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Management of the design process : human resource allocation in factory of the future

Guangying Jin

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THÈSE PRÉSENTÉE

POUR OBTENIR LE GRADE DE

DOCTEUR DE

L'UNIVERSITÉ DE BORDEAUX

ECOLE DOCTORALE DES SCIENCES PHYSIQUES ET DE L'INGÉNIEUR
SPECIALITE : PRODUCTIQUE

Par Guangying JIN

**MANAGEMENT OF THE DESIGN PROCESS:
HUMAN RESOURCE ALLOCATION IN FACTORY OF THE
FUTURE**

Sous la direction de : Christophe MERLO et Philippe GIRARD

A soutenir le 11 Juillet 2019

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Titre: Gestion du processus de conception: allocation des ressources humaines dans l'usine du futur

Résumé: Avec le développement rapide de l'Internet des objets et de l'économie mondiale basée sur Internet, les relations entre les différents concepteurs du monde entier sont de plus en plus importantes et sont façonnées par de nombreux nouveaux défis, telles que la multiplication des données et des informations, la personnalisation de masse, la collaboration mondiale, la pénurie de ressources, une technologie dynamique, etc. La réussite du processus de conception dépend de l'efficacité de la communication entre les acteurs du processus de conception. Cela conduit à une allocation de plus en plus complexe des ressources humaines et à une gestion des risques de plus en plus difficile dans les projets de conception. De nombreuses entreprises et instituts ont mis au point leur propre méthode d'allocation des ressources humaines et de gestion des risques pour le processus de conception. Cependant, ces méthodologies prennent en compte les compétences et l'expertise du concepteur, mais ne pensent que rarement à l'interaction de groupe, à l'expérience de collaboration et à l'analyse de la personnalité du concepteur. Par conséquent, dans ce travail, nous proposons une allocation de ressources humaines prenant en compte les idées ci-dessus pour gérer efficacement le processus de conception.

Mots clés : Allocation de ressources humaines, Processus de conception, Collaboration, Portefeuille de projets, Gestion des risques

Title: Management of Design process: Human resource allocation in factory of the future.

Abstract: With the rapid development of internet of things and the internet driven global economy, the relationship among various designers from all over the world are getting closer, and the relationships among them in the project are shaped by many new challenges such as multiplication of data and information, mass customization, global collaboration, scarcity of resources, dynamic technology, etc. The engineering design depending on the efficiency of communication between actors in the design process. This leads to an increasingly complex of the human resource allocation and a more and more difficult risk management in design project. Many companies and institutes have developed their own human resource allocation and risk management method to the design process. However, these methodologies consider about the skills and expertise of the designer, but rarely think about the group interaction, group's ability to work together and the personality analysis of the designer. Therefore, in this work, we propose human resource allocation which consider about the ideas above to effectively managing the design process.

Keywords: Human resource allocation, Design process, Collaboration, Multi-Project, Project portfolio, Risk Management

Unité de recherche

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(2019). Selection of design project with the consideration of designers' satisfaction factors and collaboration ability. <i>Computers & Industrial Engineering</i> , Volume 131. https://doi.org/10.1016/j.cie.2019.03.032	Chapter 3
(2018). Management of the design process: Human resource evaluation in factories of the future. <i>Concurrent Engineering</i> , 26(4), 313–327. https://doi.org/10.1177/1063293X18802888	Chapter 2 Chapter 4
(2017), Management of the Design Process: Human Resource Allocation in Factories of the Future. <i>INSIGHT</i> , 20: 19-22. doi:10.1002/inst.12175	Chapter 2
Management of design process: Risk management in factory of the future. <i>New Information Communication Sciences and Technology for Sustainable Development (NICST 2017) International France-China Work shop</i> , Cl érmont-Ferrand, France (2017) (ISBN 978-2-9544948-0-7, EAN 9782954494807). https://arxiv.org/ftp/arxiv/papers/1904/1904.00614.pdf	Chapter 4
Management of design process: Human resource allocation in factory of the future. <i>The 20th World Congress of the International Federation of Automatic Control (IFAC world congress)</i> , Toulouse, France (2017).	Chapter 2

<p>Management of the Design Process: Human resource allocation in Factory of the Future with the consideration of experience working together ability. <i>Sino-france international workshop on New Information Communication Sciences and Technology for Sustainable Development (NICST 2018)</i>, Shiyan, China (2018) (ISBN 978-2-9544948-0-7, EAN 9782954494807).</p>	<p>Chapter 2</p>
<p>Management of the Design Process: Human Resources Allocation and Project Selection in Factories of the Future. <i>l'Association Française d'Ingénierie Système (AFIS 2018)</i>, Nancy, France (2018).</p>	<p>Chapter 2 Chapter 3 Chapter 4</p>
<p>Management of the design process: Human resource allocation in factory of the future. <i>L'Association Française d'Ingénierie Système (AFIS 2016)</i>, Toulouse, France (2016).</p>	<p>Chapter 2</p>

INTRODUCTION

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Problem demonstration

The Industry 4.0, also known as the 4th Industrial Revolution is a new approach to organize the factory, characterized by the use of a set of digital technologies, which can support the roadmap towards a sustainable future (Quezada et al. (2017)). In the Industry 4.0, factories have to cope with the need of rapid product development, flexible production as well as complex environments (Brettel (2014)). The potential of productivity growth particularly lies in the improvement of brainwork and decision making processes, and collaboration at all levels can help to accelerate this process (Schuh et al. (2014)). Industry 4.0 is able to offer productivity gains, because the technological advancement allows to significantly improve collaboration in three parts: communication, coordination and cooperation (Schuh, Potente and Varandani (2014)). By utilizing advanced information analytics, networked machines will be able to perform more efficiently, collaboratively and resiliently, and such trend is transforming manufacturing industry to the next generation, namely Industry 4.0 (Lee and Kao (2015)). One core characteristic of Industrie 4.0 is raising collaboration productivity across departments which can lead to a better competitiveness of companies (Schuh et al. (2014)). The Industry4.0 integrates production facilities, ware housing systems, logistics, and even social requirements to establish the global value creation networks (Wang and Wan et al. (2016), Frazzon et al. (2013)). Therefore, in the industry 4.0, the next wave of production processes and production automation will be designed and commissioned virtually in one integrated process and through the collaboration of producers and suppliers (Rüßmann et al. (2015)). Because of internet driven economy and increasing of global competitive pressure, the Industry 4.0 (Stock and Seliger (2016)) will impact the design of manufacturing and service systems, and the workplace.

Design is a human activity related to human needs regarding the necessity to change the present state of the environment (Rosenman and Gero (1998)). Human can use the process of the environment changing to create a new product. Thus, the product design can be a source of competitive advantage for companies and is an important driver of company performance (Homburg et al. (2015)). Because of, on the one hand, increases of global competitive pressure and product development process complexity, and, on the other hand, decreasing of product development cycle, design actors must

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collaborative more and more closely to enhance design efficiency (Robin et al. (2007)). The design process corresponds to the place where the knowledge is created and used by the actors to develop the product (Robin and Girard (2010)). It is a labor intensive process culminating in the proposal of a product or process (Thomas et al. (2007)). It is the set of activities that must be carried out to meet design objectives, corresponding to a product definition in a specific context (Girard and Robin (2006)).

Depending on the development of internet of things (IOT) (Osseiran et al. (2017), (Gubbi et al. (2013)) and global internet driven economy, the relationship organization between different designers (who will be involved in design process) have been changed. The designers (from all over the world) can communicate and collaborate with each other very easily and frequently without any kinds of intermediary in design process. Therefore, they can establish a virtual team (Carlson et al. (2017)) to work together with each other and simultaneously control one design process with the different IOT in anytime and anywhere. In here, the Virtual teams are work arrangements where team members are geographically dispersed, have limited face-to-face contact, and work interdependently through the use of electronic communication media to achieve common goals (Dulebohn and Hoch (2017)). Therefore, the future organization structure in design process will be the point-to-point structure without any intermediary. The success of large projects, it is quite importantly on how effectively people collaborate, communicate and work together in teams (Karageorgos (2015)).

The challenge of resource allocation is a fundamental feature of corporate strategy (Levinthal (2016)). In any organization, resources are limited: it leads to find the most efficient and optimum improvement plan to achieve the highest possible overall readiness (Ahmadi et al. (2015)). In recent years, human resources, equipment and other resources conflict are serious because the lack of effective means of resource management causes the limited resources difficult to reasonably be allocated (Li et al. (2017)).

Depending on the change of future organization structure in design process, which we have been talked above, the human resources allocation in design process becomes much more complex to grasp. The influence of an efficient resource allocation

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problem is important for a company because of the growing decentralization of investment decisions around the world (Francis et al. (2009)).

A project, among a project portfolio, is selected by cost, quality and time (Babu and Suresh (1996), Khang and Myint (1999)). A company able to minimize project time and cost simultaneously, and increase project quality may have a significant advantage over its competitors (Chen and Weng (2009), Tran et al. (2017)). The Project Management Triangle (Haughey (2011), Thorne (2016)), which is explained that quality of work is constrained by the project's budget, deadlines and scope, is a model of the constraints of project management used to analyze projects. However, the triangle is insufficient for a project success because it omits crucial dimensions of success including impact on the project team members, such as their satisfaction with the positioned projects and their communication and collaboration ability with other team members in the positioned projects. Therefore, managers have to pay more attention to the collaboration and communication ability between the different combinations of the actors when they allocate different actors to different projects. At this moment, they should analyze the group's ability to work together of the future team members. The group's ability to work together has been found to provide team members with opportunities to learn how their expertise and skills "fit" together and therefore, how to work as a collective unit (Reagans et al. (2016)). In addition group's ability to work together can also provide the quality of the relationship with new collaborators, which will directly influence the collaborative work performance.

The dynamic and complex nature of design tasks and the specialized knowledge of team members in design projects make difficult to control members' behavior (Ding et al. (2014)). Meanwhile, studying 7,939 business units in 36 companies, Gallup researchers found significant connections between satisfaction and the business unit outcomes of customer satisfaction, productivity, profit, employee turnover and accidents (Stringer (2013), Harter et al. (2002)). Therefore, it is better for the project manager to position designers in one or several projects (multi-project), according their skills, knowledge and satisfaction. In here, the satisfaction is related to the designers' expectations: project objectives, workload, work environment, working atmosphere, salary and so on. In addition, research has shown that a significant number of design projects fail due to social issues such as team or personality conflicts.

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However, only a limited number of empirical studies have been undertaken to understand the impact of individuals' personalities on design project. Based on the observations of Kihlander (2011) accumulated over time from a global R&D department, designers and design teams are vulnerable to a great multitude of psychological pitfalls (Nikander et al. (2014)).

In future design process, because of the reason that the collaboration and communication between designers in future organization structure are very flexible and frequent, technical mistakes or errors and behavioral problems of designers will rapidly affect other co-workers depending on the intricate relationships with others. Therefore, managing the human risk is now essential and conditions the success of future design process. One of the most important risks is that the organization tends to require effective professional teamwork in a high risk environment because design experts have deep professional knowledge and are supposed to have fewer personal problems and conflicts between the members (Juhász (2010)). In here, the high risk can be seen as the tremendous influence to the company by the teamwork. There will exit a risk of poor performance of actors' relationships, which increasing the time delay and quality for the project completion.

Research objective and related work

According to the problems we have discussed above, the first objective of this research is to approach the multi-project human resources allocation problem with the consideration of the horizontal ability (skill, availability, occupancy rate, education, age and so on), personality analysis and group's ability to work together for the design process in the factory of the future. The second objective is to approach the allocation problem with the consideration of designers' satisfaction. Finally, the third objective is to approach the human risk management problem with the consideration of personal and interdependent affect.

Depending on the main objective of the research, the related works of this research can be seen as follows:

- 1. Understanding related concepts.*

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In-depth understanding the concepts of design, design process, Industry 4.0, Factory of the future, Communication and Collaboration, Personality, Group's ability to work together, etc. It should find the characteristic and elements in Industry 4.0, which can help use to find the relationship with the concept of design, design process, communication and collaboration. The personality concept, in here, should mainly focus on the personality analysis for design area.

2. *Understand the change of future human resource allocation in design process.*
With the knowledge of Industry 4.0 and Factory of the future, exactly to understand the impact of Industry 4.0 to the change of human resource organization structure in design process for factory of the future. In here, we should integrate the knowledge of Industry 4.0 to the resource organization structure in the design process to find the difference with the traditional resource organization structure.
3. *Research the priority method of multi-projects.*
It has to propose a criterion to define the priority among different projects. After that, according to the criterion of project we should find the corresponding project constraints, which will affect the priority of the project.
4. *Research of horizontal ability*
Apart from the skill, other properties of designer will affect the design project performance. In here, we have to find all the elements which will affect work and project performance. Then, we have to define a criterion to evaluate the horizontal ability.
5. *Research of group interactions and personal relationship*
To analysis the group interactions and personal relationship, it is important to find the factors, which can affect the interactions and relationship. After found the factors, we can propose a mathematical method to calculate the group interactions and personal relationship ability.

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6. *Research of personality*

First of all, it is important to deeply understand the impact of personality to the composition of designers in design project. Meanwhile, we have to find personality test inventory. Afterwards, the detailed relationship between the successful of the design project and personality traits should be proposed.

7. *Research of group's ability to work together.*

To find the relationship elements, which affect the group's ability to work together, and identify the different group's ability to work together types are the most important research in this part. And then, we can think about a mathematical method to achieve the final group's ability to work together value.

8. *Research of satisfaction of designer to design projects*

To get the satisfaction level of designer to the design projects, it is very important to find the satisfaction factors. Afterwards, we have to find a methodology to calculate multi-projects satisfaction level and collaboration level for different combination of the projects. At the final, we will define the final allocated multi-project to designer.

9. *Research of risk management methodology for design process.*

In order to create the risk management method in the design process, we have to comprehend the knowledge about the risk management process, especially to understand the whole standard of ISO 31000 (International standard of organization in design process). In addition, we have to find the risk management criteria elements and propose a mathematical method to release the result of criteria. From then on, we can integrate the risk management criteria to the ISO 31000 to release the risk management process for the design process.

Thesis structure

The thesis structure organized follows and Figure 1.

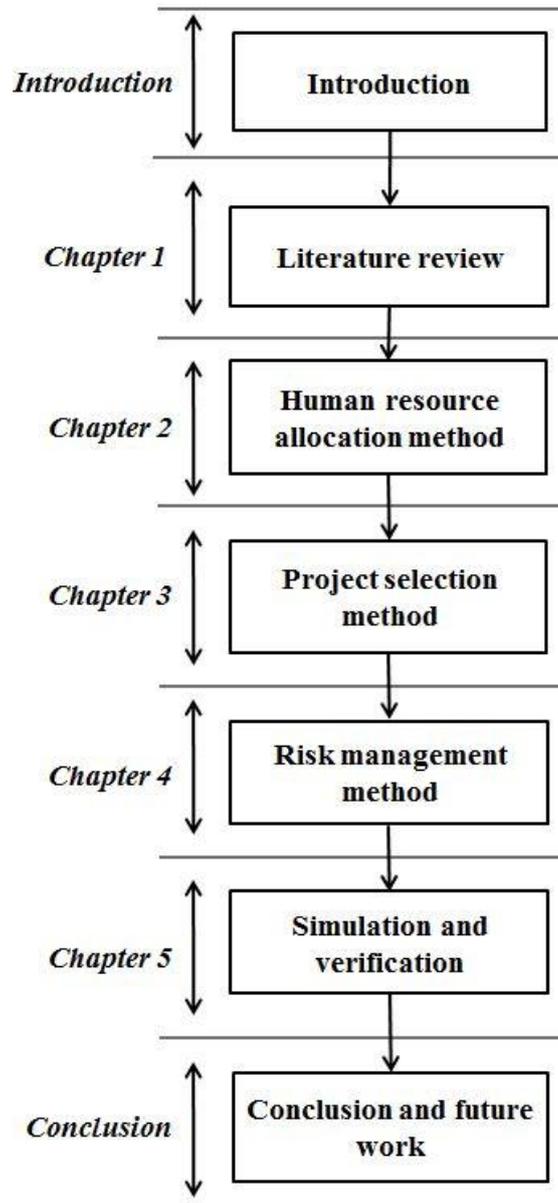


Figure 1 – Thesis structure

Introduction:

This section introduces the research background explaining why it is essential for future factory to renew human resource allocation method in the design process. This chapter points out the motivations of this thesis and briefly discusses the problems in

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the relationship of designer in traditional industry. The related work of the research is also presented in this chapter. Finally, the thesis structure is presented.

Chapter 1:

This chapter discusses the relevant literature from various fields. Firstly, the main concepts and contents of design, design process, industry 4.0, personality and work together experience are explained, as well as the comparison between traditional resource organization structure and future resource organization structure in design process. Then it introduces the related work for human resource allocation methodology and project selection methodology. Finally, there is a simple summary for this chapter.

Chapter 2:

This chapter proposes a human resource allocation methodology for design process to analysis the different kinds of aspects for the selection of candidate designer. In this methodology, we will firstly identify the priority of the multi-project and define the needs of these projects. Then, depending on this priority level and needs of the projects, finding the satisfaction actors with the different aspects of analysis.

Chapter 3:

This chapter proposes a project selection methodology for design project to analysis the different kinds of aspects for the selection of candidate design project. In this methodology, we will firstly propose a model to measure the designer's satisfaction level to the design project. After that, a calculation of collaboration ability method for designer, which will define the final selected design projects, will be introduced.

Chapter 4:

This chapter proposes a risk management methodology for design process to analysis the different kinds of risks in candidate designer. In this methodology, we will firstly assess the risk in the candidate actor with the consideration of interdependent effect of the risk. Then, depending on the effect of the risk and constraints of the risk response budget, we will find the appropriate risk response strategy.

Chapter 5:

Introduction

This chapter proposes a case study to simulate the whole human resource allocation methodology. Then the result of the simulation can verify the process of horizontal ability selection, risk management, personality analysis and group's ability to work together.

Conclusion:

This part concludes this thesis, stating the main contributions. It ends with a discussion of future work that can be based on the contributions made by this thesis.

CHAPTER 1 LITERATURE REVIEW

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List of Observation

ANP = Analytic Network Process.

CE = Concurrent Engineering.

FBS = Function-Behavior-Structure.

HRM = Human Resource Management.

IoT = Internet of Things.

MCDM = Multi-criteria decision making.

P-P-O = Product-Process-Organization.

Introduction

In this chapter, we firstly introduce the concepts of project, principles of project management and project portfolio. After that we mainly focus on the human resource allocation, which includes principles and practice, team composition and related work for human resource allocation. Apart from that, we illustrate the challenge of resource management for project portfolio. In addition, we mainly identify and summarize the existing literature related to the concept of design, design process and Product-Process-Organization (P-P-O) model. Then, we introduce the evolution of the design process organization. In this part, we illustrate the impact of industry 4.0 to the designers' organization structure in future design process. Additionally, based on the impact, we will propose the future organizational structure for design process. At the final, there will be a simple conclusion.

1.1 Project management

1.1.1 Project: definition and lifecycle

In order to discuss the project management, it is important to understand the concept of a project. A project is a temporary endeavor undertaken to create a unique product, service, or result (Kathy (2015), Rose (2013)). A project is also a temporary organization to which resources are assigned to do work to bring about beneficial change (Turner (2016)). Projects are different from operations in that they end when their objectives have been reached or the project has been terminated (Kathy (2015)). Meanwhile, projects are crucial frameworks to implement change (Rodriguez (2017)).

The attributes of the project can be seen as follows (Kathy (2015)):

- *A project has a unique purpose.* Every project should have a well-defined objective. For example, many people hire firms to design and build a new house, but each house, like each person, is unique.

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- *A project is temporary.* A project has a definite beginning and a definite end. For a home construction project, owners usually have a date in mind when they'd like to move into their new home.
- *A project is developed using progressive elaboration or in an iterative fashion.* Projects are often defined broadly when they begin, and as time passes, the specific details of the project become clearer. For example, there are many decisions that must be made in planning and building a new house. It works best to draft preliminary plans for owners to approve before more detailed plans are developed.
- *A project requires resources, often from various areas.* Resources include people, hardware, software, or other assets. Many different types of people, skill sets, and resources are needed to build a home.
- *A project should have a primary customer or sponsor.* Most projects have many interested parties or stakeholders, but someone must take the primary role of sponsorship. The project sponsor usually provides the direction and funding for the project.
- *A project involves uncertainty.* Because every project is unique, it is sometimes difficult to define the project's objectives clearly, estimate exactly how long it will take to complete, or determine how much it will cost. External factors also cause uncertainty, such as a supplier going out of business or a project team member needing unplanned time off. Uncertainty is one of the main reasons project management is so challenging, because uncertainty invokes risk.

A project stands out by its life cycle, which is generally presented as consisting of phases. The number of phases and their names may vary from one application, application area or one author to another. The engineer responsible for a project will sometimes have to define the phases of the project for which he / she is responsible, taking into account the parameters specific to the project or company culture. These

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differences in no way limit the validity or the relevance of the model below in four phases that are proposed to the engineer to follow (Ordre (2011)) :

- **Identification phase:** the request is clarified, the objectives specified and the overall project identified with respect to the product or service to be delivered, the constraints to be respected and the implementation strategy.
- **Definition phase:** the project content is defined more precisely, a detailed planning is established for its duration; deadlines, resources and expenditures, as well as management policies and procedures are circumscribed.
- **Implementation phase:** the product or service is actually carried out according to the planned plan and in accordance with the requirements of the applicant.
- **Closing phase:** the product or service is delivered to the applicant, the project is evaluated and its administrative closure completed.

Meanwhile, an example of project lifecycle can be seen as Figure 1.1.

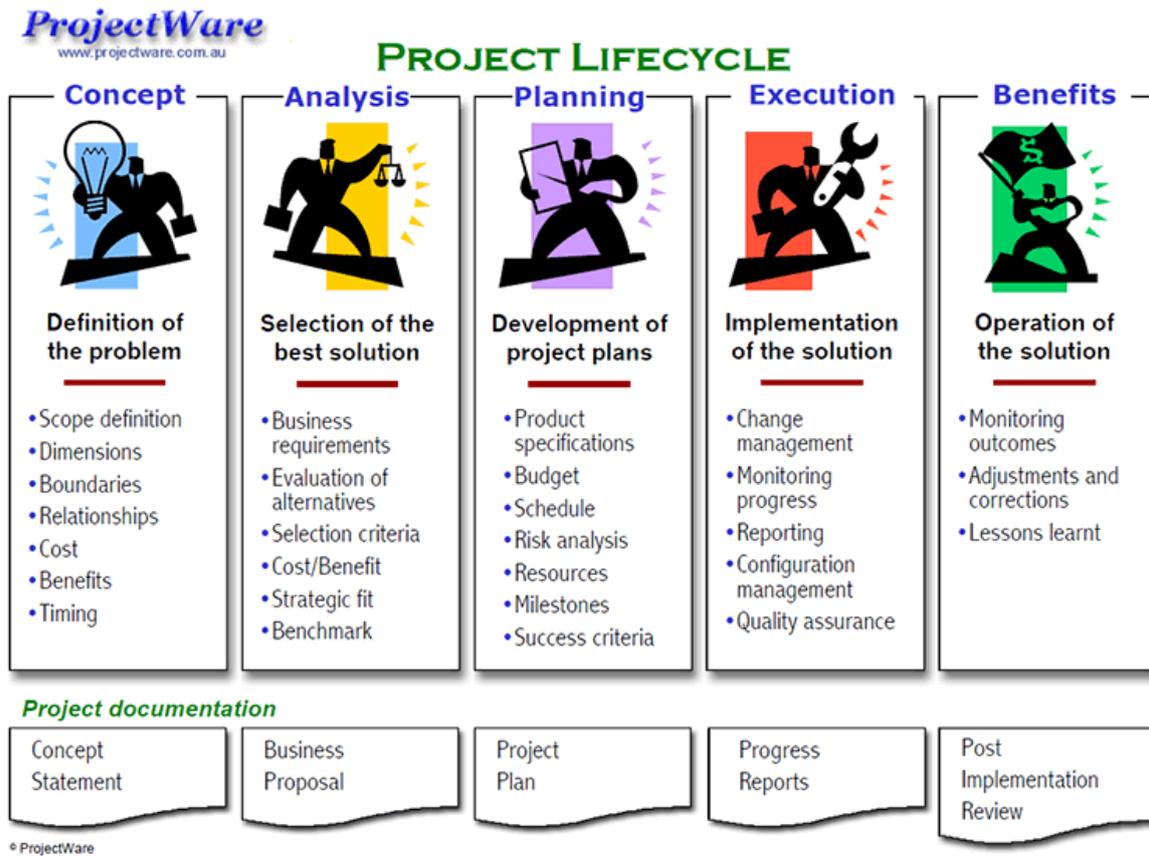


Figure 1.1 – Project lifecycle (ProjectWare (2002), Ordre (2011))

In the Figure 1.1, project lifecycle can be divided as five steps (Concept, Analysis, Planning, Execution and Benefits). The step of “Concept” part is to define the problem of the project such as the scope definition problem, dimensions problem and so on. The step of “Analysis” part is to select the best solution. The “Planning” part is to develop the project plans such as define the product specifications, budget, schedule and so on. The part of “Execution” is to implement the solution in the “Analysis” part. At the final, the “Benefits” part is to operate the solution such as monitoring outcomes, adjustments and corrections and so on.

1.1.2 Principles of project management

The project management is the means by which the work of the resources assigned to the temporary organization is managed and controlled to deliver the beneficial change (Turner (2016)). Meanwhile, project management is planning, organizing,

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coordinating, leading, and controlling resources, risk management, communication, monitoring and review to accomplish the project objective (Gido et al. (2014)).

In the last few decades, project management has become a hot topic and has been recognized as a central management discipline (Bianco and Caramia (2009)). Project management is the process which defines the objectives of the project (both the change and the benefit it should deliver), and the means of obtaining the objectives, and then monitors progress towards their successful delivery (Turner (2016)). Traditionally, all the project management is carried out under the certain constraints of cost, time and scope, and these three factors (commonly called 'the triple constraint') are represented as a triangle (Figure 1.2) (Haughey (2011)).



Figure 1.2 - Project management triangle (Haughey(2011))

The detailed description of the project management triangle can be seen as follows (Thorne (2016)):

- **Time:** A project's activities can either take shorter or longer amount of time to complete. Completion of tasks depending on a number of factors such as the number of people working on the project, experience, skills, etc.
- **Cost:** It's imperative for both the project manager and the organization to have an estimated cost when undertaking a project.
- **Scope:** Scope looks at the outcome of the project undertaken. This consists of a list of deliverables, which need to be addressed by the project team.
- **Quality:** Quality is not a part of the project management triangle, but is the ultimate objective of every delivery. The project management triangle represents quality.

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However, the triangle is often misused to define success as delivering the required scope, at a reasonable quality, within the established budget and schedule (time). The Project Management Triangle is clearly insufficient as a model of project success because it omits crucial dimensions of success including impact on stakeholders, learning and user satisfaction. Therefore, it is very important to consider about the other dimensions to manage a project.

In companies, project managers must not only strive to meet specific scope, time, cost, and quality requirements of projects, but they must also facilitate the entire process to meet the needs and expectations of the people involved in or affected by project activities (Kathy (2015)). There is a significant growth in the adoption of project management disciplines to accomplish work in different sectors and industries (Winter and Szczepanek (2008)). As businesses scramble to keep up with fast-moving competitors, riding the tsunami of change becomes critical to success, and this emphasis on change increases the importance of project management, because a rapid rate of change brings a greater need for projects (Verzuh (2015)). Project management has gone beyond being merely a personal skill set and it is now considered as an organizational competency (Verzuh (2015)).

There are ten of these areas for the project managers must have knowledge and skills, briefly described as follows (Kathy (2015), Turner (2016)):

- *Project portfolio Management* is a management approach that aims to align project efforts with the corporate strategy and optimize the efficient use of resources throughout the organization. In here, the organization that adopt projects as a means to achieving change and delivering results often find it difficult to prioritize projects and to make best use of their resources. To achieve the best results the organization should manage the portfolio in a coordinated way, prioritizing resources and coordinating interfaces between the projects.
- *Project integration management* is an overarching function that coordinates the work of all other knowledge areas. It affects and is affected by all of the other knowledge areas.

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- *Project scope management* involves working with all appropriate stakeholders to define, gain written agreement for, and manage all the work required to complete the project successfully.
- *Project time management* includes estimating how long it will take to complete the work, developing an acceptable project schedule given cost-effective use of available resources, and ensuring timely completion of the project.
- *Project cost management* consists of preparing and managing the budget for the project.
- *Project quality management* ensures that the project will satisfy the stated or implied needs for which it was undertaken.
- *Project human resource management* is concerned with making effective use of the people involved with the project.
- *Project communications management* involves generating, collecting, disseminating, and storing project information.
- *Project risk management* includes identifying, analyzing, and responding to risks related to the project.
- *Project procurement management* involves acquiring or procuring goods and services for a project from outside the performing organization.
- *Project stakeholder management* focuses on identifying project stakeholders, understanding their needs and expectations, and engaging them appropriately throughout the project.

1.1.3 Project portfolio

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The management of multiple projects – including portfolio management – is now the dominant model in many organizations for strategy implementation, business transformation, continuous improvement and new product development (Winter and Szczepanek (2008), Winter et al. (2006)). The success of any project depending on the capability of the project members (human resource in project) to communicate timely and effectively (Rodriguez (2017)). Projects, since they are unique, novel and transient, are inherently risky more so than the routine work of organizations. Risk management is therefore an essential part of project management (Turner (2016)).

In our research, we will mainly focus on the part of Project Portfolio Management (priority of the multi-project), Human Resource Management and Risk Management in the whole project management areas.

It is very important to identify the priority multi-project, when several projects are scheduled, in order to, promptly, solve the human allocation problem of this project. Multi-project problem environments define the nature of business in most manufacturing and service companies, and Lova et al. (2000) state that 84% of the companies work with multiple, simultaneous projects and Payne (1995) notices that 90%, by value, of all projects occur in the multi-project context (Beşikci et al. (2015)).

Multi-project contexts are extensively common in contemporary business (Turner (2008), Ruigrok et al. (1999), Whittington et al. (1999)), and even though influential thinkers (Bennis (1968), Toffler (1971) predicted this situation decades ago, research on these multi-project settings has traditionally been sparse (Engwall and Jerbrant (2003)). Traditional resource constrained project scheduling problem assumes perfect shared information in multi-project cases (Zheng et al. (2014)).

However, due to the rapid growth of globalization and Internet technology, project environments are becoming more and more distributed (Zheng et al. (2014), Lee et al. (2003)). Therefore, priority of the multi-project becomes much more complex to grasp.

1.2 Focus on human resource allocation

1.2.1 Principles and practices

In the project management literature, human resource management practices are found to contribute to project success by facilitating knowledge management (Popaitoon and Siengthai (2014)). The large majority of the research and literature in the area of Human Resource Management (HRM) focuses on the positive impact of HRM systems and practices, and outcomes such as employee well-being, organizational effectiveness and wider societal contributions have long been the focus to argue that HRM can make a positive contribution to the organization and broader society (for example, see Beer et al. (1984)).

There are four main basic functions, which can be seen as follows (DeCenzo et al. (2005)):

- “*Staffing*” is the recruitment and selection of potential employees, done through interviewing, applications, networking, etc. It can be also seen as the process of strategic human resource planning or human resource allocation.
- “*Training and development*” is the next step in a continuous process of training and developing competent and adapted employees.
- “*Motivation*” is the key to keeping employees highly productive. It comprises motivating theories and job design, performance appraisals, rewards and compensation, and employee benefits.
- “*Maintenance*” is related about the safety and health of the employee, the communication and relationships among employees.

In project management, resource allocation is management. In project management, resource allocation is the scheduling of activities and the resources required by those activities while taking into consideration both the resource availability and the project time (Tulasi and Rao (2015), Name (2014)). Human resources allocation problem

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always face the challenge on revealing unknown or implicit parameters in decision-making processes (Lili (2017)). This challenge especially with the respect of the research and development projects where the performance strongly depending on human resources capabilities (Certa et al. (2009)). The appropriate allocation of human resources has appositive effect on organizational performance (López-Torres and Prior (2016), Yu et al. (2013)). Human resources can play a decisive role in the success of an organization, and managers are seeking more efficient tools to optimize the use and the allocation of their available resources among the different services or systems, with an aim to maximize or to minimize certain functions related to the performance and productivity ((Bouajaja et Dridi (2017)).

The consideration factors for decision-makers involved in human resource allocation can be seen as follows (Picos and Ordoñez (2016)):

- Project characteristics: project requirements, project objectives, work load and project delivery date.
- Personal Qualifications: referring to skills utilization and expertise.
- Group Relationships: referring to personal relationships with co-workers and managers.
- Personal aspiration: referring to harmonic environments.

According Hendriks et al. (1999), multi-project situation causes issues in the allocation of limited human resources, and Academics suggest flexible resource plan to consider the availability of resources and specialized knowledge like experience for example (Loredo and Picos (2014)). However, when project managers want to select and allocate the candidate actors to different projects, they are not only considering about the skills for employee but also thinking about horizontal abilities (Emiliano (2015)), such as skill, age, education, availability and so on. For the horizontal abilities, it means the overall factors, which can impacts more or less the quality and time delay of the completion of project, combination for the personal ability, and not just considering about the depth of related skills. Indeed, research demonstrates that

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employees positively respond to environments of the organizations when a good match is available amongst their personality and the physiognomies of the environment (Khan and Rasheed (2015)). It means that the personality of the employee will affect the communication and collaboration relationship environment in the human resource organization. Thereby, the personality analysis is essential for the human resource allocation. In addition, teams composed of individuals who have experience working together have a more accurate and shared sense of who knows what on the team (Faraj and Sproull (2000), Larson et al. (1996), Lewis (2003), Moreland et al. (1996), Wegner (1986, 1995), (Reagans et al. (2005)). The likelihood of collaboration is threatened by the very complex organizational structure built to support it, and team processes and project outcomes are harmed if not well managed (Löhr et al. (2017)). Therefore, the analysis of the collaboration and communication ability is very important for the human resource allocation.

The ultimate aim of human resources allocation is to reach a station which staffs match post very well, to enhance the organization's overall performance, and studies have shown that the labor productivity of the best employee is three times higher than the worst staff on the same position (Zhang (2010)). However, in an organization, a specific post will need to be allocated to a person optimally chosen according to the system's overall, rather than choose the best employees to one post (Zhang (2010), Kennedy (2011)). This means that allocation of personnel need a good identification and selection process to select out the right staff which is of corresponding skills, knowledge and experience, age and so on (Zhang (2010)).

The collaboration is a process in which entities share information, resources and responsibilities to jointly plan, implement, and evaluate a program of activities to achieve a common goal (Camarinha and Afsarmanesh (2008)). It implies sharing risks, resources, responsibilities, and rewards, which if desired by the group can also give to an outside observer the image of a joint identity. One understands intuitively that collaboration is a risky game (Arend (2006)), especially for small and medium enterprises exactly due to their higher limitations, and it means that the question of collaboration remains one of the fundamental problems of firms (Zolghadri et al. (2008)). Meanwhile, suppliers' involvement will be failed in some new product development projects due to dysfunctions during their collaboration for some

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unanticipated reasons (Zolghadri et al. (2011)). Collaboration involves mutual engagement of participants to solve a problem together, which implies mutual trust and thus takes time, effort, and dedication. Collaborative partnering improves the odds of a project being completed at or below budget (Fackler (2016)). When individuals engage in collaborative problem solving, they bring unique ideas and competencies to bear on the problem and facilitate the cross-checking of a solution as it unfolds (Mangalaraj et al. (2014), Hinsz et al. (1997)).

For the reason of collaborative structure for the future organization, the collaboration and communication among actors are much more frequent and difficult to manage than before. Apart from that, working smarter means to work in a global project team where the collaboration results develop the team into a high-performance team (Olaisen and Revang (2017)). Therefore, there will have a tendency for the company to pay more attention to the collaboration and communication ability among the different combination of the actors when project manager allocate different actors to the multi-project. The success of large Project does not depending only on the expertise of the people involved in the various project tasks, but also quite importantly on how effectively they collaborate, communicate and work together in teams (Karageorgos (2015)). Apart from that, when it is confronted with the multi-project management, the resources allocation is crucial (the frequent and fluent communication relationship makes the allocation problem complex) for the performance of the future organization.

1.2.2 Team composition

Team composition consists of demographic composites, personality traits, knowledge and skills, and a blend of team members' ability (Zawawi and Nasuridin (2016), Savelsbergh et al. (2010)). Numerous psychology studies have emphasised the role of designer personality in creativity, specifically noting how personality traits contribute to creativity and exceptional performance levels (Chang et al. (2015), Callaghan (2008)). Historically, team composition has focused on relatively enduring member attributes such as personality, ability, values, functional background and demographics (Bell et al. (2017)). It has long been suggested that personality traits underlie human's adaptation to the environment and influence biological fitness

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(Huang et al. (2014), Nettle (2006), Hettema (1979)). The current study was designed to particularly test the impact of team personality composition on the initial status of cohesion (Acton (2016)). One potential contingency of the task conflict and team performance relationship is the personality composition of the team (Bradley et al. (2013)). Therefore, group performance can be influenced by the group's personality composition (Kramer et al. (2014), Bradley et al. (2013)). The personality will affect the group and team collaboration and communication ability among different actors in the design team. However, there is very limited research about the personality analysis in the composition of the design team. In the future, designers will communicate and collaborate with a frequent higher knowledge information sharing situation in the design process. In here, personality of the designer will not only influence the creativity and performance but also will impact the interaction among the designers to affect the knowledge sharing and collaboration efficiency in the design process. Therefore, personality analysis is very important for the human resource allocation process in the factory of the future.

Then, in order to be successful in design project, design teams must be composed of people who work together very well. The influence of experience on performance can be seen in any work scheduling policy (Corominas et al. (2010)) Therefore, when project manager selects different candidate designers from all over the world, he should consider about the ability of group's to work together. The aim of this consideration is to obtain project performance of greater value through the selection of most capable individuals. In the project team, an increase in cumulative experience working together promotes more effective coordination and teamwork (Reagans et al. (2005)). For the group's ability to work together, it provides individuals with the opportunity to learn who knows what, resulting in a more efficient division of labor, and, with increased group's ability to work together, individuals become more willing to share knowledge and information, increasing their ability to coordinate across their specialized roles (Reagans et al. (2005)). Group's ability to work together has been found to provide team members with opportunities to learn who knows what and therefore to divide their labor to utilize expertise available on the team most effectively (Reagans et al. (2016)). The positive effect that group's ability to work together can have on team performance has been documented in a variety of teams (Reagans et al. (2016)), Pisano and Edmondson (2001), Reagans et al. (2005)).

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In this work, we will consider that for group's ability to work together combines collaborative satisfaction, years of collaboration, number of collaborations, and personality.

In the design team, a more collaborative spirit among project members have been found to improve cost performance, such as elimination of cost overruns, controlling overall costs, and reducing administration costs (Horava et al. (2017), Sparkling et al. (2017), Fackler (2016), Löfgren (2009), Keil (2007)). In here, the collaboration is seen as constrained by context but, if structured and rewarded, it will bring important motivational and cognitive benefits (Hammond (2017)). When people work together, there will be a variety of communication and collaboration with the different levels of relationship satisfaction. With the low level of the group communicate and collaborate relationship satisfaction, there will be a poor efficiency of the project completion time and low quality of the final designed products. Failures of coordination and communication are well documented causes of the majority of air crashes, medical failures, and industrial disasters (Kozłowski and Ilgen (2006)). In here, the more years of this kinds of working together relationship will cause the worse project completion results. Apart from that, a low satisfaction in communicate and collaborate relationship will cause conflict among actors in the project. O'Neill and McLarnon (2017) wrote that conflict is inevitable wherever interdependencies conflict in teamwork is a regular occurrence. Importantly, comparatively more attention has focused on understanding the types and intensity of conflict issues within teams (DeChurch et al 2013). By contrast, high level of the group communication and collaboration satisfaction will decrease the project completion time and increase the quality of the final products.

1.2.3 Related work for human resource allocation

Over the past 20 years, there are many kinds of human resource allocation approaches for multi-project management. In early days, a popular approach of human resource allocation for the project management was heuristic Operational Research (OR) (Boctor (1990), Browning et al. (2010)). The goal of the heuristic OR is on the prioritize activities in multi-projects in order to optimize an objective function such as

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minimizing the delay to each project or overall portfolio (Browning et al. (2010)). The allocation of different resources to the multi-project, in the heuristic OR method is mainly consider about the availability of resource, without considering the collaboration and communication among different resources. A distributed Multi-Agent system (Adhau et al. (2012)), which is also a multi-project resource allocation method, is using auctions based negotiation approach for resolving the resource conflicts and allocating multiple different types of shared resources amongst multiple competing projects (Adhau et al. (2012)). The target of Multi-Agent system is focus on the expertise of the resource but never considering about other properties (education, personal satisfaction, experience, occupancy rate) and never thinking about the collaboration ability among the resources, which can also affect more or less the quality and time delay of the project. Introduce the concept of Inter-relationships in System Management (Aritua et al. (2009)), which implies that in a system, individual components affect each other and influence actions. However, there is not any method to approach the problem about resource allocation with the consideration of inter – relationship. The approaches for the Linear Programming Model (Gomar et al. (2002)), the Non Linear Program for Multi-Project R&D (Wu et al. (2006)) and the Multi-criteria Assessment Model (Shen et al. 2003) are mainly focus on one or multi-skills of the resources. Some of them consider about the human resource relationship but none of them take personality analysis and working together ability into account in the resource allocation process.

