. A scale ranging between 0 and 10 is also assigned for each activity.

- Social interaction refers to the level of communications required by the task. '0' indicated absolutely no social interaction required, where '10' indicated an extremely social interaction required.
- Analysis refer to understanding the problem you're trying to solve. '0' means the problem is clear, where '10' corresponded to the ambiguity of the problem.
- Design refers to figuring out how to organize the solution. '0' means the solution of task is already known or trivial, where '10' means very difficult solution is required by the task.

3.3 Productivity

This section discusses how productivity of individuals are measured and its relationship with team members personality.

In PMTA the effects of MBTI and Belbin personalities are measured based on capability between each personality and type of task. This capability is demonstrated by conducting the following procedures:

- Gather the tasks performed by each team member.

- Classify the tasks based on the criteria mentioned in section 3.2.
- Measure productivity of team member for each task type.
- Correlate between personalities and tasks characteristics.

The productivity is still in debate, it usually refers to the output per the effort. In PMTA, productivity refers to the delay. Equation 3.1 shows how the productivity is measured by PMTA.

$$Productivity(i) = \frac{EstimatedTime_i}{ActualTime_i} \tag{3.1}$$

where:

- $Productivity(i)$: the Productivity in task '**i**'
- $EstimatedTime_i$: The estimated time to finish the task '**i**'.
- $ActualTime_i$: The Actual time taken to finish the task '**i**'.

3.4 Technical profile

It has been proven the significant of technical profile in project success and team composition[15]. Technical profile refers to specialized area of activity, human knowledge in a particular area or expert knowledge. Technical profile is measured based on history of team member in team by finding the category of tasks the team member has usually performed [85, 86]. In PMTA, technical profile is measured by cumulative volume of production for each task type as it is shown in equation 3.2. This equation reveals the characteristic of the tasks performed by each team member.

$$Expert_{(T,M)} = \frac{\sum_{j=1}^{i} TaskT_{\mathbf{i}} * TaskE_{\mathbf{i}}}{CapacityM}, \quad for \quad i = 1, 2, \ldots, N \tag{3.2}$$

Where:

- $Expert_{(\mathbf{T})}$ represents the experience of team member '**M**' in Task type '**T**'.
- $TaskE_{\mathbf{i}}$ represents the effort (in hours) spent on Task **i**.
- $TaskT_{\mathbf{i}}$ represents the percentage of task '**i**' score achieved by Type '**T**'.
- $Capacity_{\mathbf{M}}$ represents the capacity (in hours) of team member '**M**'.

The purpose of equation 3.2 to be correlated with developers' personalities to find any significant relationship, if any. Relationships such as: what are characteristics for tasks performed by each personality.

3.5 Task allocation theory

This study also aims to use correlations, if any, between the personalities and performance to formulate an equation that finds capability between each team member and task (equation 3.3).

$$Capability(Person_j, Task_i) = \frac{(Cr_{ij} + Ur_{ij} + Co_{ij} + Di_{ij} + Aa_{ij} + De_{ij})}{(Cr_i + Ur_i + Co_i + Di_i + Aa_i + De_i)} \tag{3.3}$$

where:

- $Capability(p, i)$: Capability of person j to perform task i.
- Cr_i, Ur_i, Co_i, Di_i, Aa_i and De_i represent degree of Creativity, Urgency, Communicate, Difficulty, Analysis and Design levels of task "i" respectively. A value between 0-10 is given for each.

- Cr_{ij}, Ur_{ij}, Co_{ij}, Di_{ij}, Aa_{ij} and De_{ij} represent result of multiplying the score of each $task_i$ characteristics by score of these characteristics in $person_j$. E.g.: Cr_{ij} = Cr_i * Cr_j.

The result of this equation is a scale ranging between -1 and 1, where -1 indicates "no capability" and 1 indicates the best capability. The PMTA model aims to allocate tasks to developers with maximum possible capability scores.

Chapter 4

Research Methodology

In this chapter, the research methodology, which is used to validate the research assumptions and PMTA model, is presented. The primary approach chosen for this study is a case study. This case study is used to demonstrate the relationship between task's characteristics and personalities. In addition, an experiment is conducted to validate the proposed model and its effectiveness.

4.1 Study Protocol

This thesis has undergone three stages (Figure 4.1). In first stage, a case study was conducted find correlations between personalities and task types based on their productivity. In this stage, the personalities are determined using Belbin and MBTI tests, which are a survey of questions. The characteristics scores are assigned by team leader of the team who participate in the case study. The productivity is measured based on the equations shown in model chapter and reset of this chapter. The correlations are built based on score of characteristic of task vs. productivity for each personality.

Secondly, significant relationships between tasks and personalities were used to build the PMTA model. This model calculates a value called capability which

has a range from -1 to 1. The model objective to assign tasks to developer with maximum capability values. This value increases by having a positive relationships and it decreases by having negative relationships. If there are no relationships, the value goes to zero.

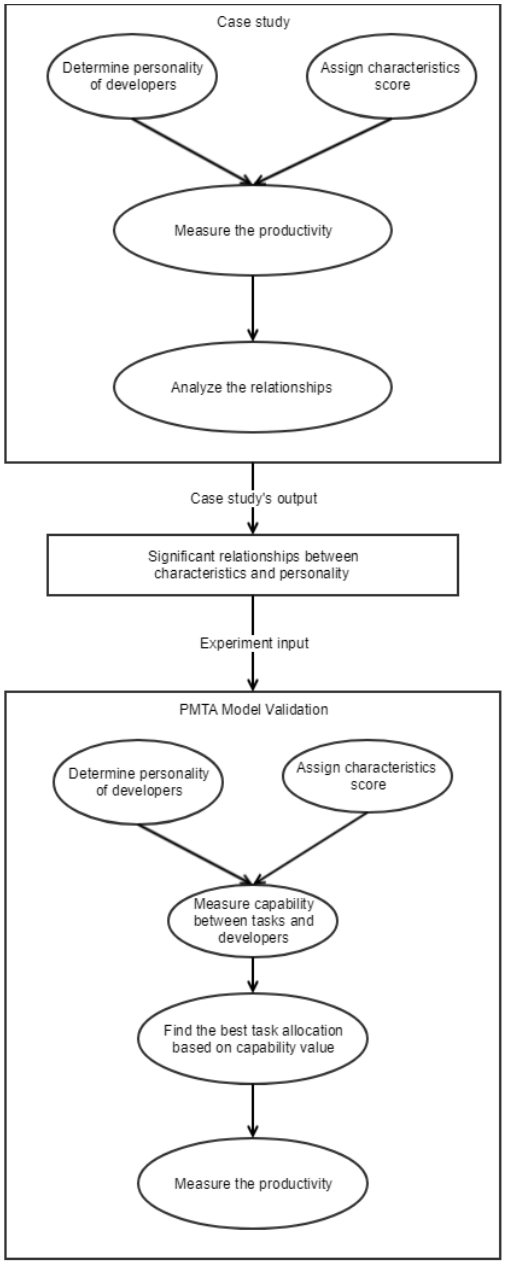
Finally, an experiment was conducted to validated the PMTA model and its effectiveness, in this experiment, same steps which are carried out at the case study, are carried out at the experiment. The only new step which is the task allocation process. The case study did not affect task allocation process. However, in case study, the task allocation is based on PMTA model.

4.2 Case Study

The data for this study were gathered at one of major software development organizations located in Palestine. Guest et al.[87] and Latham[88] suggest a team size should be between 6 to 12 participants in homogeneous groups, so in this study a team consists of 11 team members are participated in the case study. All team members also have the same role in the team which is a back-end developer. The case study does not consider the effect of developers experience or learning effort in the project, so the team members with less than two years experience in the team are excluded. In the team, there are two developers who have joined the team not long ago, so they were also excluded. As a result, only 11 members have participated in the case study. The team consists 9 males and 2 females.

The team applies the agile methodology in project management. The iteration period is 3 weeks. At the beginning of each iteration, the team meets to plan the upcoming works in the next iteration. This meeting is called the sprint

FIGURE 4.1: Study Protocol



planning meeting. During this meeting, the following activities are undertaken by the team:

- Determine the capacity of the team.

- An estimation of each product backlog item.
- Decide which user stories will be implemented in the next iteration.
- Assign tasks to the team members.

The task allocation is often a random process. In addition, there is no constraint that prevents team members to work on any task.

The project is a Web-based application, on which the team has been working for 4 years. The project is an outsourced software development project to an external client. The details of the project and the task descriptions have been hidden due to the company's privacy policy.

4.3 Data Collection

The case study data was collected over three iterations, hence each iteration takes 15 working days. The reason for picking the data during this period is because in these iterations the team is able to deliver a product release. So, it is expected to collect various kinds of data during this period.

In the beginning, the team was asked to specify their personality using MBTI and Belbin tests. Then, at the beginning of each iteration, the team leader has been asked to fill the score of each task's characteristics. He has also been asked to fill the estimated time to finish each task. Finally, at the end of each iteration, the team leader filled the actual time taken to complete the tasks.

4.4 Data Analysis

Approximately 413 tasks were collected and analyzed. The data was analyzed using the following procedures:

4.4.1 Measuring the personality score

The Belbin and MBTI tests are self-report questionnaires consisting of a set of questions, each question has a score, which represents a score related to one or more personalities. The score for each personality dimension is computed by finding the sum of scores for each group of questions associated with that dimension. The personality of biggest score represents the personality of the participant. In Belbin, it is possible to have more than one maximum value. For instance, in this case study, four developers had two maximum scores. These developers are treated to have two personalities.