Hence, in the rest of this work, we will consider about the priorities of the multi-projects, mandatory requirement of projects (expertise), horizontal properties (education, availability, and etc.), collaboration ability of different combination of actors, personality analysis and group's ability to work together for the design process.

1.3 Resource management for project portfolio

1.3.1 Issue

In project management, there are many kinds of challenges such as the resource management for simultaneous project selection (Shariatmadari et al. (2017), modelling of project networks with time constraints (Caramia and Guerriero (2011)) and so on.

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In here, design project selection is the first important part of design project management. It is a process allowing to assess each project idea and select the project with the highest priority (Pacific (2011)). Available project alternatives usually far exceed the number of projects that can be executed with an organization's limited resources at any given time, and choosing the right projects in a particular context is seldom easy (Engwall and Jerbrant, (2003)). Therefore, academics and practitioners have sought to develop methods to address the project selection problem (Kaiser et al. (2015)).

Recently, both practitioners and academicians have been more interested in considering the issues of the relationship between project management decisions and possible problems (Yang and Lin (2013)). Additionally, project selection is a very complex decision-making process in project management since it is affected by many critical factors such as the market conditions, probability of technical success, government regulations, etc. (Wang et al. (2009), Bard et al. (1988)). In here, the critical factors also comprise constrained resource (Bianco et al. (2016), Caramia, M, Bianco (2009)), strategy of company, budget and risk (problems of organization, investment of people). The purpose of the project selection process is to analyze project viability and to approve or reject project proposals based on established criteria (Ghorabae et al. (2015)). Critical success factors can be served as the fundamental criteria to prevent possible causes of failures with an effective project selection process, taking into account company strategic objectives, project manager's experience and the competitive environment (Costantino et al. (2015)). Research and development project selection requires consideration of uncertain and/or subjective multiple criteria, and the selecting and determining relative importance of criteria will differ according to the goals and objectives of the sponsoring organization (Tuzkaya and Yolver (2015)).

1.3.2 Taking into account of the expectations/satisfactions of team members

The idea of human comfort has a long history, which applied traditionally to architecture and interior design historical research to enable scholars to understand how people used space in their homes and community buildings to make themselves

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‘comfortable’; It has more recently been applied to defining norms and standards for interior environmental conditions in public spaces such as office buildings (Vischer (2003)). The satisfaction of employees with their jobs and leaders has been extensively studied in the business and organizational communication fields (Men (2014)). Low employee satisfaction has been recognized by scholars as a negative consequence of bad human resource allocation processes (Loredo and Picos (2014)).

The satisfaction of the employee is related to the different kinds and levels of the needs for the employee. Maslow (1943) stated that people are motivated to achieve certain needs, and when one need is fulfilled, a person seeks to fulfill the next one, and so on (McLeod (2007)). One of the best-known theories explaining the needs of people is the model for Maslow's Hierarchy of Needs (Maslow (1954), Huitt (2004)). Maslow (1954) proposed that human needs can be captured in a hierarchical structure, and the model he proposed is shaped like a pyramid, with the most basic levels of human needs for life, such as sufficiency needs, at the bottom, and the need for the most abstract desires at the top (Lee and Hanna (2015)). The model for the Maslow's Hierarchy of Needs can be seen as Figure 1.3.

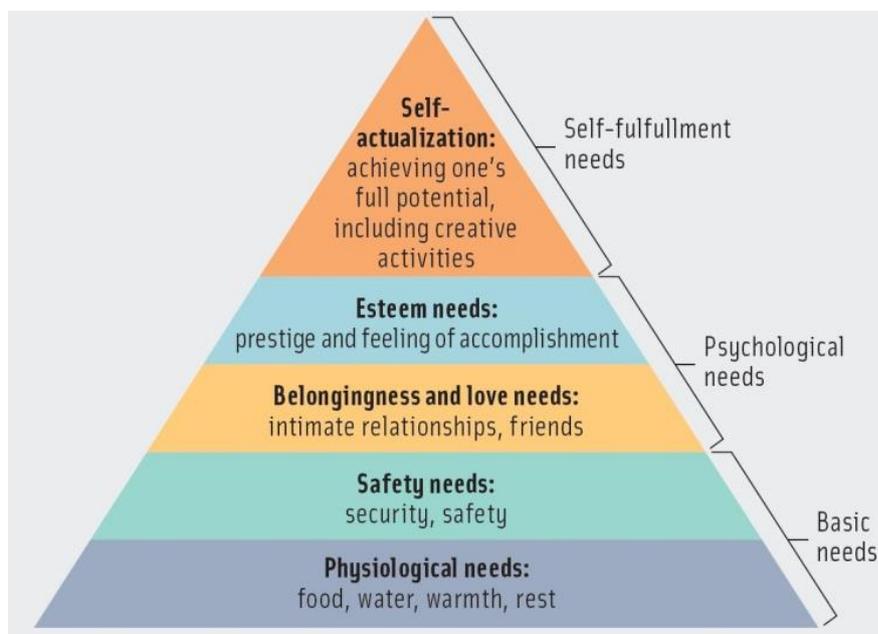


Figure 1.3 - Maslow's hierarchy pyramid (Poston (2009))

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The explanation of hierarchy of needs in Figure 1.3 can be shown as follows (Cherry (2014)):

- **Physiological Needs:** These include the most basic needs that are vital to survival, such as the need for water, air, food and sleep. Maslow believed that these needs are the most basic and instinctive needs in the hierarchy, because all needs become secondary until these physiological needs are met.
- **Security Needs:** These include needs for safety and security. Security needs are important for survival, but they are not as demanding as the physiological needs. Examples of security needs include a desire for steady employment, health insurance, safe neighborhoods and shelter from the environment.
- **Social Needs:** These include needs for belonging, love and affection. Maslow considered these needs to be less basic than physiological and security needs. Relationships such as friendships, romantic attachments and families help fulfill this need for companionship and acceptance, as does involvement in social, community or religious groups.
- **Esteem Needs:** After the first three needs have been satisfied, esteem needs becomes increasingly important. These include the need for things that reflect on self-esteem, personal worth, social recognition and accomplishment.
- **Self-actualizing Needs:** This is the highest level of Maslow's hierarchy of needs. Self-actualizing people are self-aware, concerned with personal growth, less concerned with the opinions of others and interested fulfilling their potential.

Therefore, when project managers want to select design project, it is very important for them to consider about the satisfaction for the designer to the selected projects.

Meanwhile, many academics use different ways to represent the satisfaction factors of the employee. Kapur (2018) think there are mainly 11 factors (job security, opportunities to make use of skills and abilities, people management, compensation/pay, supervisor support, working environmental conditions, job characteristics, relationship with the co-workers, job duties, flexibility to balance life and work issue and educational Qualifications.) that can influence the employee job

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satisfaction. Herzberg proposes Two Factor Theory (Herzberg (1976)), which is probably the most often cited point of view, and the main idea of this theory is that employees in their work environment are under the influence of factors that cause job satisfaction and factors that cause job dissatisfaction (Aziri (2011)). Therefore, in the Two Factor Theory, the satisfaction factors can be mainly divided as two main factors (Hygiene factors and Motivators), and the two parts also have sub-factors separately (company policies, supervision, interpersonal relations, work conditions, salary, status and job security for Hygiene factors, and achievement, recognition, work itself, responsibility, advancement and growth for Motivator factors). Depending on the working of Herzberg (1965), Locke et al. (1964) and Zalewska (2001), Sypniewska (2014) finds that generally, the definition of job satisfaction includes factors that can be grouped into four areas: economic aspects of work, interpersonal relationships, activities and tasks, and working conditions. Rahman et al. (2017) think that as indicated by Frederick Herzberg, motivating factors comprise six job content-related factors that include incorporate accomplishment, job acknowledgment, work or job itself, obligation, progression, and growth opportunities.

1.3.3 Related work and overview

Decision making is the study of identifying and choosing alternatives based on the values and preferences of the decision maker (Harris (1998) and Fülöp (2005)). The selection of an appropriate decision making techniques is not an easy task and depending on the concrete decision problem, as well as on the objectives of the decision makers, and sometimes “the simpler the method, the better” but complex decision problems may require complex methods, as well (Fülöp (2005)).

Multi-criteria decision making (MCDM) is a well-known branch of decision making (Pohekar and Ramachandran (2004)). It concerned with structuring and solving decision and planning problems involving multiple criteria (Majumder (2015)). MCDM helps a decision maker which quantifies particular criteria based on its importance in presence of other objectives (Kumar et al. (2017)).

Current Decision making studies show new techniques more powerful than multi-criteria calculation. Especially, different techniques consider logics inference

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and semantic operations, probability and prediction algorithms in decision making. Case Based Reasoning (Riesbeck and Schank (2013), Aamodt and Plaza (1994)) is an artificial intelligence decision making method based on reusing the outcomes of previously solved problems: when a new problem arises, the decision making process begins with an effort to find the closest matching solution to the problem within a set of historical solutions (Osuszek and Stanek (2015)). In case-based reasoning, a reasoner remembers previous situations similar to the current one and uses them to help solve the new problem (Kolodner (1992)). Therefore, the reasoner can use previous results to infer the solutions of future problems. There is recent work that develops case-based reasoning within a statistical framework and formalizes case-based inference as a specific type of probabilistic inference (Hüllermeier (2007), Dippon et al. (2002)). Case-based inference concerns that exploiting experience in the form of previously observed cases in order to predict the outcome of a new situation (Hüllermeier (2007), Ontañón and Plaza (2012)). Case-based inference has important aspects in common with statistical (prediction) methods and, more generally, with approaches to machine learning (Hüllermeier (2007)). Decision tree is a decision support tool that uses a tree-like graph or model of decisions and their possible consequences, including chance event outcomes, resource costs and utility (Chang (2011)). Decision tree is one of the most widely used and practical methods for inductive inference (Maja (2006)). In decision trees it often focuses on probabilities (Kamiński et al. (2018)). Bayesian networks (Pearl (2011)) are directed acyclic graphs that allow efficient and effective representation of the joint probability distribution over a set of random variables (Friedman et al. (1997)). Generalizations of Bayesian networks that can represent and solve decision problems under uncertainty are called influence diagrams (Xiong et al. (2013)). Grey system for decision-making is about making decision using such decision models that involve grey elements or combine the general decision model and grey systems models to approach the problem of choosing and picking a plan of action under uncertain conditions (Liu and Lin (2006)). In this case, the choice can be most likely influenced by the decision maker's prior experience, attitude, and willingness to take a certain amount of risk (Liu and Lin (2006)). The focus of grey systems theory is on the uncertainty problems of small samples and poor information that are difficult for probability and fuzzy mathematics to handle (Liu and Lin (2006)). In recent years, the grey system theory has been widely used to forecast or predict in various fields such as grey prediction model for

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traffic demand (Yang and Zhang (2013)), electricity demand (Zhou et al. (2006)), and internet access population (Wu and Chen (2005)) (Mondal and Pramanik (2015)).

However, in our research the project selection decision making process is to let the designers to directly evaluate the satisfaction level of design projects, and to find the most satisfactory multi-projects. Therefore, there is no need to use the previous observed designer satisfaction cases to infer or predict the outcome of new designer satisfaction level. Meanwhile, there are no random variables of the designer satisfaction level, no uncertainty of the satisfaction level result and no probability distribution. Additionally, the decision making problem in our research is not related to the uncertainty decision problem and the prediction problem. Thus, the Case Based Reasoning, Decision Tree, Bayesian networks and Grey system theory are not adaptable for our research. These methodologies are more adaptable for the artificial intelligence or machine learning.

Meanwhile, the objective of our research is to approach project portfolio management problems. The main critical studies of project portfolio management are focuses on its practices of project selection (Artto et al. (2004), Elonen and Artto (2003), PMI (2006)), choosing the most appropriate multi-projects is a significant aspect of project portfolio management (Danesh et al. (2018)). Meanwhile, the project portfolio decision process is characterized by multiple goals and strategic considerations (Cooper et al. (2001)). Therefore, multiple factors of the projects should be taken into account for the stakeholders and apply the measurement model for these factors to release the priority of the projects. In here, it should allow diverse and often incommensurable factors to be compared to one another in a rational and consistent way to release the weight or priority of the factors. MCDM methods can fulfil these requirements; for example, their scoring techniques are used for large portfolios while pair-wise comparison methods are more suitable for smaller projects (Danesh et al. (2018)). Meanwhile, the use of multi-criteria matrix (scoring models) is recognized as a best practice (Benaija and Kjiri (2015)) to determine the priorities of the projects. Additionally, project portfolio management success is closely associated with the degree of understanding of its issues and the quality of decisions made at the portfolio level which can be addressed using MCDM methods (Danesh et al. (2018)). Therefore,

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MCDM method is more adaptable to approach the decision making problem in our research.

Numerous project selection methodologies have been developed to solve multiple domain issues in project selection, and each with its own advantages and disadvantages. Chen and Askin (2009) proposed a Mixed-Integer Programming (MIP) model with an Net Present Value maximization objective function and used an implicit enumeration procedure to solve the project selection problem (Shariatmadari et al.(2017)). Liu and Wang (2011) presented an optimization model using Constraint Programming (CP) for project selection problem with time-dependent resource constraints. Huang and Zhao (2014) discussed a project selection problem in which there are no historical data about the project parameter values. Meade and Presley (2002) discuss the various criteria on which the selection decision is made and how these criteria interact, and they proposed a multi-attribute selection framework, which is represented as an ANP (Analytic Network Process) model, to approach the project selection problem. Ghorabae et al. (2015) presented a multi-criteria group decision-making approach for project selection problem.

When project managers want to select design projects, the satisfaction for designer to project values, relationship with colleagues, recognition, and personal development, which will make it possible to improve the criteria of cost, quality, delays, and to reduce risks (related to problems of organization, investment of people, etc.).

However, few empirical studies have investigated to the problem of multi-project selection problem with the consideration of designers' satisfaction to the multi-project and the collaboration ability with other designers in the multi-project. In here, the collaboration ability is related to the conflict and harmonic atmosphere in the design project team environment, which means the difference of the satisfaction attitudes among designers will affects the collaboration ability among them. Although several methods have been proposed to treat project selection problem in above, there is no method that takes into account designer's satisfaction to design project and collaboration ability between designers in design project.

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Hence, according to the problems we have discussed above, our main objective is to let project manager to select most comfortable projects to designer, which will consider about the satisfaction influence factors (personal responsibilities, constraints of design project, design work environment, salary and welfare, and personal aspirations) for the designer and collaboration ability between designers in the positioned design project team. Meanwhile, in this work, we will propose a project selection methodology with the consideration of these two issues.

1.4 Particular context of design project

1.4.1 Design and design process

The word “design” is used by many professions (artists, architects, all disciplines of engineering) and is claimed by each (Buede and Miller (2016)). The American Heritage Dictionary (Berube, (1991)) defines design as (Buede and Miller (2016)):

1. To conceive in the mind; invent: design his dream vacation.
2. To form a plan for: design a marketing strategy for the new product.
3. To have a goal or purpose; intend.
4. To plan by making a preliminary sketch, outline, or drawing.
5. To create or execute in an artistic or highly skilled manner.

In engineering, the design can be seen as a process that covers various necessary steps going from the identification of market needs till the realization of the product (Brunel et al. (2008)). The engineering design is also defined as component, or process to meet desired needs, and it is a decision making process (often iterative) in which the basic sciences, mathematics, and engineering sciences are applied to convert resources optimally to meet a stated objective (Tayal (2013)).

For the organization, it can be seen as the social entities that are goal-directed, are designed as deliberately structured and coordinated activity systems, and are linked to the external environment (Daft (2012), Simon (1991), Simon (2000)). The system, which is the cornerstone of the organization, is a set of objects, components,

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sub-systems together with relationships between the objects and between their attributes. (Hall et al. (1956)).

From the basis of FBS (Function-Behavior-Structure) Framework (Qian and Gero (1996)), the function is the teleology (purpose) of the design object. The Structure: describes the components of the object and their relationships (such as the relationship among actors involved in design process). The Behavior corresponds to the attributes that can be derived from the design object's structure. Meanwhile, the designer constructs connections between Function, Behavior and Structure of a design object through experience (Gero and Kannengiesser (2004)). The design process is a sequence of events and a set of guidelines that helps define a clear starting point that takes the designer from visualizing a product in his/her imagination to realizing it in real life in a systematic manner—without hindering their creative process (Haik et al. (2015)). The engineering design process is a series of steps that engineering teams use to guide them as they solve problems (Tayal (2013)). There are various forms of the systematic design process, and different people list as few as four steps to as many as nine. However, essentially though, they all revolve around the same following basic principles (Haik et al. (2015)):

- Analysis of Task

- Conceptual design

- Embodiment design

- Detailed design

The engineering design process is not sequential and parallel. It is now networked and collaborated. Modern manufacturing enterprises must use the computer network and database technology effectively to collaborate with partners and to achieve enterprise-wide integrated management of product design (Wang et al. (2016)).

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A collaborative design process gathers actors which have to achieve a common objective linked to a new product, information and knowledge sharing with a high level of activities coordination. Hence, such a collaboration is the key factor for an efficient design process, and a connection between the product, the process and the organization (Girard (2004)) is essential. Yan et al. (2002) have proposed a quantitative approach the issue about collaborative design process modeling in the Concurrent Engineering (CE) (Huang et al. (2014)). In here, a quantitative model of the product design process in CE based on the network of product - process design activity pairs is presented to describe both the impact of the upstream product design on the downstream process design and the process design's ability of discovering the faults in the product design (Yan et al. (2002)). Compared with other modelling methods (only focused on the influences from the upstream design's modification to the downstream design), it focus on the design iterations caused by the downstream design's discovery of the upstream design's faults as well as the upstream design's impacts on the downstream design (Yan et al. (2002)). In here, when downstream process designers find the faults in the product design, they can directly inform the product designers. Therefore, the informed product designers can revise their design, and the related process designs will also be revised by the process designers. Therefore, the product designer and the process designer can collaborative together to increase the product development efficiency. However, the modelling method mainly focuses on the design activity scheduling problem and occupancy rate of the resource problem while other properties of the resource (collaboration ability, personality ability and so on) are also very important for the collaboration among designers.

The design environment is defined as the context in which the project manager wants to place the designers in order to achieve the design objectives (Girard et al. (2006)). In the product aspect, design environment concerning about nature, complexity and status in process of the product (Suh (1990), Eynard (1999), Girard (2006)). In addition, especially in the design process (Perrin (2001)), design environment can be seen as the type of design (routine, innovative or creative), and/or the type of collaboration (Joly (1995), Dameron (2000)).

The concept of type of routine, innovative and creative design can be seen as follows:

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- **Routine Design** can be defined as the design that proceeds within a well-defined state space of potential designs. That is, all the variables and their applicable ranges, as well as the knowledge to compute their values, are all directly instantiable from existing design prototypes.
- **Innovative Design** can be defined as non-routine design that proceeds within a well-define state space of potential designs. What distinguishes it from routine design is that the designs produced are outside the routine or normal space.
- **Creative Design** can be defined as non-routine design that uses new variables producing new types and, as a result, extending or moving the state space of potential designs.

The collaboration is an essential factor of the design activities performance (Rose et al. (2009)). Meanwhile, collaboration is at the heart of every common project and authors agree on that collaboration between partners may bring prosperity and business success (Zolghadri and Girard (2006)). The design team is characterized by the duality individual / group, where the individual is at the service group (Gottlieb (2003)), and this involves collaborative and cooperative interactions, at particular moments during the project (Renaud et al. (2012)). The quality of collaboration between organizations (in the increasingly common case of projects within distributed companies) and between project actors (the latter enacting different roles) is a decisive performance factor (Baron et al. (2015), Xue et al. (2014)).

Increasingly, the efficient work team in an appropriate design environment based on the most efficient type of collaboration (P. Girard (2006)).

The design environment parameters can then be defined as follows (Girard (2006)):

- The design framework (design objectives, fields of competence, performance objectives, designers, resources, budget, etc.)
- The description of the new design context in order to implement
- The process model of the to-be situation

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- The to-be organization of the design center (the place that can be organized in a way where designer can create an architectural and design environment and experience.).
- The to-be activities and the performance levels achieved.

1.4.2 Product-Process-Organization Model

Robin and Girard, (2007) have proposed the P-P-O (Product – Process – Organization) model (Figure 1.4) to describe the design system, which integrates elements linked to the product, process and organization (Robin et al., (2007)). The P-P-O model (Robin and Girard (2010)) allows to identify and manage relationships between factors influencing performance of the design process. Compared with other model describing the design system, P-P-O model not only integrates elements linked with the product, process and organization, but also takes into account clearly the human aspects (Girard and Robin (2006)).

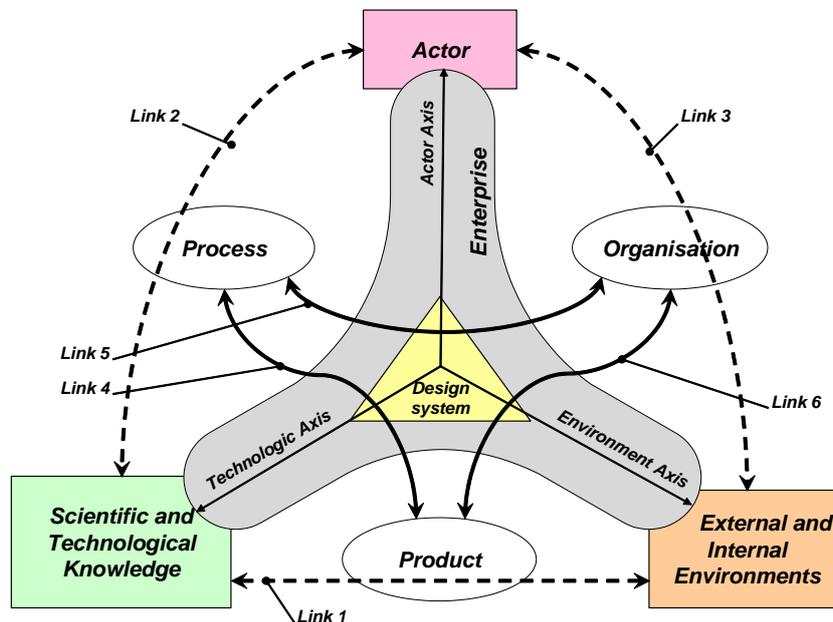


Figure 1.4 - Design system modelling, interactions between factors influencing the design system
(Robin and Girard, 2007)

The description of the P-P-O model can be seen as follows (Robin and Girard 2007):

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- The Product model: It acts as a link between knowledge and external / internal environments (link 1, Figure 1.4), and the product is the expression of the scientific and technological knowledge of an enterprise and permits to evaluate its position on a market.
- The Process model: It corresponds to the place where the knowledge is created and used by the actors to develop the product, and it connects actor and knowledge (link 2, Figure 1.4).
- The Organization model: It joins up actor and external/internal environments (link 3, Figure 1.4). In here, the organization has to favour allocation of adapted human resources to a specific situation in a particular context.

Collaborative knowledge appears during the progress of the project and the mutual evolution of the product, process and organization models (links 4–5-6, Figure 1.4).

Thanks to such a representation of the design context (Figure 1.4), the decision-maker can analyze the design situation and identify particularities of each project (Robin and Girard 2007). In the Figure 1.4, we can find that the P-P-O model not only considers about the scientific and technological knowledge, internal and external environment, but also takes into account human factors.

1.4.3 Evolution of the design process organization

Traditionally, the relationships among actors in an industrial design process organization take place according to a hierarchical decisional structure (Figure 1.5). However, in today's global and Internet-driven economy, the rapid movement of people and goods across borders means the traditional hierarchical organizational structure can slow down functions in a company (Russell (2005)).

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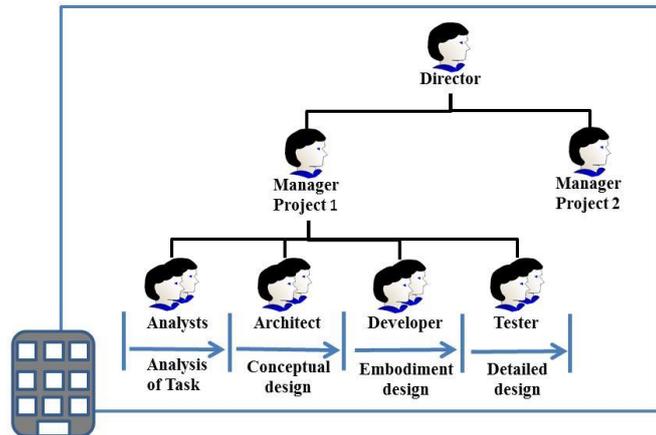


Figure 1.5 - Hierarchical organization structure

From the Figure 1.5, we can find that the relationship among different designers (Analyst, Architect, Developer and Tester) is very fixed. In here, designers only adjust their work to the manager's or director's knowledge. Meanwhile, if an enterprise wants to apply completely new organizational structure rather than redesigning it from top to bottom, it will lead to confuse among employees as to who has authority (Gill (2011)). In addition, the strength of the organizational structure depending upon the abilities of the superiors, and if lead by a weak leader, the entire hierarchy below suffers leading to lot of frustrations, break-room gossips, attrition etc (Ashim (2009)). In traditional design project, actors required for a project belong to the inside of the company.

Apart from that, there are intermediaries (managers) when designers want to collaborate with each other. So, it is very difficult for them to have frequent and fluent communication and collaboration. However, Previous researchers (e.g., Borca and Baesu (2014), Byrne and LeMay (2006)) have argued that effective employees communication is positively related to organizational outputs such as organizational commitment and employees satisfaction (Jacobs et al. (2016)).

In this kind of organization, the human resource assessment and management would focus more on individual performance and less on ability to work together (Watkins (2016)). The teams of people working together for a common purpose have been a centerpiece of human social organization (Kozlowski and Ilgen (2006)). Therefore, if a company wants to outstrip its competitors, it needs to influence not only how people

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work but also how they work together (Duhigg (2016)). Hence, in this case, traditional hierarchical organizational structure can slow down decisions and their implementation.

Depending on the rapid development of global Internet of Things (IoT) (Gubbi et al. (2013)) in Industry 4.0, product design teams are a growing phenomenon in many organizations, such as the product design team members can be combined or organized together from all over the world. The IoT infrastructure is based on many technologies such as Ambient Intelligence, Internet Protocol, Communication technologies (WiFi, Bluetooth, ZigBee), Embedded devices (RFID or wireless sensor networks) and applications (Reaidy et al. (2015)). IoT connects a variety of things or objects around us that can interact with each other (Rong et al. (2015)).

Nowadays, the engineering design process is networked and collaborated. Modern manufacturing enterprises must use the computer network and database technology effectively to collaborate with partners and to achieve enterprise-wide integrated management of product design (Wang et al. (2016)). For example, the European FP7 MSEE Integrated Project (MSEE 2011), which is Manufacturing Service Ecosystem, aims to create a new Virtual Factory Industrial Models, where service orientation and collaborative innovation will support a new renaissance of Europe in the global manufacturing context (Chen (2015)). In the future, designers will collaborate and communicate frequently in the design process and simultaneously control the design process.

Therefore, according to the new concept of the industry 4.0 (Horváth et al. (2015), Lee et al. (2015)), factory of the future (European (2013), Factory (2015)), and collaborative network (Schoenthaler (2015)), the traditional hierarchical structure will change to the future organization structure (Figure 1.6) in design process, which is an horizontal integration through company outsiders.

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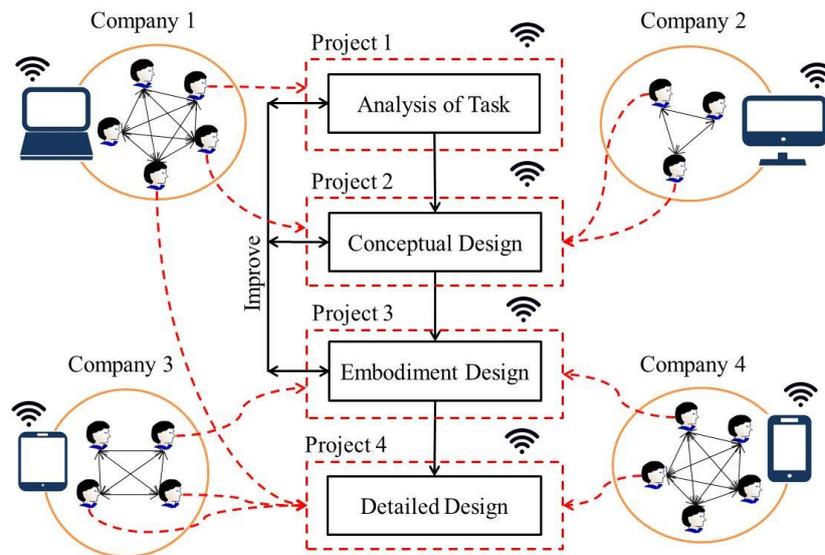


Figure 1.6 - Future organizational structure for design process

Now involvement in a design process can be a one single step in the whole design process (Analysis of Task, Conceptual Design, Embodiment Design or Detailed Design in Figure 1.6), and it is more flexible for the companies to allocate design project role to the different actors. Currently, industrial companies are pushed to take ‘glocal’ actions, i.e. thinking globally but acting and staying economically compatible with the local context (Marques et al. (2017), Ad-hoc (2013)). Meanwhile, the demand for collaboration among enterprises is keeping increase (Zacharewicz et al. (2017)). Therefore, in the Figure 1.6, it is possible for actors from all over the world companies (internal and external designers), and the connections between actors do not stop at the internal borders of the company but also include external partners. Because of the development of the technology of IoT (Internet of Things) (Gubbi et al. (2013)) and the global economic integration, the connection between companies are getting more close than before, and future resource organization structure will be the horizontal and point-to-point structures without any intermediary (Jin et al. (2017)). Moreover, collaboration enables more employees to work together in order to address challenges in different areas (Schuh, Potente and Wesch-Potente (2014), Lu et al. (2007)). These collaborative organizational forms allow them to pursue goals such as co-designing (Zolghadri et al. (2008)), co-manufacturing, co-marketing, etc. (Agostinho et al. (2016), Malone and Crowston (1994)). In addition, all the designers involved in the design process can simultaneously control the whole design process with the IoT. It means that both internal and external actors can collaborate and communicate with

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each other directly without any kinds of intermediary. They can share the knowledge and information with each other more frequently and fluently than before.

1.4.4 Overview

Even if the P-P-O model can describe the design system which integrates elements linked with the product, process and organization, it cannot explain in detail the relationship (different links in Figure 1.4) between every design factors (Actor, Scientific and Technological knowledge, and Internal and External Environments). It means that the P-P-O model only conceptually explains the design system. Because of the new concept in Industry 4.0, the organization structure in design process will change from hierarchical decision structure to the horizontal and point-to-point structures without any intermediary. Therefore, the relationship between Actor and Scientific and Technological knowledge (Link 2 in Figure 1.4), and Actor and Internal and External Environments (Link 3 in Figure 1.4) in design system will change. Meanwhile, there will be many new problems: problem in performance of actors' relationships and risk of actors' error in design project, problem in group's ability to work together in design project and problem in personality conflict in design projects.

Hence, in this work, one of our main objective is to explain the relationships between Actor and Scientific and Technological knowledge (Link 2 in Figure 1.4), and Actor and Internal and External Environments (Link 3 in Figure 1.4) in design system according to the future organization structure and associated new problematics.

Conclusion

In this chapter we firstly illustrated the concept of concepts of project, principles of project management and project portfolio. After that we introduced principles and practice of human resource management. Then, we found the insufficient of designer satisfaction in the traditional project management triangle. Meanwhile, from the related work for human resource allocation, we can find the limitations of the existing human resource methods. In the related work for resource management for project portfolio, the Multi-criteria decision making method will be the most suitable

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approach for the project selection problem. In the impact of industry 4.0 on traditional relationships among designers in the whole design process; depending on the Industry 4.0, we can create the future organization structure for the design process.

CHAPTER 2 HUMAN RESOURCES

ALLOCATION METHODOLOGY

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List of Observation

AG = Average Gap of one property of the horizontal ability for the entire group.

AHP = Analytic Hierarchy Process.

APWG = Ability of a Person Work in a Group.

E = total number of Actors.

F = Total numbers of horizontal properties (8 in our case)

FFM = Five-Factor model.

GAWT = Group's Ability to Work Together.

H_{ab} = the number of projects worked together between actor 'a' and actor 'b'.

MEAN = the mean of the normative sample.

NGPA = Normalized Group Personality Ability.

NM = number of group members.

NTN = Normalized Total Number.

NU = Total number of personal experience working together actors.

NZS = non-zero scores.

PCE = Personal Collaboration Experience.

$PREWTA_{ab}$ = Pair Experience Working Together Ability between actor 'a' and actor 'b'.

Q = Number of collaborated actors.

SD = Standard Deviation of the normative sample.

SL_{ab} = Satisfaction level for actor 'a' to actor 'b'.

TAVG = Total average gap.

X_{max} = The the maximum value for variable X.

X_{min} = The minimum value for variable X.

X_{norm} = The normalized value.

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NY_{ab} = the number of years worked together between actor 'a' and actor 'b'.

ZS = Score of Zero.

Introduction

In this chapter, we firstly introduce the whole process of human resource allocation methodology. Then depending on the whole process, we detail the allocation techniques step by step.

The whole process of human resource allocation

The whole process of human resources allocation can be seen in the Figure 2.1.

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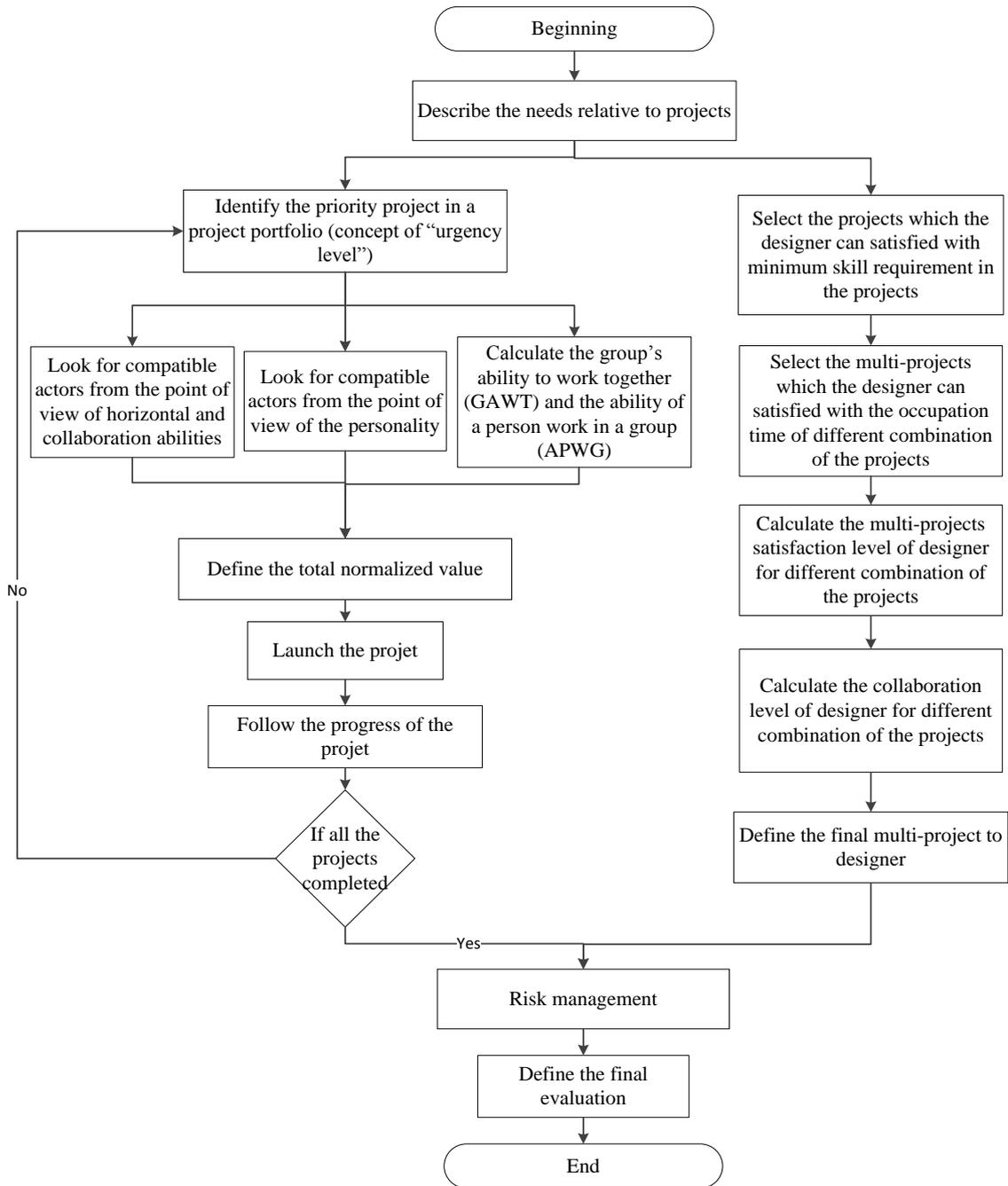


Figure 2.1– Whole process human resources allocation methodology

Firstly, it is necessary to describe the needs relative to projects, such as the required skills and occupation time of projects. After that, there are two branch processes. The left part of branch is to allocate designers to projects, and the right part of branch is to select projects to designers. For the left part of branch, firstly, it is necessary to

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identify the priority project, when several projects are scheduled, in order to, promptly, solve the human allocation problem of this project. When a project manager allocates candidate actors to multi-projects, it is very important for the manager to understand which project is the most urgent project. After that, he will look for compatible actors for the priority project, according to the mandatory needs and requirements of this project. To help the decision making along of this process, we propose to calculate their analyzing:

- The horizontal ability of the actors and the collaboration ability. The horizontal ability means the overall factors, which can impacts more or less the quality and time delay of the completion of project, and these factors are related to the human requirements of the project. The collaboration ability corresponds to communication conflict and harmonic atmosphere in the design project team environment. The main target of these two steps is to find the most efficient collaboration and communication of different combinations of actors to increase the project completion speed and quality.
- The personality of the actors
- The ability of a group to work together and the ability of a person (individual) to work in a group. It takes into account the consideration of the mutual cooperation, satisfaction, years of experience and projects of experience. In here GAWT values are same among some of the candidate combination groups, we calculate the APWG between the actors to identify them.

For the left part of branch from the step “Select the projects which the designer can satisfied with minimum skill requirement in the projects” to “Define the final multi-project to designer”, we will explain in detail in Chapter 3.

After all these two branch processes, we can manage the risk for designers and define the final evaluation. The step of “Risk Management” part, we will explain in detail in Chapter 4.

2.1 Identify the priority project and describe the relative needs

The multi-project situation causes issues in the allocation of limited human resources. Also, when we want to appropriately allocate actors to different projects, we need to, firstly, identify the priority selection of actors to different projects. It means that we need to evaluate the urgency level of the different projects. We use a diamond chart to display the constraints of the project (Figure 2.2).

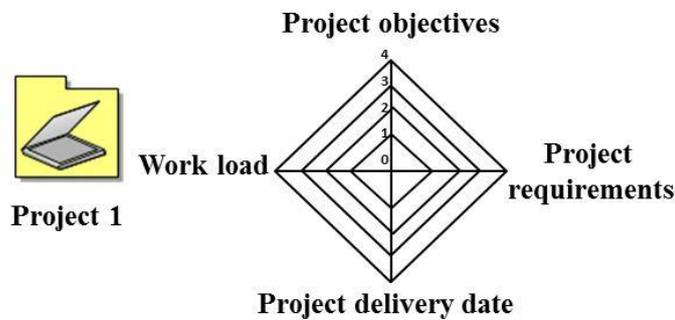


Figure 2.2 - Constraints for the project

Every constraint can be approached according 4 levels, as follows in the Table 2.1.

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Table 2.1- Project urgency level description

Level of constraints	Constraints	Expectations
Critical-4	Objectives	Objective brings extremely high profits.
	Requirements	Failure of Project requirements will cause Critical damage to the company.
	Delivery date	Project delivery date is extremely urgent.
	Work load	Huge work load.
Important-3	Objectives	Objective brings a lot of profits.
	Requirements	Failure of Project requirements will cause certain degree of damage to the company.
	Delivery date	Project delivery date is urgent.
	Work load	Big work load.
Normal-2	Objectives	Objective brings some profits.
	Requirements	Failure of Project requirements will cause normal damage to the company.
	Delivery date	Project delivery date is not urgent.
	Work load	“Normal” work load.
Low-1	Objectives	Objective brings a little profit.
	Requirements	Failure of Project requirements will cause a light damage to the company.
	Delivery date	Project delivery date is very late.
	Work load	Little work load.

Then, we define that the project urgency depending on the level of these constraints. Also, we propose to simultaneously take into account these constraints, as follows in Figure 2.3.

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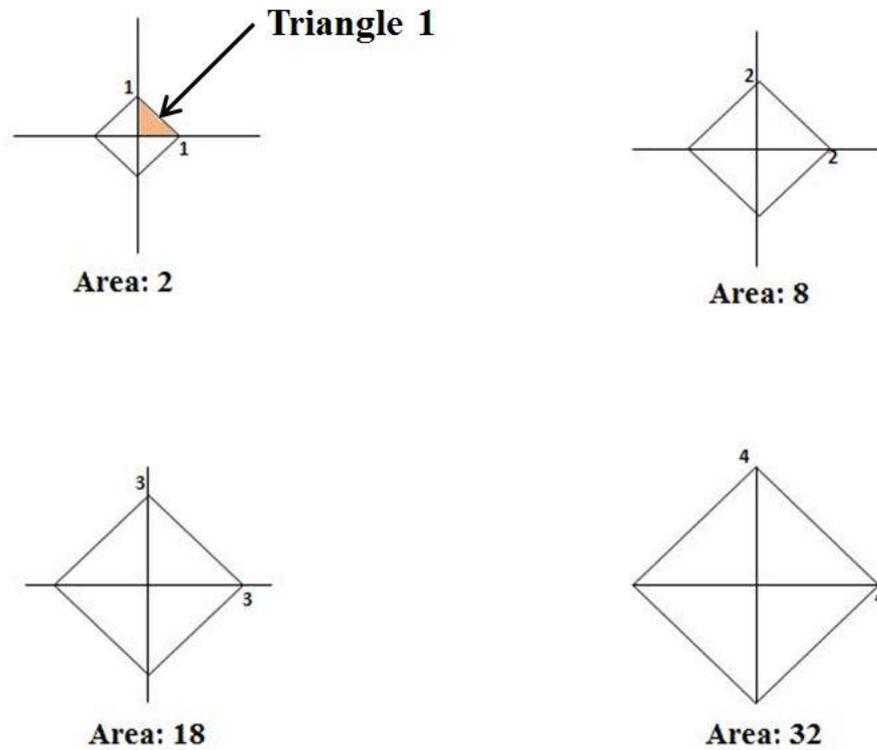


Figure 2.3 – Different Urgency level areas for project.

Here, the area of the graph corresponds to the urgency level of the project. The larger the area associated to the project is, the higher the level of the urgency is. For the area calculation process of the “Triangle 1” in Figure 2.3, we can see the different triangle area calculation process in Figure 2.4 and Figure 2.5.

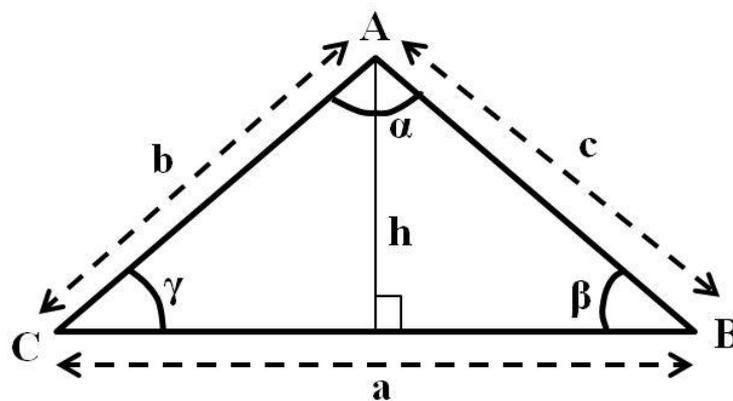


Figure 2.4 - Calculation of triangle area depending on the Law of Sines

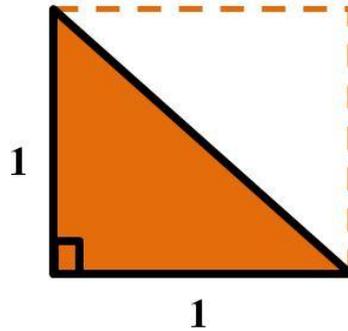


Figure 2.5 - Calculation of right-angled triangle area

In the Figure 2.4, we can find the Law of the Sines is $\frac{a}{\sin \alpha} = \frac{b}{\sin \beta} = \frac{c}{\sin \gamma}$. Therefore, the area of “Triangle 1” (Figure 2.3), for example, is $0.5 (1 \times 1 \times \sin 90 \times 0.5)$. But, here, for right-angled triangle like Figure 2.5, the area is $\frac{1}{2}$ the area of the square ($\frac{1 \times 1}{2} = 0.5$) in Figure 2.5. However, in our work we use a calculation using the Law of Sines, because we will have ordinary triangles in the rest of this work (and not right-angled triangles).

After that, we propose 4 levels of urgency, for a project, depending on the range of the area associated to the project (Table 2.2): Low, Normal, Important and Critical.

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Table 2.2- Project urgency level description

Critical-4	$18 < \text{Area} \leq 32$	Objectives	Objective brings extremely high profits.
		Requirements	Failure of Project requirements will cause Critical damage to the company.
		Delivery date	Project delivery date is extremely urgent.
		Work load	Huge work load.
Important-3	$8 < \text{Area} \leq 18$	Objectives	Objective brings a lot of profits.
		Requirements	Failure of Project requirements will cause certain degree of damage to the company.
		Delivery date	Project delivery date is urgent.
		Work load	Big work load.
Normal-2	$2 < \text{Area} \leq 8$	Objectives	Objective brings some profits.
		Requirements	Failure of Project requirements will cause normal damage to the company.
		Delivery date	Project delivery date is not urgent.
		Work load	“Normal” work load.
Low-1	$\text{Area} \leq 2$	Objectives	Objective brings a little profit.
		Requirements	Failure of Project requirements will cause a light damage to the company.
		Delivery date	Project delivery date is very late.
		Work load	Little work load.

After that, for example, the Figure 2.6 shows the different levels of constraints of a project.

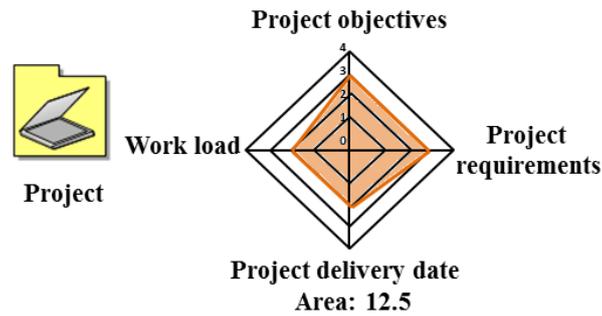


Figure 2.6 - Urgency level for the project

In this example, the area is 12.5 ($0.5 \times 3 \times 3 \sin 90 + 0.5 \times 3 \times 2 \sin 90 + 0.5 \times 2 \times 2 \sin 90 + 0.5 \times 2 \times 3 \sin 90$). With such a result, this project could be ranked with an “Important level”.

2.2 Look for compatible actors from the point of view of horizontal and collaboration abilities

2.2.1 Horizontal ability analysis: looking for compatible actors

When project managers want to select and allocate the candidate actors to different projects, they are not only considering about the skills for employee but also thinking about horizontal abilities (Emiliano (2015)). The horizontal abilities include all factors which can impact more or less quality and time delay of the project. These factors are relative to the human requirements of the project. Project managers say that sometimes the education background of the employee and his/her skills are taken for granted (Picos and Ordoñez, (2016)).

We identify 8 properties for the horizontal ability, which are traditional required for a project and expected by a manager. The properties are: Skill, Creativity, Availability, Occupancy rate, Personal satisfaction, Education, Experience and Age. The exactly description of every level for the different properties can be seen as the Table 2.3.

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Table 2.3- Grade level description for different horizontal properties

Grade of Level	Skill	Creativity	Availability	Occupancy Rate	Personal Satisfaction	Education	Experience	Age
Level 1	Novice Actor	Expressive Creativity	Intense	20%	Very Dissatisfied	No Diploma	0-2.99 years	Under 25
Level 2	Advanced beginner	Technical Creativity	Very Hard	40%	Dissatisfied	High School Diploma or equivalent	3-5.99 years	25-34
Level 3	Competent	Inventive Creativity	Hard	60%	Neutral	Bachelor's Degree or equivalent	6-8.99 years	55 and above
Level 4	Proficiency	Innovative Creativity	Normal	80%	Satisfied	Master's Degree or equivalent	9-11.99 years	35-44
Level 5	Expert	Emergent Creativity	Easy	100%	Very Satisfied	Doctoral degree or equivalent	12 years and up	45-54

Depending on the skills acquisition model of Dreyfus (Dreyfus (2004)), we identify 5 levels for each properties, for the skills from the Novice to the Expert. According to Taylor's hierarchy of creativity (Taylor (1975), Liu and Schonwetter (2004)), we can define the different creativity levels from a Technical Creativity to an Emergent Creativity. The property of Availability is a criterion (from Intense to Easy) allowing to evaluate the difficulty of “obtaining” actors. The Occupancy rate is the ratio of human needed time to the total amount duration of the project. Indeed, different actors can have different roles, and can be allocated to the different projects with different percentages of possession time. Therefore, it is very important for the project manager to know the occupancy rate of future actors of project. We propose five levels, from a value of 20% (actors very committed in other projects) to a value of 100% (total availability for the project). For the range of personal satisfaction, we propose that it is progressing from Very Dissatisfied to Very Satisfied. For the property of education, because of different countries have different education structures, the graduation is not easy. We choose to have a scale from No Diploma to Doctoral Degree or Equivalent.

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The experience property in the Table 2.3, only means the length (years) of the work experience. Depending on the research of relationship between job experience and job performance by McDaniel et al. (1988), we can define the different experience levels from 0-2.99 years to 12 years and up. In the research of relationships, the job is to analyze the performance of concurrent designs because job experience is a dynamic variable in the design work. Therefore, the choice of experience levels is just right for our study (engineering design). For the property Age, depending on the research of relationships between Age and Job performance (Warr (1993)), for all kinds of work types (Equipment service engineers, Skilled manufacturing operators, Semi-skilled assembly workers and etc.), we can propose that the members from age 45 to 54 have the highest work performance, while under the age 25 have the lowest work performance. Note, however, that such a classification for this last property is very subjective.

The Figure 3.5 shows an example of representation of the non-weighted horizontal ability of an actor.

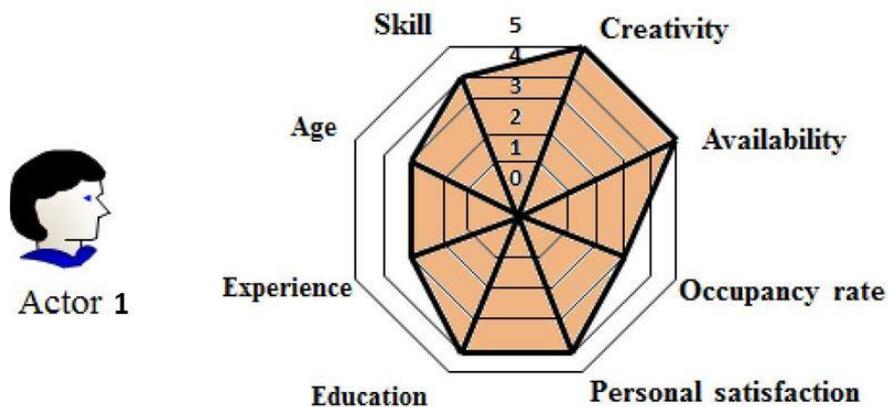


Figure 2.7 - Non-weighted horizontal ability of actor 1

Here, project managers define and describe the mandatory horizontal properties needs relative to the project (example like Figure 2.8).

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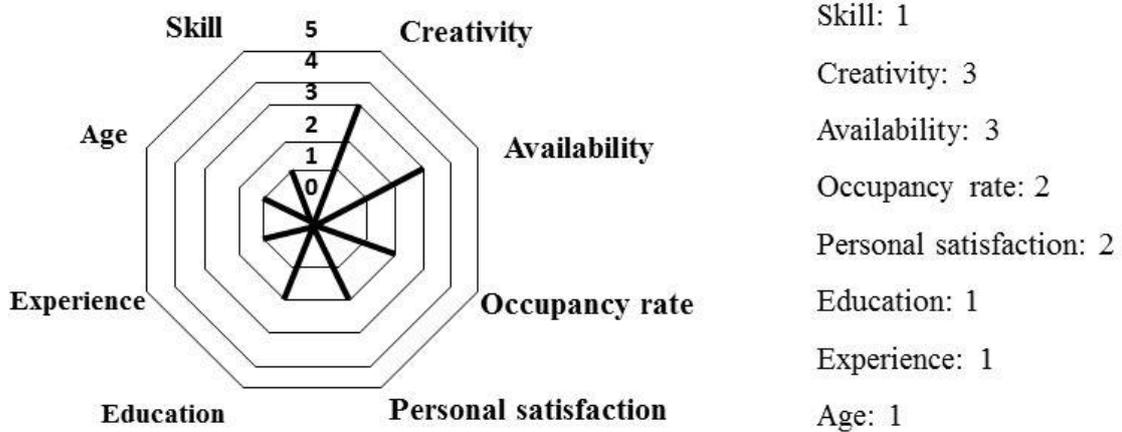


Figure 2.8 Mandatory needs of project

Then, they can select candidate actors fulfilling the mandatory needs of the project. For the rest of the study, we want to identify if one property is more important (weight) than another for a given project. To rank the properties (skill, creative, age, experience, education, personal satisfaction, occupancy rate and availability) relative to each other, for each project, we use the pairwise comparison of importance among all the properties, and, depending on a benchmark on project constraints, we define the relative length of levels for all properties. In here, for the pairwise comparison, we use the AHP (Analytic Hierarchy Process) (Saaty (2008)) methodology to define the weight of every property. The AHP is used to derive relative priorities on absolute scales (invariant under the identity transformation) from both discrete and continuous paired comparisons in multilevel hierarchic structures (Saaty (2013)). The Fundamental scale for pairwise Comparisons can be seen as Table 2.4.

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Table 2.4- Fundamental scale for pairwise Comparisons (Saaty (2008))

Intensity of Importance	Definition	Explanation
1	Equal importance	Two elements contribute equally to the objective
3	Moderate importance	Experience and judgement moderately favor one element over another
5	Strong importance	Experience and judgment strongly favor one element over another
7	Very strong importance	One element is favored very strongly over another; its dominance is demonstrated in practice
9	Extreme importance	The evidence favoring one element over another is of the highest possible order of affirmation
Intensities of 2, 4, 6, and 8 can be used to express intermediate values, and reciprocals for inverse judgments(such as 1/3,1/5,1/7,1/9)		

Project manager can use the Table 2.4 to pairwise compare two properties depending on the objective of design project. After that we can calculate the right eigenvector of the pairwise comparison result matrix, and release the weights of all the 8 horizontal properties. An example of the 8 horizontal properties pairwise comparison matrix and the calculation of associated weights can be seen as Table 2.5.

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Table 2.5 - Example of pairwise comparison and calculation of the weight associated to the 8 horizontal properties, thanks to the AHP methodology (Saaty (2008))

To From	Skill	Creativity	Availability	Occupancy Rate	Personal Satisfaction	Education	Experience	Age	W
Skill	-	4	1	2	1/2	1	1	1	0.7
Creativity	1/4	-	9	1	1	1/3	1	1	1.0
Availability	1	1/9	-	3	1	1	1	1	0.9
Occupancy Rate	1/2	1	1/3	-	1	1	1	1	0.6
Personal Satisfaction	2	1	1	1	-	1/5	1	1	0.7
Education	1	3	1	1	5	-	1/3	1	0.8
Experience	1	1	1	1	1	3	-	1	0.6
Age	1	1	1	1	1	1	1	-	0.5

Note. W: Weight.

To complete the Table 2.5, project managers use the principles of the Table 2.4.

Now, we use these results to weight the different properties applied to the case of the Figure 2.7, we obtain the Figure 2.9.

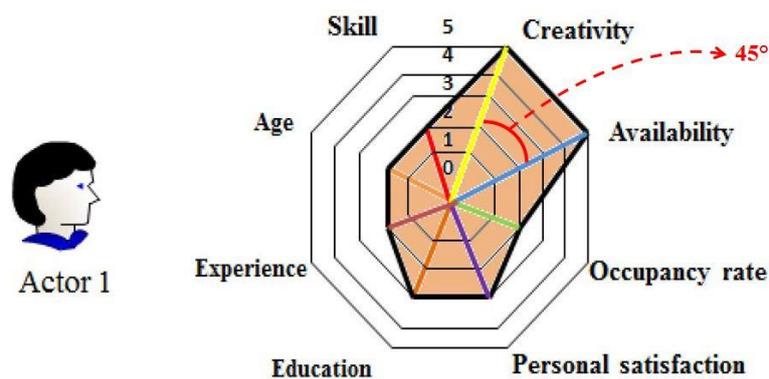


Figure 2.9 Weighted horizontal ability for the Actor 1

To obtain the new level of each property, we multiply the initial value by the weight associated to each property, for a given project. For example, for the “Skill”, the initial level is 4 (Figure 2.7), and after multiply the weight of skill (0.7) in Table 2.5 with the

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initial value, we can get the result 2.8 (4×0.7). After that we can round the value 2.8 to the nearest whole number and get the result 3. Therefore, the weighted skill level for the Actor 1 is 3. Then, we can calculate the area of the orange graph through the triangle area calculation process in Figure 2.4. In the Figure 2.8, we can find that there are 8 triangles, and after the calculation, the area of the orange graph is 26.16 ($\frac{1}{2} \sin 45^\circ \times (5 \times 5 + 5 \times 2 + 2 \times 3 + 3 \times 3 + 3 \times 2 + 2 \times 2 + 2 \times 2 + 2 \times 5)$). The area is to say candidate actors with a relevant horizontal ability.

After that, depending of the horizontal ability, project manager can select designers to the project. For the horizontal ability area, the larger will be the better.

2.2.2 Group interaction and personal relationship

In order to optimize the resource allocation, project managers need to consider about group interactions and personal relationships. The communication performance of the project members is one of the key factors contributing to the success or failure of the project (Hepworth et al. (2015)). If the team members are capable of sharing the data smoothly and solving the issues collaboratively, it will certainly enhance the team members' understanding toward project conditions, thereby enhancing the overall performance of the project (Chen et al. (2013)). Working together in a team is facilitated only if each member of the team has a theory of the other members' mind, ability, concepts and intents (Juhász (2010)). Coordination of actions depending on the communicative exploitation of the participants' common ground – that great mass of knowledge, beliefs, and suppositions which the participants believe they share (Jones (2016), Harris (1996)). As the participants interact, furthering their joint project, their common ground is also very important which includes everything they have experienced so far as well as what the participants presuppose to be the state of activity at the moment (Jones (2016), Harris (1996)).

In addition, the group interactions and personal relationships will influence the satisfaction of each member in the teamwork, and the strength of conflicts about interactions between team members, which will directly affect the work performance and project completion efficiency. The good group interactions and personal

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relationships are affected by a harmonic environment, trust among all the actors, aspiration, motivation, personal satisfaction, personality, etc. Therefore, the most important success key factors among actors are common “ground”, which means that it is better to have small horizontal properties gap between them to increase the efficiency of communication and harmonic environment and to have a good group interactions and personal relationships. Indeed, very often, the efficiency of the collaboration, information exchange, interaction between actors concerning about the gap between their horizontal abilities. In here, company managers must calculate the total gap of horizontal properties among actors to choose the most adaptive collaboration of candidate actors.

The Total Average Gap (TAVG) is the group interactions and personal relationships gap. To be able to calculate the total average gap between the actors in a group, we have to, firstly, calculate the average gap of each property for the entire group, then, we can summarize the results to obtain the Total Average Gap.

$$AG = \frac{\sum_{m=1}^{E-1} \sum_{h=m+1}^E |y_m - y_h|}{\sum_{m=1}^E (E - m)} \quad (2.1)$$

Note. AG = Average Gap of one property of the horizontal ability for the entire group.
E: total number of Actors.

In here, AG is the sum of the absolute subtraction value for the same property between two actors, divided by the members of actors. Meanwhile, “y” is the level value of the property.

An example of calculation group interaction and personal relationship gap result can be seen as the Figure 2.10.

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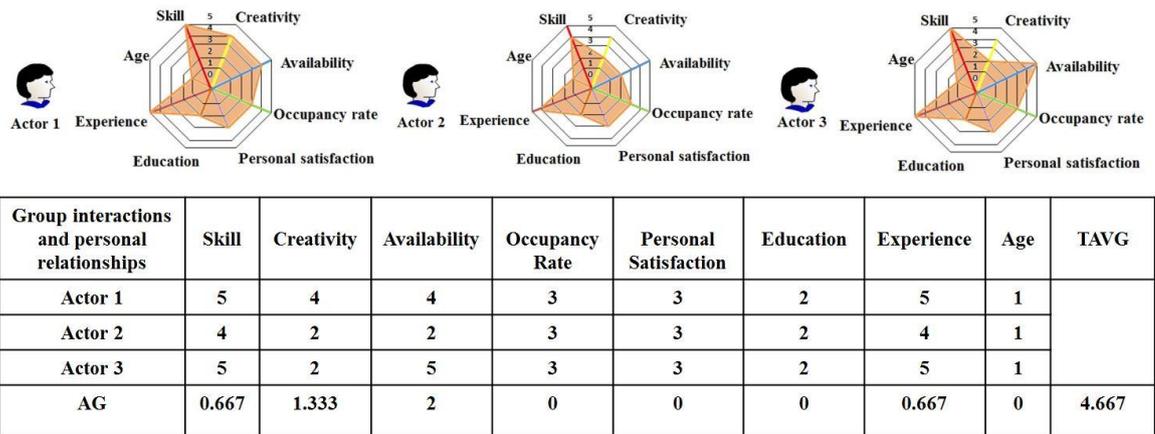


Figure 2.10 – Example for Group Interactions and Personal Relationships gap.

For the calculation of AG, we use the equation (2.1) to release it. Such as the AG for Skill, we understand that the gap between Actor 1 and Actor 2 is 1 (5 - 4), gap between Actor 1 and Actor 3 is 0 (5 - 5), and gap between Actor 2 and Actor 3 is 1. Hence, the AG for the group Actor1, Actor 2 and Actor 3 is 0.667.

In this example: $M = 3$

$$\begin{aligned}
 AG &= \frac{\sum_{m=1}^2 \sum_{h=m+1}^3 |y_m - y_h|}{\sum_{m=1}^3 (3 - m)} \\
 &= \frac{|y_1 - y_2| + |y_1 - y_3| + |y_2 - y_3|}{(3 - 1) + (3 - 2) + (3 - 3)} \\
 &= \frac{|5 - 4| + |5 - 5| + |4 - 5|}{2 + 1} \\
 &= \frac{1 + 0 + 1}{3} = \frac{2}{3} = 0.667
 \end{aligned}$$

Then, we can calculate the TAVG, as follows:

$$TAVG = \sum_{n=1}^F AG_n \quad (2.2)$$

Note. TAVG: Total average gap. AG = Average Gap of one property of the horizontal ability for the entire group. F = Total numbers of horizontal properties (8 in our case).

In this case:

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$$\begin{aligned}
 TAVG &= \sum_{n=1}^8 AG_n \\
 &= 0.667 + 1.333 + 2 + 0 + 0 + 0 + 0.667 + 0 \\
 &= 4.667
 \end{aligned}$$

After that, we need to calculate all the combinations of possible groups of actors, and select the lowest group interactions and personal relationships gap to define the final actors to the project. The reason why the project manager needs to select the lowest gap is that the higher gap between actors existing, the higher risk environment, which will cause tremendous effect to the company, emerging. The lowest gap will increase the efficiency of the collaboration, information exchange and interactions between the actors. We can take an example of calculation. In here, we want to select 3 actors between 5 compatible actors. The detailed example can be seen as Figure 2.11.

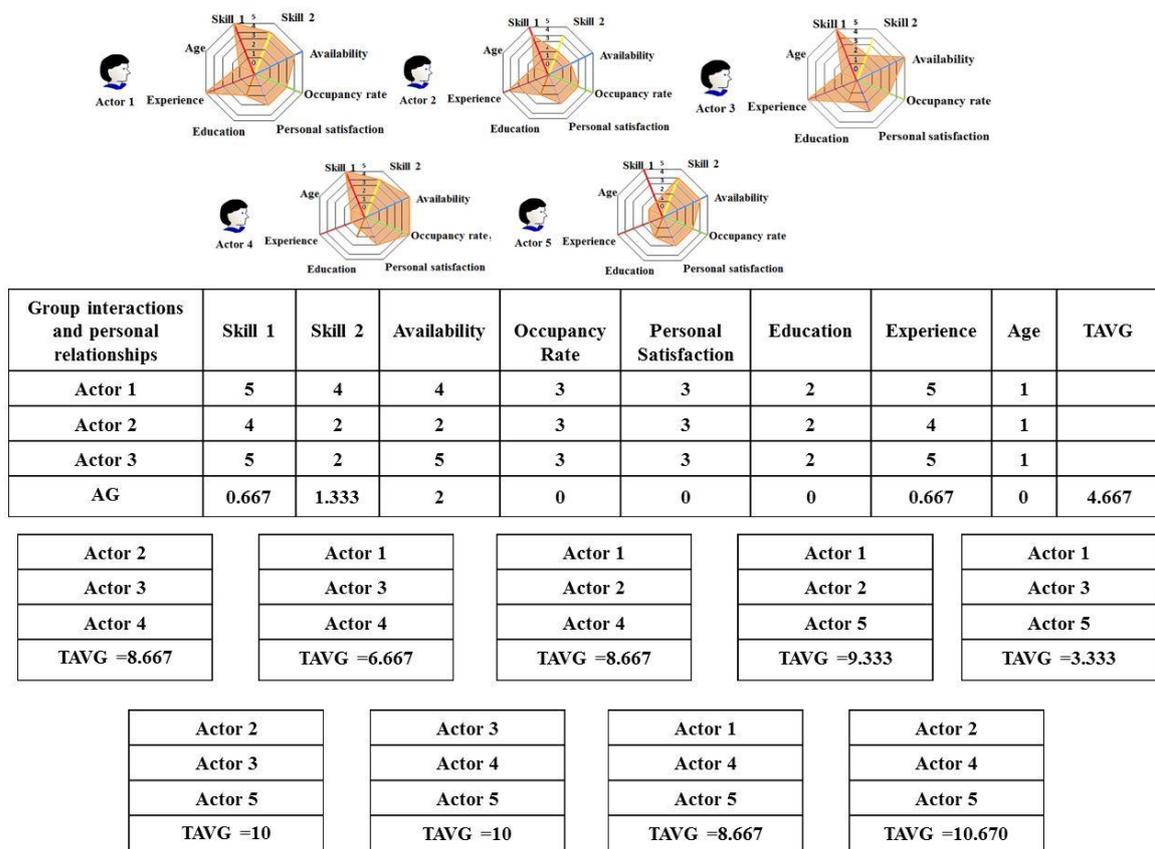


Figure 2.11 - Example of 3 actors selection between 5 compatible actors

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From the Figure 2.10, we can find that there are 10 combination types. Meanwhile, the group Actor 1, Actor3 and Actor5 has the lowest TAVG value (3.333).

2.3 Look for compatible actors from the point of view of personality

2.3.1 Personality analysis

From Cost commitment and incursion in the product development life cycle (Buede & Miller (2016), Haik et al. (2015)), we understand that mistakes made in the conceptual design have extremely negative impacts (high percentage of cost to fix the mistakes at the end of process) on the final product, while the mistakes made in the detailed design step have little negative impacts. Meanwhile, because of the reason that many kinds of designers will communicate and collaborate frequent in future design process, project managers should find the designers who have personalities allowing to communicate and collaborate with other designers in harmonious environment, and prevent the occurrence of conflicts between them, which could cause the mistakes in the design process.

To analyze the personality of the candidate actors, we can introduce the Five-Factor model (FFM) (McCrae and Costa (2013), McCrae et al. (2002)) of personality, which firstly claimed by Tupes (1961) & Norman (1963). The five personality factors are Neuroticism (N), Extraversion (E), Openness (O), Agreeableness (A) and Conscientiousness (C). The FFM is the most widely accepted solution to the problem of describing trait structure (McCrae & Costa (2013)), and it can reflect individual differences in personality. One of the most popular measures of the FFM is the Revised NEO Personality Inventory (NEO-PI-R) (Costa and McCrae (1992)). The NEO-PI-R is a 240-items questionnaire that assesses 30 specific facets (8 items for each of the specific facet), 6 for each of the five basic personality factor. For example, the personality factor Neuroticism contains 6 facets of Anxiety (N1), Angry Hostility (N2), Depression (N3), Self-Consciousness (N4), Impulsiveness (N5) and Vulnerability (N6). Meanwhile, the facet Anxiety (N1), contains 8 items (questions), such as the item “I often worry about things that might go wrong”, which relative to

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the individual anxiety. All the 240-items in NEO-PI-R are answered on a 5-point (rated on a 1 to 5) Likert scale, which is ranging from strongly disagree to strongly agree (McCrae et al. (2005)). NEO PI-R can describe the personality in terms of these five basic dimensions or factors, and scores provide good estimates of these five factors by summing the six facets in each domain (Kallasmaa et al. 2000). In 2005, Costa and McCrae published the NEO PI-3 model (McCrae et al. (2005), Fountoulakis et al. (2014)), it is an improved version of the NEO PI-R increasing the readability of last version. From here, we use this Inventory to analyze the candidate actors' personality. After getting the raw scores (240-item questionnaire score), these raw scores will be converted to T-scores (Equation (2.3)), which will be used to calculate the domain factor scores.

$$T = 50 + 10 \frac{x - MEAN}{SD} \quad (2.3) \text{ (Iverson (2011))}$$

Note. x : A raw score to be standardized.

MEAN: the mean of the normative sample.

SD: Standard Deviation of the normative sample.

The T scores are standardized scores that take into account the scores obtained by other persons in the normative sample that has been used for the scoring of the test, and like equation (2.3), T-scores have a mean of 50 and a standard deviation of 10 (Costa and McCrae (2008)). In here, the standard deviation of 10 means a difference of 10 units in T-scores, such as a score of 65 is two standard deviations above the 45. The T-scores are based on various normative samples (Singer (2005)). Such as, for example, depending on the standardization of the NEO-PI-3 in the Greek general population (Fountoulakis et al. (2014)), the value of SD and MEAN for the personality factor Neuroticism are 89.06 and 19.59. Meanwhile, after finishing the NEO-PI-R personality questionnaires, if the raw score of personality factor Neuroticism result is 131, the T-score for the Neuroticism will be 71.41 ($50 + 10 \frac{131-89.06}{19.59}$). A higher

T-score means a stronger trend of corresponding domain of personality. For example, individuals who have a high score of neuroticism are more likely than average to be moody and to experience such feelings of anxiety, worry, fear, anger, frustration, envy, jealousy, guilt, depressed mood, and loneliness (Shah et al. (2017), Goldberg (1993)). In addition, in coherence with the NEO PI-R T-scores classifications, Costa and

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McCrae (1992) characterized the scores scale of each facet or personality domain: A score less than 35 is designated as very low; between 35 and 45, as low; between 45 and 55, as average; between 55 and 65, as high; and above 65, as very high (Detrick and Chibnall (2006)). The relationship table between personality tendency and score range of the NEO PI-3 inventory is presented Table 2.6.

Table 2.6 - personality tendency and score range (PsyPro Corporation and PAR Staff (2014), Andreassen et al. (2013), Wilberg et al. (2009), Costa Jr and McCrae (2008))

Personality Traits	Rank	Description	T-Score Range
Conscientiousness	Very High	Very purposeful, strong-willed, and determined	score \geq 65
	High	purposeful, strong-willed, and determined	65 > score \geq 55
	Average	Not purposeful nor lackadaisical in working	55 > score \geq 45
	Low	Lackadaisical in working	45 > score \geq 35
	Very Low	Very lackadaisical in working	35 > score
Neuroticism	Very High	Very fear, sadness, embarrassment	score \geq 65
	High	Fear, sadness, embarrassment	65 > score \geq 55
	Average	Not fear nor calm	55 > score \geq 45
	Low	Calm, even-tempered, relaxed	45 > score \geq 35
	Very Low	Very calm, even-tempered, relaxed	35 > score
Openness to experience	Very High	Very active imagination and aesthetic sensitivity	score \geq 65
	High	Active imagination and aesthetic sensitivity	65 > score \geq 55
	Average	Not Active imagination nor conventional	55 > score \geq 45
	Low	conventional in behavior	45 > score \geq 35
	Very Low	Very conventional in behavior	35 > score
Agreeableness	Very High	Very fundamentally altruistic	score \geq 65
	High	fundamentally altruistic	65 > score \geq 55
	Average	Not fundamentally altruistic nor	55 > score \geq 45

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		disagreeable	
	Low	disagreeable or antagonistic	45 > score ≥ 35
	Very Low	Very disagreeable or antagonistic	35 > score
Extraversion	Very High	Very assertive, active, and talkative	score ≥ 65
	High	Assertive, active, and talkative	65 > score ≥ 55
	Average	Not Assertive nor reserved	55 > score ≥ 45
	Low	Reserved, independent, and even-paced.	45 > score ≥ 35
	Very Low	Very Reserved, independent, and even-paced.	35 > score

In the Table 2.6, we can find the relationship between different personality ranks and T-scores ranges with the detailed personality description of every rank. We will use this table to define the final five personality traits tendency level for each candidate actors.

2.3.2 Look for compatible actors taking into account their personality

In past decades, there is very a limited research about the personality analysis for the composition of design team members. Kichuk & Wiesner (1997) proposed a report to illustrate the personality gap between the successful design teams and unsuccessful counterparts with the consideration of Big-five personality model. The personality analysis result for successful and unsuccessful design teams can be seen in the Table 2.7.

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Table 2.7 - Personality analysis result for the successful and unsuccessful design teams (Kichuk and Wiesner (1997))

Personality Trait	Mean	
	NZS subset	ZC subset
Conscientiousness	101.7	96.5
Extraversion	94.3	86.5
Neuroticism	55.8	68.6
Agreeableness	98.4	89.7
Openness to experience	85.5	82.6

Note. NZS subset = Non-Zero Scoring subset (e.g., successful subset).
 ZC subset = Zero scoring subset (e.g., failing subset).

The Table 2.7 illustrates the personality gap between the successful design teams and unsuccessful counterparts. In here, to make this test, all the actors were randomly assigned to teams of three for a design exercise, and, in total, there was the 117 teams created. After that, every team had to simultaneously complete same engineering design project (design and build a bridge). One the projects of all the teams have been completed, each designed product (prototype of bridge) has been scored by specially trained research assistants. From then on, all the 117 teams have been divided as two subsets: the 17 teams that received a Score of Zero (ZS subsample) on their product and the 100 teams that received a Non-Zero Scores (NZS subsample) on their product. The personality comparisons between two subsamples were made in order to determine if there were characteristics that distinguished successful teams (e.g, the NZS subset) from unsuccessful teams (e.g., the ZS subset). For the personality testing, they used the NEO-PI inventories. They firstly let all the actors to complete the 240-item questionnaire in NEO-PI, and calculated the raw score of every Big-five personality domain (Conscientiousness, Extraversion, Neuroticism, Agreeableness and Openness to experience) for every actor. After that, they calculated the mean value for every Big-five personality domain in the two subsamples. For example, the value 101.7 in Table 2.7 is the result of the sum of the Conscientiousness values for all the actors of the NZS subset, divided by the total number of actors (100 teams of three: 300 actors) in the NZS.

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In the table, we can see that, except the personality trait of Neuroticism, other personality traits (Conscientiousness, Extraversion, Agreeableness and Openness to experience) values for successful subset (NZS subset) are higher than the unsuccessful subset (ZS subset). It means that a Conscientiousness, Extraversion, Agreeableness and Openness to experience have positive effect to the design team performance, while Neuroticism has negative effect to the design team performance. Therefore, depending on this tendency and the relationships between personality tendency and scores range in Table 2.6, we propose the Big-Five personality criteria rank for a design projects (Table 2.8).

Table 2.8- Big-Five personality criteria ranks for design projects

Rank \ PT	Conscientiousness	Neuroticism	Openness to experience	Agreeableness	Extraversion
5	Very High	Very Low	Very High	Very High	Very High
4	High	Low	High	High	High
3	Average	Average	Average	Average	Average
2	Low	High	Low	Low	Low
1	Very Low	Very High	Very Low	Very Low	Very Low

In this table, the rank of every Personality Trait is ranged from 1 to 5, which just match to 5 tendency levels in Table 2.6 (from Very Low to Very High). However, because of the reason that the personality of Neuroticism has negative on the success of design project, we can use opposite trend (from Very High to Very Low) to define the Neuroticism property rank. For the description from rank 1 to 5 for every Big-five personality domain, we always use the personality rank description of the Table 2.6.

After that, in the Table 2.7, the gaps of personality traits between NZC subset and ZC subset are different with each other. Thus, we have to calculate the absolute value of all the gaps of personality traits between NZC subset and ZC subset, and make the comparison among them to define the weight of every personality traits. The weights associated to the different personality traits for design projects can be shown in Table 2.9.

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Table 2.9- Weight for different personality traits in design project

PT	Absolute value of gap of PT	Weight
C	$101.7 - 96.5 = 5.2$	0.406
E	$94.3 - 86.5 = 7.8$	0.609
N	$68.6 - 55.8 = 12.8$	1
A	$98.4 - 89.7 = 8.7$	0.68
O	$85.5 - 82.6 = 2.9$	0.227

Note. PT = Personality traits. C = Conscientiousness. N = Neuroticism. O = Openness to experience. A = Agreeableness. E = Extraversion.

For easier use, we decide to have the values of the weight between 0 and 1. Therefore, because the PT Neuroticism has the highest gap value, it is associated to a weight equal to 1.

Then, we have to divide each absolute value of gaps of the Personality Traits by the highest gap value. For example, the weight associated to the Agreeableness is

$$\frac{98.4 - 89.7}{12.8} = 0.68.$$

Now, it is possible to combine the Big-Five personality criteria rank for design project table and Weights for different personality traits for design projects (Table 2.9).

An example is shown Figure 2.13.a and Figure 2.13.b.

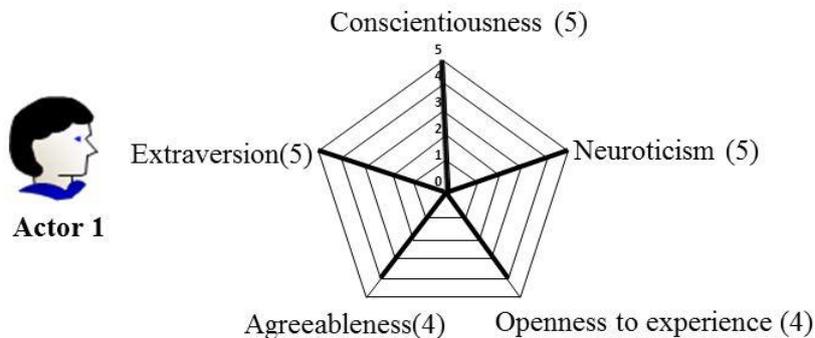


Figure 2.13.a – Big-Five personality criteria of an actor for design projects

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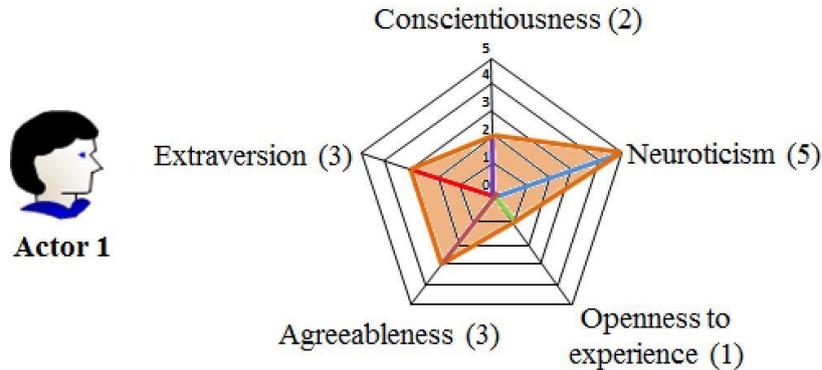


Figure 2.12.b – Example of weighted personality ability of an actor for design project

The personality ability of an actor for design project is the personality ability which will affect creativity, communication, collaboration and knowledge sharing with other actors in design teams. In the Figure 2.12.b, we can see the five Personality Traits (Conscientiousness, Neuroticism, Openness to experience, Agreeableness and Extraversion). Depending on the personality criteria rank for design projects Table 2.8, the rank of the 5 Personality Traits is ranged from 1 to 5. The colored line in the Figure 2.12.b represents each weighted Personality Trait, which is the combination of the rank value with the weight value (Table 2.9). For example, the initial rank of Extraversion for the actor was 5. The weight of this PT being 0.609 (see Table 2.9), the weighted PT of extraversion becomes 3 (round the value 5×0.608 to the nearest whole number). Meanwhile, we can find that the trait Neuroticism has the highest weighted value (5). It means that the trait of Neuroticism for the designer has the greatest impact to the communication and collaboration in the design team (harmonic environment), compared the other four traits. Also, because of the Neuroticism has negative effect to the design team performance, the higher value of Neuroticism Figure 2.12.b leads to the lower rank of personality Neuroticism T-score (Table 2.8).