4.4.2 Measuring the productivity score

The productivity score is measured by finding the difference between the actual time and estimated time taken to finish a task. There are three possible values for the productivity:

1. Positive value: means that there is a delay in delivering the task because the task is completed behind schedule.

2. Zero: which means the task is completed on schedule.

3. Negative value: means that the task is completed ahead of schedule.

4.4.3 Measuring the technical profile score

One of the aims of the study is to identify the technical profile for each member by finding characteristics from his/her history. For example, team leaders usually work on tasks that require communication with other people outside the team. As a result, the team leader gains good experience related to communicating with others. Incoming iterations, the task allocation should consider

technical profile to obtain the best efficient team allocation. Each task has a set of characteristics, including difficulty, urgency, creativity, communication, analysis, and design. The history answers the following questions:

- Is there a relationship between task characteristics and personalities based on the amount of effort spent on the task?
- For each task characteristic, which personality did the most?
- For each personality, which task characteristic he or she is usually assigned?

4.4.4 Measuring the tasks characteristics

Every characteristic has a score out of 10. For instance, a task could be difficult, urgent and require deep analysis. In this study, the task is considered to have one of the six characteristics, if the score of this characteristic is larger than the average scores for all other characteristics in that task. Equation 4.1 shows the method to check the existence of any characteristic in the task.

$$Exist(char) = \begin{cases} true & \text{if } charScore \geq AVGScore \\ false & \text{otherwise} \end{cases} \tag{4.1}$$

Where:

- $char$: represents a task characteristic
- $charScore$: the score for the characteristic $char$
- $AVGScore$: The average score for all characteristics

Definition 1. A master characteristic is a characteristic $char$ that has a maximum score $charScore$ (Max($charScore_1$,...,$charScore_n$))

Also, one characteristic could overcome the effect of the other characteristics. In this study, this characteristic is called the master characteristic. A characteristic is considered a master characteristic if the score of this characteristic has the maximum characteristic score in a task.

$$Master(char) = \begin{cases} true & \text{if } charScore = MaxScore \\ false & \text{otherwise} \end{cases} \tag{4.2}$$

where:

- $MaxScore$: The maximum characteristic score in the task.

In this study, the existence of a certain characteristic (Equation 4.1) is used to discover positive relationships. The reason for selecting this is because positive relationships is found by being productive in the task because it contains a certain characteristic even if the task contains other characteristics.

On the other hand, a master characteristic (Equation 4.2) is used to discover negative relationships. The reason for this is that it's very important to make sure that a certain characteristic hides the effect of other characteristics to prove the negative relationship in this characteristic.

4.4.5 Analyzing relationships

In this study, the Tableau[89], an interactive data visualization tool focused on Business Intelligence, is used to find the correlations between personalities and performance of team members.

The relationships between personalities and task characteristics are determined using the Trend Lines Model[1]. A linear trend model is computed for productivity (Delay) given each task characteristic. The trend model is computed

[1]https://onlinehelp.tableau.com/current/pro/desktop/en-us/trendlines_terms.html

for each personality to determine if there is a relationship or not, and what the kind of this relationship is. This trend line is built based on the hypotheses of the study (Section 4.5).

The p-value is used to confirm if a relationship is significant or not by accepting the relationship with p-value $\leqslant 0.5$ only. In addition, the line slope is used to determine whether a relationship is a positive or a negative relationship. A line with zero slope indicates a neutral relationship. Equation 4.3 shows the possible types of relationships.

$$RelationshipType(slope) = \begin{cases} Positive & \text{if } slope < 0 \\ Neutral & \text{if } slope = 0 \\ Negative & \text{if } slope > 0 \end{cases} \tag{4.3}$$

where:

- $slope$: The slope of the trend line.

4.5 Hypotheses of the study

The goal of this research is to analyze the relationships between human personality with characteristics of task. So, the following are the alternative hypotheses that are derived from the goal of this research.

H_1: There are relationships between team member personality and difficult task using Belbin Team Roles.

H_2: There are relationships between team member personality and urgent task using Belbin Team Roles.

H_3: There are relationships between team member personality and creative task using Belbin Team Roles.

H_4: There are relationships between team member personality and interaction task using Belbin Team Roles.

H_5: There are relationships between team member personality and analysis task using Belbin Team Roles.

H_6: There are relationships between team member personality and design task using Belbin Team Roles.

H_7: There are relationships between team member personality and difficult task using MBTI Team Roles.

H_8: There are relationships between team member personality and urgent task using MBTI Team Roles.

H_9: There are relationships between team member personality and creative task using MBTI Team Roles.

H_{10}: There are relationships between team member personality and interaction task using MBTI Team Roles.

H_{11}: There are relationships between team member personality and analysis task using MBTI Team Roles.

H_{12}: There are relationships between team member personality and design task using MBTI Team Roles.

H_{13}: There are relationships between team member personality and technical profile using Belbin Team Roles.

H_{14}: There are relationships between team member personality and technical profile using Myers-Briggs Type Indicator (MBTI).

Chapter 5

Results & Discussion

In this chapter, results of the study, including a statistical analysis of the data as well as validation of the PMTA model are presented. The chapter is organized as follow: It starts with a brief overview of the DataSet that has been collected. Next, the relationships between task characteristics and personalities are analyzed and determined. Finally, the result of the experiment, which is conducted to validate the effectiveness of proposed PMTA model, is illustrated.

5.1 Personality profiles

Table 5.1 shows personality profiles for each developer who participated in the case study. The personality profiles are shown for both Belbin and MBTI indicators. The table shows that 6 out of the 9 Belbin's team roles are found in the team. Unfortunately, Monitor Evaluator, Specialist, and Team worker team roles are not found in the participant sample for this study. Additionally, Four developers have two maximum scores of Belbin's team roles, so they are considered to have two team roles. The table also shows that the participant sample has eight MBTI roles. The ISFJ role is found in 3 developers, the ISTJ role is

found in 2 developers, while the other roles are unique in each of the remaining developers.

TABLE 5.1: Data Showing Personality of Members for both Belbin and MBTI.

Developer	Belbin	MBTI
1	Implementor and Coordinator	ESFJ
2	Implementor and Complete Finisher	ISTJ
3	Shaper	ISFJ
4	Coordinator	ENFJ
5	Implementor	ISFJ
6	Plant	ENTP
7	Complete Finisher	ISTJ
8	Coordinator and Plant	ENTJ
9	Implementor and Resource Investigator	ISFJ
10	Plant	ESTJ
11	Resource Investigator	ENFP

The table indicates the existence of some correlations between Belbin and MBTI roles:

- MBTI role for Implementor developer is always xSxJ.
- MBTI role for Plant developer is always ExTx.
- MBTI role for Coordinator developer is always ExxJ.
- MBTI role for Resource Investigator developer is always xxFx.
- MBTI role for Complete Finisher developer is always ISTJ.

Some of these correlations could be generalized because it refers to more than three developers (e.g., Implementor and Plant). We cannot, however, generalize the other correlations since they occur in only two developers. The results show (Table 5.1) that Implementor is the most frequent role(4/11). On the other hand, Shaper is the least frequent role which is found in only one developer.

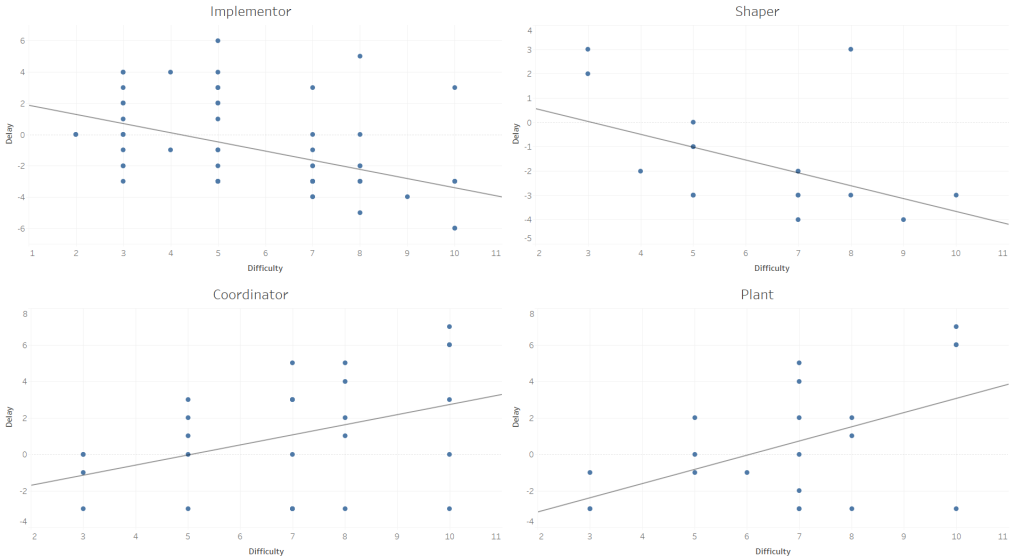
5.2 Difficulty

This section shows the relationships between difficult tasks and personalities based on the productivity of developers to perform the difficult tasks. Hence, in this thesis, task difficulty refers to estimated time required to finish the task.