After that, it is possible to calculate the personality ability of an actor for design projects. The personality ability means an ability to communicate and collaborate with other actors in the design projects. In here, we calculate the total area of the Figure 2.12.b. Here, the total area of the graph is: $(0.5 \times 2 \times 5 \sin 72^\circ + 0.5 \times 5 \times 1 \sin 72^\circ + 0.5 \times 1 \times 3 \sin 72^\circ + 0.5 \times 3 \times 3 \sin 72^\circ + 0.5 \times 3 \times 2 \sin 72^\circ) = 15.69$.

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Now the project managers can select candidate actors taking into account the comparison among personality ability of candidate actors (Figure 2.12.b). In here, the more of the design project personality area means the better of personality ability.

After that we can make the sum of the personality ability for all the actors in one combination group to calculate the Group Personality Ability (GPA). For example, in the Figure 2.11, if the personality ability for Actor1, Actor2 and Actor3 is 15.69, 12.75 and 13.82, the GPA for this combination is: $(15.69 + 12.75 + 13.82) = 42.26$.

2.4 Calculate group's ability to work together and ability of a person work in a group

2.4.1 Calculate group's ability to work together

Because of the IoT and internet driven global economy, designers are involved in different design projects with collaboration among different kinds of designers. In the factory of the future, it will be very easy for the designers to meet with new collaborated actors who have been worked together before. In such a context, it seems relevant to analyze the working together ability in a group for different design projects in order to find the most harmonious and effective collaboration and also decrease potential mistakes in the design process.

In here, the group's ability to work together means the combination of years of collaboration and communication in the past with the attitude of satisfaction. The experience work together relationship between two actors can be seen as Figure 2.13.

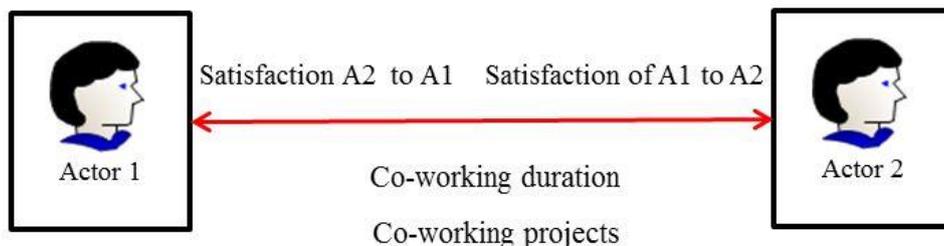


Figure 2.13 - Ability to work together between two actors

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In the Figure 2.13, Actor1 and Actor 2 have already communicated and collaborated together in the past. In this experience of communication and collaboration, each actor has its own satisfaction. This satisfaction is necessarily linked to the length of communication time (duration) and to the number of projects worked together.

In here, we define the evaluation criteria of the satisfaction property in the Table 2.10.

Table 2.10- Personal satisfaction evaluation criteria

Satisfaction	Rank
Very Dissatisfied	0
Dissatisfied	1
Neutral	2
Satisfied	3
Very Satisfied	4

In the Table 2.10, the satisfaction tendency can be divided in 5 ranks, from “Very Dissatisfied” rank to the “Very Satisfied” rank. The satisfaction range means the satisfactory level for communication and collaboration with other actors in the past.

In here, under the same satisfaction level, the more number of cooperative projects and long projects between two designers means the more experience working together ability of this pair. Therefore, we can suppose that they are more capable of working together in new projects.

After understanding the relationship of co-working experience between two actors, we can define the objective function of the Group’s Ability to Work Together (GAWT) (equation (2.4)).

$$GAWT = \frac{\sum_{n=1}^{NM-1} \sum_{m=n+1}^{NM} (PREWA_{nm})}{\sum_{n=1}^E (E - n)} \quad (2.4)$$

$$PREWTA_{ab} = \left(\frac{SL_{ab} + SL_{ba}}{2} \right) \cdot NY_{ab} H_{ab} \quad (2.5)$$

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Note. GAWT = Group's Ability to Work Together. $PREWTA_{ab}$ = Pair Experience Working Together Ability between actor 'a' and actor 'b'. SL_{ab} = Satisfaction Level for actor 'a' to actor 'b'. NY_{ab} = the number of years worked together between actor 'a' and actor 'b'. H_{ab} = the number of projects worked together between actor 'a' and actor 'b'. NM = Number of Members in the group. $NY_{ab} = NY_{ba}$. $SL_{ab} \neq SL_{ba}$. $H_{ab} = H_{ba}$.

When we calculate the GAWT, we should firstly calculate the pair experience working together ability (PREWTA: Equation (2.5)) between every pair of actors. The PREWTA is a pair ability of work together. In here, we should firstly release the average value of both sides of satisfaction, and multiply with the number of years and projects of experience working together. If there is no relationship between two actors, the PREWTA value for these two actors is 0. Then, we can make the average of the PREWTA value for every two actors in the group, to release the final GAWT value.

Such a value will allow to understanding the most harmonious and effective collaboration combination in a group. The objective is, the best collaborations combination in a group, to decrease the design process mistake and prevent the final product accidents.

An example of GAWT calculation is shown in Figure 2.14.

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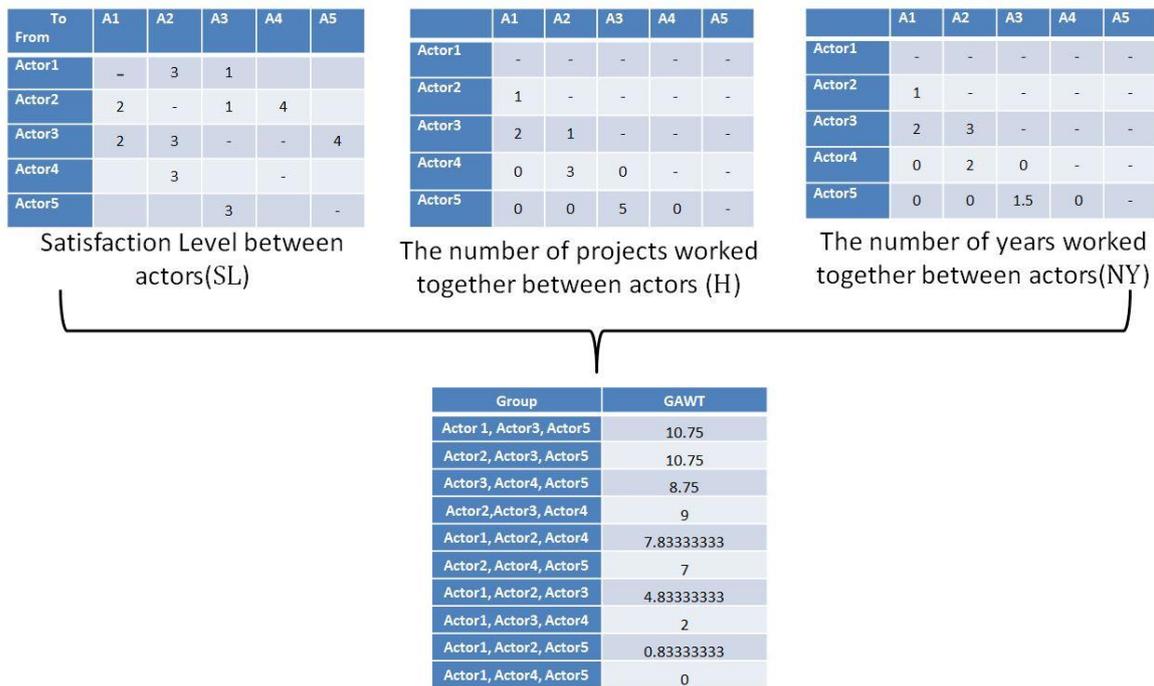


Figure 2.14 An example of GAWT calculation

In the Figure 2.14, there are 10 actors and project needs three actors. Therefore, through the table of “Satisfaction Level between actors (SL)”, “The number of projects worked together between actors (H)”, “The number of years worked together between actors (NY)”, equation (2.4) and equation (2.5), we can calculate the GAWT value for different combination groups (bottom table in the figure). In the table, for example, the group Actor2, Actor3 and Actor5, the GAWT value is:
$$\frac{\left(\frac{1+3}{2}\right) \times 1 \times 3 + \left(\frac{4+3}{2}\right) \times 5 \times 1.5 + \left(\frac{0+0}{2}\right) \times 0 \times 0}{(3-1) + (3-2) + (3-3)}$$
 = 10.75. Meanwhile, the group Actor1, Actor3 and Actor5 has the highest value (10.75).

2.4.2 Ability of a person to work in group

If the values of GAWT are the same among different combinations of actors, we have to distinguish these combinations through the comparison of the total ability value of A Person to Work in a Group (APWG). Because of the reason that, in the factory of the future, designers can communicate and collaborate with many kinds of designers from all over the world, they will have many kinds of experience to work together with other designers. The more ability of experience work together with other designers

Chapter 2 Human resources allocation methodology

means the better adaptability of the collaboration with the new design project members.

For the personal experience working together relationship can be seen as the Figure 2.15.

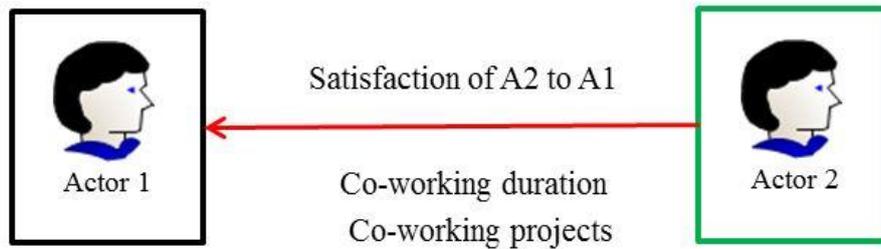


Figure 2.15 - Ability of a person to work in a group relationship for Actor 1

In the Figure 2.15, we can find that the ability of a person to work in a group for Actor1 will be defined by the number of projects and years worked together between Actor 1 and other collaborated actors (Actor 2), and the satisfied attitude of collaborated actor (Actor 2). The reason why we only use the satisfied attitude for collaborated actor (Actor 2) is that personal collaboration ability is determined by others' attitudes rather than by oneself. The objective function of Ability of a Person Work in a Group (APWG) can be seen as equation (2.6).

$$APWG_a = \sum_{n=1}^Q (H_{an}NY_{an}SL_{na}) \quad (2.6)$$

Note. APWG = Ability of a Person Work in a Group. NU = Total number of personal experience working together actors. H = the number of projects worked together. NY = Duration of the collaboration. SL = Collaborated actors' satisfaction. Q = Number of collaborated actors in the group.

For the calculation of APWG (Equation (2.6)), it is the sum of the experience of co-working ability ($H_{an} \cdot NY_{an} \cdot SL_{na}$) from the main actor (a) to all the other collaborated actors (n) in the group. In the equation (2.6), the ' SL_{na} ' means the

Chapter 2 Human resources allocation methodology

satisfaction attitude of collaborated actors (n) to the main actor (a), and 'NY' means the the duration of cooperation (NY) between main actor and collaborated actor.

After that we can make the sum of APWG value for all the group members (different candidate combination actors), and compare the sum value among the groups (the groups have the same value of GAWT) to define the final allocation. In here, the larger of the sum value means the better of the group communication and collaboration performance.

We keep on the example in the Figure 2.14. In the figure, there are two same highest GAWT value (10.75) groups. They are the combination Actor1, Actor3 and Actor5, and the combination Actor2, Actor3 and Actor5. Therefore, to identify these two groups, depending on the table of "Satisfaction Level between actors (SL)", "The number of projects worked together between actors (H)" and "The number of years worked together between actors (NY)" in Figure 2.14, and equation (2.6), we can get the APWG for each actor (Table 2.11).

Table 2.11 - Personal satisfaction evaluation criteria

Actor	APWG
Actor1	10
Actor2	30
Actor3	29.5
Actor4	24
Actor5	30

From the Table 2.11, we understand the APWG value for all the 5 actors, such as the APWG value for Actor1 is: $((2 \times 1 \times 1) + (2 \times 2 \times 2) + 0 + 0) = 10$. After that we can use the group total APWG value to identify the two same GAWT value (10.75) groups.

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Table 2.12 - Group total APWG for the same value (10.75) groups in Figure 2.14

Group	Total APWG
Actor1, Actor3, Actor5	69.5
Actor2, Actor3, Actor5	89.5

From the Table 2.12, the value of total APWG for the group Actor1, Actor3, Actor5 is: $(10+29.5+30) = 69.5$. Meanwhile, in the table, we can find that the group Actor2, Actor3 and Actor5 has the highest total APWG value (89.5).

2.5 Define the total normalized value

The final selection of the designers is to evaluate the three abilities (Horizontal and group interaction ability, personality ability and group's ability to work together). However, if there is an inconsistency between these three factors, project manager should make a trade-off among the three factors depending on the other constraints (cost, time and quality of project completion) in the company. To make the trade-off among these three factors, we have to normalize the three values between 0 and 1. The Min-Max normalisation (Raschka (2014)), often simply called "normalization", is an approach allowing to scale the data to a fixed range, consisting in rescaling the range of features to the range in $[0, 1]$. A Min-Max normalisation is typically done via the Equation (2.9).

$$X_{norm} = \frac{X - X_{min}}{X_{max} - X_{min}} \quad (2.9)(Raschka (2014))$$

In the Equation (2.9), the X is an original value and X_{norm} is the normalized value. X_{min} is the minimum value for variable X , and X_{max} is the the maximum value for variable X . If X_{max} is equal to X_{min} then X_{norm} is set to 0.5. Therefore, we can use the Min-Max normalisation to normalize the three ability analysis result value between 0 and 1.

After that, project manager can calculate final Normalized Total Numbers (Equation (2.10)) for these two factors.

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$$NTN = NTAVG + NGPA + NGAWT \quad (2.10)$$

Note. NTN = Normalized Total Number. NGPA = Normalized Group Personality Ability. GAWT = Normalized Group' s Ability to Work Together.

In the Equation(2.10), the NTAVG, NGPA, and NGAWT is the normalized value. Project manager can use NTN (Normalized Total Number) value to define the allocation.

The example of NTN calculation for the 10 combination types in the example Figure 2.11 and Figure 2.14 is shown in Table 2.13.

Table 2.13– Example of NTN calculation

Group	TAVG	NTAVG	GPA	NGPA	GAWT	NGAWT	NTN
Actor 1, Actor3,Actor5	3.33	0	31	0.70	10.75	1	1.7
Actor2, Actor3, Actor5	10	0.91	40	1.00	10.75	1	2.91
Actor3, Actor4, Actor5	10	0.91	28	0.60	8.75	0.81	2.32
Actor2,Actor3, Actor4	8.67	0.73	25	0.50	9	0.84	2.07
Actor1, Actor2, Actor4	8.67	0.73	25	0.50	7.83	0.73	1.96
Actor2, Actor4, Actor5	10.67	1	12	0.07	7	0.65	1.72
Actor1, Actor2, Actor3	4.67	0.18	10	0	4.83	0.45	0.63
Actor1, Actor3, Actor4	6.67	0.45	15	0.17	2	0.18	0.8
Actor1, Actor2, Actor5	9.33	0.82	23	0.43	0.83	0.08	1.33
Actor1, Actor4, Actor5	8.67	0.73	20	0.33	0	0	1.06

In the Table 2.14, for example, NTAVG for the group Actor1, Actor2, Actor3 is:

$$\left(\frac{4.67-3.33}{10.67-3.33}\right) = 0.18. \text{ Meanwhile, the NTN value for the group Actor1, Actor2, Actor3 is:}$$

$$(0.18 + 0 + 0.45) = 0.63. \text{ In the table, the highest value of NTN is 2.91. Therefore,}$$

finally, project manager should allocate Actor2, Actor3 and Actor5 to the project.

Conclusion

In this chapter, we propose a human resource allocation methodology. In this methodology, we firstly identify the priority of the project. In here, through the different assigned project urgency levels, we can order the multi-project to select candidate actors for these projects. After that, analysis the horizontal ability and calculate the group interaction and personal relationship ability value to find the best combination of group in a good group interactions, personal relationships and harmonic environment. Afterwards, we propose a method to analysis the personality ability of candidate designer. With the personality analysis process, project manager can select candidate actors, who have most favorable personality for design team, to the project, and to understand the individual collaboration harmonious environment degree in the team context. At the final, we analyze the group's ability to work together of the different combination group in candidate actors. In this part, we calculate the GAWT values to find the most harmonic and collaboration effective combination group to decrease the design process mistake and prevent the final product accident. In here, if the GAWT values are the same among different combination groups, we can consider the APWG value for all group members to define the final allocation of the candidate actor.

Taberero and Wood (Taberero and Wood (1999)) worked that self-evaluative reactions to performance for employee were recorded on their satisfaction level. However, the importance of employee satisfaction always neglect for the company in the past years (Boudreau (2004)). Therefore, the objective of the following chapter is to analyze designer satisfaction in the project selection process.

CHAPTER 3 PROJECT SELECTION

METHOD

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List of Observation

AHP = Analytic Hierarchy Process.

$AWSG_k$ = Average Weighted Pair Satisfaction Gap in kth project.

AWTSL = Average value of Weighted Total Satisfaction Level.

F1 = Hygiene Factors.

F2 = Motivator Factors.

J = Total number of projects.

NP = Number of the projects in the portfolio.

SF = Satisfaction sub-factor.

SSF = Satisfaction sub-sub-factors.

ST = Strength of social relationship between two designers.

TAWPSG = Total Average Weighted Pair Satisfaction Gap.

TK = Total number of kth sub-sub-factors of jth sub-factor of ith factor.

TND = Total Number of Designers involved in same project.

UI = User Interface.

U_{ijk} = Weighted satisfaction of the kth influence sub-sub factor of jth influence sub-factor of ith influence factor.

V_{ij} = Weighted satisfaction of the jth influence sub-factor of the ith influence factor.

W_i = Weighted satisfaction of the ith influence factor.

WSG_{ij} = Weighted Satisfaction Gap between designer i and designer j.

WTSL = Weighted Total Satisfaction Level for the designer.

Z = Total number of sub-factors in ith main factor (6 for F1 and 5 for F2).

Introduction

In this chapter, we firstly introduce the whole process of project selection methodology. Then depending on the whole process, we introduce the project selection method step by step, including select projects which the designer can be satisfied with minimum skill requirement and occupation time, calculate the multi-project satisfaction level of designer, and collaboration level of designer for different combination of the projects. In here, for the satisfaction level of the designer, we will brainstorm different factors in design project which can affect designer's satisfaction. After that, we will propose a measurement model to calculate the WTSL (Weight Total Satisfaction Level) to define the designer's satisfaction level with the design project. For the part calculation of collaboration level of designer, we will consider about Individual perception of strength relationship and project satisfaction gap between designers. Here after, project manager can use the result of collaboration ability to define the final assigned multi-projects for the designers.

3.1 Design project selection process

Projects selection must be concerned with a global, organized, shared and governed within the organization. To a true centralized strategic method, the project selection should be approached for a systemic and structured way. The trajectory of project selection strategy with the consideration of mandatory requirement, satisfaction and collaboration ability of designer can be seen as Figure 3.1.

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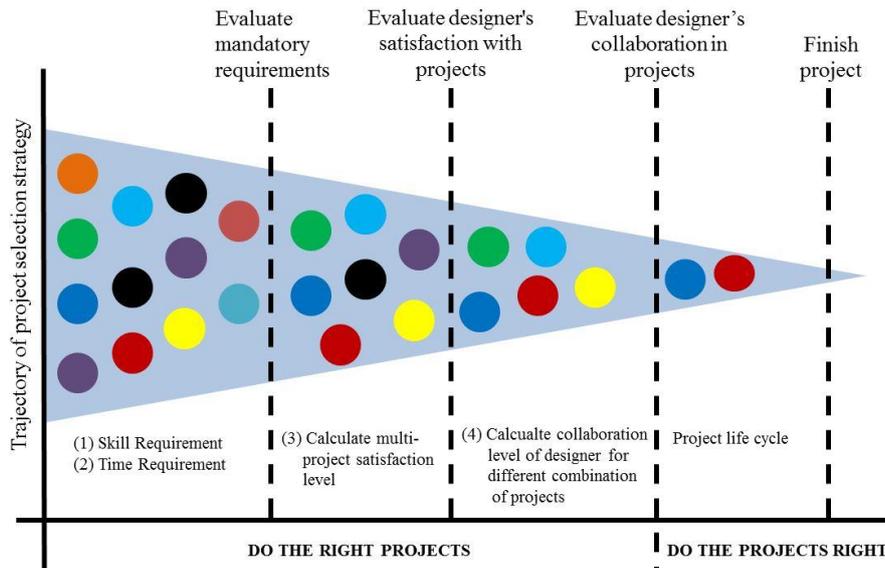


Figure 3.1 - Trajectory of project selection strategy.

In the Figure 3.1, we can find that there are four time points (Evaluate mandatory requirements, Evaluate designer's satisfaction with projects, Evaluate designer's collaboration in projects and Finish project). Before we effectively launch and execute projects (Do THE PROJECT RIGHT), we have to select the valid projects (DO THE RIGHT PROJECTS). In here, the selection process of the valid projects should be filtered step by step. First of all, in the first time point, the mandatory requirements of the candidate projects should be satisfied by the designer. After that, the candidate projects should be satisfied by the designer. Then, the designer should effectively collaborate with other designers in the candidate projects. At the final, the right projects can be positioned to the designers and they can do the projects right.

Depending on the trajectory of project selection strategy in Figure 3.1, the whole process of design project selection in this paper can be seen in the Figure 3.2.

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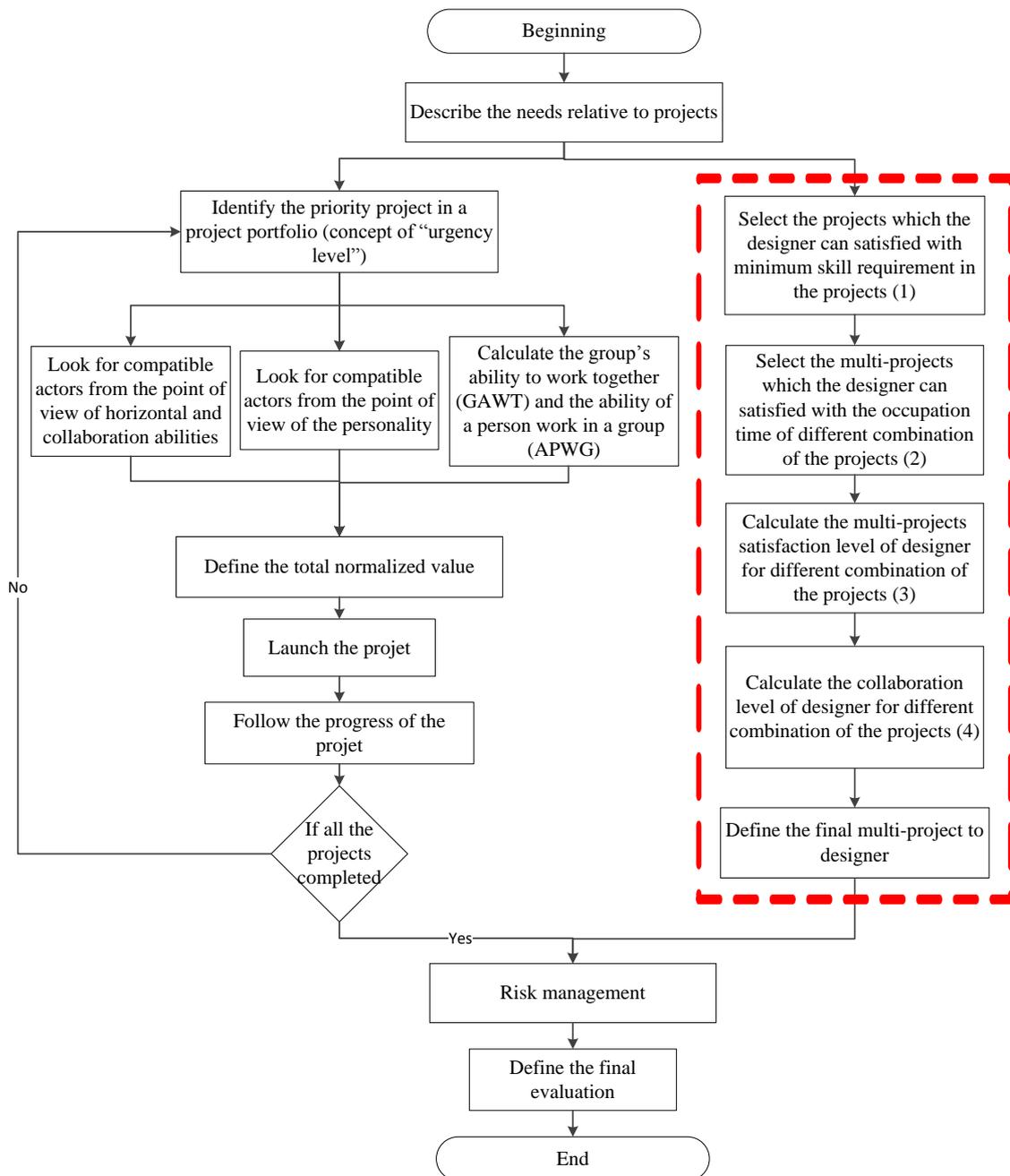


Figure 3.2 - Process diagram for design project selection methodology (part of the red dotted frame).

In this chapter, we only consider about the right branch part (part of the red dotted frame in the Figure 3.2) of whole the human resource allocation process. First of all, we should select the projects which the designer can satisfied with the minimum skill requirement in the project. In here, the skill requirement for design project can be UI (User Interface) design, graphic design basics, design software, and etc. After that we will make further selection of multi-projects which the designer can satisfied with the

occupation time of different combination of the projects. Afterwards, we have to calculate the multi-projects satisfaction level and collaboration level of designer for different combination of the projects. At the final, we will define the final multi-project to designer, and the process will be finished.

3.2 Select the projects with the constraints of minimum skill requirement and occupation time

It is a new type of resource constraints in which staff members are involved where staff members can have several skills with different proficiency, i.e., a staff member is able to perform more than one kind of activity as well as the time need is complete the task assign depending on the staff individual skill (Al-Anzi et al. (2010)). For every design project, there will be one or several mandatory minimum skill requirements (User Experience design, User Interface design, Information architecture, Graphic design, and etc.) to complete the project. These skills are mandatory requirement for the candidate designers. Meanwhile, when the designers are involved in the design project, they have to put in time to finish the design project. Therefore, there must have a minimum required occupation time in the design project for the candidate designers to finish the project. Thus, the skill ability and the occupation time (mandatory requirements of the project) should be available for designers before the project manager want to select suitable design project. It means that the designers must be capable and have the time to complete the project.

In here, for the skill, depending on the skills acquisition model of Dreyfus (Dreyfus (2004)), we can identify the skill level as Table 3.1.

Table 3.1 - Relationship between skill level corresponding rank

Skill level	N	A	C	P	E
Rank	0	1	2	3	4

Note. N = Novice. AB = Advanced Beginner. C = Competent. P = Proficient. E = Expert.

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From the Table 3.1, we can understand the skill level can be ranged from Novice to Expert with the corresponding rank. In here, the higher number of the rank means the designer will be more professional performers to complete the project.

Hence, the relationship between designer and project can be seen as Figure 3.3.

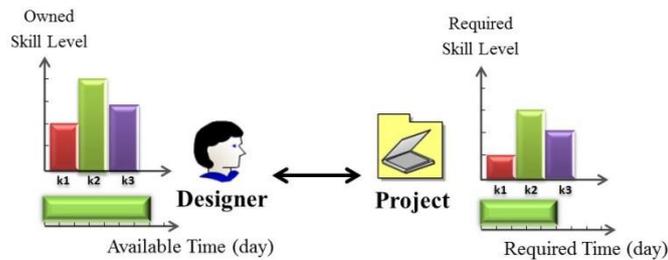


Figure 3.3 - Relationship between designer and project

In the Figure 3.3, we can find that three skills (K1, K2 and K3) are needed by the project with the different minimum required levels (Advanced Beginner for K1, Proficient for K2 and Competent for K3). Meanwhile, the designer has skill K1, K2 and K3 with the corresponding rank Competent for K1, Expert for K2 and Proficient for K3. Therefore, skill level for the designer is satisfied with project required skill level (the skill K1 ($2 > 1$), the skill K2 ($4 > 3$) and the skill K3 ($3 > 2$)). In addition, the available time for the designer also satisfied with the project required time (7 days $>$ 5days). Therefore, mandatory skill requirement and occupation time of the project can be satisfied by the designer.

Apart from that, for the multi-project, the available time for the designer should be larger than the sum of multiple projects' occupation time, and the all the skill levels of the designer should also be larger than the every required skill level for all the multiple projects.

3.3 Calculate the multi-projects satisfaction level of designer for different combination of projects

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After select the multi-projects, which occupation time and skill level requirement is satisfied by designers, it is possible for the designers to select the most satisfactory one or several projects for them. With the consideration about the different employee satisfaction factor representation ways, especially for the Two Factor Theory, in the chapter “Literature Review” and levels of hierarchical needs in Figure 1.3, we will present satisfaction factors of designers like Table 3.2.

Table 3.2- Factors, sub-factors and sub-sub-factors affecting designer satisfaction

Satisfaction factor (F)	Satisfaction sub-factor (SF)	Satisfaction sub-sub-factors (SSF)
Hygiene Factors (F1)	Design project policies (SF1.1)	Rules and policies of organization (SSF1.1)
	Supervision (SF1.2)	Supervisory styles (SSF1.2)
	Work conditions(SF1.3)	Design workstyle - Teamwork or Individualistic (time) (SSF1.3.1)
		Design workstyle - Virtual or Real style (time) (SSF1.3.2)
		Design workplace environment conditions (SSF1.3.3)
	Salary (SF1.4)	Competitive of salary and welfare compare to other similar organizations (SSF1.4)
	Status (SF1.5)	Status of designer within the organization (SSF 1.5)
	Security (SF1.6)	Probability to keep the job (SSF1.6)
Motivator Factors (F2)	Design project its self (SF 2.1)	Project objectives (SSF2.1.1)
		Project workload (SSF2.1.2)
		Project delivery date (SSF2.1.3)
		Project requirements (SSF2.1.4)
	Achievement (SF 2.2)	Sense of achievement in project (SSF2.2)
	Recognition (SF 2.3)	The recognition of designer by project manager (SSF2.3)
	Responsibility (SF 2.4)	Task or needed work (SSF2.4)
	Growth (SF 2.5)	Career development, ability development (SSF2.5)

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From the Table 3.2, we can find that there are 2 main factors (F1, F2) affect designer satisfaction, and every main factor has several sub-factors respectively (6 sub-factors for F1 and 5 sub-factors for F2), and every sub-factor also has one or several sub-sub-factors respectively. In the two main factors, the Hygiene Factors (F1) is the factors are referred to as the maintenance factors and comprise of the physiological, safety and love needs from Maslow's hierarchy of needs (Figure 1.3), they are not directly related to the design project but the conditions that surround doing the design project (Dartey-Baah and Amoako (2011)). The motivator factors, according to Herzberg, pertain to the job content, they are intrinsic to the job itself and do not result from "carrot and stick incentives", and they comprise the physiological need for growth and recognition (Dartey-Baah and Amoako (2011)). In the sub-factors, design project policies (SF1.1) include rules and policies of organization, such as flexible working hours, dress code, breaks, vacation, etc. Supervision (SF1.2) means the project manager different supervision styles (philosopher, theoretician, technician and etc) (Shellene (2015)). Within the organization, good and appropriate working conditions (SF1.3) contribute in performing one's job duties in an appropriate manner, and design work conditions comprise design workstyles (Teamwork or Individualistic, and Virtual or Real style) and design workplace conditions (enough space, proper furniture, technology, lightning, electricity, heating and cooling equipment in accordance to the weather conditions, availability of clean drinking water, restrooms and so forth). Salary (SF1.4) is the pay or salary structure for the designer who involved in the project. The appropriate and reasonable salary (the equal and competitive to those in the same industry in the same domain) will directly influence the satisfaction of designer. For the Status (SF 1.5), designer's status within the organization can directly lead to designer disappointment and frustration. Therefore, it should be familiar and retained. Security (SF1.6) is the probability of designers to keep the job. Designers do not want to be fired during the project and they need security and stable to keep the project. Design project its self (SF2.1), includes all the constraints of the project (Project objectives (SSF2.1.1), Project workload (SSF2.1.2), Project delivery date (SSF2.1.3) and Project requirements (SSF2.1.4)). The constraints should be meaningful, interesting and challenging for the employee to perform and to get motivated. Designers must have a sense of achievement ((SF 2.2)) in their work. Thus, project manager should provide information that which kind of achievements

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they can get from the design project. Apart from that, the recognition (SF 2.3) of designers by project manager will also affect satisfaction of the designers. In here, project manager should provide information on how the he will recognize the designer if the task of the designer is completed successfully. The responsibility (SF 2.4) means allowance of project manager to the designers for greater responsibility for planning and controlling their design work, as a means of increasing motivation and satisfaction. For the Growth (SF 2.5), there must be growth (Career development and ability development) and advancement opportunities in the project to motivate the employees.

All the information relative to the project and the design environment (questionnaire in Table 3.2) will be provided by the project manager before the project selection (before the project manager positioned designer to the candidate design projects).

Using the Table 3.2, we can now introduce the measurement model, allowing to calculate the designer's level of satisfaction with the project via the WTSL (Weighted Total Satisfaction Level). Depending on the main factors, sub-factors and sub-sub-factors in Table 3.2, we can create the measurement model (Figure 3.4) to calculate the WTSL (Weight Total Satisfaction Level) to define the designer's level of satisfaction with the project.

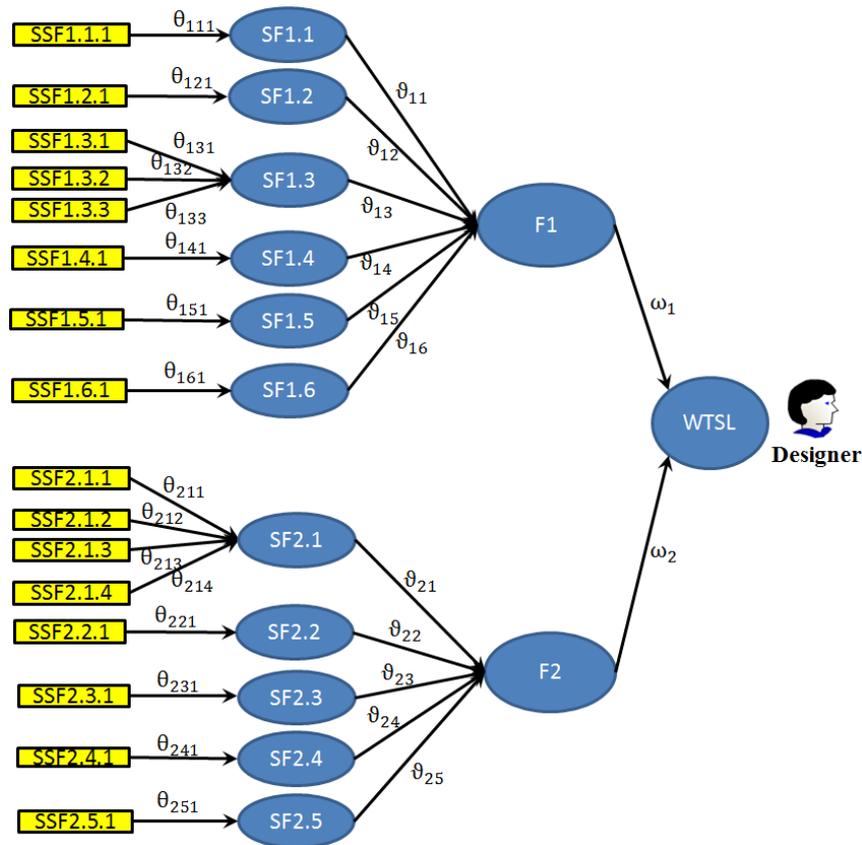


Figure 3.4 - Measurement model of Weighted Total Satisfaction Level (WTSL) for designer relative to one project

First of all, we have to let the designer to define the weight ω for 2 main factors (F), weight ν for sub-factors (SF) and weight θ for sub-sub-factors (SSF). In here, designers can use the AHP (Analytic Hierarchy Process) (Saaty (2008)) methodology to define it. For AHP method, it is used to derive relative priorities on absolute scales (invariant under the identity transformation) from both discrete and continuous paired comparisons in multi-level hierarchic structures (Saaty and Vargas (2013)). The Fundamental scale for pairwise Comparisons can be seen as Table 3.3.

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Table 3.3 - Fundamental scale for pairwise Comparisons

IOI	Definition	Explanation
1	Equal importance	Two elements contribute equally to the objective
3	Moderate importance	Experience and judgement moderately favor one element over another
5	Strong importance	Experience and judgment strongly favor one element over another
7	Very strong importance	One element is favored very strongly over another; its dominance is demonstrated in practice
9	Extreme importance	The evidence favoring one element over another is of the highest possible order of affirmation
Intensities of 2, 4, 6, and 8 can be used to express intermediate values.		

Note. IOI = Intensity of Importance.

Project manager can use Table 3.3 to pairwise compare the every two main factors, sub-factors and sub-sub-factors depending on the different needs of designers. After that we can calculate the right eigenvector of the pairwise comparison result, and release the weights (ω , ν and θ) of all the factors.

Meanwhile, the condition of the weights can be seen as the equation (3.1) through equation (3.6).

$$\sum_{i=1}^2 \omega_i = 1, \quad (3.1)$$

$$\omega_i \in [0, 1]. \quad (3.2)$$

$$\sum_{j=1}^Z \vartheta_{ij} = 1, \quad (3.3)$$

$$\vartheta_{ij} \in [0, 1]. \quad (3.4)$$

$$\sum_{k=1}^{TK} \theta_{ijk} = 1, \quad (3.5)$$

$$\theta_{ijk} \in [0, 1]. \quad (3.6)$$

Note. ω_i = Weight for i th influence factor. ϑ_{ij} = Weight for j th influence sub-factor of i th influence factor. Z = Total number of sub-factors in i th main factor (6 for F1 and 5 for F2). TK = Total number of k th sub-sub-factors of j th sub-factor of i th

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factor. θ_{ijk} = Weight for kth influence sub-sub factor of jth influence sub factor of ith influence factor.

Equation (3.2) means a weight $\omega \in [0, 1]$ near 0 represents that the importance of one satisfaction influence factor is not important than another satisfaction influence factor which contains a weight near 1. Meanwhile, the summation of all the values of two (all the satisfaction influence factors) weights is equal to 1 (equation (3.1)). Meanwhile, equation (3.4) means a weight $\vartheta \in [0, 1]$ near 0 represents that the importance of one sub-factor in one satisfaction influence factor is not important than another sub-factor which contains a weight near 1. Meanwhile, the summation of all the values of sub-factors' weight is equal to 1 (equation (3.3)). Additionally, equation (3.6) means a weight $\theta \in [0, 1]$ near 0 represents that the importance of one sub-sub-factor in one satisfaction sub-factor is not important than another sub-sub-factor which contains a weight near 1. Meanwhile, the summation of all the values of sub-sub-factors' weight is equal to 1 (equation (3.5)).

After the designer has defined the weights of five main factors and all the corresponding sub-factors, the designer has to evaluate the satisfaction level of all the sub-factors.

Then, we can calculate the WTSL (Weighted Total Satisfaction Level). The calculation process of the total satisfaction level for the different satisfaction influence factors can be seen as the equation (3.7) through equation (3.10).

$$WTSL = \sum_1^2 W_i \quad (3.7)$$

$$W_i = \omega_i \cdot \sum_{j=1}^Z V_{ij} \quad (3.8)$$

$$V_{ij} = \vartheta_{ij} \cdot \sum_{k=1}^{TK} U_{ijk} \quad (3.9)$$

$$U_{ijk} = \theta_{ijk} \cdot s_{ijk} \quad (3.10)$$

Note. WTSL = Weighted Total Satisfaction Level for the designer. W_i = Weighted satisfaction of the ith influence factor. ω_i = Weight for the ith influence factor. V_{ij} = Weighted satisfaction of the jth influence sub-factor of the ith influence factor. ϑ_{ij} = Weight for the jth influence sub-factor of the ith influence factor. U_{ijk} = Weighted

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satisfaction of the k th influence sub-sub factor of j th influence sub-factor of i th influence factor. θ_{ijk} = Weight of the k th influence sub-sub-factor of the j th influence factor of i th influence factor. s_{ijk} = Satisfaction of the k th influence sub-sub-factor of the j th influence sub-factor of the i th influence factor. Z = Total number of sub-factors in i th main factor. TK = Total number of sub-sub-factors in j th sub-factor.

In the equation (3.10), the satisfaction evaluation criteria for sub-sub-factors (s_{ijk}) can be seen as the Table 3.4.

Table 3.4- Satisfaction evaluation criteria for sub-sub-factors

Satisfaction	Rank (S_{ijk})
Very Dissatisfied	-2
Dissatisfied	-1
Neutral	0
Satisfied	1
Very Satisfied	2

Note. S_{ijk} = Satisfaction rank of the j th influence sub-factor.

Project manager should firstly let designers to define the weight (depend the AHP method) for satisfaction factors, sub-factors and sub-sub factors in Table 3.2. And let the designers to evaluate the rank (depend on the Table 3.4) for provided design project satisfaction factor information questionnaires (Table 3.2). After that, depending on the equation (3.7) through equation (3.10) to release the WTSL value.

After the WTSL, we have to calculate the Average Weighted Total Satisfaction Level (AWTSL) because of the reason that there can be one or several projects in the portfolio. The calculation process of AWTSL can be seen below (3.11):

$$AWTSL = \frac{\sum_{m=1}^{NP} WTSL_m}{NP} \quad (3.11)$$

Note. AWTSL = Average value of Weighted Total Satisfaction Level. NP = Number of the projects in the portfolio.

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We can take an example to introduce the calculation process of AWTSL. We will consider about 7 designers and 10 design projects. The owned skill level and available time for the 7 designers can be seen as the Figure 3.5.

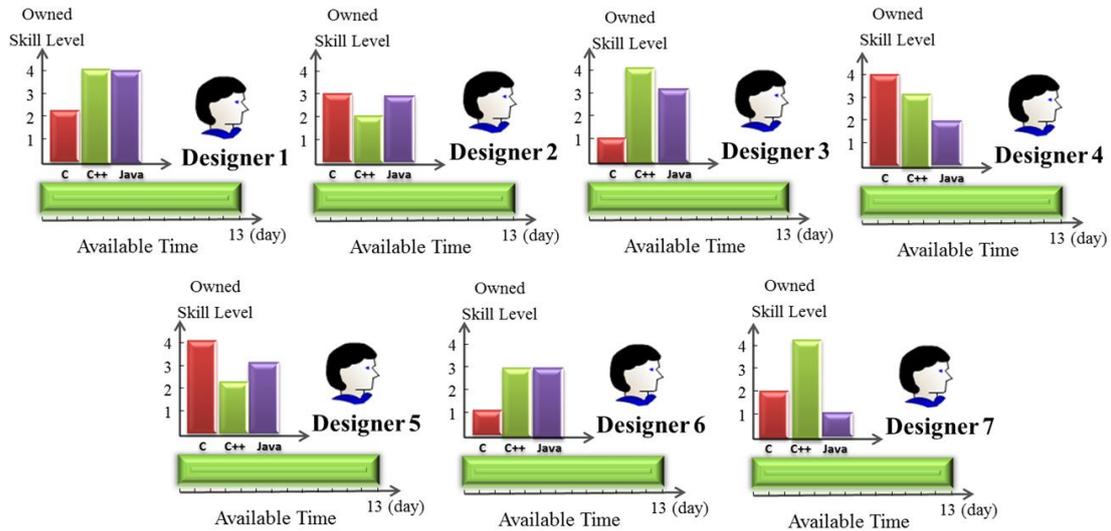


Figure 3.5 - Owned skill level and available time for designer

From the Figure 3.5 we can find that the designers have three software development skills (C, C++ and Java) with the different skill levels. In here, C, C++ and Java are the 3 popular software programming languages. Meanwhile, there also has different length of free time (Available Time).

Mandatory skill requirements and required time for the 10 projects can be seen as Table 3.5.

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Table 3.5- Mandatory skill requirements and required time for the candidate design projects

Project	C	C++	Java	RT	NRD
Project1	3	2	2	2	4
Project2	1	3	3	2	2
Project3	4	2	4	2	1
Project4	3	2	4	6	2
Project5	0	3	2	3	1
Project6	1	3	3	1	1
Project7	2	4	4	15	4
Project8	2	2	1	3	1
Project9	3	2	4	1	2
Project10	2	3	4	14	3

Note. RT = Required Time for the project. NRD = Number of Required Designers
Through the Figure 3.5 and Table 3.5, we can find that the Project3, Project4, Project7, Project9 and Project10 can be directly filtered because of the reason that all the required skill levels or the required time for these projects are larger than owned skill levels for the 7 designers. Therefore, the Project1, Project2, Project5, Project6 and Project8 will be the remaining candidate projects. After that, depending on the different combination of the projects, we have to find the multi-projects for every designer which can meet the available time condition for the designer. The possible multi-projects type for 7 designers which can meet the available time for them can be seen as Table 3.6.

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Table 3.6 - Different combination of projects in the condition of designer available time

Designer	Multi-project
Designer1	project2
	project2, project6
	project5
	project5, project6
	project6
	project6, project8
	project8
Designer2	project1
	project1, project8
	project8
Designer3	project2
	project2, project5
	project2, project5, project6
	project2, project6
	project5
	project5, project6
	project6
Designer4	project1
	project5
	project8
Designer5	project1
	project8
Designer6	project1
	project1, project5
	project1, project5, project6
	project1, project6
	project5
	project5, project6
	project6
Designer7	project8

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The 7 designers can be satisfied with all the mandatory skill levels and required time of all the multi-projects in Table 3.5. Therefore, these multi-projects will be the first step of the selection result. After that, for the multi-project in Table 3.6, there will be totally 6174 ($7 \times 3 \times 7 \times 3 \times 2 \times 7 \times 1$) multi-project combination types among these 7 designers. However, the number of designers assigned to these projects should be equal to the Number of Required Designers (NRD) for the candidate projects in Table 3.5. Therefore, after the filtering, 42 multi-project combination types will be selected.

After that, we can analyze the designers' satisfaction level to these design projects. Project manager can firstly provide the project satisfaction sub-sub-factors information questionnaires (Table 3.2), and let the designers to fill the questionnaires. For the weight of every satisfaction main factor, sub-factor and sub-sub-factors in Table 3.2, designers can define them through the AHP method. In here, designer can use fundamental scale for pairwise comparisons in Table 3.3 to pairwise compare the factors, sub-factors, sub-sub-factors separately and release the weights (ω , ν and θ) of them. The pairwise comparison result and weight of the importance of the factor, sub-factors and sub-sub-factors for Designer1 can be seen from Table 3.7 to 0.

Table 3.7- Pairwise comparison result and the weight of the importance of 2 main satisfaction factors for Designer 1

Main factors	Hygiene Factors (F1)	Motivator Factors (F2)	W(ω)
Hygiene Factors (F1)	1	3	0.75
Motivator Factors (F2)	1/3	1	0.25

Table 3.8- Pairwise comparison result and the weight of the importance of 6 satisfaction sub-factors for Hygiene Factors (F1) for Designer 1

Sub-factors	SF1.1	SF1.2	SF1.3	SF1.4	SF1.5	SF1.6	W(ν)
Design project policies (SF1.1)	1	3	2	1	4	1	0.28
Supervision (SF1.2)	1/3	1	6	2	4	5	0.30
Work conditions(SF1.3)	1/2	1/6	1	1	1	1	0.09
Salary (SF1.4)	1	1/2	1	1	3	4	0.18
Status (SF1.5)	1/4	1/4	1	1/3	1	1/2	0.06
Security (SF1.6)	1	1/5	1	1/4	2	1	0.09

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Table 3.9- Pairwise comparison result and the weight of the importance of 5 satisfaction sub-factors for Motivator Factors (F2) for Designer 1

Sub-factors	SF2.1	SF2.2	SF2.3	SF2.4	SF2.5	W(v)
Design project its self (SF 2.1)	1	2	2	1	2	0.29
Achievement (SF 2.2)	1/2	1	4	2	4	0.31
Recognition (SF 2.3)	1/2	1/4	1	1/2	1	0.10
Responsibility (SF 2.4)	1	1/2	2	1	3	0.21
Growth (SF 2.5)	1/2	1/4	1	1/3	1	0.09

Table 3.10- Pairwise comparison result and the weight of the importance of 3 satisfaction sub-sub-factors for Work conditions (SF1.3) for Designer 1

Sub-sub-factors	SSF1.3.1	SSF1.3.2	SSF1.3.3	W(θ)
Design workstyle - Teamwork or Individualistic (time) (SSF1.3.1)	1	4	5	0.66
Design workstyle - Virtual or Real style (time) (SSF1.3.2)	1/4	1	4	0.25
Design workplace environment conditions (SSF1.3.3)	1/5	1/4	1	0.09

Table 3.11- Pairwise comparison result and the weight of the importance of 4 satisfaction sub-sub-factors for Design project its self (SF 2.1) for Designer 1

Sub-sub-factors	SSF2.1.1	SSF2.1.2	SSF2.1.3	SSF2.1.4	W(θ)
Project objectives (SSF2.1.1)	1	2	4	1	0.38
Project workload (SSF2.1.2)	1/2	1	4	2	0.31
Project delivery date (SSF2.1.3)	1/4	1/4	1	1/2	0.09
Project requirements (SSF2.1.4)	1	1/2	2	1	0.22

The weight results ($W(\omega)$, $W(v)$ and $W(\theta)$) from the Table 3.7 to 0 are released from the principal right eigenvector of the pairwise comparison result matrix in Table 3.7 to 0. For the other weights of sub-sub-factors except weights in Table 3.10 and 0 will be 1 because of the reason that there is only one sub-sub-factor for the every sub-factor except sub-factors in Table 3.10 and 0. Such as the weight of Supervisory style (SSF1.2) equal to one because there is only one sub-sub-factor for the sub-factor Supervision (SF1.2.1).

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After that, designer can evaluate the rank for all the satisfaction factors in Table 3.2. Then, we can use equation (3.1) through equation (3.11) to calculate the Average Weighted Total Satisfaction Level (AWTSL) value. The example of evaluation of satisfaction factors (Project 2) and the result value of AWTSL value for all the multi-projects for the Designer1 can be seen as Table 3.12 and Table 3.13.

Table 3.12 Evaluation result of the satisfaction factors in Project 2 for designer1

F	ω_i	SF	ϑ_{ij}	Satisfaction sub-sub-factors (SSF)	θ_{ijk}	Rank
F1	0.75	SF1.1	0.28	Fixed work schedule would be Monday-Friday from 8:30 AM to 5:00 PM. Break for Statutory holiday	1.00	1
		SF1.2	0.30	The project manager is very motivated to provide direction and support	1.00	1
		SF1.3	0.09	Work with all team members all time (100% time) to ensure the quality and clarity of deliverables(SF1.3.1)	0.66	2
				30% time with virtual work environment and 70% time with real work environment(SF1.3.2)	0.25	2
				Adjustable chairs, task lights, sit-to-stand desks and keyboard trays so designers can adjust their workspaces to meet their needs and outdoor areas for short breaks (SF1.3.3)	0.09	0
		SF1.4	0.18	400€ of salary, the health insurance, a generous 401 K, the opportunity for a bonus and more (SSF1.4.1)	1.00	-1
		SF1.5	0.06	Hired as an assistant designer	1.00	1
SF1.6	0.09	Designers will not be fired until the end of the project	1.00	1		
F2	0.25	SF2.1	0.29	Delivering an industry-leading offering and an obsession with customer satisfaction(SSF2.1.2)	0.38	1
				3 types of weblogs client software, 2 types of desktop client software, 500 user requirement survey and acceptance testing result and user documentation (SSF2.1.2)	0.31	0
				October 2, 2018(SSF2.1.3)	0.09	1
				Users can see public blog posts, comment on public blog posts, and subscribe to all blog posts or categories of blog	0.22	1

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				posts using RSS feed readers (SSF2.1.4)		
		SF2.2	0.31	Because this is a project of a very famous multinational software development company. After the project is completed, the designer will have a high achievement.	1.00	0
		SF2.3	0.10	Because the position is an assistant designer, and it is not so important and difficult for the design project, the designer's ability will not be fully recognized by the project manager and company.	1.00	0
		SF2.4	0.21	Generate clear ideas, concepts and designs for creative assets from beginning to end. Meanwhile, create wireframes and mockups to effectively communicate interaction and design ideas(SF2.4.1)	1.00	1
		SF2.5	0.09	Knowledge of and experience in weblogs software development, previous experience iterating on software development, and previous experience working with a distributed team (SF2.5.1)	1	2

Note. SIF = Satisfaction Influence Factor. F1 = Hygiene Factors. F2 = Motivator Factors. SF = Sub-Factors. SF1.1 = Design project policies. SF1.2 = Supervision. SF1.3 = Work conditions. SF1.4 = Salary. SF1.5 = Status. SF1.6 = Security. SF2.1 = Design project its self. SF2.2 = Achievement. SF2.3 = Recognition. SF2.4 = Responsibility. SF2.5 = Growth.

Depending on the Table 3.12, and equation (3.7) through equation (3.10), the Weighted Total Satisfaction Level (WTSL) for project 2 is $0.68 \times (0.75 \times (0.28 \times 1 \times 1 + 0.3 \times 1 \times 1 + 0.09 \times (0.66 \times 2 + 0.25 \times 2 + 0.09 \times 0)) + 0.18 \times 1 \times (-1) + 0.06 \times 1 \times 1 + 0.09 \times 1 \times 1) + 0.25 \times (0.29 \times (0.38 \times 1 + 0.31 \times 0 + 0.09 \times 1 + 0.22 \times 1) + 0.31 \times 1 \times 0 + 0.1 \times 1 \times 0 + 0.21 \times 1 \times 1 + 0.09 \times 1 \times 2)$. After that we can release the result of AWTSL. The AWTSL value for all the candidate designers can be seen in Table 3.13.

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Table 3.13 AWTSL value for all the candidate multi-projects in Table 3.6

Designer	Multi-project	AWTSL
Designer1	project2	0.68
	project2, project6	0.46
	project5	0.67
	project5, project6	0.45
	project6	0.23
	project6, project8	0.44
	project8	0.65
Designer2	project1	0.58
	project1, project8	0.62
	project8	0.65
Designer3	project2	0.72
	project2, project5	0.74
	project2, project5, project6	0.7
	project2, project6	0.68
	project5	0.75
	project5, project6	0.69
	project6	0.63
Designer4	project1	0.45
	project5	0.48
	project8	0.72
Designer5	project1	0.65
	project8	0.36
Designer6	project1	0.72
	project1, project5	0.77
	project1, project5, project6	0.76
	project1, project6	0.73
	project5	0.82
	project5, project6	0.78
	project6	0.73
Designer7	project8	0.56

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After that, we can calculate the sum of AWTSL values for all the 42 multi-project combination types. The result of 10 highest sum of AWTSL value can be seen as Table 3.15.

Table 3.14- 10 highest sum of AWTSL value for all the 42 multi-project combination types

Type	Multi-project combination types (Designer1-Designer2-Designer3-Designer4-Designer5-Designer6-Designer7)	sum of AWTSL
T1	project2-project1project8-project2project5-project1-project1-project1project5 project6-project8	3.9
T2	project2-project1project8-project2-project1-project1-project1project5project6 -project8	3.9
T3	project2-project1project8-project2project5-project1-project1-project1project6 -project8	3.9
T4	project2-project1project8-project2project5project6-project1-project1-project1 project5-project8	3.9
T5	project2-project1-project2project5-project1-project1-project1project5project6 -project8	3.9
T6	project2-project1project8-project2project5project6-project1-project1-project1 project5project6-project8	3.9
T7	project2-project1project8-project2project6-project1-project1-project1project5 -project8	3.9
T8	project2-project1-project2-project1-project1-project1project5project6-project 8	3.8
T9	project2-project1project8-project2project6-project1-project1-project1project5 project6-project8	3.8
T10	project2-project1-project2project5-project1-project1-project1project6-project 8	3.8

From the Table 3.14, we can find that the 7 multi-project combinations (T1, T2, T3, T4, T5, T6 and T7) have the highest sum value of AWTSL (3.9). However the project manager can only positioned one type of multi-project combination to the 7 designers. Therefore, we have to identify these 7 multi-project combinations through analyzing the collaboration level of 7 designers in these 7 multi-project combinations.

Therefore, to identify these 7 multi-project combinations, we can calculate the collaboration level for designers in these 7 multi-project combinations.

3.4 Calculate the collaboration level of designer for different combination of the projects

When designers want to involve in the multi-projects that they satisfied, they have to think about the collaboration relationship with other designers in different candidate combination of the projects. The collaboration relationship between two designers can be seen as the Figure 3.6.

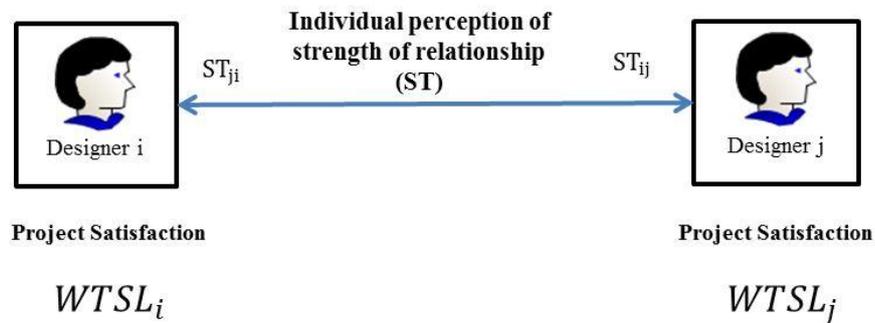


Figure 3.6- Collaboration relationship between two designers

In the Figure 3.6 we can find that the two designers have their own weighted total satisfaction level (WTSL) value. Meanwhile, between the two designers, there is individual perception of strength of relationship (ST), which is the social relationship between two designers. The ST will be defined by the two designers. For the criteria to define the individual perception of strength of relationship (ST), thanks a lot for the Ann Betz and Ursula Pottinga (Ann and Ursula (2012)) who have been proposed seven levels of personal, group and organizational effectiveness. For the Seven Levels of Effectiveness, it provides a road map of human effectiveness which elegantly and clearly shows not only where we are, but where we want to go to find that new level of thinking so badly needed in today's world (Ann and Ursula (2012))). The Seven Levels of Effectiveness can help designers to discover how to identify and shift their level of effectiveness with other collaborated designers. Therefore, we can use the Seven Levels of Effectiveness to define the criteria of the individual perception of strength of relationship (ST). The criteria to define the individual perception of

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strength of relationship (ST) (from main designer to collaborated designer) can be seen as Table 3.15.

Table 3.15- Criteria of individual perception of strength of relationship (ST) from main designer to collaborated designer (Ann and Ursula (2012)))

SRE	Description	ST values
Synchronicity	Focus on creating a positive experience for all.	0.7
Innovation	Ability to set aside ago perceived restrictions and explore possibilities from all angles	0.6
Engagement	The desire to bring value, to be a contributor	0.5
Courage	The willingness to take a stand against previously held negative	0.4
Frustration	The feeling that the external world must be resisted	0.3
Fear	belief that one must protect against almost certain	0.2
Hopelessness	fundamental inability to see or work towards a positive future	0.1

Note. SRE: Strength of relationship effectiveness.

In Table 3.15, the strength of relationship effectiveness can be divided as seven levels, which can just match to the 7 values of individual perception of strength of relationship (ST). In here, the higher value of ST means higher strength of relationship effectiveness from main designer to collaborated designer. Apart from that, if the two collaborated designers don't know the each other, we can select the rank of "Courage" (ST value 0.4) in Table 3.15 because of the reason that the "Courage" is the median strength of relationship effectiveness, and for those who the designer does not know, the average value of the strength will be appropriate.

Therefore depending on collaboration relationship in the Figure 3.6 and the criterial of individual perception of strength of relationship (ST) in Table 3.5, the calculation process of the Total Average Weighted Pair Satisfaction Gap (TAWPSG) can be seen as equation (3.12) to equation (3.14).

$$TAWPSG = \sum_{k=1}^J (AWPSG_k) \quad (3.12)$$

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$$AWPSG_k = \begin{cases} \frac{\sum_{i=1}^{TND-1} \sum_{j=i+1}^{TND} (WPSG_{ij})}{\frac{TND(TND-1)}{2}}, & (TND \neq 1) \\ 0, & (TND = 1) \end{cases} \quad (3.13)$$

$$WPSG_{ij} = |WTSL_i - WTSL_j| \cdot \frac{ST_{ij} + ST_{ji}}{2} \quad (3.14)$$

Note. TAWPSG = Total Average Weighted Pair Satisfaction Gap. $AWSG_k$ = Average Weighted Pair Satisfaction Gap in kth project. J = Total number of projects. TND = Total Number of Designers involved in same project. WSG_{ij} = Weighted Satisfaction Gap between designer i and designer j. WTSL = Weighted Total Satisfaction Level. ST = Strength of social relationship between two designers.

Because of the reason that the collaboration relationship (Figure 3.6) is related to the individual perception of strength of relationship (ST) and weighted total satisfaction level (WTSL), we have to firstly calculate the Weighted Pair Satisfaction Gap ($WPSG_{ij}$) value between two collaborated designers (equation (3.14)). In here, the satisfaction gap is the absolute value of the satisfaction gap between the two designers for the same project. The reason why we make the subtraction of the WTSL value between two designers is that project satisfaction gap between two designers will have a direct impact to the collaborative efficiency. The gap is smaller means the collaboration efficiency will be higher. In contrast, the gap is bigger means there are conflicts and disharmony between them, which will reduce collaboration efficiency. Meanwhile, in the equation (3.14), the weight of satisfaction gap is the average value of individual perception of strength of relationship (ST) with each other. After that, we can calculate the Average Weighted Pair Satisfaction Gap (AWPSG) for all the collaboration pairs in the same project (equation (3.13)). In the equation (3.13), we have to calculate sum of the WPSG values for all the collaboration pairs, and then divide this sum by the total number of collaboration pairs ($\frac{TND(TND-1)}{2}$) in the project. In fact, you can

easily prove (by induction) that for n designers on a project, there are $\frac{n(n-1)}{2}$ possible collaboration pairs. In the equation (3.13), if the TND value is equal to 1, which means only one designer involved in the project, AWPSG value will be 0 because of the reason that there is no satisfaction gap between the designer and himself. After that, we can calculate Total Average Weighted Pair Satisfaction Gap (TAWPSG) for all the

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design projects (equation (3.12)). In the equation (3.12), the “J” means the total number of projects. Then, project manager can use the result of TAWPSG value to define the collaboration ability for the designer in different combination of candidate design projects. In here, higher value of TAWPSG means the conflicts between designers are more likely to occur which will cause lower collaboration ability. Finally, the project manager can use the TAWPSG value to define the final assigned multi-projects for the designers.

The example of the calculation of TAWPSG, we can keep on the example in Table 3.14. To calculate the Total Average Weighted Pair Satisfaction Gap (TAWPSG) value, we have to understand which designers have involved in same projects, their weighted satisfactions of the projects (WTSL), the ST between every two collaborated designers. The WTSL value for designers who will be positioned in Type 1 (T1 in Table 3.14) multi-project combinations and the individual perception of strength of relationship (ST) among the 7 designers can be seen as Table 3.16 and Figure 3.7.

Table 3.16- WTSL value for 7 designers in Type1 (T1 in Table 15)

Project	Designer	WTSL
Project1	Designer2	0.58
	Designer4	0.45
	Designer5	0.65
	Designer6	0.72
Project2	Designer1	0.67
	Designer3	0.72
Project5	Designer3	0.75
	Designer6	0.82
Project6	Designer6	0.73
Project8	Designer2	0.59
	Designer7	0.56

Note. WTSL = Weighted Total Satisfaction Level.

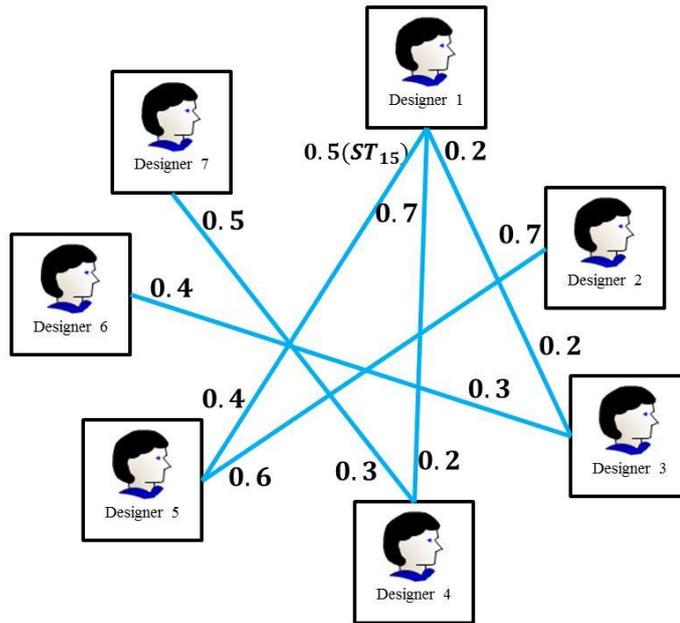


Figure 3.7 Individual perception of strength of relationship (ST) among 7 designers

In the Figure 3.7, there are 6 pairs of designer know each other (blue line), and they can define the different ST value with each other. Even though, other pairs they do not know each other, we can set the rank of “Courage” (ST value 0.4) in Table 3.15 between them because of the reason that the “Courage” is the median strength of relationship effectiveness, and for those who the designer does not know, the average value of the strength will be appropriate. Therefore, there will be totally $21 \left(\frac{7 \times (7-1)}{2} \right)$ pairs of social relationship with the different ST values with each other. Meanwhile, depending on the Table 16, we can calculate the number of the pairs of collaboration for Project1 is $6 \left(\frac{4 \times (3-1)}{2} \right)$, Project2 is $1 \left(\frac{2 \times (2-1)}{2} \right)$, Project5 is $1 \left(\frac{2 \times (2-1)}{2} \right)$, Project6 is $0 \left(\frac{1 \times (1-1)}{1} \right)$, Project8 is $1 \left(\frac{2 \times (2-1)}{1} \right)$. Therefore, through the Table 3.16, Figure 3.7, and equation (3.13) and equation (3.14), we can calculate the AWPSG value for Project1 in Type1 (T1) multi-project combination (Table 3.14). The result of AWPSG value for project1 is

$$0.061 \left(\frac{|0.58-0.45| \times \frac{0.4+0.4}{2} + |0.58-0.65| \times \frac{0.6+0.7}{2} + |0.58-0.72| \times \frac{0.4+0.4}{2} + |0.45-0.65| \times \frac{0.4+0.4}{2} + |0.65-0.72| \times \frac{0.4+0.4}{2}}{\frac{4(3-1)}{2}} \right).$$

Meanwhile, we can use the same way to calculate AWPSG value for other projects in

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the Type1. After that, according to equation (3.12) to release Total Average Weighted Pair Satisfaction Gap (TAWPSG) value for all the 7 same highest sum of AWTSL value of multi-project combinations (T1, T2, T3, T4, T5, T6 and T7 in Table 3.14). The result of TAWPSG values for all the 7 types can be seen as Table 17.

Table 3.17 TAWPSG values for 7 same highest sum of AWTSL value of multi-project combinations in Table 3.14

Type	Multi-project combination types (Designer1-Designer2-Designer3-Designer4-Designer5-Designer6-Designer7)	TAWPSG
T1	project2-project1project8-project2project5-project1-project1-project1project5project6-project8	0.100
T2	project2-project1project8-project2-project1-project1-project1project5project6-project8	0.106
T3	project2-project1project8-project2project5-project1-project1-project1project6-project8	0.106
T4	project2-project1project8-project2project5project6-project1-project1-project1project5-project8	0.130
T5	project2-project1-project2project5-project1-project1-project1project5project6-project8	0.094
T6	project2-project1project8-project2project5project6-project1-project1-project1project5project6-project8	0.165
T7	project2-project1project8-project2project6-project1-project1-project1project5-project8	0.106

In the Table 3.17 we can find that even though the sum of AWTSL values are the same among 7 types in Table 3.14, the TAWPSG values are different. Meanwhile, the T5 multi-project combination (project2 for designer1, project1 for designer2, project2 and project5 for designer3, project1 for designer4, project1 for designer5, project1, project5 and project6 for designer6, and project8 for designer7) get the smallest value of TAWPSG. Therefore, the project manager should positioned multi-project to the designer depending on the T5.

Conclusion

In this chapter, we propose a design project selection methodology with the consideration of satisfaction of designer to the design projects and collaboration ability of designer. For the satisfaction of designer to the design projects, we have consider about five main factors (Satisfaction of the Personal responsibility, Satisfaction of the constraints in design project, Satisfaction of work environment, Satisfaction of Salary and welfare, and Satisfaction Personal Aspirations), which consist of different sub-factors respectively, that influence the designer. Then, through the result of Average Weighted Total Satisfaction Level (AWTSL), project manager can find the most satisfactory combination of design projects for designers. After that, if the AWTSL values are the same among different combination projects, we can analysis collaboration ability of designer in the different combination projects to identify them. For the factors of collaboration ability between two designers, we mainly consider the factors of individual perception of strength of relationship (ST) and project satisfaction gap between two designers in same involved project. Then, through the result of Total Average Weighted Pair Satisfaction Gap (TAWPSG), project manager can find and select smallest value of the multi-project combination type the designers.

CHAPTER 4 RISK MANAGEMENT

METHOD

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List of Observation

AHP = Analytic Hierarchy Process.

B = Risk response strategy implementation budget.

C_j = Implementation cost for strategy T_j .

D_n = nth Detection.

DP_a = Net of direct and indirect dependence of actor "a".

FMEA = Failure mode and effects analysis.

I_a = Net of direct and indirect influence of the actor "a".

IRPN $_n$ = the nth Interpersonal Risk Priority Number.

ISO = International Standard of Organisation.

K = Total number of risk existing actors.

M = Number of the affected actors by the risk existing actor.

MACTOR = Matrix of Alliances and Conflicts: Tactics, Objectives and Recommendations.

$MCDV_{a,n}$ = Convergence and Divergence value for error in risk existing actor "a" with the nth effected actor.

MID = direct influence matrix.

$MID_{a,b}$ = direct influence from the actor "a" to actor "b".

$MIDI_{a,b}$ = direct and indirect influence from the actor "a" to actor "b".

N = Number of errors in one actor.

O_n = nth Occurrence.

P_m = affection percentage from risk existing actor to affected actor.

PRPN $_n$ = nth personal Risk Priority Number.

R = the reciprocal of absolute risk aversion and called the risk tolerance.

S_{kl} = Severity of the lth error in kth risk actor.

WBS = Work Breakdown Structure.

Introduction

In this chapter, we firstly introduce the concept of risk, risk management process and related work for risk management. After that we introduce the whole process of our risk management methodology. Then depending on the whole process, we introduce the management method step by step, including context analysis, risk assessment and risk treatment. In here, for the context analysis and risk assessment part, we will brainstorm potential errors and corresponding effects of these errors, and assign the severity, detection and occurrence of these errors; then, we will calculate the total Risk Priority Number. Apart from that, in risk treatment part, we will identify the potential risk response strategies and estimate the risk response effect for these strategies to the risk existing actor. Here after, we will construct an optimization model to select most appropriate strategies to the risk existing actors.

4.1 Concept of risk

In order to discuss the risk management, it is important to understand the concept of the risk. Risk is described as an event, which has occurrence characteristics (potentiality to occur) and consequence characteristics on the project objectives (impact in the event of occurrence) (Marmier et al. (2014)). Meanwhile, risk is an uncertain consequence of an event or an activity with respect to something that humans value (Aven and Renn (2009)). Depending on the ISO (2009), the risk can be also defined as the effect of uncertainty on objectives. In here, the uncertainty is a potential, unpredictable, unmeasurable and uncontrollable outcome (Knight (2012), Crouhy et al. (2006)), and the risk is a consequence of actions taken in spite of uncertainty (Mun (2006), (Antunes and Gonzalez (2015))).

Every project type faces risks, whatever the size or topic concerned (Marmier et al. (2013)). Meanwhile, there are many types of risks depending on the different kinds of risk categorizations. Among these different types of risks, we will mainly focus on manageable risks. In here, a manageable risk is a risk which can be brought under the selected tolerable threshold by mitigative investments that still preserve the economic livelihood of a company (Oboni and Oboni (2014)). The social, political, and economic risks, which have a greater possibility of managing them through risk

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management techniques, are more related to the management arena both at macro and micro levels, and these concepts are further elaborated as follows (Zahedi (2008)).

- *Social risks*: social risks are determined by the value systems that are set by a particular society in a particular time. Values are enduring beliefs that specific modes of conduct or states of existence are socially preferable to their opposites (Rokeach (1973)). Values establish the standards by which everything in society is judged (Mendenhall (1995)). Social risks might include:
 - ✓ Criminal acts (e.g. theft, robbery, sabotage)
 - ✓ Civil torts (e.g. trespass, slander and libel)
 - ✓ Substance abuse (e.g. drunkenness, drug-induced behaviors)

- *Political risks*: Political risk is the possibility of unwanted consequences of political activity; it is the uncertainty associated with political activities and events (Mendenhall (1995)). Companies might face three types of political risk:
 - ✓ Forced divestment, which occurs when a government wishes to acquire the assets of a company against the company's will (at most, with no compensation). Forced divestment can take two forms: expropriation (usually the takeover of one firm) and nationalization (usually the takeover of an entire industry) (Mendenhall (1995)).
 - ✓ Unwelcome regulations, which are any unexpected government-imposed requirements that make it less profitable for a company to operate in a particular location (e.g. income taxes, restrictions on reinvestment).
 - ✓ Interference with operations, which is any government activity that makes it difficult to operate effectively (e.g. encouragement of

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unionization, voicing of negative sentiments about the managers) (Mendenhall (1995)).

- *Economic risks:* Economic and financial risks include labor or material supply issues, changes in interest rates and potential unavailability of loan finance. Some of the important risks in this category are: market risk, liquidity risk, credit risk, operational risk and legal risks.
 - ✓ Market risks: market risks are the risk of loss due to changes in the prices of financial assets (Lopez (2007)).
 - ✓ Liquidity risk: liquidity risk occurs in the event that cash inflows and current balances are insufficient to cover cash outflow requirements, often necessitating costly asset liquidation to generate temporary cash inflows (Culp (2002)).
 - ✓ Credit risk: Credit risk is the risk of the actual or possible nonperformance by a firm. Credit risk is the possibility that counterparty may default by failing to repay its debt obligations in a timely manner (Lopez (2007)).
 - ✓ Operational risk: Operational risk is the risk of direct or indirect loss resulting from inadequate or failed internal processes, people and systems or from external events (Esch (2005)). This risk is due to some events such as failure in computer systems, personnel quality, supervision and control. Operational risk tends to arise when personnel either fail to perform their duties or have ill-specified responsibilities (Culp (2002)).
 - ✓ Legal risk: the risk that a firm will incur a loss if a contract it thought was enforceable actually is not. In addition, unexpected changes in laws and regulations can expose firms to potential loss as well (Culp (2002)).

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In our research, we mainly focus on the operational risk, especially failures in personal quality (human errors). For the hidden risks in the future design projects, various factors for human may contribute to an increase in incidents and accidents. A study by the Institute of Nuclear Power Operations showed that at least 92% of the underlying causes of accidents were caused by people (Gordon (1998)). Meanwhile, present technological development towards high hazard systems requires a very careful consideration by designers of the effects of “human errors” which are commonplace in normal, daily activities, but unacceptable in large-scale systems (Hood (2003)). Human error has been implicated in 70 to 80% of all civil and military aviation accidents (Shappell and Wiegmann (2000)).

4.2 Risk management process

The risk management is the process used to systematically manage exposures to risk (Zahedi (2008)). Risk management can be applied to an entire organization, at its many areas and levels, at any time, as well as to specific functions, projects and activities (ISO (2009)). Risk management consists in measuring and steering all of risks with the consideration of all the synergies (Wolke (2017)). Risk management is essential for every project and it should be a systematic process (Pritchard and PMP (2014)). Risk management generally has the aim of identifying and managing risk in order to be able to deal with it when it occurs through for example eliminating, minimizing or controlling the risk (Th äuser (2017)).

There are six steps in the process of risk management (Zahedi (2008)):

- Identify: Identify risks before they become realities.
- Analyze: Transform risk data into decision-making information by evaluating the probabilities, timeframes and potential impacts of each risk, then classify and prioritize them.
- Plan: Use the decision-making information to formulate plans and contingencies for mitigating the potential impact of each risk.

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- Track: Monitor the effectiveness of those plans by reanalyzing risk data.
- Control: Correct for deviation from the risk mitigation plans.
- Communicate: Provide internal and external information and feedback loops to monitor changes in the risk environment (Pacific (2003)).

Importantly, risk management is not simply about compliance or about stifling risk-taking; Elahi (2013) argues that in a world of complexity and rapidly changing environments, effective risk management may be a source of competitive advantage (Becker and Smidt (2016)). Nowadays, a sound management of risk is a crucial determinant of the success of a project due to an increased attention to the variability of actual quality, time, and cost performance compared to the expected one as a consequence of a growing pressure on reducing time and costs (Cagliano et al. (2015)).

The ISO 31000 (Purdy (2010)) is a standard which aims to provide organizations with guidance and a common platform for managing different types of risks, from many sources irrespective of the organizations size, type, complexity, structure, activities or location (Harb (2009)). The risk management process in ISO 31000:2009 can be seen as the Figure 4.1.

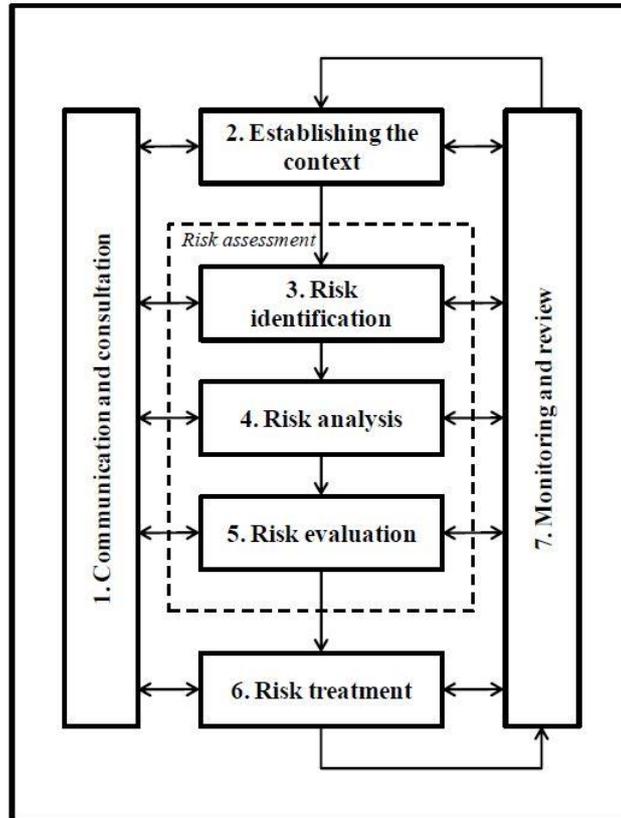


Figure 4.1- Risk Management Process (ISO (2009))

In the Figure 4.1, we can find that the process model consists of the following 7 main steps (ISO (2009), Oehmen et al. (2010)):

1. **Communication and consultation:** Communication and consultation with external and internal stakeholders should take place during all stages of the risk management process. It should facilitate the exchange of necessary information and coordination.
2. **Establishing the context:** By establishing the context, the objectives, scope and criteria for the remaining risk management process are defined. This addresses external as well as internal factors of companies.
3. **Risk Identification:** This is mainly concerning about the identify sources of risk, areas of impacts, events (including changes in circumstances) and their causes and their potential consequences.

4. Risk analysis: Risk analysis involves developing an understanding of the risk. Risk analysis provides an input to risk evaluation and to decisions on whether risks need to be treated, and on the most appropriate risk treatment strategies and methods.
5. Risk evaluation: The purpose of risk evaluation is to assist in making decisions, based on the outcomes of risk analysis, about which risks need treatment and the priority for treatment implementation.
6. Risk Treatment: Risk treatment involves selecting one or more options for modifying risks, and implementing those options. Once implemented, treatments provide or modify the controls.
7. Monitoring and review: Both monitoring and review should be a planned part of the risk management process and involve regular checking or surveillance.

In here, the main approach for the process model is to provide a generic risk management framework that is applicable to different industries and different problem scopes.

The FMEA (Failure Mode and Effect Analysis) (Mikulak et al. 2008) is a risk management technique. It is numerical risk analysis method and a quality tool used to determine the potential errors of a product or system and to identify their reasons and effects (Elarnur Adar et al. (2017)). Preventing the risks in process and product problems before they occur is the purpose of FMEA (Mikulak et al. 2008) methodology.

4.3 Related work for risk management

In the over 20 years, there are many types of risk management methodologies for developed different kinds of organizations. Interactions-based Risk Clustering Algorithms are an additional clustering methodology, which takes into account the interactions between risks, in terms of existence and strength (Marle et al. (2013)).