5.2.1 Difficulty vs. Belbin

This section shows the relationships between Belbin's profiles and the productivity to perform the difficult tasks (Hypothesis H_1). Based on Belbin classification, four personalities have significant relationships with task difficulty. As shown in figure 5.1, the relationship is positive in the Implementor (69 difficult tasks) and Shaper (18 difficult tasks) team roles. On the other hand, they are negative for Plant (47 difficult tasks) and Coordinator (53 difficult tasks) team roles. For the Complete Finisher and Resource Investigator, the relationships aren't significant.

FIGURE 5.1: Difficulty vs Belbin



These results agree with the observations of Belbin, according to the implementor and Shaper team roles. However, the results disagree with Belbin who said that Plant tends to solve a difficult problem. Moreover, Plant and Complete Finisher team roles, which have negative relationships, have a common weakness, which is ignoring the details and small things. This weakness could be the reason that they are not productive in difficult tasks, since the difficult task in this study based on an amount of effort required to the task, which contains a lot of details.

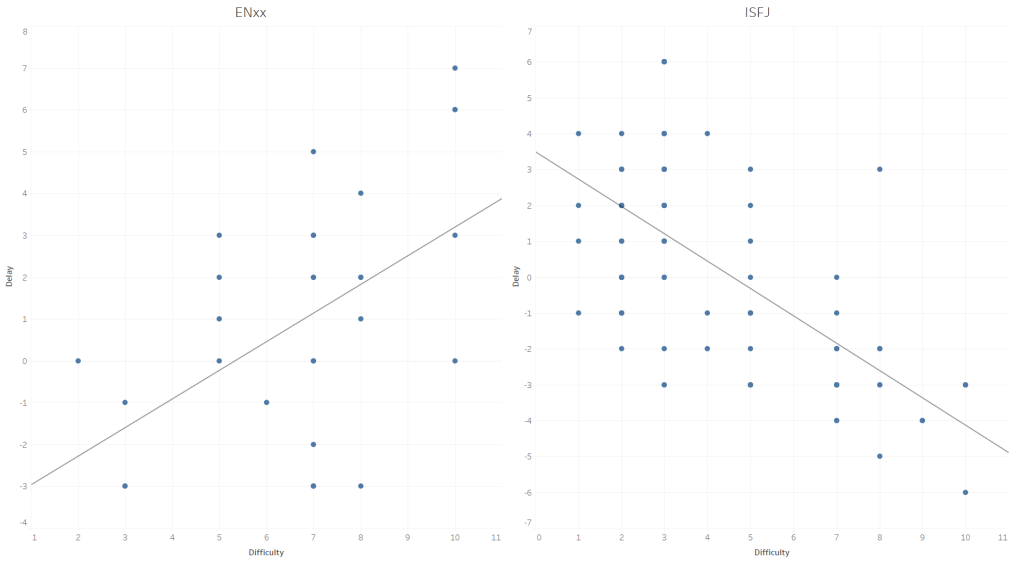
5.2.2 Difficulty vs MBTI

This section shows the relationships between MBTI team roles and productivity in difficult tasks(Hypothesis H_7). Based on MBTI classification, ISFJ team role (115 difficult tasks) has a significant relationship with task difficulty. This relationship also is positive as it's shown in figure 5.2 below. On the other hand, the figure also shows that ENxx team roles (30 difficult tasks) have a significant negative relationship with task difficulty.

According to MBTI, ENxx personalities rely on their imagination and ability to see the big picture. On the other hand, difficult tasks may require various knowledge and abilities which require some help from others. This contradiction could cause weaknesses in performing difficult tasks.

The ISFJ team roles have the ability to work for long periods of time and put tremendous amounts of energy into doing any task subsequently resulting in an increase in their productivity in the difficult task.

FIGURE 5.2: Difficulty vs MBTI



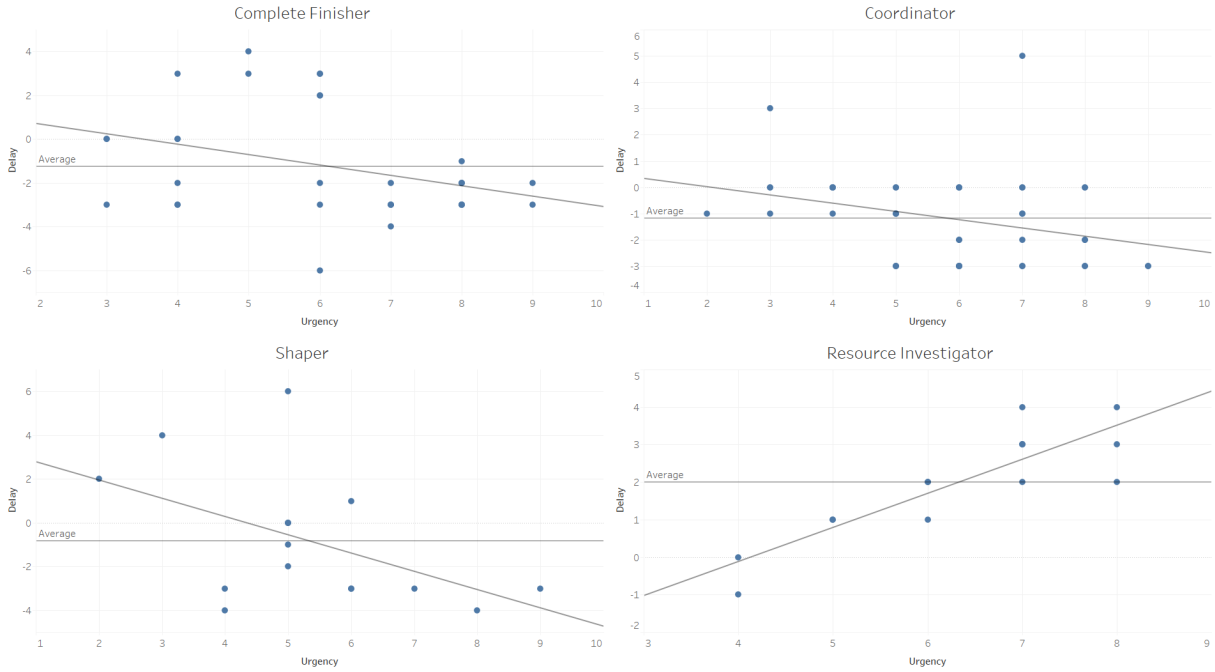
5.3 Urgency

This section shows the relationships between urgent tasks and personalities based on the productivity of developers to perform the urgent tasks(Hypothesis H_2 and H_8), which refers to time sensitivity of a task in a particular situation as well as the importance of the task.

5.3.1 Urgency vs Belbin

Figure 5.3 shows that there are three Belbin roles, which are Complete Finisher(33 urgent tasks), Coordinator(44 urgent tasks), and Shaper(16 urgent tasks), have significant positive relationships with task urgency. On the other hand, it also shows that Resource Investigator (15 urgent tasks) has a significant negative relationship with task urgency. Lastly, the relationships in Implementor and Plant team roles aren't significant.

FIGURE 5.3: Urgency vs Belbin



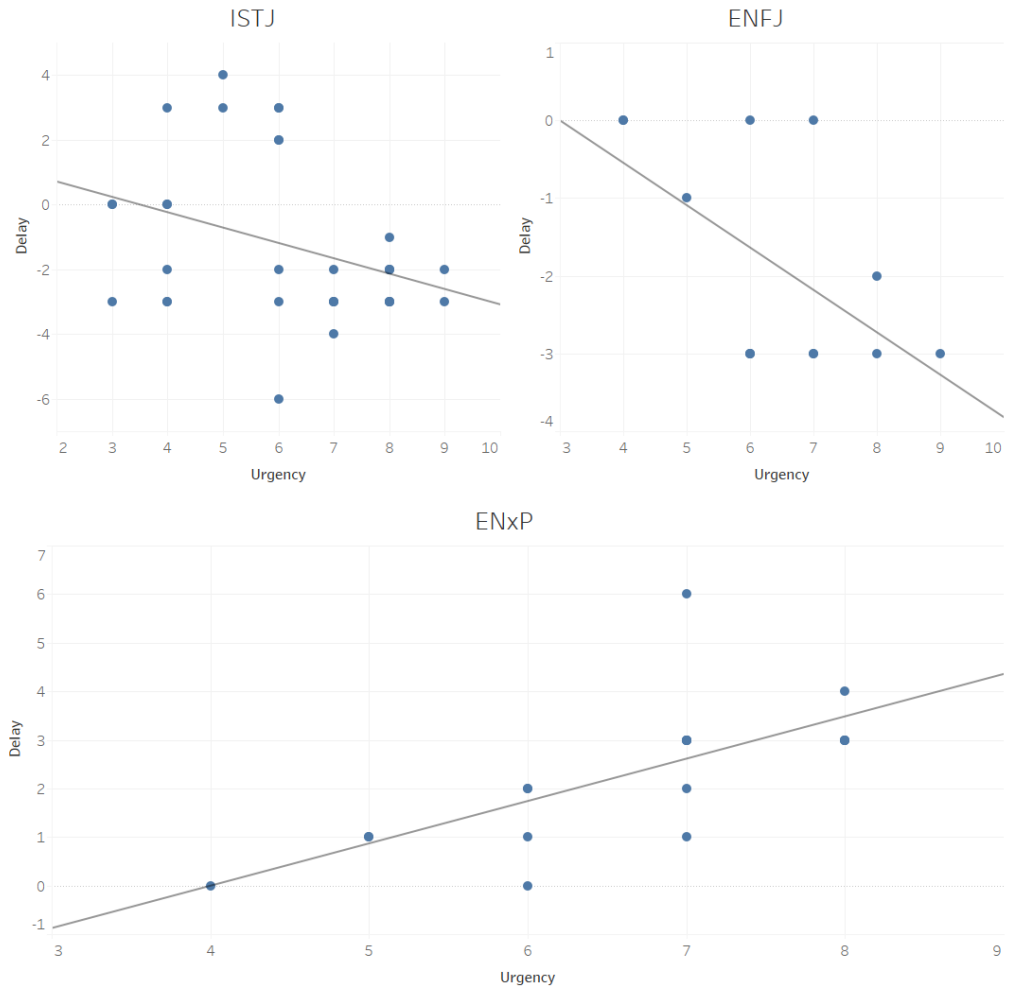
The results are expected based on Belbin team roles characteristics. For instance, Complete Finisher, Coordinator and Shaper tend to deliver on time, thrive on pressure, be mature and confident. These characteristics are very important in working on urgent issues. On the other hand, Resource Investigator team role gets bored very easily, so he/she isn't productive under pressure.

5.3.2 Urgency vs MBTI

Figure 5.4 shows that ISTJ(33 urgent tasks) and ENFJ (13 urgent tasks) have significant positive relationships with urgent tasks. On the other hand, ENxP (20 urgent tasks) roles show a significant negative relationship with task urgency.

The results are expected due to the way of making decisions by the different roles. ISTJ and ENFJ personalities make decisions quickly, due to the **J** letter,

FIGURE 5.4: Urgency vs MBTI



which refers to the speed in making decisions. In contrast to EN**P** personalities who make decisions slowly due to the **P** letter.

5.4 Creativity

This section shows the relationships between creative tasks and personalities based on the productivity of developers to perform the creative tasks (Hypothesis H_3 and H_9). Hence, in this thesis, creative task refers to novelty of the task for the team member.

5.4.1 Creativity vs Belbin

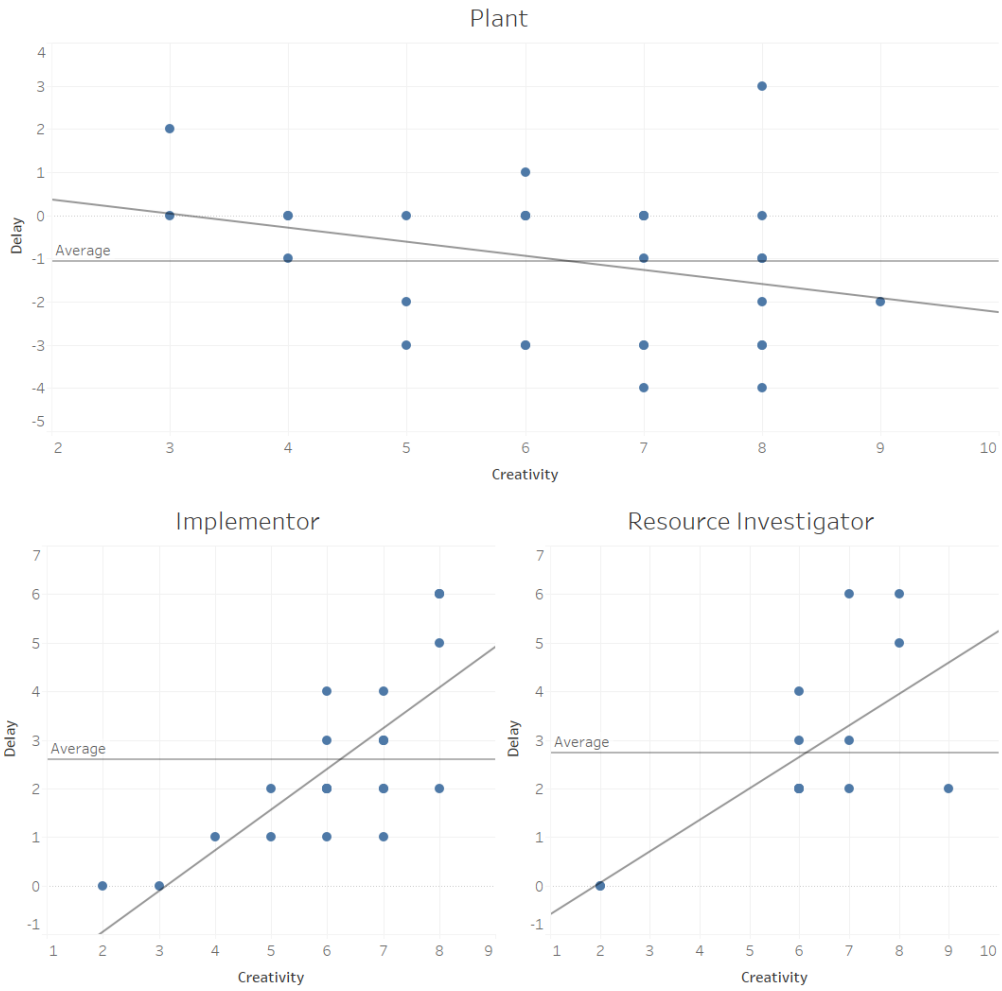
Regarding the task's creativity, Figure 5.5 shows that Plant (31 creative tasks) is the only team role that has a significant positive relationship with creative tasks. On the other hand, the figure shows that the Implementor (25 creative tasks) and Resource Investigator (15 creative tasks) team roles have a significant negative relationship with creative tasks. The relationships in Complete Finisher, Coordinator and Shaper team roles are not significant.

The results agree with Belbin who says that Plant is creative. Belbin also says that implementor team role is not creative. In addition, Resource Investigator team role is a weak response to challenge, and consequently, Resource Investigator is not productive in creative tasks which require an ability to solve the challenges.

5.4.2 Creativity vs MBTI

Figure 5.6 shows that ExTJ roles (21 creative tasks) have a significant positive relationship with task creativity. On the other hand, xxFx roles(34 creative tasks) show a significant negative relationship with task creativity. Creativity depends on thinking outside the box[90]. Moreover, in MBTI roles, ExTJ team roles deal with things rationally and logically, in contrast to xxFx team roles who take the emotions into consideration. This contrast explains why ExTJ team roles have

FIGURE 5.5: Creativity vs Belbin

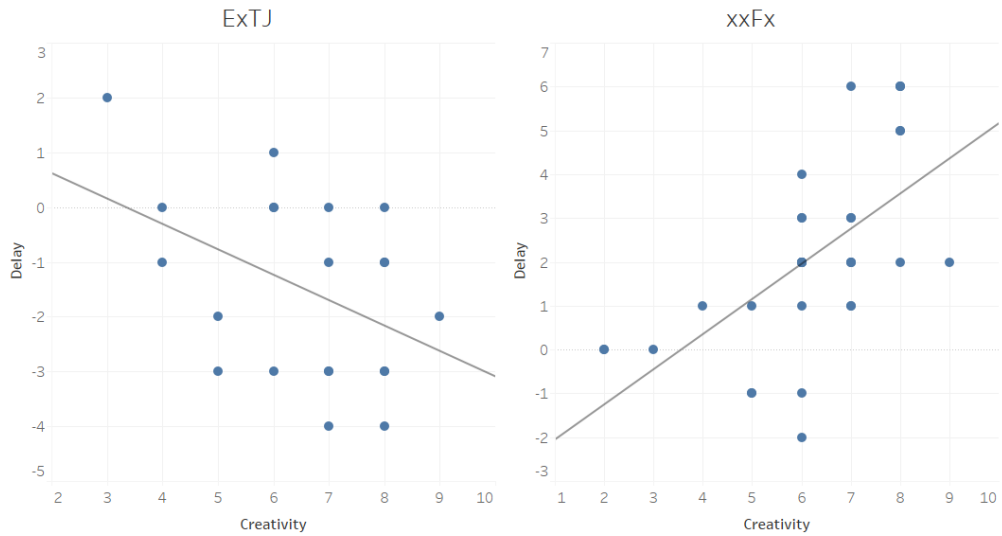


a positive relationship, while xxFx team roles have a negative relationship with creativity.

5.5 Social interaction

In this section, the relationship between the tasks that required a communication skill, and Belbin and MBTI personalities are presented (Hypothesis H_4 and H_{10}).

FIGURE 5.6: Creativity vs MBTI

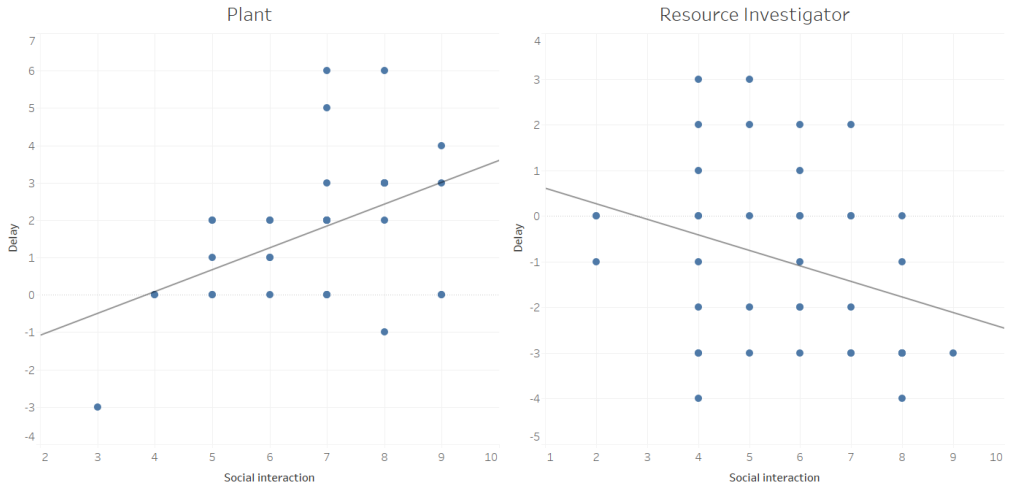


5.5.1 Social interaction vs Belbin

In social tasks, there are two significant relationships (Figure 5.7). First one is a positive relationship which is found in Resource Investigator team role(40 social tasks). The second one is a negative relationship which is found in Plant team role(36 social tasks). In addition, the relationships for other team roles are not significant.