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Firstly, it allows to identify the possible risk interactions with the binary matrix representation, and then, transforms the matrix to a numerical one using the principles of AHP (Analytic Hierarchy Process) (Saaty (1980)). In the part of risk interactions, however, it is just separately considering about the direct effect of the risk, even though it can have indirect effect. Zhang (2016) proposed an optimization model which considers the risk interdependence and its two directions for selecting risk response strategies. In here, even though, Zhang provided an approach to measure risk interdependence with the consideration of strength of risk interdependence but it is also impossible with this method to confront with the problem of indirect effect between risks. A risk management methodology (Kwan and Leung (2011)) for project risk dependencies was proposed in 2011. In this methodology, the different possibility of the risk dependencies between two risks are taken into account. However, for the analysis of the risk, this method only considers about the probability and impact of the risk while the detection of the risk is a very important attribute for the risk too. The methods of Using Interconnected Risk Maps (Correa et al. (2013)) and of the A System of System Approach (Cavallo and Ireland (2014)) have the same problems about the consideration of detection of the risk.

Risk treatment is concerned with changing the magnitude and likelihood of consequences, to achieve a net increase in benefit (Purdy, 2010). The project risk response planning aims to identify actions that can reduce the threats to the realization of the project objectives at minimum cost (Fang et al., 2013). Also, the risk response strategy selection is an important issue in project risk management (PRM) (Zhang and Fan, 2014). However, many studies on risk identification and assessment have been found, whereas risk response has seldom been addressed in the existing studies (Fan et al., 2015), (Seyedhoseini et al., 2008). The approaches involved in the existing studies about project risk response strategy selection can be mainly classified into four categories: the zonal-based approach, the trade-off approach, the WBS-based approach and the optimization-model approach (Zhang and Fan 2014).

Fang et al., 2013 proposed an integrated framework for risk response planning under resource constraints in large engineering projects. In here, project risk response planning aims identifying actions that can reduce the threats to the realization of the project objectives at minimum cost, which includes the identification and assignment

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of one or more persons (the “risk response owner”) to take responsibility for each agreed-to and funded risk response action (Fang et al., 2013). In this framework, there are five steps for project risk response planning: building project risk network, defining objective function, identifying budget constraints, identifying potential response actions and optimizing risk response plan. In the “building of the project risk network” step, the framework considers about the risk interactions among different actors but doesn’t use it for “identifying potential response actions” step. In the zone-based approach (Ali Hatefi et al., 2007), (Datta and Mukherjee, 2001), the risk response strategies can be selected by zones. In here, two selected criteria, which consider about the different factor of the risk, will match to the horizontal and vertical axis. However, it has a limitation that only two criteria can be considered and it is very difficult to simultaneously describe multiple factors (more than two factors) of the risk. The Trade-off approach (Zhang and Fan, 2014) is a method for selecting project risk response strategies. In here, the optimal solution could be obtained so that the most desirable risk response strategies to cope with the risk events can be determined, which is based on an iterative process which involves making trade-offs between the project budget, time and quality according to objective requirements and managers' judgments. However, this method only considers about the independent risk response effect in the work activity while it is very important to analyze the interdependent risk response effect problem. The Work Breakdown Structure (WBS) is a way of organizing project elements into a hierarchy that simplifies the tasks of budget estimation and control, and helps to determine just exactly what costs are being estimated (Boehm et al., 2000). The WBS is always used to breakdown engineering into many smaller, more manageable chunks, and risk can be broken down into many smaller risk management chunks (Sigmund and Radujković, 2014). In addition, it relates risk response strategy selection to work activities based on project WBS analysis (Zhang and Fan, 2014). However, it is unknown whether the strategies obtained are optimal solution to the strategy selection problem while a set of strategies may be generated for all the activities in WBS (Zhang and Fan, 2014).

The research of the risk, in this work, will mainly focus on error of personnel quality (human error / human risk). More precisely, we will focus on the risk of the error for a designer. The main objective in this part is to propose a risk management methodology to manage the risk of the error designer. Meanwhile, we will use the concept of the

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ISO 31000 and FMEA to propose our risk management methodology, in such a context. Principles of the ISO 31000 will help us to develop the process of risk management. The concepts of the FMEA methodology will help us to describe the risks (criteria) in order to better identify and then analyze them. Finally, we will include principles of the MACTOR methodology, which is methodology whose propose is to define the matrix of alliances, conflicts, tactits and objectives between the actors of a project to formulate associated recommendation. It is a rod for propeptive and analysis of “the game” of the actors, in a project. It seeks to identify potential power relations, conflict and synergy on a project. The goal is to anticipate and manage potential conflicts in order to secure the progress of the project.

Therefore, in this work, we will propose an optimization model, which can confront with the defects of other approaches that it to say that the integrated framework cannot analysis the interdependent effect for the risk response strategy, only two criteria can be considered in zone-based approach, the trade-off approach only considers about independent risk response effect and it is unknown whether the strategies obtained are optimal solution to the strategy selection problem for the WBS-based approach: such a model allows to analyze the personal and interdependent risk response effect, and select the optimized risk response strategies with the constraints of the risk response implementation cost and expected utility of the strategies for design project.

4.4 Risk management process for future organization structure

In this chapter, we consider about the risk manage part (part of the red dotted frame in the Figure 4.2) in the whole human resource allocation methodology (Figure 4.2).

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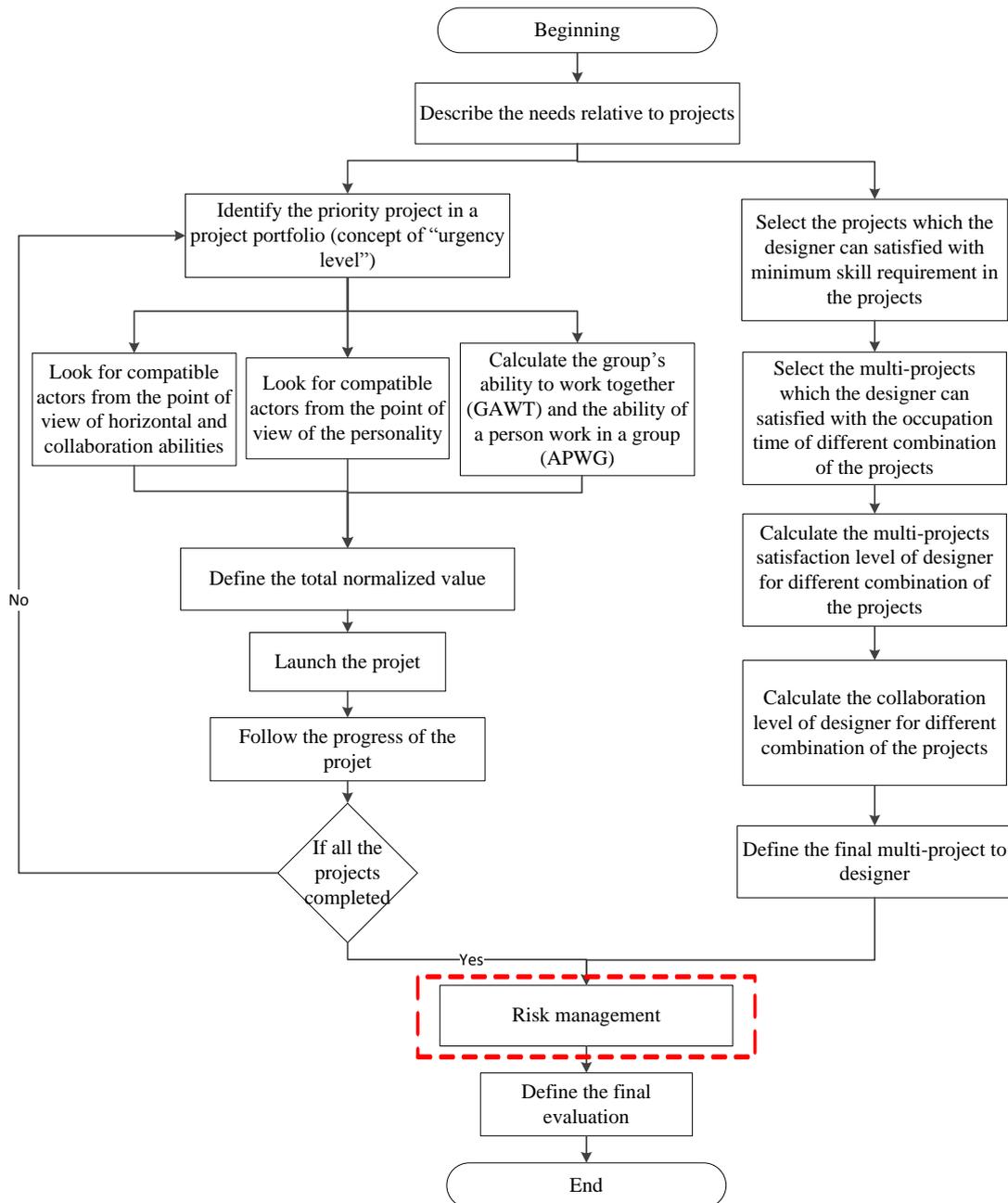


Figure 4.2- Risk Management part in the whole human resource allocation process

We describe the whole risk management methodology in the design process, as follows (Figure 4.3).

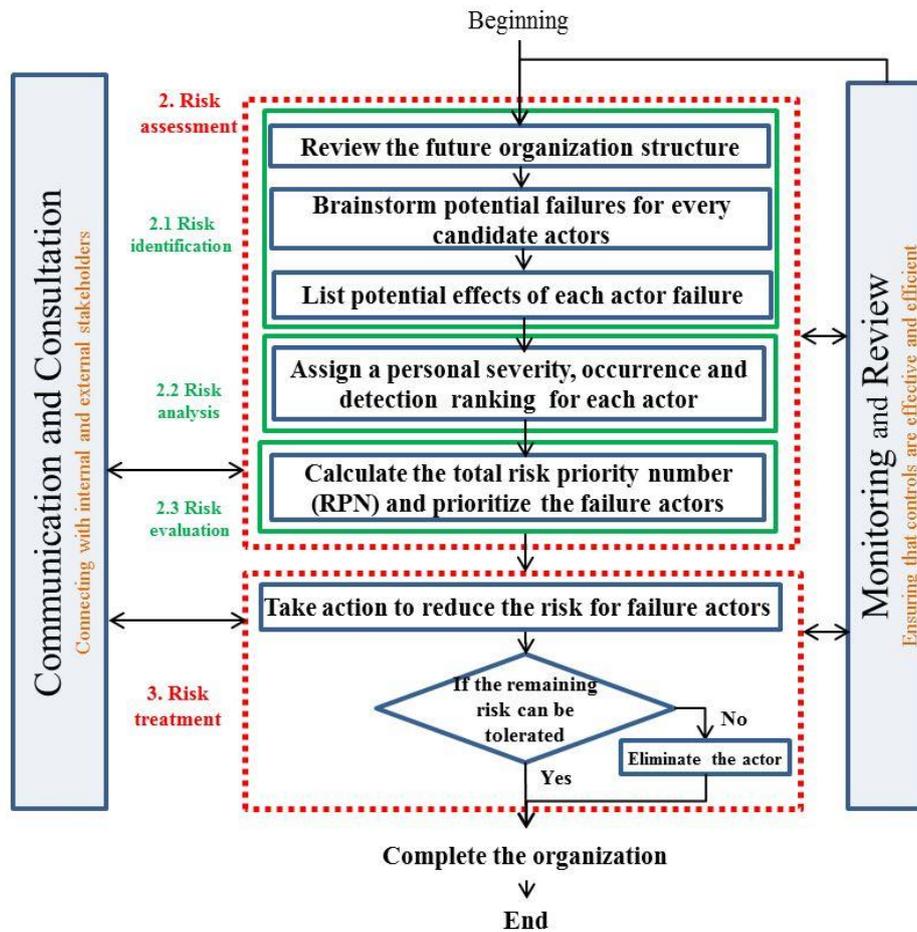


Figure 4.3 - Risk Management Process for future organization structure

According to the previous steps (selection of designers taking into account their profile, personality and ability to work in a group, and selection of projects taking into account designers' satisfaction), project manager has to brainstorm potential errors and/or shortcomings of the candidate designers and brainstorm corresponding impacts of these errors. Then, the assigns a personal severity, detection and occurrence rank for each designer, depending on the FMEA methodology. After that, calculates the Risk Priority Number (RPN) to define the affection of the risk in the designer to the design process. At the final, in the risk treatment part, we can propose a methodology to reduce the risk in error actor, and check if the remaining of the risk can be tolerated. If the risk can be tolerated, the organization will be completed and the project will be launched. Otherwise, project manager should eliminate the actor, and redefine its organization.

4.5 Context analysis and Risk assessment

4.5.1 Review the organization structure

In an organization, the independent risk seldom exists. Personal error of one actor can affect other corresponding actors, with direct and/or indirect effects according the power relationship (Elmsalmi et al. (2014)). The error risk relationship between two actors can be seen in the Figure 4.4.

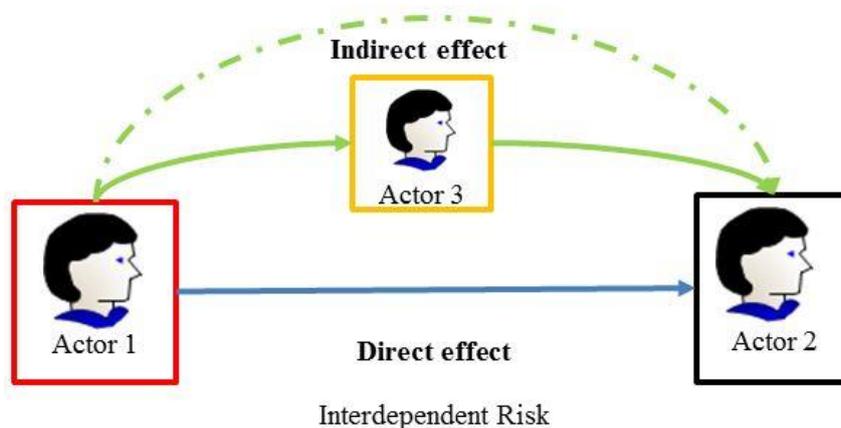


Figure 4.4 - Error risk relationship between actors

In the Figure 4.4, we can find that the error effect relationship between two actors can be divided as direct effect (blue arrow from Actor1 to Actor2) and indirect effect (green dotted arrow from Actor1 to Actor2). In here, the direct effect means the existing error in the actor 1 will cause the Actor2 produce error. In addition, the indirect effect means that the error in the Actor 1 will also influence Actor2 via transitional actors (Actor3), which just like the domino effect. Therefore, when we consider about the influence of the risk in one actor, we should not only consider about the personal error but also think about the direct and indirect influence error to other actors. Also, the risk type will be divided as two parts Personal risk (Personal factors in Actor1) and Interdependent risk (Interdependent risk for blue and green arrow). The total risk level for the error existing actor (Red rectangle for actor 1) can be the total value of personal risk with the interdependent risk. The factors to determine the risk description of an error and its effects are the Severity, the Detection and the Occurrence. The definition of the three factors is shown as follows:

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- **Severity** – The consequence of the error should it occur.
- **Occurrence** – The probability or frequency of the error occurring.
- **Detection** – The probability of the failure being detected before the impact of the effect is realized.

The evaluation criteria rank for the severity, detection and occurrence will be introduced in section 4.5.2.

4.5.2 Brainstorm potential errors and corresponding effects

In our research, we focus on the human error, which means that something has been done that was "not intended by the actor; not desired by a set of rules or an external observer; or that led the task or system outside its acceptable limits" (Mahboob and Zio, 2018), (Senders and Moray, 1995). A risk can have favourable (positive) or unfavourable (negative) effects. The unfavourable effect will increase the expected loss by increasing the impact of the other risk, while the favourable effect will reduce the expected loss by impact of the other risk (Zhang 2016). The common potential positive and negative human errors relative to the designer and corresponding effects can be seen in the Table 4.1.

The evaluation of criteria ranks for the severity, detection and occurrence can be seen in the Table 4.1, Table 4.2 and Table 4.3.

Table 4.1 - Severity Evaluation Criteria

Effect	Type	Description	Rank
Negative High effect	Product	Failure to meet the Functional definition of the product	3
	Process	Overall design process is disordered and chaotic	
	Organization	Communication and teamwork conflicts have reached levels of violation of laws and regulations. Totally lost social impact.	
Negative Medium effect	Product	Failure to meet the Organic definition of the product	2
	Process	Functional definition process is disordered and chaotic	
	Organization	Communication and teamwork conflicts lead to organizational paralysis. Lose a medium part the social impact	
Negative	Product	Failure to meet the Operational definition of the product	1

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Low effect	Process	Organic and operational definition process is disordered and chaotic	
	Organization	Communication and teamwork conflicts reduce design efficiency. Lose a small part the social impact	
No effect	Product	No effect to the design of product	0
	Process	No effect to the design process	
	Organization	No effect to the design organization	
Positive Low effect	Product	Success to meet the Operational definition of the product	-1
	Process	Organic and operational definition process is well ordered	
	Organization	Communication and teamwork rarely increase design efficiency. Gain a small part the social impact	
Positive Medium effect	Product	Success to meet the Organic definition of the product	-2
	Process	Functional definition process is well ordered	
	Organization	Communication and teamwork often improve design efficiency. Gain a medium part the social impact	
Positive High effect	Product	Success to meet the Functional definition of the product	-3
	Process	Overall design process is well ordered	
	Organization	Communication and teamwork greatly improve design efficiency. Totally gain the social impact	

Table 4.2- Detection Evaluation Criteria

Opportunity for Detection	Description	Rank
No detection opportunity	No current detection method; Cannot detect or is not analysed	5
Not likely to detect at any stage	Company has a weak detection capability	4
Moderate to detect at any stage	Company has a moderate detection capability	3
Easy and comprehensive to detect at any stage	Company has a strong detection capability	2
Detection not applicable; Error prevention	Error cause or error mode cannot occur because it is fully prevented.	1

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Table 4.3- Occurrence Evaluation Criteria

Likelihood of Error	Description	Rank
Very High	Error is inevitable with new design, new application	5
High	Frequent errors associated with similar designs or in design simulation and testing	4
Moderate	Occasional errors associated with similar designs or in design simulation and testing	3
Low	No observed errors associated with almost identical design or in design simulation and testing	2
Very Low	Error is eliminated through preventive control	1

From the Table 4.1, we can find that the effect of the error can be positive and negative to the design process. In here, the positive value of the severity rank means that the actors will have a behaviours inclined to make an error (mistake) and cause a negative effect to the design process, while the negative value of the severity rank means the actors will have a behaviours inclined to defeat this error and make a positive effect to the design process.

The identification of the ranks depends on the experience of previous design projects, and project managers can get the rank information through the interview with the candidate actors).

4.5.3 Calculate the total risk priority number

According to the FMEA methodology, a Risk Priority Number (RPN) will be determined for each potential error mode and effect, by multiplying the ranking for the three factors (Severity \times Occurrence \times Detection). FMEA hinged on Risk Priority Number for root causes of the potential error modes to appraise the risk of the system and prioritize the actions that need to be taken (Chan et al. (2017), Goel et al. (2007)). Those error modes with the highest RPNs should be attended to first, although special

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attention should be given when the severity ranking is high regardless of the RPN (Mikulak et al. (2008)).

The process allowing to understand RPN calculation is presented here after (Figure 4.5).

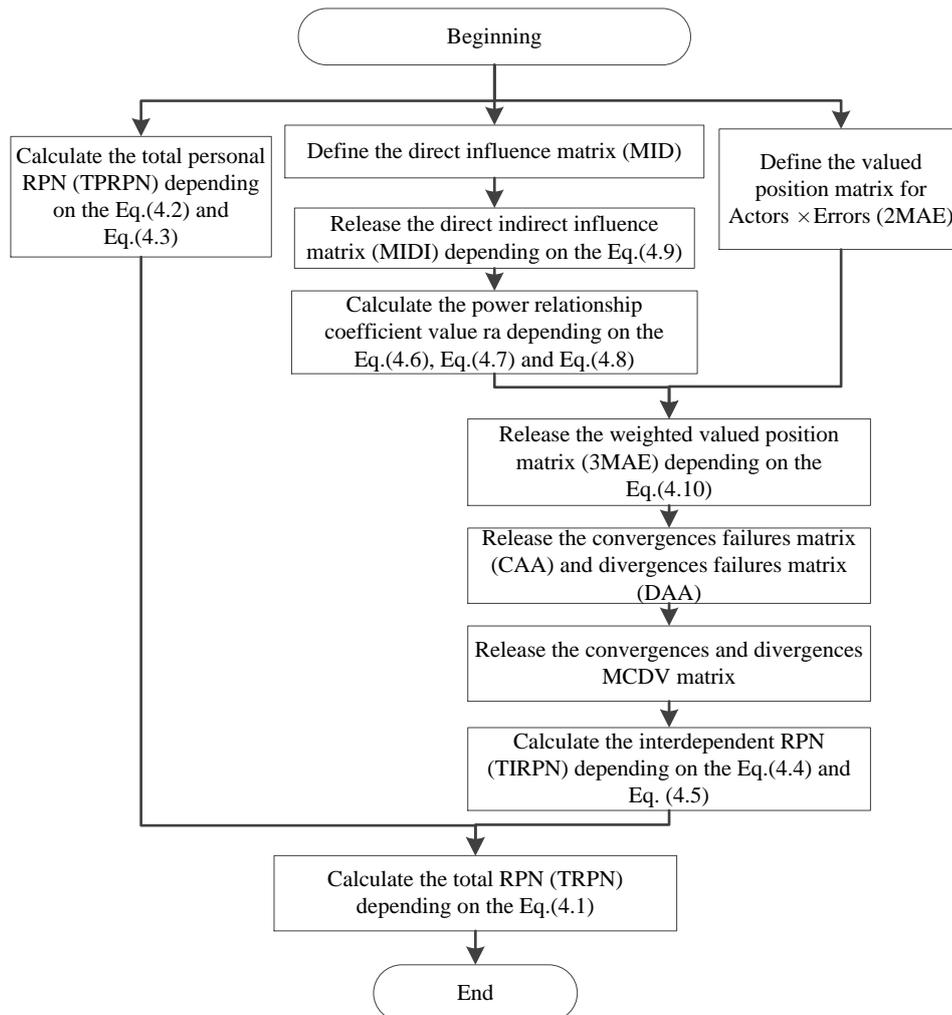


Figure 4.5 - TPRPN calculation process

In the calculation process, we can see that when we calculate the total risk priority number related to an actor, we have to, firstly, calculate the total personal RPN (Table 4.4, Eq. (4.2) and (4.3)) and total interdependent RPN (Equation (4.4) and Equation (4.5)) respectively, and combine them together to get the total RPN (Equation (4.1)). Therefore, firstly, we have to complete the Table 4.4 and calculate the PRPN (Eq. (4.2) and (4.3))

$$TRPN = TPRPN + TIRPN \quad (4.1)$$

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$$TPRPN = \sum_{n=1}^{TNE} (PRPN_n) \quad (4.2)$$

$$PRPN_n = S_n \times D_n \times O_n \quad (4.3)$$

$$TIRPN = \sum_{n=1}^M (IRPN_n) \quad (4.4)$$

$$IRPN_n = TPRPN \times MCDV_{a,n} \quad (4.5)$$

$$r_a = \frac{I_a - MIDI_{a,a}}{\sum_a I_a} \cdot \frac{I_a}{I_a + DP_a} \quad (4.6)$$

$$I_a = \sum_b (MIDI_{a,b}) - MIDI_{a,a} \quad (4.7)$$

$$DP_a = \sum_b (MIDI_{b,a}) - MIDI_{a,a} \quad (4.8)$$

$$MIDI_{a,b} = MID_{a,b} + \sum_c (\min(MID_{a,c}, MID_{c,b})) \quad (4.9)$$

Note. TRPN = Total RPN. TPRPN = Total Personal RPN. PRPN_n = nth personal RPN. TNE = Total Number of Errors in the person. S_n = nth severity. D_n = nth Detection. O_n = nth Occurrence. TIRPN = Total interdependent RPN. IRPN_n = the nth Interdependent RPN. MCDV_{a,n} = Convergence and Divergence value for error in risk existing actor “a” with the nth effected actor. M = Total number of corresponding effected actors. I_a = Net of direct and indirect Influence of the actor “a”. DP_a = Net of direct and indirect Dependence of actor “a”. MIDI_{a,b} = direct and indirect influence from the actor “a” to actor “b”. MID_{a,b} = direct influence from the actor “a” to actor “b”.

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Table 4.4- Calculation of total personal risk priority number for an actor

Actors	Error modes	Effects	S	D	O	PRPN
Actor a	Communication conflict	Delay of design project	3	2	2	12 = PRPN ₁
	Abuse of design software	Design accident/insecurity for user	2	3	3	18 = PRPN ₂
TPRPN						30

Note. S: Severity. D: Detection. O: Occurrence. PRPN_n = nth Personal Risk priority number. TPRPN = Total Personal Risk Priority Number.

For example, in the Table 4.4, the values for PRPN₁ (Personal Risk Priority Number for the error “communication conflict”) and PRPN₂ (Personal Risk Priority Number for the error “abuse of design software”) are 12 ($3 \times 2 \times 2$) and 18 ($2 \times 3 \times 3$). Therefore, the TPRPN (Total Personal Risk Priority Number) is 30 (12+18).

To adapt the FMEA methodology to a point-to-point organization model, and consider about the direct, indirect, favorable and unfavorable effects, we have to think about the total interdependent risk priority number (TIRPN) (Equation (4.4) and (4.5)).

Then, we have to calculate the Total Interdependent Risk Priority Number (TIRPN). For that, we have to define the matrix of Direct Influence (MID) and the matrix of Direct and Indirect Influence (MIDI), thanks to the MACTOR (Matrix of Alliances and Conflicts: Tactics, Objectives and Recommendations) methodology (Coates et al. (1994)). This methodology allows to reveal the real relationship among actors, by introducing the relationship of power between actors. In here, the more power of one actor contains means the more effect of error influence to other actors. Thanks again to the MACTOR method to take into account the direct and indirect influences (Equation (4.9)) between two actors. In here, the indirect influence is exerted through the use of the influence with other intermediary actors (Bendahane et al. (2004)). In the MACTOR methodology, the potential influence of one actor over another is recorded on a scale from 0 to 3 (none, weak, average, strong) (Coates et al. (1994)) (Eq. (4.9)). An example is given here after (Table 4.5).

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Table 4.5– Example of Matrix of Direct Influence MID

From \ To	Actor a	Actor b	Actor c
Actor a	-	1	2
Actor b	2	-	1
Actor c	2	1	-

Then, thanks to the Matrix of Direct Influence and to the Equation (4.9), we can complete the Matrix of Direct and Indirect Influence (Example of Table 4.6).

Table 4.6– Example of Matrix of direct and indirect influence MIDI

From \ To	Actor a	Actor b	Actor c	Influence (I _i)	Sum (Dependence)
Actor a	3	2	3	5	
Actor b	3	2	3	6	
Actor c	3	2	3	5	
Dependence (DP _i)	6	4	6	-	16
Sum(Influence)				16	-

Thanks to the MIDI (Table 4.6) and the equations, we can calculate power relationship coefficient r_i for all the actors. For example, for the Actor “a”, the values of its Influence $I_{Actor\ a}$ and its Dependence D_{Actora} are $((3+2+3) - 3) = 5$ and $((3+3+3) - 3) = 6$. Then, using the Equation (4.6), the r_{Actor1}^* is $((((5-3)/ (16)) \times (5/ (5+6)))) = 0.0568$. In

here, we have to consider the $r_{Actor\ a} = N \cdot \frac{r_i^*}{\sum r_i^*}$ to be the final result of coefficient value for the reason of facilitate understanding and calculation. In here, the N means the number of actors. Therefore, the result of the r_{Actor1} is $0.65 (3 \times (0.0568/0.2636))$.

Then, the methodology MACTOR allows to analyze the behaviours of actors of a system according to their objectives, projects and means of action. It allows to reveal a

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number of strategic issues and to underline the key questions for the future on which they have convergence and divergence (Elmsalmi et al. (2014)). In here, the main objective of this method is to research the possible convergences and divergences of the different actors relative to the objectives of a project (Mabrouk et al. (2014)). To adapt the MACTOR method to our work, we research possible convergences and divergences of the different actors relative to the different human errors. The convergence or divergence error means the more error infectious or less error infectious to the other actors. The more convergence level of error two actors have, the more error two actors will be infected with each other. For the valuation, the rank of the error of an actor is evaluated with a scale from -3 to 3, according to whether the error level is positive (the actor is strongly inclined to error) or negative (the actor is strongly inclined to defeat this error). The explanation of the rank of errors is shown as follows:

- 3: The actor feels that he is inclined to make this error and feels that the error is low important to him.
- 2: The actor feels that he is inclined to make this error and feels that the error is medium important to him.
- 1: The actor feels that he is inclined to make this error and feels that the error is high important to him.
- 0: The actor is not sure that he is inclined to make this error or defeat this error.
- -1: The actor feels that he is inclined to defeat this error and feels that the error is low important to him
- -2: The actor feels that he is inclined to defeat this error and feels that the error is medium important to him
- -3: The actor feels that he is inclined to defeat this error and feels that the error is high important to him

The example of valued position matrix for Actors \times Errors can be seen as the Table 4.7.

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Table 4.7- Valued position Matrix for Actors × Errors (2MAE)

Actors	CC	TC	ADS	UDP
Actor a	3	2	0	0
Actor b	1	2	0	1
Actor c	2	1	1	0

Note. CC: Communication Conflict. TC: Teamwork Conflict. ADS: Abuse of Design Software. UDP = Unordered Design Process.

In the Table 4.7, we can find that only Actor “a” has the positive value two errors, which just match the error existing actor in Table 4.4. Meanwhile, Actor “b” and “c” have the negative values in one or some errors, such as the error part of Teamwork Conflict in Actor “b”, contains the value -1. It means that Actor “b” can defend Teamwork Conflict error and have a positive effect to the risk, which means reduce the influence of the error.

After the calculation of the power coefficient value (r_a) for every actor, we multiply this value to the 2MAE (valued position matrix for Actors × Errors) (Table 4.7) to get the 3MAE (weighted valued position matrix for Actors × Errors) (Equation (4.10)).

$$3MAE_{a,i} = 2MAE_{a,i} \cdot r_a \quad (4.10)$$

The example of the weighted valued position matrix for Actors × Errors can be seen as the Table 4.8.

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Table 4.8 Weighted valued position Matrix for Actors × Errors (3MAE)

Actors	CC	TC	ADS	UDP
Actor a	1.95	1.30	0	0
Actor b	1.71	3.42	0	1.71
Actor c	1.30	0.65	0.65	0

Note. CC: Communication Conflict. TC: Teamwork Conflict. ADS: Abuse of Design Software. UDP = Unordered Design Process.

In the table, for example, the Actor “a”, the value of Communication Conflict is: $(3 \times 0.65) = 1.95$.

Depending on the 3MAE, we can release the valued matrix of convergences (3CAA) and the valued matrix of divergences (3DAA). The 3CAA and 3DAA for the example in Table 4.8 is shown in Table 4.9 and Table 4.10.

Table 4.9 Valued matrix of convergences (3CAA)

To From	Actor a	Actor b	Actor c
Actor a	-	4.19	2.6
Actor b	4.19	-	3.54
Actor c	2.6	3.54	-

Table 4.10 Valued matrix of divergences (3DAA)

To From	Actor a	Actor b	Actor c
Actor a	-	0	0
Actor b	0	-	0
Actor c	0	0	-

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Then, we combine values of convergences and divergences, and define the final Matrix of Convergences and Divergences Value (MCDV). For the combination of the convergences and divergences, we should make the sum value between the 3CAA and the 3DAA, then, divide by 9 (the absolute value of 3CAA and 3DAA level is range from 0 to 9). The value in the matrix of MCDV, concerning about the power effect and common error level from one actor to the other actor, which will be the interdependent effect level from one actor to another actor. An example of the result matrix for MCDV can be seen in the Table 4.11.

Table 4.11- MCDV matrix for 3 actors

From \ To	Actor a	Actor b	Actor c
Actor a	-	0.47	0.29
Actor b	0.47	-	0.40
Actor c	0.29	0.40	-

After that, depending on the matrix of MCDV, we can calculate the IRPN_n in the equation (4.5). The reason why multiply $MCDV_{a,n}$ with the PRPN is that when we consider about the interdependent, we use the weight of interdependent effects and Personal RPN to define the final interdependent RPN. An example of IRPN_n for the Actor “a” in Table 4.11 is shown in Table 4.12.

Table 4.12 An example of Interdependent Risk Priority Number (IRPN_n)

Actor	IRPN _n
Actor a	0
Actor b	14.1
Actor c	8.7
TIRPN	22.8

Note. TIRPN = Total interdependent RPN. IRPN_n = the nth Interdependent RPN.

In the table, for example, the value of IRPN_c is: $(30 \times 0.29) = 8.7$. Meanwhile, the Total Interdependent Risk Priority Number (TIRPN) for the Actor “a” is: $(0 + 14.1 + 22.8) = 22.8$.

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Hereafter, thanks to the equation (4.1), we calculate the Total RPN for all the error existing actors. The example of Total RPN for Actor “a” in the Table 4.12 is: $(30 + 22.8) = 52.8$. Finally, the project manager can prioritize the “error” actors depending on the Total Risk Priority Number and for future action plans (take action to eliminate or reduce the high-risk). The higher value of Total RPN the actor has, the more priority level he has.

If, despite the actions put in place, the risk is still not tolerable, the actor will not be selected in the design project team.

Throughout the design process, project managers have to monitor and review all the risk management process to ensure that controls are effective and efficient. Meanwhile, project managers have to communicate and consult all the internal and external stakeholders (different areas of expertise) about analyzing and evaluating risk to ensure that different views are appropriately considered for the evaluation of the risk.

4.6 Risk treatment

The whole process of risk response strategy selection (i.e. the step “Take action to reduce the risk for error actors” in the Figure 4.3) can be seen in Figure 4.6.

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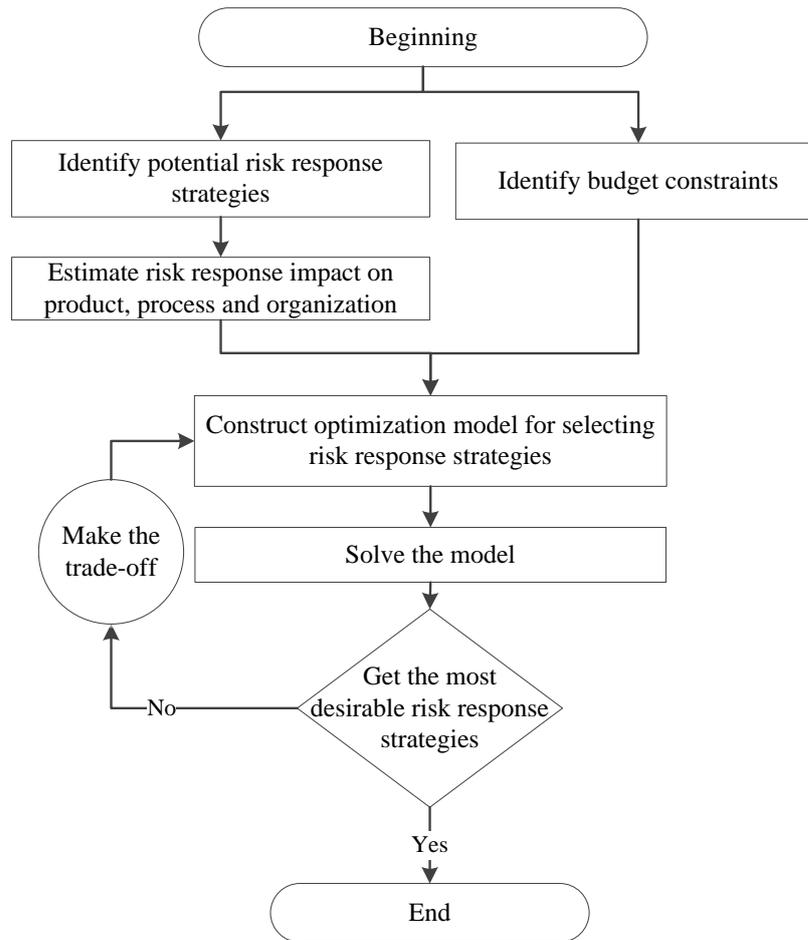


Figure 4.6 - Process of risk response strategy selection

Firstly, it is necessary to identify potential risk response strategies and budget constraints, when all the risks have been analyzed and evaluated, in order to, promptly, solve the mitigation of the risk. When the project manager thinks about the risk response strategies, he has to find strategies according to the risk analysis result. After that, he estimates risk response strategy according its impact on the product, the process design and the organization. Afterwards, he has to use optimization model for selecting risk response strategies. The main objective of this model is to find the highest expected utility for the strategies while the strategy implementation cost is not over the budget. Then, he can solve the model, and check if he gets the most desirable risk response strategies. If the strategies have not the expected effect, he needs to make the trade-off and reconstruct the optimization model for reselecting other risk response strategies. Otherwise, he can apply the final risk response strategies.

4.6.1 Identification of potential risk response strategies

Designer risk (error) has often been cited as a primary cause or contributing factor in disasters and accidents in industries. It can lead to many kinds of affections in the design process. The example of risks and their corresponding effects on the product, the process, and the organisation can be seen in the Table 4.13.

Table 4.13– Common designer risks and corresponding effects to the design project

Cause	Typologies of Risk	Examples	Effects
Lack of product specification knowledge	Product	Abuse of product specifications	Failure in the main function of product
Lack of design technique knowledge		Misused design software	Low quality of product
Lack of design process knowledge	Process	Unordered design process	Design accident
Lack of structural design knowledge		Failure in structural design	Low efficiency of design
Lack of teamwork	Organization	Teamwork conflict	Low efficiency of design team
Lack of communication		Communication conflict	Low efficiency of communication
Lack of foresight		Mistakenly considered the social impact	Lost social impact (religion, culture, age, lifestyle, citizenship, and etc.))

In order to mitigate the human risk relative to the designer, it is necessary to put in place different strategies: training, course, education, etc. Meanwhile, the manager

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must identify what the exact training needs are through the use of needs assessment, goal analysis, and/or performance (Morrison et al., 2010).

An example of the common risk response strategies can be seen as Figure 4.7.

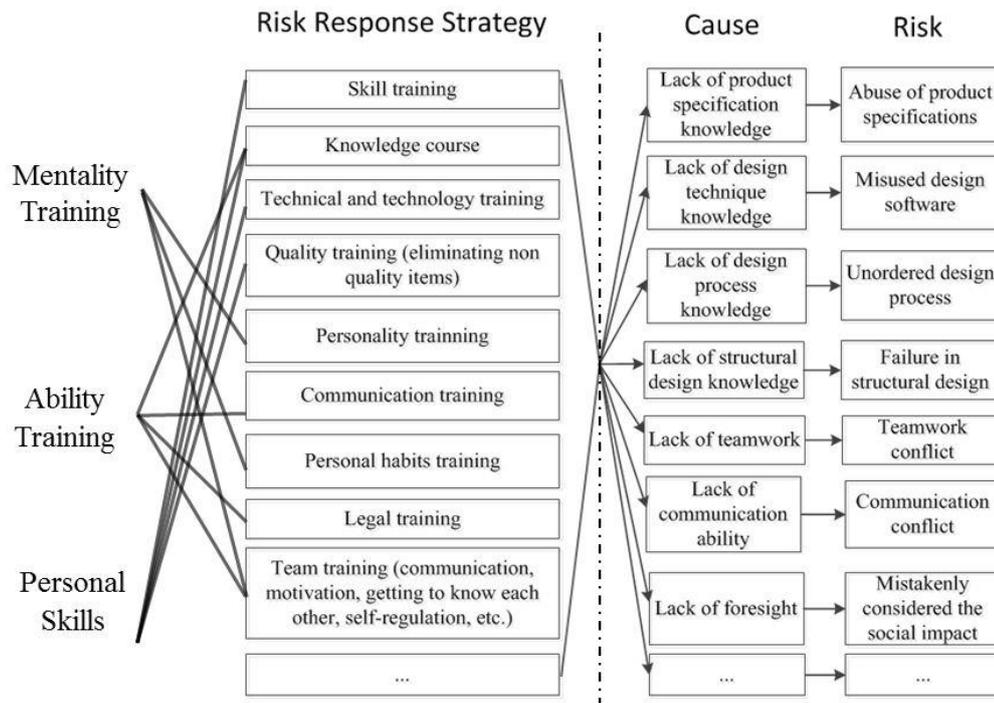


Figure 4.7 - Common risk response strategies to the corresponding cause of the designer risk

Risk response strategies can be classified in 3 parts. The mentality training aims to establish the mentality of individuals or employees (or other social relationships) and thereby create suitable psychological conditions for accomplishing a task. The competency training is the foundation of training and building the competency base of individuals or employees (or other social relationships). It includes understanding (content mastery and control) and support (managerial, coordinating, legal, safety etc.) of the tasks performed. The personal skills cover the analytical expertise in expertise and specialized fields, as well as proficiency in the use of related tools. Meanwhile, depending on the source of the risks, the manager can define the appropriate risk response strategy.