According to Belbin, Resource Investigator team role is communicative, sociable and having a set of good communication skills. On the other hand, Belbin says that Plant team role has poor communication skills. So, the results agree with Belbin according to the task that required communication skills. Belbin also says that Shaper has poor communication skills, however, these result isn't found in this study.

FIGURE 5.7: Social interaction vs Belbin



5.5.2 Social interaction vs MBTI

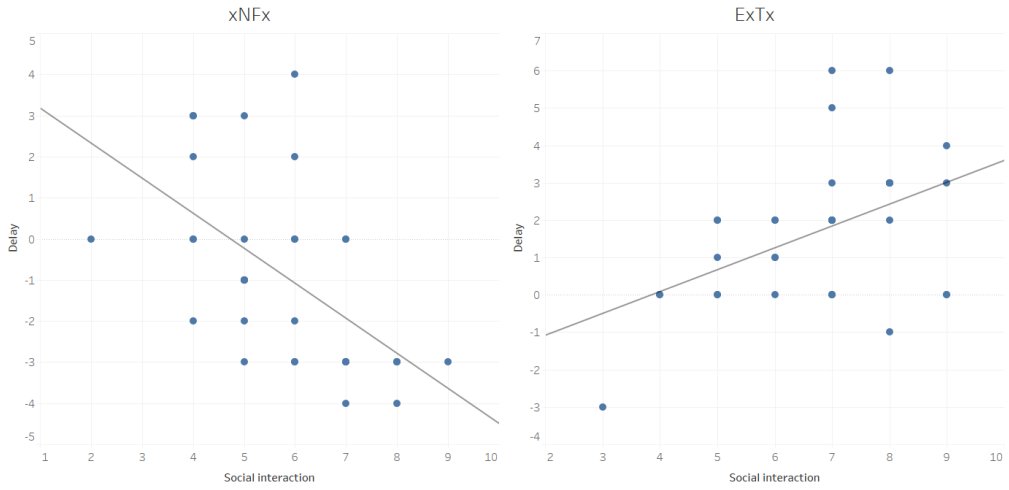
The relationships in MBTI team roles, which are shown in figure 5.8, xNFx roles have a significant positive relationship with social tasks(35 social tasks). On the other hand, ExTx roles show a significant negative relationship with social tasks(36 social tasks).

The results show that NF's personalities have good communication skills, this result agrees with Colvin-Sterling[65] results which say that NF personalities communicate and work with others.

5.6 Analysis

This section shows the relationships between analysis tasks and personalities based on the productivity of developers to perform the analysis tasks (Hypothesis H_5 and H_{11}). Hence, analysis refers to understanding task's problem. In analysis tasks, it is noticed that all significant relationships found are negative.

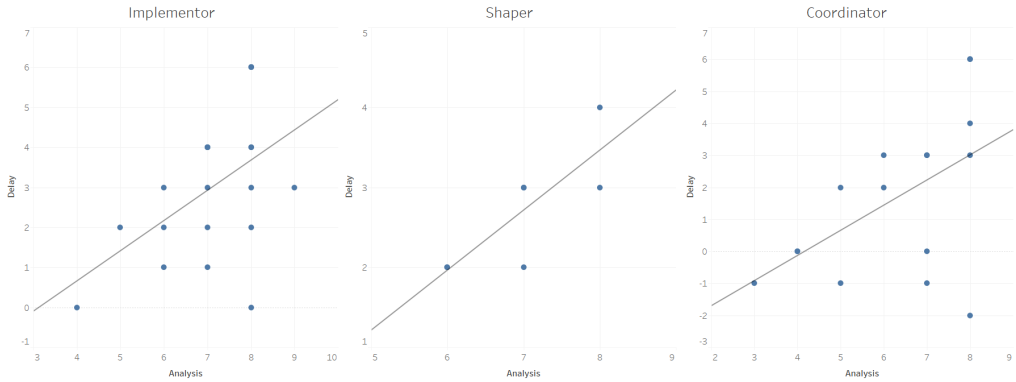
FIGURE 5.8: Social interaction vs MBTI



5.6.1 Analysis vs Belbin

Figure 5.9 shows that Implementor(20 analysis tasks), Coordinator(15 analysis tasks), and Shaper(7 analysis tasks) team roles have a significant negative relationship. According to Belbin, Implementor and Coordinator team roles suffer from an unclear problem, so they are not productive in analysis tasks, because analysis tasks require working on an unclear problem.

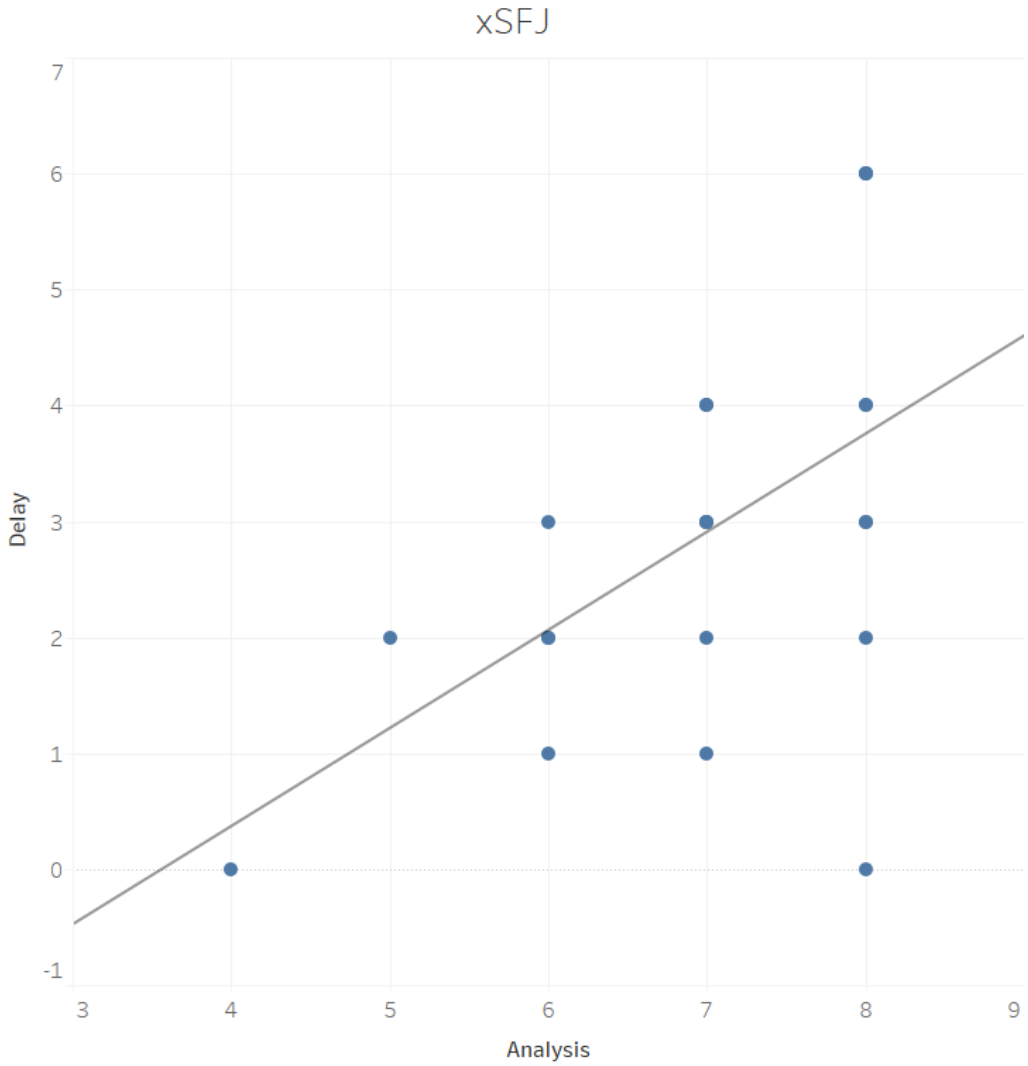
FIGURE 5.9: Analysis vs Belbin



5.6.2 Analysis vs MBTI

Similar to Belbin, In MBTI, xSFJ roles(22 analysis tasks) have a negative relationship. Hence, there is no positive relationship. Figure 5.10 shows the xSFJ relationship with analysis tasks.

FIGURE 5.10: Analysis vs MBTI



Vicente Rodríguez Montequín et al.[44] concluded that N's personalities are

good at analysis. In this study, there is no positive relationship. The results show SFJ's personalities are not productive in analysis tasks. This result tends to contradict Colvin-Sterling[65] result which says SJ's personalities have the skills of analysis.