4.6.2 Estimation of the impact of the risk response

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response effect ($\Delta TIRPN$) (Interdependent risk for direct arrow and indirect dotted arrow). To calculation process of the $\Delta TRPN$, is presented hereafter (Figure 4.9).

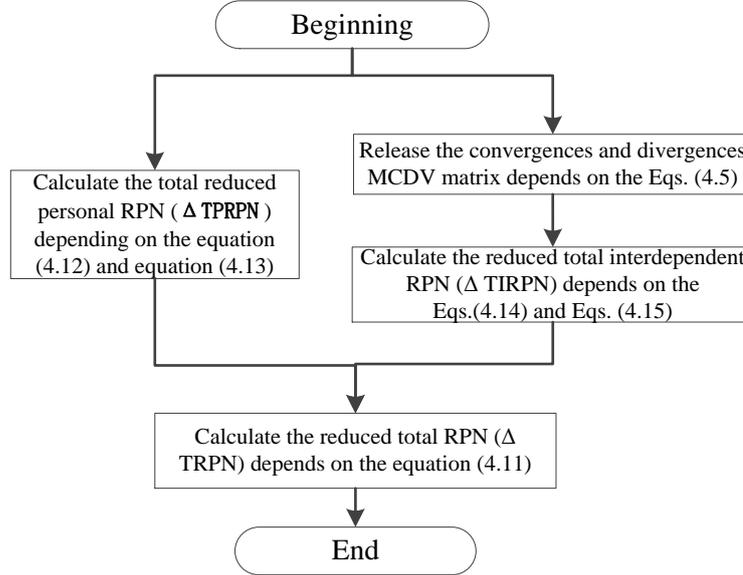


Figure 4.9 - Reduced total RPN calculation process

In the $\Delta TPRN$ calculation process, we can see that when we calculate the reduced total RPN for an error of an actor, we have to, firstly, calculate the reduced total personal RPN ($\Delta TPRPN$) and, the reduced total interdependent RPN ($\Delta TIRPN$) respectively (Equation (4.12) and Equation (4.14)), and combine them together to get the final $\Delta TRPN$ (Equation (4.11)).

$$\Delta TRPN = \Delta TPRPN + \Delta TIRPN , \quad (4.11)$$

$$\Delta TPRPN = \sum_{n=1}^N \Delta PRPN_n , \quad (4.12)$$

$$\Delta PRPN_n = S_n D_n O_n - (S_n - \Delta S_n)(D_n - \Delta D_n) (O_n - \Delta O_n) , \quad (4.13)$$

$$\Delta TIRPN = \sum_{m=1}^M \Delta IRPN_m , \quad (4.14)$$

$$\Delta IRPN_m = \Delta TPRPN \times MCDV_m \quad (4.15)$$

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Note. $\Delta TRPN$ = Total reduced RPN. $\Delta TPRPN$ = Total Personal reduced RPN. $\Delta PRPN_n$ = nth Personal reduced RPN. S_n = nth severity. D_n = nth Detection. O_n = nth Occurrence. ΔS_n = the reduction of severity for nth error. ΔD_n = the reduction of detection for nth error. ΔO_n = the reduction of occurrence for nth error. p_m = affection percentage from risk existing actor to affected actors. N = Number of errors for one actor. M = Number of the affected actors by the risk existing actor. $MCDV_m$ = Convergence and Divergence value for error in risk existing actor with the m_{th} effected actor.

In the equation (4.13), the ΔS , ΔD and ΔO mean the reduced severity, detection and occurrence of the risk after implementation the risk response strategies. Such as for the ΔD , it can be a strategy to relying on a human or a mechanism to detect and prevent the error (establish communication mediators for designers who lack communication ability to prevent communication conflicts), and for the ΔS and ΔO , it can be a strategy of design technique knowledge training, which can reduce the severity and occurrence of the misuse of a design soft-ware.

The ΔS , ΔD and ΔO parameters can be evaluated by the trainers or training institutions according to empirical data and experience in the field. An example of the $\Delta TPRPN$ calculation process can be seen in the Table 4.14.

Table 4.14- Example of the $\Delta TPRPN$ calculation process

RRS	Actor	Error	Effect	S	D	O	RPN	
Skill Training	Actor 1	Abuse of Product Specification	Failure in the Main Function	3	2	4	24	
			Definition of product	$\Delta S(1)$	$\Delta D(1)$	$\Delta O(2)$		
				2	1	2	4	
			$\Delta PRPN_1$	24-4			19	
		Failure in structural design	Low efficiency of design	2	4	5	40	
				$\Delta S(0)$	$\Delta D(1)$	$\Delta O(1)$		
				2	3	4	24	
			$\Delta PRPN_2$	40-24			16	
		$\Delta TPRPN$			$\Delta PRPN_1 + \Delta PRPN_2$			35

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Note. RRS: Risk response strategy. S: Severity. D: Detection. O: Occurrence. RPN: Risk priority number.

Several errors can be associated to the same designer. In the example of the Table 4.14, we can see that there are two errors (Abuse of Product Specification and poor communication) for the A1. We can firstly calculate the reduced personal RPN (ΔPRPN_1 and ΔPRPN_2) for every error, separately, and combine them together to release the final ΔTPRPN .

Matrix of Convergence and Divergence Value (MCDV) in equation (4.15) can be directly getted from the equation (4.5).

4.6.3 Construction the optimization model

To let the project manager evaluate and select most suitable risk response strategies, there is necessary to have an objective function, to approach the issue above. In here , we will introduce the expected Utility Function. The expected utility is used in a rather sophisticated way, employing subjective probabilities and involving nonmonetary payoffs (Gilboa, 2009). Expected Utility Theory (EUT) states that the decision maker (DM) chooses between risky or uncertain prospects by comparing their expected utility values, i.e., the weighted sums obtained by adding the utility values of outcomes multiplied by their respective probabilities (Mongin, 1997). In economics, people do, and should maximize expected utility (Gilboa, 2009). In order to end up with a utility function and a probability measure, such that individual's decisions are being made so as to maximize the expected utility (Gilboa, 1987).

To construct our optimization model, the expected loss of a Risk actor R_j is Total Risk Priority Number (TRPN_j), and the expected loss TRPN is the multiplication of the likelihood of occurrence, severity and detection of the different Risk R_j . In order to reduce the expected loss of the risk, for each actor, different risk response strategies ($T = \{T_1, \dots, T_m\}$) must be proposed and selected to cope with the risks before the project implementation. After the risk response strategies are distributed to the different risk actors, it is possible to estimate the implementation cost of the distributed risk response strategies and the effects of risk response strategy. Therefore, our main objective is to increase the utility of risk response strategies while decreasing the implementation cost of these strategies.

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After that, depending on the expected utility function, the optimization model for selecting risk response strategies is shown as follows:

$$F(x) = E[U(x)] = \sum_{j=1}^m \sum_{k=1}^n W_k U(x_{jk}). \quad (4.16)$$

$$\sum_{j=1}^m \sum_{k=1}^n c_j x_{jk} \leq B, \quad (4.17)$$

$$x_{jk} \in \{0,1\}, \quad (4.28)$$

$$S_{kl} - \sum_{j=1}^m \Delta S_{jkl} x_{jk} \leq 2. \quad (4.19)$$

Note. W_k = Weight of risk actor R_k . c_j = Implementation cost for strategy T_j . T_j = j th risk response strategy. B : Risk response strategy implementation budget. S_{kl} : Severity of the l th error in risk R_k . ΔS_{jkl} = impact of j th risk response strategy to the l th error for the risk R_k . x_{jk} = the response strategy T_j is implemented/not implemented to the risk actor R_k .

The objective function (4.16) allows to maximize the expected utility for the project manager. In here, W_k means the critical error level for the risk R_k , which is ranged from 0 to 1. The critical error level will be defined by the calculation of the total RPN, which is not only considering the personal risk of an actor but also thinking about interdependent risk. Because it is possible to allocate one same strategy to several risks, we have to summarize all the affections for this strategy. Constraint (4.17) ensures that the cost of implementing risk response strategies meets the budget requirement. C_j , in the constraint (4.17), is the cost of implementing j th response strategy to one actor and $\sum_{k=1}^n c_j x_{jk} \leq B$ is the total j th cost of implementing the j th risk response strategy to all the affected actors. The value for the constraints (4.18) will be the alternative 1 or 0, which is the binary integer decision variable. In here, if the x_{jk} value is 1, the response strategy T_j is implemented to the risk actor R_k otherwise the x_{jk} value is 0. In addition since in the design project, it is unacceptable for the design project to have error in Functional definition step (High effect in Table

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4.1), after implementing the risk response strategies to the actor, we have to ensure that the severity of the risks for actor is less than or equal to Medium effect (Table 4.1). In the equation (4.19), S_{kl} is the severity of the l_{th} risk of the risk R_k . In addition, ΔS_{jkl} is the impact of j_{th} risk response strategy to the l_{th} error for the risk R_k . Therefore, the equation (4.19) allows to ensure that the result severity of the risk is less than or equal to 2 (Medium effect).

The definitions of the utility function and weighting function are described in details in sections 4.6.3.1 and 4.6.3.2.

4.6.3.1 Defintion of the utility function

In the above objective function, the optimization goal is to maximize the project manager expected utility. The utility can be described mathematically as a function of hierarchically ranked preferences for objects of choices - e.g. goods, states of the world (Clavien et al., 2016). For the design project, unlike other persons who make gambling and lottery with the attitude of risk-neutrality and risk seeking, the attitude of design project managers are supposed to be risk aversion (Hirshleifer et al., 1992), Indeed, when risk response strategies are deployed to the different risk existing actors, they would like to gain benefits without uncertainty and refuse a fair gamble, which has an expected benefits value of zero. Therefore, we introduce a concave utility function due to the fact that the utility function may imply that the project manager is risk averse (Zhang, 2016)). In the concave utility functions, the exponential utility function adds risk to the utility function, looking to define how managers will avoid risk. Both theory and practical experience have shown that it is often appropriate to use a particular form of utility function called the exponential (Kirkwood, 2002). In the context of utility maximization, exponential utility has been widely used because of its nice analytic tractability, and in particular, it shows fundamental separation properties when dealing with contingent claims (Mereu et al., 2017). Hence, in the process of risk response strategies allocation problem in design project, we can use risk-averse exponential utility function to define our utility function (4.20).

$$U(x_{jk}) = 1 - e^{-\alpha(x_{jk}^{\alpha_{jk}})}, \quad (4.20)$$

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$$\alpha = \frac{1}{R}, \quad (4.21)$$

$$\alpha > 0. \quad (4.22)$$

In the utility function (4.20), the a_{jk} is the estimated risk response effect (Δ TRPN) after implementing j th risk response strategy to cope with the risk R_k . $\alpha > 0$ stands for the coefficient of Absolute Risk Aversion (ARA), which is a constant over time for the exponential utility (CARA utility) (Bodnar, 2015). R is the reciprocal of the Absolute Risk Aversion and called the risk tolerance. Risk tolerances obtained from different executives within the same organization vary tremendously, and generally, those lower in the organization have lower risk tolerances (Lee, 2016). In the light of a rule of thumb (Howard, 1988), the risk tolerance (the reciprocal of absolute risk aversion) tends to be about one-sixth of equity (Zhang (2016)).

4.6.3.2 Definition of the weighting function

The weighting function W_k denotes the risk weight of risk R_k , and satisfies $W_k \in (0, 1)$. In this work, we define that the weight of the risk R_k can be seen as the proportion of k_{th} TRPN in the total TRPN for all the risk existing actors (equation (4.17)). TRPN combine the personal risk effect to interdependent risk effect, which can be represented as the total strength of the risk.

$$W_k = \frac{TRPN_k}{\sum_{k=1}^K TRPN_k} \quad (4.23)$$

Note. K = Total number of risks. $TRPN_k = k_{th}$ actor Total Risk Priority Number.

Though the equation (4.23), we can calculate the weight W_k for the utility function.

The example of the calculation of the strength of the risk (W_k), we can keep on the example in Table 4.12. The example of Total Risk Priority Number for Actor “a” in the Table 4.12 is 52.8. Therefore, we can also use the same way to calculate the Total Risk Priority Number for Actor “b” (64) and Actor “c” (16) in the Table 4.12. Thus, the strength of the risk (W_k) for Actor “a” is: $(\frac{52.8}{52.8+64+16}) = 0.451$.

Conclusion

In this chapter, we proposed a risk management methodology. In this methodology, we firstly analysed the context and assessed risk for the human risk. In here, through the calculation of the Total Risk Priority Number (TRPN), project managers can understand the affection of the risk associated to the designers in the design process. After that, we explained the risk treatment part: we studied how choose and implement a risk response strategy by estimating corresponding effects on the product, on the process and on the organization. We constructed an optimization model to select the most appropriate strategies, considering about the utility function of the budget of the different strategies.

CHAPTER 5 SIMULATION AND

VERIFICATION

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List of Observation

AHP = Analytic Hierarchy Process.

APWG = Ability of a Person Work in a Group.

AWPSG = Average Weighted Pair Satisfaction Gap.

AWTSL = Average Weighted Total Satisfaction Level.

CAA = Matrix of Convergence.

CAD = Computer-aided design.

CAVE = Cave Automatic Virtual Environment.

DAA = Matrix of Divergence.

GAWT = Group's Ability to Work Together

GPA = Group Personality Ability.

MCDV = Matrix of Convergences and Divergences of the actors for the error.

MEAN = the mean of the normative sample. SD = Standard Deviation of the normative sample.

MID = Direct Influence Matrix.

MIDI = Direct Indirect Influence Matrix.

N = Number of collaboration designers.

NGAWT = Normalized Group's Ability to Work Together.

NGPA = Normalized Group Personality Ability.

NTAVG = Normalized Total Average Gap.

NTN = Normalized Total Number.

PCE = Personal Collaboration Experience.

ST = Strength of Relationship.

TAVG = Total Average Gap.

TAWPSG = Total Average Pair Satisfaction Gap.

TPRPN = Total Personal Risk Priority Number.

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TRPN = Total Risk Priority Number.

WTSL = Weighted Total Satisfaction Level.

Δ TIRPN = Reduced Total Interdependent Risk Priority Number.

Δ TPRPN = Reduced Total Personal Risk Priority Number.

Δ TRPN = Reduced Risk Priority Number.

2MAO = Matrix for Actors \times Errors.

Introduction

In this chapter, we firstly give an overview of the illustrative case. Then, we will make the simulation and verification for three main methodologies. One is for human resource allocation simulation and verification, another one is for project selection simulation and verification, and the final is for risk management simulation and verification. In the human resource allocation simulation and verification, we will simulate and verify the horizontal ability, communication and collaboration ability, personality analysis, group's ability to work together, risk management separately. Meanwhile, in the project selection simulation and verification, we will simulate and verify project selection process with the constraints of minimum skill requirement and occupation time, calculation of the multi-projects satisfaction level of designer for different combination of projects, and calculation of the collaboration level of designer for different combination of the projects. Finally, the risk management simulation and verification, we will simulate the assessment of the risk for risk existing designers and select appropriate risk response strategies for these designers. To make the simulation and verification for all the processes, we have developed a web application with the implementation of human resource allocation, project selection and risk management methodologies.

5.1 Illustrative case

To simulate and verify all the methods in this paper, we introduce an illustrative case which is a made-up example but tends to be as realistic as possible. Here we provide a general introduction of the illustrative case.

German automotive design company is adapting virtual reality technology (gesture-control technology, manual controller, wearable device Myo, Cave Automatic Virtual Environment, etc.) to make its automotive design processes more efficient (Ross (2015)). Designers will use the technology to assemble prospective vehicle designs in a virtual 3D environment. Meanwhile, design team currently uses a manual controller to manipulate components in the company's virtual testing space – known as the Cave Automatic Virtual Environment (CAVE). Additionally, combine the IOT and virtual reality technology, designers from all over the world can work

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inside CAVE, and they will have the ability to interact with components and other designers more easily and freely. Therefore, designers allocation to design projects and select design projects to designers in design process is more flexible (it is very easy for the project manager to recruit acceptable designers for project all over the world and also easy to find suitable projects to the designers), flowed by the complex of communication and collaboration among designers with the difficult resource allocation management problems (various personality conflicts and cooperative dissatisfaction, lack of collaboration ability) in the CAVE and project selection problem with the consideration of satisfaction of the designers and collaboration in the positioned projects. Thus, the automotive design company needs to analyze not only project part but also designer part (allocate designers to design projects and select design projects to designers) to more effectively confront the future communication and collaboration problems in the design process. And our proposed methods in this paper can solve these problems.

In this case study, we consider about 4 design projects with the different constraints, and 10 designers. In here, we have to firstly input the four project information. The input page for the project can be seen in Figure 5.1.

Human Resource Allocation
— Factory of the future

Project CandidateActors ResourceAllocation ProjectSelection RiskManagement

Insert a new project:

Company	Project Name	Project Objective	Project Requirement	Project Delivery Date	Project Work Load	Required Designers(quantity)	Required Project Time(day, month, year)
PENTAGRAM Management Companies	<input type="text"/>	1 ▾	1 ▾	1 ▾	1 ▾	<input type="text"/>	0 <input type="text"/> 0 <input type="text"/> 0 <input type="text"/>
Required Skill	Required Creativity	Required Availability	Required Occupancy Rate	Required Personal Satisfaction	Required Education	Required Experience	Required Age
<input type="text"/>	1 ▾	1 ▾	1 ▾	1 ▾	1 ▾	1 ▾	1 ▾
Weight of skill	Weight of creativity	Weight of availability	Weight of occupancy rate	Weight of personal satisfaction	Weight of education	Weight of experience	Weight of age
0.0 ▾	0.0 ▾	0.0 ▾	0.0 ▾	0.0 ▾	0.0 ▾	0.0 ▾	0.0 ▾

Figure 5.1 – project information input page

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In the Figure 5.1, we have to firstly click the button “Project”, and it will display the project information insertion form (table in the Figure 5.1). Project manager can insert all the information about the project in this table and click the button “Insert Project”. In the Figure 5.1, to define the requirement and weight of horizontal properties (Weight of skill, Weight of creativity, Weight of availability and so on), project manager can tap the button Required of horizontal properties (Required skill, Weight of availability and so on in Figure 5.1) and Weight of horizontal properties (Weight of skill, Weight of availability and so on in Figure 5.1), and we can get the AHP method information like Figure 5.2.

The screenshot shows a web browser window with two main components. On the left is a form titled "Insert a new project:" with a table for project details. On the right is a help page titled "Description of Horizontal Properties" and "Description for different creativity level".

Project Information Form:

Company	Project Name	Project Objective	Project Requirement
PENTAGRAM Management Companies		[1]	[1]
Required Skill	Required Creativity	Required Availability	Required Occupancy Rate
	[1]	[1]	[1]
Weight of skill	Weight of creativity	Weight of availability	Weight of occupancy rate
[0.0]	[0.0]	[0.0]	[0.0]

Description for different creativity level:

Creativity Level	Description
Creativity-1 Expressive Creativity	The ability to develop a unique idea with no concern about its quality.
Creativity-2 Technical Creativity	The proficiency to create products with consummate skills, but with little expressive spontaneity.
Creativity-3 Inventive Creativity	The ability to develop a new use of old parts and new ways of seeing old things in an ingenious manner.
Creativity-4 Innovative Creativity	The ability to penetrate foundational principles or establish a school of thought, and formulate innovative departures.
Creativity-5 Emergent Creativity	The ability to incorporate the most abstract ideational principles or assumptions underlying a body of knowledge.

Description of Horizontal Properties:

Property	Description
Skill	The ability to carry out a design task with determined results often within a given amount of time, energy, or both.
Creativity	The ability to create meaningful new ideas, forms, sounds, methods, performances, and interpretations.
Availability	A criterion (from Intense to Easy) to evaluate the difficulty of obtaining actors from affiliated company.
Occupancy Rate	The percentage of the personal occupation time in the target design project.
Personal Satisfaction	The designer satisfaction with the target design project
Education	Education background of designer
Experience	The number of years of work experience
Age	It means the age of candidate designers

Help Text:

For the weight different horizontal ability properties (weight of skill, weight of creativity, weight of availability, weight of occupancy rate, weight of personal satisfaction, weight of education, weight of experience, weight of age), we can use the AHP (Analytic Hierarchy Process) method (pairwise comparison method) to define the importance (weight) of each other.

[The detailed description of the AHP method](#)
[An example to describe the process of AHP method](#)
[Calculation of all the weights of 8 horizontal properties](#)

Figure 5.2 - Weight of horizontal properties and AHP method description webpage

In the Figure 5.2, project manager can get the horizontal properties information and the AHP method introduction webpage link. Apart from that, there also has the link about the Calculation of all the weights of 8 horizontal properties. Project manager can tap the button “Calculation of all the weights of 8 horizontal properties” to go to the webpage about the calculation of weights of 8 horizontal properties (Figure 5.3).

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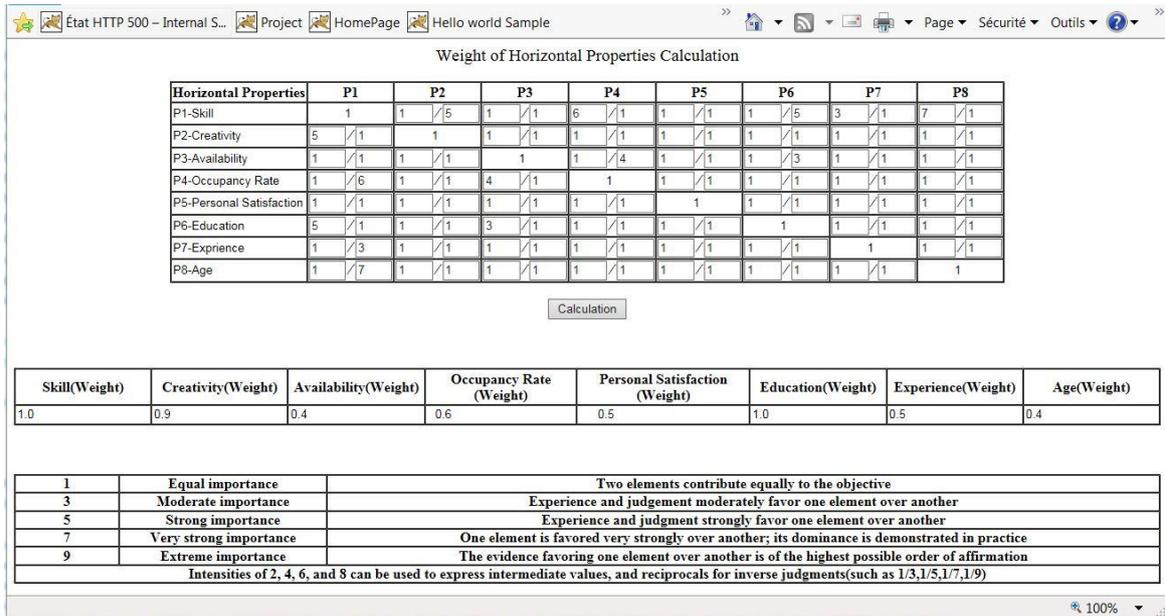


Figure 5.3 - Webpage for weight of horizontal properties calculation.

In the Figure 5.3, project manager can input the pairwise comparison value and tap the button “Calculation”, and the system can release the weight of 8 horizontal properties (middle table in Figure 5.3). After that project manager can use these weights result to input the weight of horizontal properties value in Figure 5.1.

After input all the project information, the information will be stored into the database. The information of the 4 candidate design projects can be seen as Figure 5.4.

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Company	Project Name	Project Objective	Project Requirement	Project Delivery Date	Project Work Load	Required Designers(quantity)	Required Project Time(day, month, year)
HAPPY COG Management Companies	Project1	2	2	3	2	3	3 0 0
Required Skill	Required Creativity	Required Availability	Required Occupancy Rate	Required Personal Satisfaction	Required Education	Required Experience	Required Age
CAD-1	1	1	1	1	1	1	1
Weight of skill	Weight of creativity	Weight of availability	Weight of occupancy rate	Weight of personal satisfaction	Weight of education	Weight of experience	Weight of age
0.8	0.8	0.6	0.2	1.0	1.0	1.0	0.6

Company	Project Name	Project Objective	Project Requirement	Project Delivery Date	Project Work Load	Required Designers(quantity)	Required Project Time(day, month, year)
PENTAGRAM Management Companies	Project2	1	4	2	1	3	2 0 0
Required Skill	Required Creativity	Required Availability	Required Occupancy Rate	Required Personal Satisfaction	Required Education	Required Experience	Required Age
CAD-1	1	1	1	1	1	1	1
Weight of skill	Weight of creativity	Weight of availability	Weight of occupancy rate	Weight of personal satisfaction	Weight of education	Weight of experience	Weight of age
0.5	0.3	0.4	0.8	0.9	0.2	0.9	0.6

Company	Project Name	Project Objective	Project Requirement	Project Delivery Date	Project Work Load	Required Designers(quantity)	Required Project Time(day, month, year)
PENTAGRAM Management Companies	Project3	1	3	2	1	3	2 0 0
Required Skill	Required Creativity	Required Availability	Required Occupancy Rate	Required Personal Satisfaction	Required Education	Required Experience	Required Age
JAVA-1	1	1	1	1	1	1	1
Weight of skill	Weight of creativity	Weight of availability	Weight of occupancy rate	Weight of personal satisfaction	Weight of education	Weight of experience	Weight of age
0.2	0.5	0.5	0.4	0.5	0.2	0.5	0.3

Company	Project Name	Project Objective	Project Requirement	Project Delivery Date	Project Work Load	Required Designers(quantity)	Required Project Time(day, month, year)
PENTAGRAM Management Companies	Project4	1	1	1	1	2	1 0 0
Required Skill	Required Creativity	Required Availability	Required Occupancy Rate	Required Personal Satisfaction	Required Education	Required Experience	Required Age
JAVA-1	1	1	1	1	1	1	1
Weight of skill	Weight of creativity	Weight of availability	Weight of occupancy rate	Weight of personal satisfaction	Weight of education	Weight of experience	Weight of age
1.0	0.9	0.4	0.6	0.5	0.1	0.5	0.4

Figure 5.4 – Information for 4 design projects

In the Figure 5.4, we can find that there are four project input web pages with the different project information. Project manager can input or modify the project information through the different pages. Meanwhile, the level of project constraints (Project Objective, Project Requirement, Project Delivery Date and Project Work Load) in Figure 5.4 can be defined through the Table 2.2. Apart from that, the weight of the horizontal properties (weight of skill, weight of creativity, weight of availability, weight of occupancy rate, weight of personal satisfaction, weight of education, weight of experience and weight of age) will be defined through the AHP method (pairwise comparison method).

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After that we have to input the information for the 10 candidate designers. To input the designer information, we have to click the button “CandidateActors” in Figure 5.1 and it will display the designer information input page. The input web page for the candidate designer can be seen in Figure 5.5.

The screenshot shows a web browser window with the following content:

Navigation: Project | **CandidateActors** | ResourceAllocation | ProjectSelection | RiskManagement

Section: Insert New Designer

Name	<input type="text"/>	Age	<input type="text"/>
Date Of Birth	Day: 1 ▾	Month: 1 ▾	Year: 1940 ▾
Email	<input type="text"/>	Telephone	<input type="text"/>
Gender	Male: <input type="radio"/>	Female: <input type="radio"/>	
Skill Name	<input type="text"/>	Company	PENTAGRAM Management Companies ▾
Skill Level(H)	1 ▾	Creativity Level(H)	1 ▾
Availability Level(H)	1 ▾	Occupancy Rate Level(H)	1 ▾
Personal satisfaction Level(H)	1 ▾	Education Level(H)	1 ▾
Experience Level(H)	1 ▾	Age Level(H)	1 ▾
Conscientiousness Level(P)	1 ▾	Neuroticism Level(P)	1 ▾
Openness Level(P)	1 ▾	Agreeableness Level(P)	1 ▾
Extraversion Level(P)	1 ▾	Designer Available Time(day,month,year)	0 0 0

Candidate Designer List:

Designer ID	Designer Name		
2	Designer 1	modify	delete
3	Designer 2	modify	delete
4	Designer 3	modify	delete
21	Designer 4	modify	delete
27	Designer 5	modify	delete

Input Group's ability to work together parameters

Input Number of Years	Input Number of Projects	Input Satisfaction relationship
Input	Input	Input

Input risk evaluation parameters

Input risk existing designers	Input levels of errors in designer	Input severity, detection and occurrence criteria for designer	Input direct influence parameters between designers
Input	Input	Input	Input

Figure 5.5 – designer information input page

In the Figure 5.5, the web page is to let the designer to input the personal information, such as name, age, date of birth, email, telephone, gender and so on. Apart from that, the designer has to input the level of the horizontal properties (skill, availability, personal satisfaction, experience, creativity, occupancy rate, education and age) depending on the Grade level description for different horizontal properties in Table 2.3. Additionally, designer has to fill out the NEO-PI-R personality analysis questionnaires. After that, designer can input the level of the different personality factors in the designer information input page (Figure 5.5) through the NEO-PI-R personality analysis result and Big-Five personality criteria rank for design project in Table 2.8.

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The information for all the 10 candidate designers can be seen as Figure 5.6.

Name	Age	Gender	Email	Telephone	SN	AT	Company	SL (H)	CL (H)	AL (H)	ORL (H)	PSL (H)	EL (H)	EXL (H)	AGL (H)	COL (P)	NL (P)	OL (P)	AGRL (P)	EL (P)
Designer 1	32	male	jinub@foxmail.com	0654784755	CAD-2	100	META DESIGN	4	4	5	4	3	4	4	5	5	1	4	4	5
Designer 2	25	male	jin@foxmail.com	0654784754	CAD-2	100	LANDOR	5	5	5	4	5	5	5	4	5	4	5	4	4
Designer 3	31	male	jin@foxmail.com	0654784754	CAD-3	100	LANDOR	5	4	3	3	2	4	5	3	4	3	5	4	5
Designer 4	45	male	jin@foxmail.com	0654784754	CAD-4	100	LANDOR	5	1	5	5	5	5	4	4	5	5	3	4	3
Designer 5	23	male	jin@foxmail.com	0654784754	CAD-2	100	LANDOR	2	3	2	5	5	5	4	3	4	4	5	5	4
Designer 6	33	male	acdtr@gmail.com	0654841541	CAD-1	100	PENTAGRAM	5	5	4	3	5	5	3	4	4	3	5	4	4
Designer 7	35	male	ksd@163.com	0654841545	CAD-5	200	PENTAGRAM	5	1	5	4	5	1	5	5	5	1	4	5	4
Designer 8	19	female	al23dasd@qq.com	0658480510	CAD-5	200	PENTAGRAM	1	2	5	5	5	5	5	2	5	3	5	4	5
Designer 9	20	female	asbasdf@gmail.com	0654182154	InVision-3	90	PENTAGRAM	5	5	1	5	5	4	1	4	3	4	2	5	5
Designer 10	48	male	qwe@foxmail.com	00864851548151	JAVA-1	50	PENTAGRAM	1	1	5	5	1	1	4	5	4	1	1	3	5

Note. SN=Skill Name. AT=Available Time. H=Horizontal Properties. SL=Skill Level. CL=Creativity Level. AL=Availability Level. ORL=Occupancy Rate Level. PSL=Personal Satisfaction Level. EL=Education Level. EXL=Experience Level. AGL=Age Level. P=Personality Factors. COL=Conscientiousness Level. NL=Neuroticism Level. OL=Openness Level. AGRL=Agreeableness Level. EL=Extraversion Level.

Figure 5.6 - Information for 10 candidate designers.

After we get the information for candidate projects and candidate designers, we can simulate and verify the human resource allocation and projects selection method.

5.2 Human resource allocation method simulation and verification

5.2.1 Identify the priority of the project simulation and verification

Before we allocate 10 candidate designers to the different projects, we have to identify the priority of the project. We have to find which project will be the most urgency project, and allocate the designers to the most urgency project first. Depending on the level of project constraints in Figure 5.4, and click the button “Show Project Urgency Levels” in the web page of “Project” (Figure 5.1), we can get the project urgency level for the 4 design projects like Figure 5.7.

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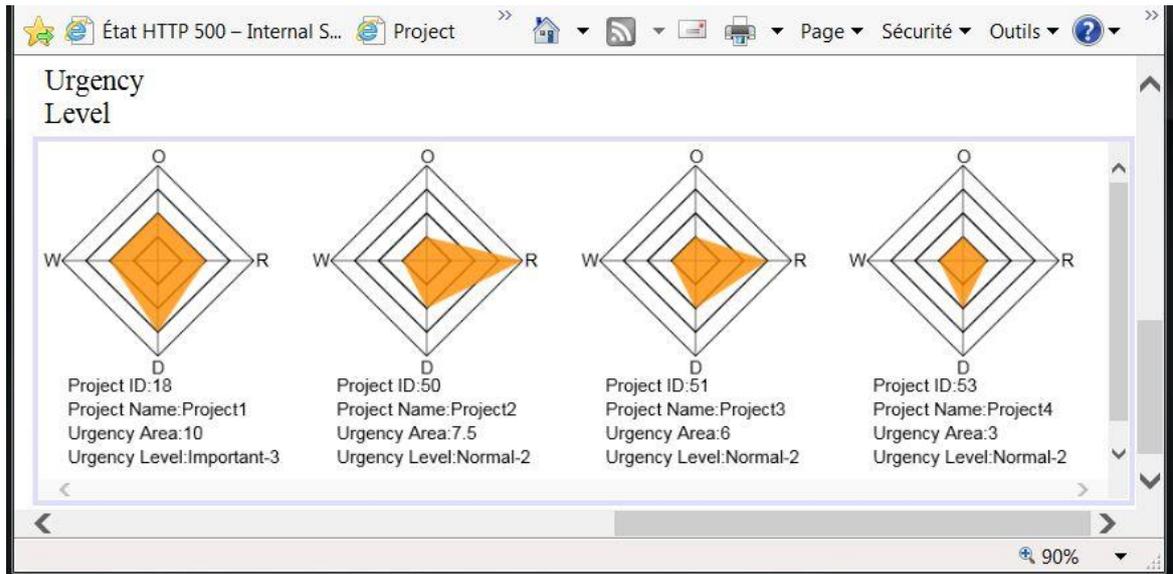


Figure 5.7– Urgency level for the 4 design projects

In the Figure 5.7, depending on the different urgency levels for project in Figure 2.3 and the project urgency level description in Table 2.2, the urgency level for Project1 (Area is 10) (Important-3) is higher than other three projects (urgency area for Project2 is 7.5, urgency area for Project3 is 6 and urgency area for Project4 is 3). It means that project manager should first select required designers for Project1.

After that we have to find the designers who must be satisfied with mandatory requirement of the Project1, such as the project required skill requirement (required skill in Figure 5.4) and the time requirement (required designer time in Figure 5.4). Because of the reason that the skill requirement for the Project1 is “CAD-1”, candidate designers who cannot be satisfied with this requirement should be filtered. In the Figure 5.6, we can find that the Designer9 (Invision-3) and Designer10 (Java-1) cannot be satisfied with this requirement. Therefore, we have to filter these two candidate designers.

5.2.2 Horizontal and communication and collaboration relationship simulation and verification

After we find the designers which satisfied with mandatory requirement of the project, we can go to the step to select horizontal ability acceptable designers. Meanwhile, we can also analysis the communication and collaboration ability for different

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combination of the designers. Firstly, designers have to accept the project mandatory horizontal property requirement. After that we can analyze and select the horizontal ability acceptable designers. In here, to get the horizontal ability of the designer, we have to understand the required maximum horizontal ability for the Project1. Therefore, in there, we can firstly tap the button “ResourceAllocation” in Figure 5.1 and we can get the web page like Figure 5.8.

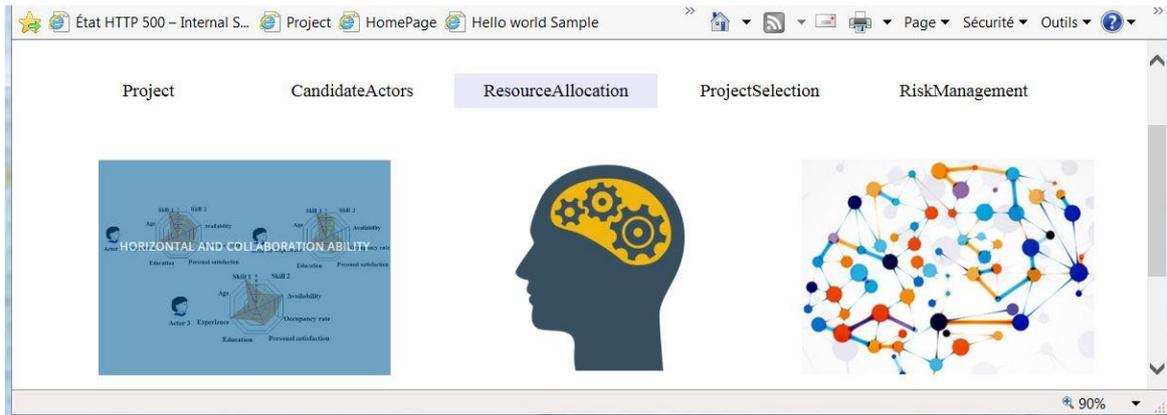


Figure 5.8 - Human resource allocation webpage

In the Figure 5.8 we can tap the left part (HORIZONTAL AND COLLABORATION ABILITY) to go to the horizontal and collaboration ability analysis page (Figure 5.9).

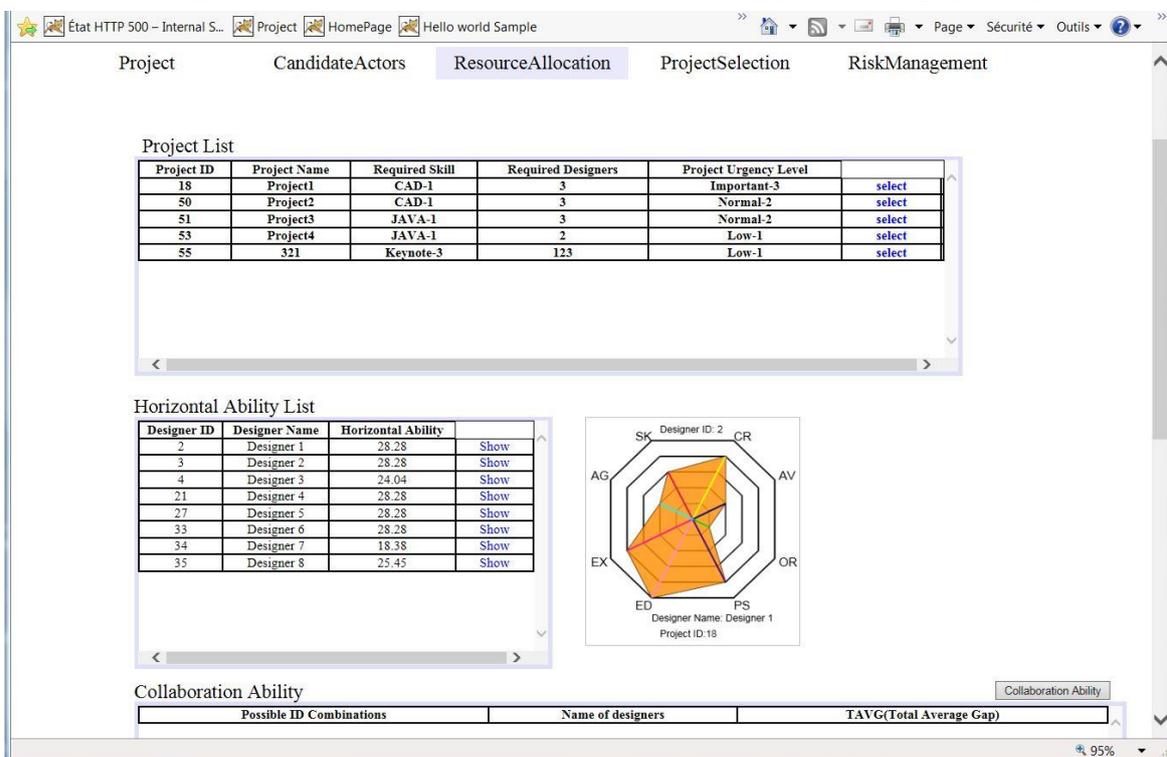
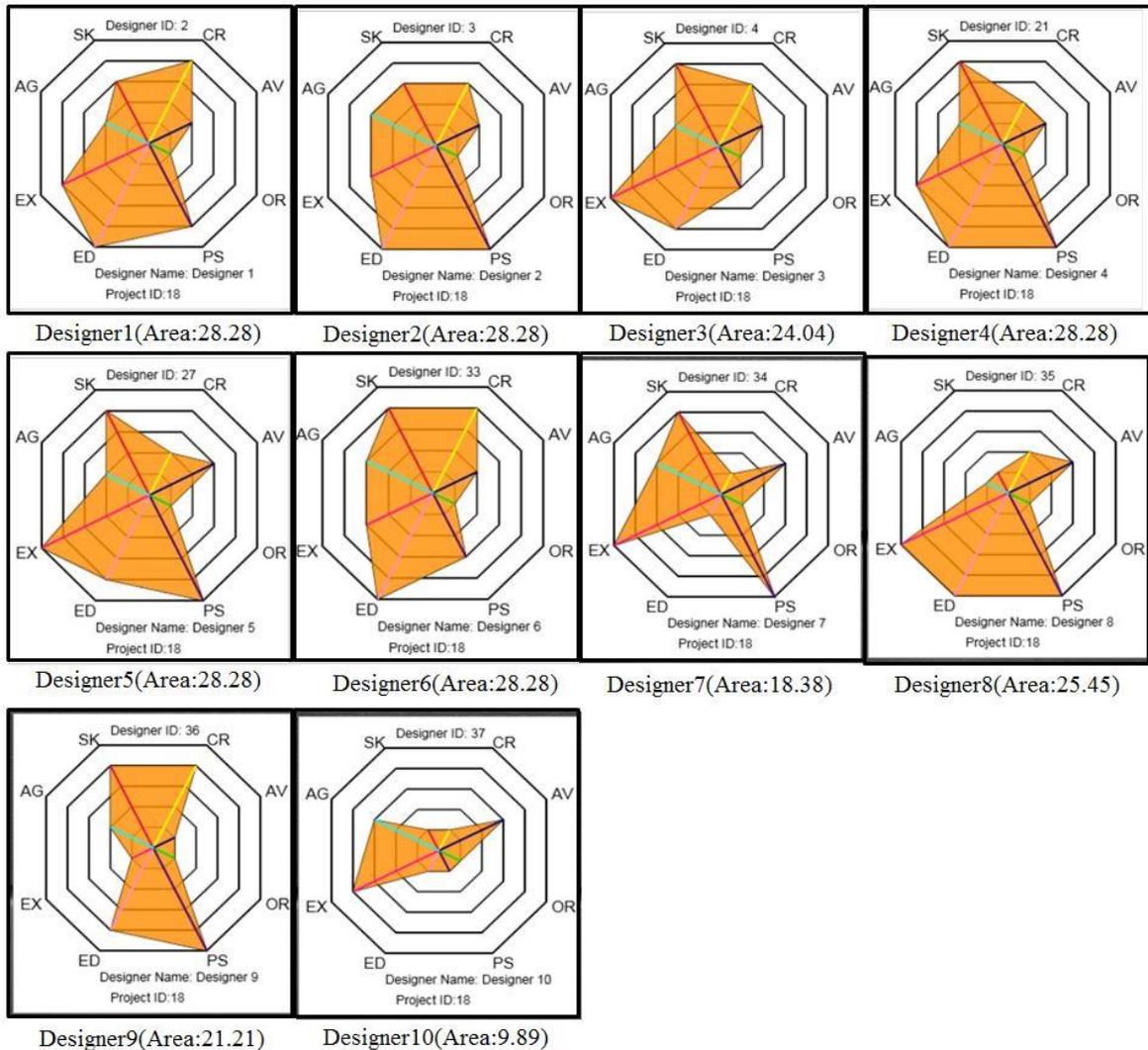


Figure 5.9 - Horizontal and collaboration ability analyze page

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Depending on the level of horizontal properties for 10 candidate designers in Figure 5.6 and weight of horizontal properties for the project1 in Figure 5.4, we can get the horizontal ability for 10 candidate designers (Figure 5.10).