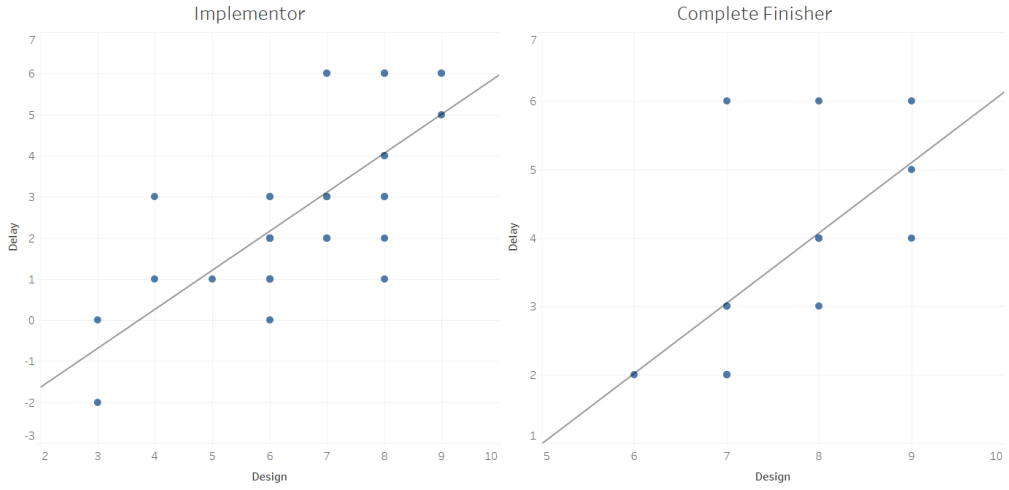
5.7 Design

This section shows the relationships between design tasks and personalities based on the productivity of developers to perform the design tasks (Hypothesis H_6 and H_{12}). Hence, design refers to figuring out how to organize task's solution.

5.7.1 Design vs Belbin

Figure 5.11 shows that Implementer(40 design tasks) and Completer Finisher(16 design tasks) team roles have significant negative relationships with design tasks. Moreover, there is no positive relationship found.

FIGURE 5.11: Design vs Belbin

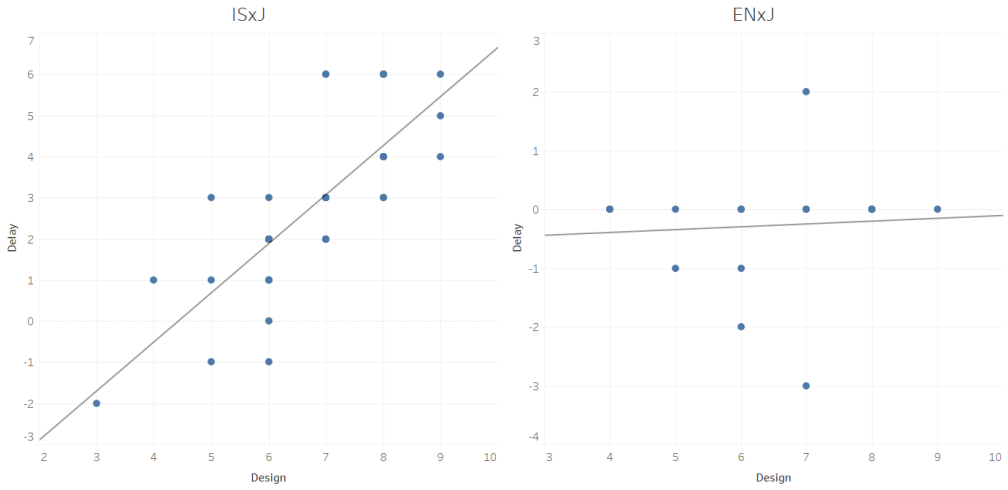


According to Belbin, Implementer team role is inflexible in accepting new ways of doing things. This may be the reason to make them not productive at design tasks which require finding new solutions. Moreover, Belbin says Plant, Shaper and Resource Investigator are productive in design tasks, which are the ability to find a solution for problems. Unfortunately, these relationships are not found.

5.7.2 Analysis vs MBTI

Regarding design tasks, figure 5.12 shows that ISxJ roles(47 design tasks) have a significant negative relationship. The figure also shows that the 91% of developers with ENxJ (18 design tasks) personalizes, have finished the design task with a delay less than zero. That means the tasks have been finished on time.

FIGURE 5.12: Analysis vs MBTI



According to MBTI roles, ISxJ team roles resist putting energy into things which don't make sense to them, so they are not good in design tasks which

require to finding new solutions. On the other hand, ENxJ team roles are imaginative, creative and enjoy new challenges. So ENxJ team roles are good in design tasks.

5.8 Technical profile

One of the study objectives is to investigate if there is a relationship between Technical profiles and personalities. In this study, the technical profile is measured based on the history of the team member in the team by finding the category of tasks that have been usually performed by each personality.

In this study, for each personality, the type of tasks' characteristics performed is calculated. The objective is to find, who performs significantly a certain type of task more than other types of task. For instance, is usually Implementor team role assigned difficult tasks?

5.8.1 Belbin vs. Technical profile

Table 5.2 shows the percentage of the existence of each tasks' characteristic for the tasks that performed by each personality. For example, 46.5% of tasks performed by Coordinator are difficult. Unfortunately, this table does not contain any significant relationship.

Table 5.3 shows the average score for each tasks' characteristic for the tasks that performed by each personality based on Belbin. For example, the average score for analysis tasks performed by Plant team role is 3.88 out of 10. Unfortunately, this table also does not contain any significant relationship.

TABLE 5.2: Belbein vs. Technical profile

Role	Difficulty	Urgency	Creativity	Social interaction	Analysis	Design
Implementor	**45.40%**	**42.76%**	**25%**	**44.08%**	**28.95%**	**42.76%**
Complete Finisher	**47.40%**	**43.42%**	**27.63%**	**46.00%**	**34.21%**	**36.84%**
Coordinator	**46.50%**	**38.60%**	**24.56%**	**46.50%**	**36.84%**	**45.61%**
Plant	**41.96%**	**36.61%**	**27.68%**	**41.96%**	**50.00%**	**48.21%**
Resource Investigator	**46.10%**	**42.11%**	**30.26%**	**52.60%**	**36.84%**	**42.11%**
Shaper	**45%**	**40%**	**22.50%**	**40.00%**	**50%**	**40%**
All	**45.28%**	**40.20%**	**26.63%**	**44.31%**	**38.98%**	**44.55%**

TABLE 5.3: Belbin: Average score for each characteristics

Role	Difficulty	Urgency	Creativity	Social	Analysis	Design
Implementor	**3.99**	**3.434**	**3.65**	**3.6**	**2.99**	**3.6**
Complete Finisher	**3.95**	**3.84**	**2.79**	**3.88**	**3.17**	**3.5**
Coordinator	**4.05**	**3.4**	**2.87**	**3.76**	**3.33**	**3.77**
Plant	**3.95**	**3.44**	**3.17**	**3.8**	**3.88**	**3.8**
Resource Investigator	**3.91**	**3.38**	**3.08**	**3.9**	**3.18**	**3.42**
Shaper	**3.93**	**3.13**	**2.4**	**3.5**	**3.5**	**3.13**
All	**3.99**	**3.47**	**2.9**	**3.74**	**3.33**	**3.63**

5.8.2 MBTI vs. Technical profile

Table 5.4 shows the percentage of the existence of each tasks' characteristic for the tasks that performed by each personality based on MBTI. For example, 46.15% of tasks performed by ENTP are designed. Unfortunately, this table does also not contain any significant relationship.

Table 5.5 shows the average score for each tasks' characteristic for the tasks that performed by each personality based on MBTI. For example, the average score for analysis tasks performed by ISFJ team role is 2.3 out of 10. Unfortunately, this table also does not contain any significant relationship.

In this study, the technical profile does not show any relationship between

TABLE 5.4: MBTI vs. Technical profile

Role	Difficulty	Urgency	Creativity	Social	Analysis	Design
ISTJ	**47.37%**	**43.42%**	**27.63%**	**46.05%**	**34.21%**	**36.84%**
ISFJ	**45.22%**	**41.74%**	**22.61%**	**41.74%**	**38.26%**	**45.22%**
ESFJ	**43.59%**	**41.03%**	**25.64%**	**46.15%**	**25.64%**	**38.46%**
ENFJ	**50%**	**36.11%**	**22.22%**	**52.78%**	**33.33%**	**44.44%**
ENTP	**35.90%**	**38.46%**	**25.64%**	**43.59%**	**43.59%**	**46.15%**
ENTJ	**46.15%**	**38.40%**	**25.64%**	**41.03%**	**51.28%**	**51.28%**
ESTJ	**44.12%**	**32.35%**	**32.35%**	**41.18%**	**55.88%**	**47.06%**
ENFP	**48.57%**	**42.86%**	**40.00%**	**45.71%**	**37.14%**	**51.43%**
All	**45.28%**	**40.19%**	**26.63%**	**44.31**	**38.98%**	**44.31%**

TABLE 5.5: MBTI: Average score for each characteristics

Role	Difficulty	Urgency	Creativity	Social	Analysis	Design
ISTJ	**3.95**	**3.84**	**2.79**	**3.88**	**3.17**	**3.51**
ISFJ	**4.04**	**2.3**	**2.58**	**3.52**	**3.18**	**3.5**
ESFJ	**3.87**	**3.31**	**2.86**	**3.87**	**2.85**	**3.79**
ENFJ	**4.14**	**3.5**	**2.72**	**3.69**	**3.25**	**3.5**
ENTP	**3.38**	**3.51**	**3.08**	**3.69**	**3.49**	**3.46**
ENTJ	**4.15**	**3.39**	**3.03**	**3.72**	**3.87**	**4.03**
ESTJ	**4.35**	**3.41**	**3.44**	**4.03**	**4.35**	**4.03**
ENFP	**4**	**3.51**	**3.57**	**3.83**	**3**	**3.66**
All	**3.99**	**3.47**	**2.9**	**3.74**	**3.3**	**3.63**

personalities and task characteristics. The reason for that probably is the tasks are allocated among developers based on developer's experiences, which do not relate to tasks' characteristic. The period, which the tasks are picked up, is relatively short. Future work should pick up tasks from a longer period.

5.9 Discussion

Tables 5.6 and 5.7 summarize the relationships between Belbin and MBTI personalities with Task characteristics. Hence, the **+** singe, which is colored green, means the relationship is positive, where the **-** sign, which is colored yellow, means the relationship is negative. Moreover, empty element, which is colored

gray, means there is no relationship.

Regarding the MBTI roles, the element value refers generalization condition. For instance, any developer with "EN" combination has a negative relationship with difficult tasks.

5.9.1 Belbin

TABLE 5.6: The Relationship between Task characteristic and Belbin roles

Role	Difficulty	Urgency	Creativity	Social	Analysis	Design
Implementor	+		-		-	-
Complete Finisher		+				-
Coordinator	-	+			-	
Plant	-		+	-		
Resource Investigator		-	-	+		
Shaper	+	+			-	

Belbin results (Table 5.6) show that 50% of relationships are significant. Moreover, 61.1% of these relationships positive, and 38.9% are negative. The results show that Implementor is productive if task requires long time only, due to the fact that he good to converts plans into practical workable activities. However, Implementor is not creative, so he is not productive if he is not familiar with task, task's problem is ambiguous and task has a difficult solution. Complete Finisher usually delivers on time, so he tends to be good at urgent issue, however, Complete Finisher is not productive if task's solution is difficult. Coordinator is usually confident, so he tends to be productive in urgent issue. However, he does not have creative ability so he is unproductive in analysis tasks, which require creative ability. He also is unproductive in difficult tasks, which requires work for long time in the task since he tends to lose his concentration easily. Plant is creative and innovative, so he to be productive in creative tasks. However, Plant can't deal tasks with too much details, which is one the main property

for difficult tasks, so he is unproductive in difficult tasks. Lastly, Plant has a poor communication skills, so it's expected to be bad in communication tasks. In contrast to Plant, Resource Investigator is productive in communication tasks because he is communicative. However, he is weak respond to challenge, so he is not good in urgent and creative tasks. Finally, Shaper thrives on pressure, so he is productive in difficult and urgent task.

5.9.2 MBTI

TABLE 5.7: The Relationship between Task characteristic and MBTI roles

Role	Difficulty	Urgency	Creativity	Social interaction	Analysis	Design
ISTJ		**ISTJ +**				**ISxJ -**
ISFJ	**ISFJ +**		**xxFx -**		**xSFJ -**	**ISxJ -**
ESFJ			**xxFx -**		**xSFJ -**	
ENFJ	**ENxx -**	**ENFJ +**	**xxFx -**	**xNFx +**		**ENxJ +**
ENTP	**ENxx -**	**ENxP -**	**ExTJ +**	**ExTx -**		
ENTJ	**ENxx -**		**ExTJ +**	**ExTx -**		**ENxJ +**
ESTJ			**ExTJ +**	**ExTx -**		
ENFP	**ENxx -**	**ENxP -**		**xNFx +**		

MBTI results show that 54.2% of relationships are significant. Moreover, 61.5% of these relationships negative, and 38.5% are positive. The results show 12 different significant relationships that describe developers capability based on their MBTI. Only one relationship is found in one mental function which are (**F**) mental. Three relationships are based on two mental functions which are **EN**, **NF**, and **ET**. Four relationships are based on four mental functions which are **SFJ**, **ISJ**, **ETJ**, **ENJ**, and **ENP**. Finally, two relationships are based on the four mental functions which are **ENFJ** and **ENFJ**. The following are significant relationships in MBTI:

1. **F**: Team roles with **F** mental use emotions instead of logic to make a decision. So, they tend to be bad in the creative task because it requires logical decisions.

2. **EN**: Those team roles prefer to work with others. However, difficult tasks required to work for a long time alone, so they are unproductive in difficult tasks.

3. **NF**: Because **NF** team roles take opinions of others into consideration, they are productive in social tasks.

4. **ET**: In contrast to **NF**, **ET** do not consider opinions of others. So, they are unproductive in social tasks.

5. **SFJ**: SFJ's may be unable to understand logic and they rely on their emotion in thinking, thus they are unproductive in analysis and creative tasks which require an ability to understand task's problem.

6. **ISJ**: ISJ's may be unable to correctly judge what really is for the best, thus they are unproductive in design tasks which require an ability to choose the best solution among many alternatives.

7. **ETJ**: ETJ's people are genuinely interested in thoughts and logical in thought, so they are productive in creative tasks. On other hands, ETJ's have difficulty listening to others, as a result that, they are bad in social tasks which require a high skills in listening to others.

8. **ENJ**: ENJ's are unproductive in difficult tasks because of **E** mental. On the other hand, ENJ's are known to be driven to turn theories into plans, thus they are productive in design tasks which refer to generating solutions.

9. **ENP**: Similar to **E**'s people, they are unproductive in difficult tasks. Moreover, they make decisions slowly, thus they are also unproductive in urgent issue.

10. **ISTJ**: Similar to **ISJ**, they are unproductive in design tasks. On the other hand, ISTJ are productive under pressure (urgent tasks), since they able to accomplish almost anything if they put their minds to it.

11. **ENFJ**: Those people are unproductive in difficult and creative task due to **F** and **EN** mental respectively. On the other hand, they are productive in social and design task due to **NF** and **ENJ** mental respectively. Moreover, ENFJ's have ability to make creative and valuable use of time, thus they are productive in urgent tasks.

12. **ISFJ**: Similar to **F**, **SFJ** and **ISJ**, they are unproductive in creative, analysis and design tasks respectively. On the other hand, ISFJ are depended on to follow things through to completion and work hard to get the job done, thus they are productive in difficult tasks.

5.9.3 Technical Profile

The results show no significant relationship based on history of previous task allocation. That means task decomposition that is used in this study does not work well. the reasons for that probably

- The tasks are allocated among developers based on developer's experiences, which do not relate to tasks' characteristic

- The data is not enough, so future work should therefore investigate more data.

So, future work should use different task decomposition which is already used in task allocation process such as technical skills.

5.10 PMTA Model Validation

In order to validate the proposed model, an experiment has been conducted on the team. In this experiment, the team leader assigned a set of tasks using capability, which is shown in equation 3.3, between the task characteristics and team member personality.

The experiment duration is one week. The same team, who have participated in the case study, have participated in experiment. The team worked on 44 tasks. The task allocation process has been done manually based on capability score calculated by equation 5.1.

5.10.1 A capability matrix

A capability matrix has been defined for the developers based on the relationships of Belbin and MBTI personalities. The matrix elements value depends on the type of relationship, which is shown in equation 5.1.

$$\text{Relationship Values} = \begin{cases} 1 & for \text{ Positive relationship} \\ 0 & for \text{ Neutral relationship} \\ -1 & for \text{ Negative relationship} \end{cases} \tag{5.1}$$

Based on tables 5.1, 5.6 and 5.7, Table 5.8 shows the capabilities between the developers and the characteristics of task. For instance, if characteristics scores of **task_x** for difficulty, urgency, creativity, social, analysis and design are 5, 6, 2, 8, 3 and 1 respectively. The capability score for **dev2** is 0.04, which is shown in 5.2.

$$Capability(dev2, task\_x) = \frac{5*1+6*1+2*0+8*0+3*-1+1*-1}{5+6+2+8+3+1} \quad (5.2)$$

TABLE 5.8: The capabilities between the developers and the characteristics of task

Developer	Difficulty	Urgency	Creativity	Social	Analysis	Design
Dev 1	0	1	-1	0	-1	-1
Dev 2	1	1	0	0	-1	-1
Dev 3	1	1	-1	0	-1	-1
Dev 4	-1	1	-1	1	-1	1
Dev 5	1	0	-1	0	-1	-1
Dev 6	-1	-1	1	-1	0	0
Dev 7	0	1	0	0	0	-1
Dev 8	-1	1	1	-1	-1	1
Dev 9	1	-1	-1	1	-1	-1
Dev 10	-1	0	1	-1	0	0
Dev 11	-1	-1	-1	1	0	0

This table is an input for the capability equation 3.3, which finds the capability between task and developer. The result of this equation is a score range of -1 to 1. The -1 means the capability is not found at all, where 1 means the capability is highly desirable. Figure 5.13 is a screenshoot that shows capability scores between tasks and developers.

Based on the result of capability results between the developers and the tasks, the tasks have been allocated to the developers resulting the maximum possible capabilities.

5.10.2 Validation result

This study aims to provide a task allocation to improve the team productivity, which refers to the delay to finish tasks. In the case study, the total expected time

FIGURE 5.13: Capability scores for the developers

Tasks	dev 1	dev 2	dev 3	dev 4	dev 5	dev 6	dev 7	dev 8	dev 9	dev 10	dev 11	Es
TA1120	-0.5833333333	-0.2083333333	-0.375	-0.25	-0.4166666667	-0.2083333333	-0.1666666667	-0.1666666667	-0.3333333333	-0.1666666667	-0.2916666667	
TA1121	-0.08333333333	0.25	0.1666666667	0.1666666667	0	-0.6666666667	0.08333333333	-0.3333333333	0.1666666667	-0.5	-0.1666666667	
TA1122	-0.5185185185	-0.2222222222	-0.3333333333	-0.03703703704	-0.4074074074	-0.2962962963	-0.1851851852	-0.1111111111	-0.3333333333	-0.2222222222	-0.2222222222	
TA1123	0.05263157895	0.3157894737	0.2105263158	0.1578947368	-0.2105263158	-0.5263157895	0.3157894737	0.2631578947	-0.5789473684	-0.1052631579	-0.6315789474	
TA1124	-0.2352941176	0	-0.05882352941	0.05882352941	-0.1764705882	-0.5882352941	0.05882352941	-0.5294117647	0.05882352941	-0.4705882353	0	
TA1125	-0.1071428571	0.2142857143	0.1428571429	0.07142857143	-0.1428571429	-0.5357142857	0.1071428571	0.07142857143	-0.3571428571	-0.25	-0.5357142857	
TA1126	-0.7142857143	-0.4642857143	-0.6428571429	-0.1428571429	-0.6785714286	-0.0714285714	-0.2142857143	-0.0714285714	-0.5714285714	-0.03571428571	-0.1428571429	
TA1127	0.25	0.625	0.5625	0.125	0.125	-0.75	0.375	0.125	-0.25	-0.3125	-0.75	
TA1128	-0.1052631579	0.4210526316	0.2631578947	-0.1578947368	0.05263157895	-0.5263157895	0.1052631579	-0.05263157895	-0.05263157895	-0.3157894737	-0.6315789474	
TA1129	0.1363636364	0.6363636364	0.5909090909	-0.09090909091	0.3181818182	-0.8181818182	0.2272727273	-0.2727272727	0.1818181818	-0.5454545455	-0.6363636364	
TA1130	-0.4482758621	-0.1724137931	-0.3793103448	-0.03448275862	-0.4827586207	-0.2413793103	0	-0.1724137931	-0.3103448276	-0.1379310345	-0.1034482759	
TA1131	0	0.2272727273	0.1363636364	0.4545454545	-0.09090909091	-0.6818181818	0.1363636364	-0.1818181818	0.09090909091	-0.4545454545	-0.04545454545	
TA1132	-0.5	-0.3888888889	-0.4444444444	0.1111111111	-0.5555555556	-0.3333333333	-0.1111111111	-0.2222222222	-0.4444444444	-0.2222222222	0	
TA1133	-0.04545454545	0.4090909091	0.3181818182	-0.1818181818	0.04545454545	-0.5909090909	0.1818181818	-0.09090909091	-0.1818181818	-0.3181818182	-0.6818181818	
TA1134	0.04	0.48	0.4	-0.04	0.08	-0.64	0.2	0.04	-0.2	-0.32	-0.72	
TA1135	-0.3846153846	0.2307692308	0	-0.3846153846	-0.07692307692	-0.3076923077	-0.07692307692	-0.07692307692	-0.07692307692	-0.2307692308	-0.6153846154	
TA1136	0	0.3103448276	0.2413793103	0.3103448276	-0.03448275862	-0.6551724138	0.1034482759	0.03448275862	-0.1034482759	-0.3793103448	-0.3793103448	
TA1137	-0.5714285714	-0.380952381	-0.4285714286	0.04761904762	-0.5238095238	-0.2857142857	-0.2380952381	-0.04761904762	-0.5238095238	-0.1904761905	-0.1904761905	
TA1138	-0.3529411765	0.05882352941	-0.2352941176	0.05882352941	-0.3529411765	-0.2352941176	0	0.05882352941	-0.1764705882	-0.1176470588	-0.2352941176	
TA1140	-0.1666666667	0.08333333333	0	0.3333333333	-0.08333333333	-0.6666666667	0	-0.5	0.3333333333	-0.5833333333	0.1666666667	
TA1142	-0.5	0.05555555556	-0.3333333333	-0.2222222222	-0.4444444444	0	-0.05555555556	0.3333333333	-0.4444444444	0.1111111111	-0.5555555556	
TA1143	0.09090909091	0.3181818182	0.2272727273	0.3636363636	-0.1818181818	-0.5909090909	0.2727272727	0.2727272727	-0.4545454545	-0.1818181818	-0.5	
TA1146	-0.3333333333	-0.04166666667	-0.125	-0.1666666667	-0.25	-0.4583333333	0.04166666667	-0.4166666667	-0.1666666667	-0.3333333333	-0.2083333333	
TA1147	-0.2666666667	0.06666666667	-0.06666666667	-0.06666666667	-0.2666666667	-0.4	0.06666666667	-0.06666666667	-0.3333333333	-0.2	-0.4	
TA1148	-0.2631578947	0.05263157895	0	0.1578947368	-0.05263157895	-0.6315789474	-0.1052631579	-0.4736842105	0.2631578947	-0.5789473684	0	
TA1149	-0.4090909091	-0.2272727273	-0.2727272727	0.2727272727	-0.3636363636	-0.4545454545	-0.1818181818	-0.1818181818	-0.1818181818	-0.3636363636	0	
TA1150	-0.5238095238	-0.04761904762	-0.380952381	-0.1428571429	-0.4761904762	-0.04761904762	-0.09523809524	0.2380952381	-0.4285714286	0.04761904762	-0.4285714286	
TA1151	-0.1764705882	0.3529411765	0.2941176471	-0.1764705882	0.2352941176	-0.7058823529	-0.05882352941	-0.5294117647	0.4117647059	-0.6470588235	-0.3529411765	
TA1152	-0.1111111111	0.05555555556	0	0.4444444444	-0.1666666667	-0.6666666667	0.05555555556	-0.3333333333	0.1111111111	-0.5	0.1111111111	
TA1153	-0.2	0	-0.1	0.4	-0.35	-0.45	0	0.2	-0.4	-0.2	-0.25	
TA1154	-0.7142857143	-0.3333333333	-0.619047619	-0.1428571429	-0.6666666667	0.04761904762	-0.2380952381	0.2380952381	-0.619047619	0.09523809524	-0.3333333333	
TA1156	-0.625	-0.2083333333	-0.5	0	-0.5833333333	0	-0.25	0.4166666667	-0.5833333333	0.08333333333	-0.4166666667	
TA1157	-0.2380952381	-0.04761904762	-0.1428571429	0.3333333333	-0.2857142857	-0.5238095238	0	-0.2380952381	-0.04761904762	-0.380952381	0.04761904762	

to finish all tasks is 2991 hours. However, the actual time was taken to finish the tasks is 3205 hours. That means the delay percentage is 107%.

In the experiment, the average capability for all developers without using PMTA model is -0.157, where the average capability for all developers using PMTA model is 0.12. The experiment results also show that the total expected time to finish all tasks is 332 hours, and the actual time was taken to finish the tasks is 315 hours. That means the PMTA help to reduce the delay from 107% to 94.9%.

Chapter 6

Conclusion

In this research, a task allocation model (PMTA) has been proposed. This model is parameterized on the basis of founded relationships between task characteristics and developers' personalities. These relationships are based on productivity which is defined as the actual time taken to complete the task divided by estimated time. Based on this concept, the PMTA model aims to find the capability between team members and tasks. The capability results are used to assign the tasks to team members.

A case study has been conducted in a Palestinian software development company to investigate the relationships between task characteristics and developers' personalities. An experiment also has been conducted to validate the proposed model. The case study result shows significant relationships between task characteristics and developers' personalities in some Belbin and MBTI team roles.

In MBTI, 54.2% of relationships are significant where 50% of relationships are significant in Belbin. It is also noticed that Belbin reveals more positive relationships than MBTI, since 61.1% of Belbin's relationships are positive, where only 38.5% MBTI's relationships are positive.

In Belbin, Implementor is the most personality who has relationships which are four, three of these relationships are negative. Shaper is the most personality who has positive relationships which are two in difficult and urgent tasks. Lastly, all relationships for analysis and design tasks are negative.

Moreover, the experiment result shows that the PMTA model helped to reduce the task completion delay from 107% to 94.9%.

Finally, the case study result does not show any significant relationships based on the technical profile. The reasons for that probably are 1) the tasks are allocated among developers based on developer's experiences, which do not relate to tasks' characteristic 2) The data is not enough, so future work should therefore investigate more data.

Chapter 7

Limitations and Recommendations for Future Research

This aims to build task allocation model that allocate the tasks based on the best correspondence between the tasks characteristics and developers personalities. However, this study mainly focuses on finding the relationships between task's characteristics and developers personalities. In model validation, the tasks have been allocated manually, as a result of that, the allocation process does not assume all available options. Thus, future work should automate this process, for instance, the genetic algorithm could be used to determine the optimal or near optimal solution.

In addition, in this study, the productivity refers to the actual time taken to complete the task, future work should consider more details such as quality of completed tasks. For example, the number of bugs caused.

Finally, this study does not show any relationship according to technical profile. Future work may consider much larger data set.

This capability could also be used as a fitness function in the Genetic Algorithm [91] which searches for the best task allocation result based on the capability equation (Equation 3.3)

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