Note. SK = Skill. CR=Creativity. AV=Availability. OR=Occupancy Rate. PS=Personal Satisfaction.

ED=Education. EX=Experience. AG=Age.

Figure 5.10 - Horizontal Ability for 10 candidate designers (Project1)

In the Figure 5.10, we can find different horizontal abilities for all the 10 candidate designers. Because of the mandatory skill requirement of Project1, we will directly filter the Designer9 and Designer10. Hence, the remaining 8 designers (Figure 5.11) can satisfy not only skill requirement but also horizontal ability requirement for Project1. To get the horizontal ability result of the remaining 8 designers for Project1,

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we have to tap the green button “select” for Project1 in Figure 5.9. After that in the “Acceptable Horizontal Ability List” Table in Figure 5.9, it will show the horizontal ability result for the remaining 8 designers (Figure 5.11). Meanwhile, we can tap the green button “select” in Figure 5.9 to show the corresponding horizontal ability figure for the 8 candidate designers in the right box.

Designer Name	Horizontal Ability
Designer 1	28.28
Designer 2	28.28
Designer 3	24.04
Designer 4	28.28
Designer 5	28.28
Designer 6	28.28
Designer 7	18.38
Designer 8	25.45

Figure 5.11 - Acceptable Horizontal Ability Designer List

Because Project1 requires 3 designers, there are totally 56 designer combination types. In these combination types, we must find the highest total horizontal ability designer combination types. In here, the total horizontal ability is the sum of the horizontal ability for the 3 designers. After the calculation, there are 10 combination types have the highest value of total horizontal ability (84.84). Therefore, to identify these types, we can analyze the collaboration and communication ability. Depending on the Equation (2.1) and Equation (2.2), we can calculate TAVG (Total Average Gap) of the Group Interactions and Personal Relationships for the 10 combination types. To get the TAVG value for top 10 combination types, we can tap the button “Collaboration Ability” in Figure 5.9. The TAVG value for the 10 combination types can be seen as Figure 5.12.

Name of designers	TAVG(Total Average Gap)
Designer1 Designer2 Designer4	4.00
Designer1 Designer2 Designer5	6.00
Designer1 Designer2 Designer6	4.00
Designer1 Designer4 Designer5	4.67
Designer1 Designer4 Designer6	4.67
Designer1 Designer5 Designer6	6.67
Designer2 Designer4 Designer5	4.67
Designer2 Designer4 Designer6	4.67
Designer2 Designer5 Designer6	6.67
Designer4 Designer5 Designer6	6.00

Figure 5.12 - The TAVG value for top 10 designer combination types

From the Figure 5.12, we can find that the TAVG value for the combination type Designer1, Designer2 and Designer4, and the type Designer1, Designer2 and

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Designer4 have the smallest value (4.00). Therefore, compare with other combination types, these two combinations have the highest efficiency of collaboration and communication.

5.2.3 Personality analysis simulation and verification

In the personality analysis process, the project manager should let all these 10 candidate designers to fill out the NEO-PI-3 personality inventory questionnaire test. The questionnaire is the self-report form with items answered on a 5-point Likert scale from “strongly disagree” to “strongly agree”. The result score of questionnaire (due to the space limitations, we only display the 8 items for the facet “N1 worry” in the factor Neuroticism) for the candidate Designer1 can be seen as the Table 5.1.

Table 5.1– NEO-PI-3 personality test result for candidate Designer1

Personality traits	Items	Score
Neuroticism		131
N1 Worry	I am not a worrier.	5
	I am easily frightened	4
	I rarely feel fearful or anxious	1
	I often feel tense and jittery	5
	I’m seldom apprehensive about the future	5
	I often worry about things that might go wrong.	2
	I have fewer fears than most people	2
	Frightening thoughts sometimes come into my head	3
N2: Anger	-	20
N3: Discouragement	-	10
N4: Self-consciousness	-	32
N5: Impulsivity	-	22
N6: Vulnerability	-	20
Extraversion	-	142
Openness	-	118
Agreeableness	-	124
Conscientiousness	-	156

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From the Table 5.1, we can find that the raw score of N1 Worry is 27 (5+4+1+5+5+2+2+3), which is the sum of the 8 items' score. Apart from that, the raw score of the factor Neuroticism is 131 (27+20+10+32+22+20), which is the sum of 6 facets' (N1, N2, N3, N4, N5, N6) raw score. After that, we can use the same way to get the raw score of other personality factors (Extraversion: 142, Openness: 118, Agreeableness: 124, Conscientiousness: 156).

From then on, depending on the Equation (2.3), we can convert raw score to the T-score. In the Equation (2.3), the raw score the mean value of the normative sample (MEAN) and the Standard Deviation of the normative sample (SD) will be defined by the professional personality analysis manual, such as the manual for the NEO-PI-3(Costa and McCrae), which collected normative sample of general population. Such as, in this example, the value of SD and MEAN for the Designer1, we can use the standardization of the NEO-PI-3 in the Greek general population (Fountoulakis et al. (2014)) to define these two values. The SD and MEAN value for five personality factors in Greek general population and the converted T-score result for the candidate Designer1 can be seen as Table 5.2.

Table 5.2– SD and MEAN value for five personality factors in Greek general population and the converted T-score for the candidate Designer1.

Personality factors	MEAN	SD	Raw-Score	T-Score
Neuroticism	89.06	19.59	131	71.41
Extraversion	108.68	15.97	142	70.86
Openness	104.83	16.31	118	58.07
Agreeableness	116.37	15.82	124	54.82
Conscientiousness	121.60	19.22	156	67.90

Note. MEAN = Mean value of the normative sample. SD = Standard Deviation of the normative sample

From the Table 5.2, we can get all the T-scores for the candidate Designer1. For example, depending on the Equation (2.3), the T-Score value of Neuroticism is 71.41 ($50 + 10 \frac{131-89.06}{19.59}$). Then, we can use the same process to get the T-scores for other candidates.

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Afterwards, we can use the result of T-scores, Table 2.6 and Table 2.8 to rank the level of the 5 personality traits for every candidate designer, and multiply the weight (round the multiplied result value to the nearest whole number) in Table 2.9 to get the final weighted personality criteria rank. The weighted criteria rank for the candidate Designer1 can be seen as Table 5.3.

Table 5.3– Weighted criteria rank for the candidate Designer1

Personality factors	T-score	Rank	weight	Weighted rank
Neuroticism	71.41	1	1	1
Extraversion	70.86	5	0.608	3
Openness	58.07	4	0.226	1
Agreeableness	54.82	4	0.68	3
Conscientiousness	67.90	5	0.406	2

In the Table 5.3, for example, the T-score for the Neuroticism (71.41) belong to the T-score range “score \geq 65” and the corresponding rank is “Very High” in Table 2.6. After that, depending on the Table 2.6, the rank value for “Very High” in personality Neuroticism is 1. Therefore, the weighted rank for the personality Neuroticism is 1 (round the value 1×1 to the nearest whole number). Meanwhile, we can also calculate the weighted rank for all the other candidate designers.

After that, we can define the design project personality ability for all the 8 candidate designers (because of the mandatory skill requirement of the Project1, Designer9 and Designer10 should be directly filtered). To get the 8 acceptable personality ability designers for Project1, we have to tap the middle part in Figure 5.8 (Personality Ability), and we can get the personality ability analysis page (Figure 5.13).

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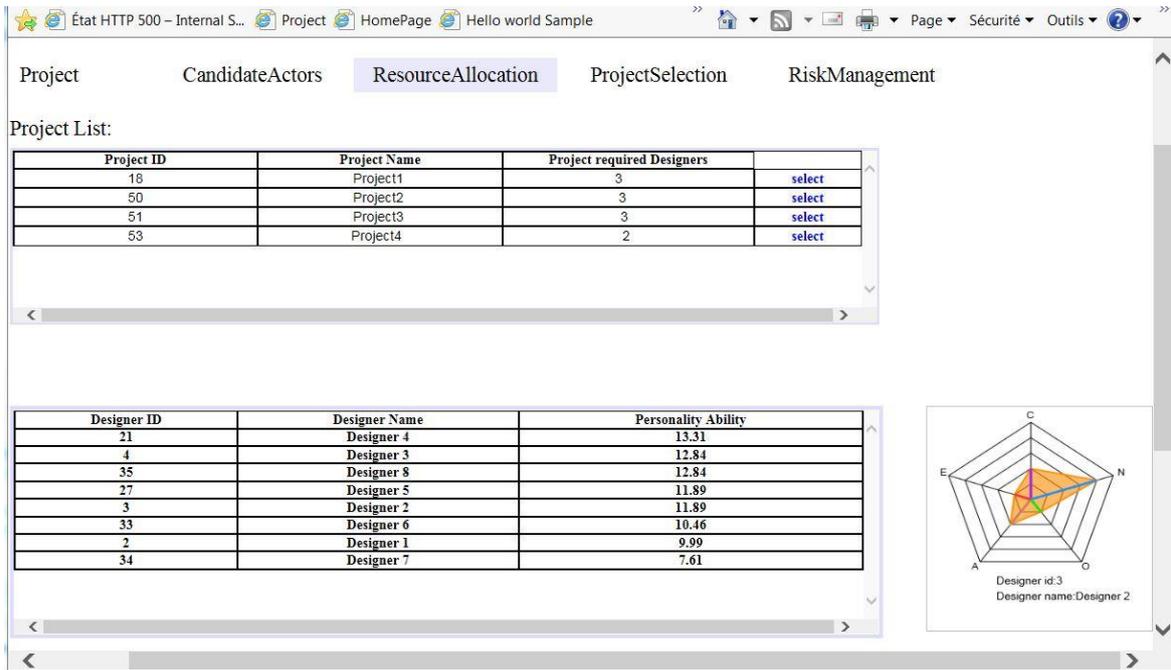
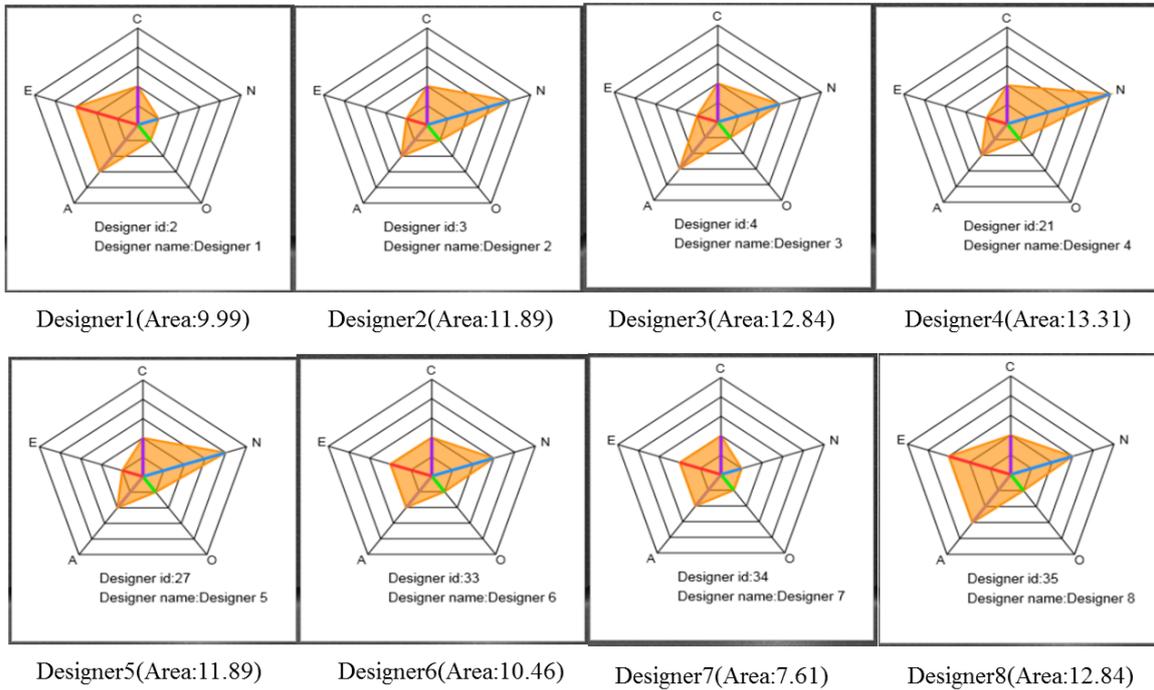


Figure 5.13 - Personality ability analysis webpage

In the Figure 5.13 we can tap the green word “select” in the table first line for Project1 to get the acceptable personality ability candidate designers (Personality Ability Acceptable Designer List in Figure 5.13). Meanwhile, in the Figure 5.13 we can also tap the green value in the Personality Ability Acceptable Designer List table, and the corresponding personality ability figure will show in right box. The acceptable personality ability designers for Project1 can be seen in Figure 5.14.

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Note. C=Conscientiousness. N=Neuroticism. O=Openness. A=Agreeableness. E=Extraversion.

Figure 5.14 – Design project personality ability for 8 candidate designers

In Figure 5.14, we can find the weighted Big-Five personality criteria rank for 8 candidate designers, and the area besides the name of the designer means the design project personality ability area for the designer, which is directly calculated by the area of orange part. Such as the Designer1 has weighted personality Conscientiousness 2, Neuroticism 1, Openness to experience 1, Agreeableness 3, and Extraversion 3, and the design project personality ability area for the Designer1 is 9.99. After we order the personality ability area from big to small, we can get the personality result like Figure 5.15 (Personality Ability Acceptable Designer List table in Figure 5.13).

Designer Name	Personality Ability
Designer 4	13.31
Designer 3	12.84
Designer 8	12.84
Designer 5	11.89
Designer 2	11.89
Designer 6	10.46
Designer 1	9.99
Designer 7	7.61

Figure 5.15 - Ordered personality ability for 8 candidate designers

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In the Figure 5.15, Designer 4 contains the highest personality area (13.31). Because there only need 3 designers for Project1, there will be totally 56 designer combination groups. The GPA (Group Personality Ability) value for top 10 combination types can be seen as Figure 5.16 (the result will show in the bottom part of the webpage in Figure 5.13).

Designer Name Combination	Group Personality Ability
Designer 4 Designer 3 Designer 8	38.99
Designer 4 Designer 3 Designer 5	38.04
Designer 4 Designer 3 Designer 2	38.04
Designer 4 Designer 8 Designer 5	38.04
Designer 4 Designer 8 Designer 2	38.04
Designer 3 Designer 8 Designer 5	37.57
Designer 3 Designer 8 Designer 2	37.57
Designer 4 Designer 5 Designer 2	37.09
Designer 3 Designer 5 Designer 2	36.62
Designer 8 Designer 5 Designer 2	36.62

Figure 5.16 - The GPA (Group Personality Ability) value for top 10 designer combination types

From the Figure 5.16, we can find that the GPA value for the combination type Designer4, Designer3 and Designer8 is the largest ($13.31+12.84+12.84=38.99$). Therefore, compare with other combination types, this combination has the highest personality ability. Hence, project manager can allocate designer4, designer3 and designer8 to the Project1.

5.2.4 Group's ability to work together simulation and verification

For the Group's Ability to Work Together, because of the reason that Project1 only need 3 designers and the mandatory skill and time requirement of the project, there will be 56 combination groups for 8 candidate designers (Designer1, Designer2, Designer3, Designer4, Designer5, Designer6, Designer7 and Designer8). To calculate the (GAWT) Group's Ability to Work Together for different combination of actors, we should understand the working together experience among them. In the first of all, we have to input the parameters of years of experience, projects of experience and satisfaction relationship among them. To input these parameters, we

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can tap the button “CandidateActors” in Figure 5.1, and we can get the table “Input Group’s Ability to Work Together” table like Figure 5.17.

Input Group's ability to work together parameters

Input Number of Years	Input Number of Projects	Input Satisfaction relationship
Input	Input	Input

Figure 5.17 - Input group’s ability to work together parameters in Figure 5.5

In Figure 5.17, we can tap the green word “Input” to input the corresponding group’s ability to work together parameters. The input parameters of years of experience, projects of experience and satisfaction relationship among them can be shown in the Figure 5.18 through Figure 5.20.

Designer Name	Designer 1	Designer 2	Designer 3	Designer 4	Designer 5	Designer 6	Designer 7	Designer 8
Designer 1	0	1	2	3	4	3	2	1
Designer 2	1	0	1	2	3	2	1	4
Designer 3	2	1	0	1	2	2	2	1
Designer 4	3	2	1	0	1	1	4	2
Designer 5	4	3	2	1	0	2	2	2
Designer 6	3	2	2	1	2	0	1	2
Designer 7	2	1	2	4	2	1	0	2
Designer 8	1	4	1	2	2	2	2	0

Figure 5.18 - Number of years working together experience

Designer Name	Designer 1	Designer 2	Designer 3	Designer 4	Designer 5	Designer 6	Designer 7	Designer 8
Designer 1	0	1	2	3	4	2	2	2
Designer 2	1	0	1	2	3	3	4	2
Designer 3	2	1	0	1	2	2	2	2
Designer 4	3	2	1	0	1	1	1	1
Designer 5	4	3	2	1	0	2	1	4
Designer 6	2	3	2	1	2	0	1	2
Designer 7	2	4	2	1	1	1	0	2
Designer 8	2	2	2	1	4	2	2	0

Figure 5.19 - Number of projects working together experience

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Designer ID	Designer Name	Designer 1	Designer 2	Designer 3	Designer 4	Designer 5	Designer 6	Designer 7	Designer 8
2	Designer 1	0	1	2	3	4	1	1	1
3	Designer 2	1	0	1	2	2	2	2	2
4	Designer 3	1	1	0	2	2	3	3	1
21	Designer 4	3	1	2	0	2	0	3	2
27	Designer 5	2	1	2	4	0	1	2	3
33	Designer 6	2	1	2	2	2	0	2	4
34	Designer 7	1	3	1	3	1	2	0	2
35	Designer 8	1	2	2	1	4	1	2	0

Note. The value is from column to row.

Figure 5.20 - Work together experience satisfaction relationship

After that, through the Figure 5.18, Figure 5.19, Figure 5.20, Equation (2.4) and Equation (2.5), we can calculate the GAWT value for all 56 combination candidate groups. To get the result of GAWT, we can tap the right part (Group’s Ability to Work Together) in Figure 5.8, and we can get the group’s ability to work together analysis webpage (Figure 5.21).

Project List:

Project ID	Project Name	Project required Designers	
18	Project1	3	select
50	Project2	3	select
51	Project3	3	select
53	Project4	2	select
55	321	123	select

Group Experience Working Together Ability List for Project1 :

Possible ID Combinations	Group	GAWT(Group's Ability to Work Together)
2 21 27	Designer 1 Designer 4 Designer 5	26.00
2 27 35	Designer 1 Designer 5 Designer 8	26.00
2 27 33	Designer 1 Designer 5 Designer 6	21.00
2 3 27	Designer 1 Designer 2 Designer 5	20.83
2 4 27	Designer 1 Designer 3 Designer 5	20.67
3 27 35	Designer 2 Designer 5 Designer 8	19.17
2 27 34	Designer 1 Designer 5 Designer 7	18.33
27 33 35	Designer 5 Designer 6 Designer 8	14.67
2 21 34	Designer 1 Designer 4 Designer 7	14.33
4 27 35	Designer 3 Designer 5 Designer 8	13.00
27 34 35	Designer 5 Designer 7 Designer 8	13.00
2 21 33	Designer 1 Designer 4 Designer 6	12.33
2 4 21	Designer 1 Designer 3 Designer 4	11.67

Figure 5.21 - Group’s ability to work together Analysis Webpage

In Figure 5.21, we can tap green button “select” for the Project1 to get the GAWT List for Project1. The top 10 GAWT values for 56 combinations can be shown in Figure 5.22.

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Group	GAWT(Group's Ability to Work Together)
Designer 1 Designer 4 Designer 5	26.00
Designer 1 Designer 5 Designer 8	26.00
Designer 1 Designer 5 Designer 6	21.00
Designer 1 Designer 2 Designer 5	20.83
Designer 1 Designer 3 Designer 5	20.67
Designer 2 Designer 5 Designer 8	19.17
Designer 1 Designer 5 Designer 7	18.33
Designer 5 Designer 6 Designer 8	14.67
Designer 1 Designer 4 Designer 7	14.33
Designer 3 Designer 5 Designer 8	13.00

Figure 5.22 - Top 10 GAWT values for 56 group combination types

In the Figure 5.22, for example, the group Designer1, Designer5 and Designer8, the

GAWT value is 26.00 $\left(\frac{\binom{4+2}{2} \times 4 \times 4 + \binom{3+4}{2} \times 2 \times 4 + \binom{1+1}{2} \times 1 \times 2}{(3-1) + (3-2) + (3-3)} \right)$. Apart from that, in the Figure

5.22, we can find the first group (Designer1, Designer4 and Designer5) and second group (Designer1, Designer5 and Designer8) have the highest value (26.00) for GAWT. Thus, project manager should select one of these two groups to the Project1.

For the selection, because there is same highest value of GAWT between these two groups, we should calculate the group (APWG) Ability of a Person Work in a Group to identify the highest same value of different combination of designers. Depending on the Figure 5.18, Figure 5.19, Figure 5.20, Equation (2.6), we can calculate the APWG for all the 8 candidate designers. The APWG result can be seen as Table 5.4.

Table 5.4– APWG result for 8 candidate designers

Designer	APWG
Designer1	82
Designer2	49
Designer3	35
Designer4	57
Designer5	134
Designer6	40
Designer7	50
Designer8	72

From the Table 5.4, we understand the APWG value for all the 8 candidate designers, such as the APWG value for Designer1 is: $(1 \times 1 \times 1 + 2 \times 2 \times 1 + 3 \times 3 \times 3 + 4 \times$

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$4 \times 2 + 3 \times 2 \times 2 + 2 \times 2 \times 1 + 1 \times 2 \times 1) = 82$. In the Table 5.4, we can find that the Designer5 has the highest ability of a person work in a group (134) while the Designer3 has the smallest ability (35). Therefore, depending on the Table 5.4, we can use the group total APWG to identify the same highest value of GAWT groups in Figure 5.22. The result of group total APWG for the highest GAWT group in Figure 5.22 can be shown in Figure 5.23 (the result will show in bottom part of Figure 5.21).

Name of Designers	Total APWG(Ability of a Person to Work in a Group)
Designer 1 Designer 4 Designer 5	273.00
Designer 1 Designer 5 Designer 8	288.00

Figure 5.23 - Total APWG value for highest same GAWT value combination group in Figure 5.22

From the Figure 5.23, we can find that the group Designer1, Designer5 and Designer8 has the highest total APWG value 288 (82+134+72).

5.2.5 Define the total normalized value

After we get the TAVG, GPA and GAWT for three abilities, to get the final NTN (Normalized Total Number), we have to firstly normalize these results depending on the Equation (2.9), and get the NTAVG, NGPA, and NGAWT values. After that depending on the Equation (2.10), we can get NTN result. In here, we can tap the button “Final Allocation”, and we can get the three parameters value input and final allocation result webpage (Figure 5.24).

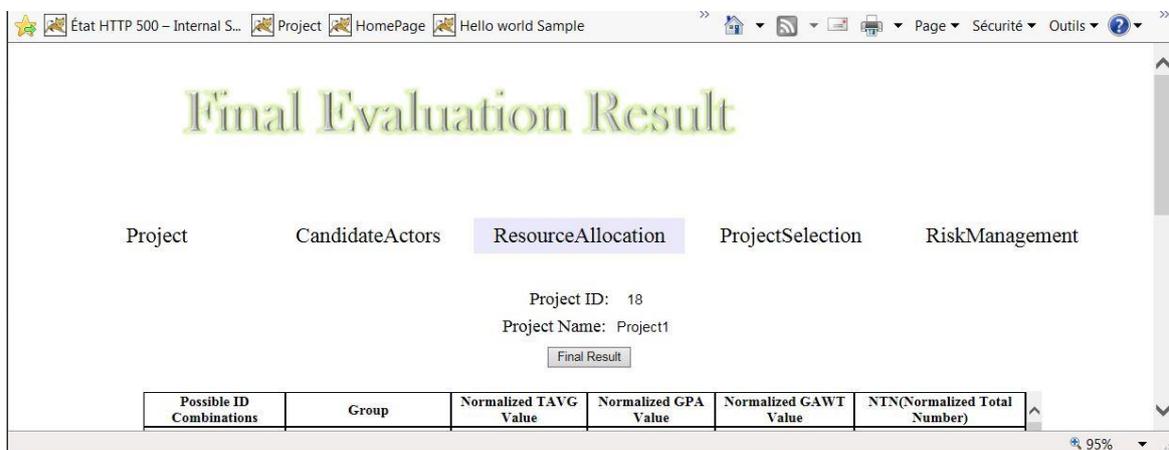


Figure 5.24 - Human resource final allocation result webpage

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In Figure 5.24, we can tap the button “Final Result”, and we can get the result of NTN. The top 10 result of NTN can be seen as Figure 5.25.

Group	Normalized TAVG Value	Normalized GPA Value	Normalized GAWT Value	NTN(Normalized Total Number)
Designer 1 Designer 4 Designer 5	0.3	0.652	1.0	1.952
Designer 1 Designer 2 Designer 4	0.4	0.652	0.371	1.424
Designer 1 Designer 2 Designer 5	0.1	0.522	0.778	1.401
Designer 2 Designer 4 Designer 5	0.3	0.826	0.207	1.333
Designer 1 Designer 4 Designer 6	0.3	0.522	0.414	1.236
Designer 2 Designer 4 Designer 6	0.3	0.695	0.114	1.109
Designer 1 Designer 2 Designer 6	0.4	0.392	0.157	0.948
Designer 4 Designer 5 Designer 6	0.1	0.695	0.028	0.824

Figure 5.25 - Normalized Total Number for final evaluation and allocation

From the Figure 5.25 we can find that the group Designer1, Designer4 and Designer5 get highest NTN value of 1.952. Therefore, project manager can allocate Designer1, Designer4 and Designer5 to the Project1 when all of TAVG, GPA and GAWT are considered. Therefore, project manager can use NTN (Normalized Total Number) value to define the final allocation.

5.3 Project Selection method simulation and verification

To test the project selection method, we have to randomly define the several designers and select the multi-projects in 4 candidate projects (Project1, Project2, Project3, Project4) to them. Therefore, in here, we define Designer1, Designer2, Designer3, Designer4 and Designer5 and select multi-projects to these 5 designers (to go to the webpage of project selection process, we have to tap the “ProjectSelection” button in Figure 5.5, and then the candidate projects and designers will display like Figure 5.26).

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The candidate Projects:

Project ID	Project Name	Input Designer Satisfaction Factors	
18	Project1	input	select
50	Project2	input	select
51	Project3	input	select
53	Project4	input	select

The tested candidate Projects:

Project ID	Project Name	
18	Project1	delete
50	Project2	delete
51	project3	delete
53	Project4	delete

The candidate Designers:

Designer ID	Designer Name	Input Designer Satisfaction Weight and Rank for design project	
2	Designer 1	input	select
3	Designer 2	input	select
4	Designer 3	input	select
21	Designer 4	input	select

The tested candidate Designers:

Designer ID	Designer Name	
2	Designer 1	delete
3	Designer 2	delete
4	Designer 3	delete
21	Designer 4	delete
27	Designer 5	delete

Input Individual Perception of Strength Relationship:

Individual Perception of Strength Relationship(ST)
input

Project Selection Analysis Result:

Result Analysis
Select

Figure 5.26 4 candidate design projects and 5 candidate designers

In the first step of the selection, the constraints of minimum skill requirement and occupation time for selected candidate projects must be satisfied by the owned skill and available time of the 5 designers. Therefore, after the first step of selection, Project3 and Project4 should be directly filtered (the skill requirement (Java) for the Project3 and Project4 is unacceptable for owned skill (CAD) of all the 5 designers). Therefore, in this step, the Project1 and Project2 can be selected, and there will be totally 243 ($3 \times 3 \times 3 \times 3 \times 3$) different multi-project combination types for the 5 designers. Meanwhile, because Project1 only needs 3 designers, some of the combination types which can not be satisfied with this requirement should be filtered. After the filtering, 50 multi-project combination types will be selected.

5.3.1 Calculate the multi-projects satisfaction level of designer for different combination of projects simulation and verification

After that, we can analyze the designers' satisfaction level to these design projects. The weight and value of the satisfaction factors in Table (3.2) will be provided by the designer himself. The designer who will select a project can define the weight for every

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satisfaction main factor and sub-factor in Table (3.2). After that, designer can evaluate the rank for all the satisfaction factors in Table (3.2). Then, we can use Equation (3.1) through Equation (3.9) to calculate the Average Weighted Total Satisfaction Level (AWTSL) value. To input the evaluation of satisfaction factors, designer has to tap the “input” button in the “The Candidate Designers” table in Figure 5.26. After that, the example of evaluation of satisfaction factors (Project 1) for the Designer1 can be displayed as Figure 5.27.

Project Name	Satisfaction Factor Name	Satisfaction Factor Weight	Satisfaction Sub-Factor ID	Satisfaction Sub-Factor Name	Satisfaction Sub-Factor Weight	Satisfaction Sub-Factor ID	Satisfaction Sub-Factor Name	Satisfaction Sub-Factor Weight	Satisfaction Sub-Factor Rank			
Project1	Hygiene Factors	0.3	1.1	Design project policies	0.2	1	Fixed work schedule would be Monday-Friday from 8:30 AM to 5:00 PM. Break for Statutory holiday	1.0	1			
			1.2	Supervision	0.3	1	The project manager is very motivated to provide direction and support	1.0	1			
			1.3	Work conditions	0.1	1	Work with all team members all time (100% time) to ensure the quality and clarity of deliverables	0.2	1			
						2	30% time with virtual work environment and 70% time with real work environment	0.3	2			
						3	Adjustable chairs, task lights, sit-to-stand desks and keyboard trays so designers can adjust their workspaces to meet their needs and outdoor areas for short breaks	0.5	1			
			1.4	Salary	0.1	1	400€ of salary, the health insurance, a generous 401 K, the opportunity for a bonus and more	1.0	0			
				1.5	Status	0.1	1	Hired as an assistant designer	1.0	2		
				1.6	Security	0.2	1	Designers will not be fired until the end of the project	1.0	2		
	Motivator Factors	0.7	2.1	Design project its self	0.1	1	Delivering an industry-leading offering and an obsession with customer satisfaction	0.3	1			
						2	3 types of weblogs client software, 2 types of desktop client software, 500 user requirement survey and acceptance testing result and user documentation	0.2	2			
						3	October 2, 2018	0.2	2			
						4	Users can see public blog posts, comment on public blog posts, and subscribe to all blog posts or categories of blog posts using RSS feed readers	0.3	0			
			2.2	Achievement	0.2	1	Because this is a project of a very famous multinational software development company. After the project is completed, the designer will have a high achievement.	1.0	1			
						2.3	Recognition	0.3	1	123123	1.0	2
			2.4	Responsibility	0.1	1	Generate clear ideas, concepts and designs for creative assets from beginning to end. Meanwhile, create wireframes and mockups to effectively communicate interaction and design ideas	1.0	1			
2.5			Growth	0.3	1	Knowledge of and experience in weblogs software development, previous experience iterating on software development, and previous experience working with a distributed team	1.0	2				

Figure 5.27 – Evaluation result of the satisfaction factors in Project1 for Designer1

Depending on the Figure 5.27, and Equation (3.5) through Equation (3.8), The Weighted Total Satisfaction Level (WTSL) for project 1 is 1.88 ($0.3 \times (0.2 \times 1 \times 1 + 0.3 \times 1 \times 1 + 0.1 \times (0.2 \times 1 + 0.3 \times 2 + 0.5 \times 1)) + 0.1 \times 1 \times 0 + 0.1 \times 1 \times 2 + 0.2 \times 1 \times 2) + 0.7 \times (0.1 \times (0.3 \times 1 + 0.2 \times 2 + 0.2 \times 2 + 0.2 \times 2 + 0.3 \times 0) + 0.2 \times 1 \times 1 + 0.3 \times 1 \times 2 + 0.1 \times 1 \times 1 + 0.3 \times 1 \times 2)$). After that we can release the Sum of AWTSL (Average Weighted Total Satisfaction Level) value for all the multi-project combination types. To get the result of AWTSL, we have to tap the button “Select” in the “Project Selection Result Analysis” Table in Figure 5.26. After that, the top 9 sum of AWTSL value for all the multi-project combination types will be shown as Figure 5.28.

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Combination Type	Designer 1 Project Name	Designer 2 Project Name	Designer 3 Project Name	Designer 4 Project Name	Designer 5 Project Name	Sum AWTSL value
Type1	Project2	Project1	Project1	Project1	Project2	6.4
Type2	Project1	Project1	Project1	Project2	Project2	6.4
Type3	Project1	Project2	Project1	Project1	Project2	6.3
Type4	Project2	Project1	Project1	Project2	Project1	6.3
Type5	Project1	Project1	Project2	Project1	Project2	6.3
Type6	Project2	Project2	Project1	Project1	Project1	6.2
Type7	Project2	Project1 Project2	Project1	Project1	Project2	6.2
Type8	Project1	Project2	Project1	Project2	Project1	6.2
Type9	Project1	Project1 Project2	Project1	Project2	Project2	6.2

Figure 5.28 - Top 9 sum of AWTSL value for all the 50 multi-project combination types

From the Figure 5.28, we can find that the 2 multi-project combinations (Type1 and Type2) have the highest sum value of AWTSL (6.4). However the project manager can only position one type of multi-project combination to the 5 designers. Therefore, we have to identify these 2 multi-project combinations through analyzing the collaboration level of 5 designers in these 2 multi-project combinations.

5.3.2 Calculate the collaboration level of designer for different combination of the projects simulation and verification

To calculate the Total Average Weighted Pair Satisfaction Gap (TAWPSG) value, we have to understand which designers have involved in same projects, their weighted satisfactions of the projects (WTSL), the ST between every two collaborated designers. To input the ST between every two collaborated designers, we have tap the button “input” in the table “Input Individual Perception of Strength Relationship” in Figure 5.26. The WTSL value for designers who will be positioned in Type 1 (Type 1 in Figure 5.28) multi-project combinations and the individual perception of strength of relationship (ST) among the 5 designers can be seen as Table 5.5 and Figure 5.29.

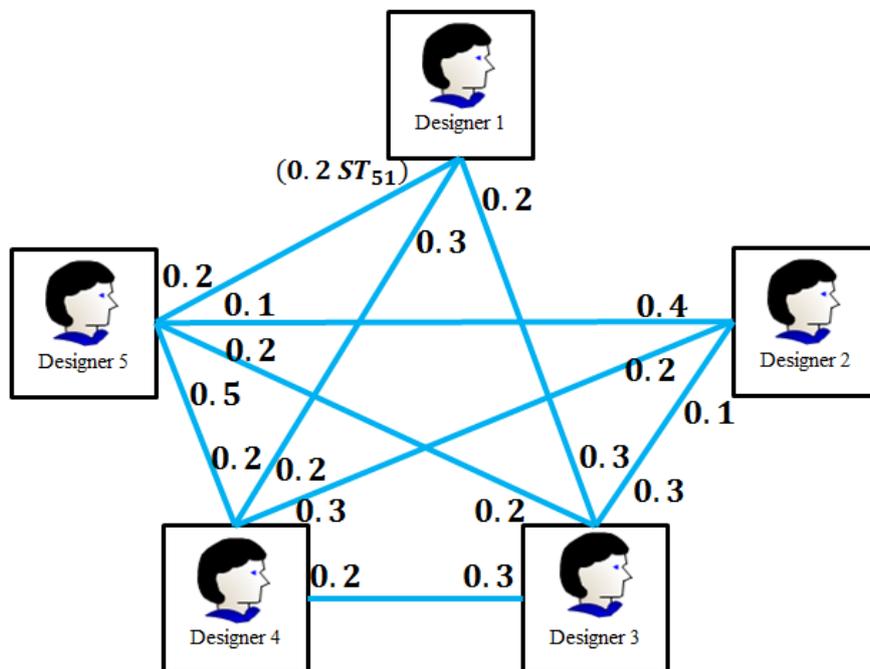
Table 5.5– WTSL value for 5 designers in Type1 (Type1 in Figure 5.28)

Project	Designer	WTSL
Project1	Designer2	1.43
	Designer3	1.47
	Designer4	1.33
Project2	Designer1	1.12
	Designer5	1.02

Note. WTSL = Weighted Total Satisfaction Level.

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Designer Name	Designer 1	Designer 2	Designer 3	Designer 4	Designer 5
Designer 1	0.0	0.4	0.3	0.2	0.2
Designer 2	0.4	0.0	0.3	0.3	0.1
Designer 3	0.2	0.1	0.0	0.2	0.2
Designer 4	0.3	0.2	0.3	0.0	0.5
Designer 5	0.2	0.4	0.2	0.2	0.0



Note. The value in top table is from column to row.

Figure 5.29- Individual perception of strength of relationship (ST) among 5 designers

In the Figure 5.29, there are 9 pairs of designer know each other (blue line), and they can define the different ST value with each other. Even though, the pair of Designer1 and Designer2 do not know each other, we can set the we can set the rank of “Courage” (ST value 0.4) in Table 3.5 between them because of the reason that the “Courage” is the median strength of relationship effectiveness, and for those who the designer does not know, the average value of the strength will be appropriate. Therefore, there will be totally $10 \left(\frac{5 \times (5-1)}{2} \right)$ pairs of social relationship with the different ST values with

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each other. Meanwhile, depending on the Table 5.5, we can calculate the number of the pairs of collaboration for Project1 is $3 \left(\frac{3 \times (3-1)}{2}\right)$, Project2 is $1 \left(\frac{2 \times (2-1)}{2}\right)$. Therefore, through the Table 6.5, Figure 5.29, and equation (3.13) to equation (3.14), we can calculate the AWPSG value for Project1 in Type1 (T1) multi-project combination (Figure 5.28). The result of AWPSG value for Project1 is 0.068 $\left(\frac{|1.43-1.47| \times \frac{0.1+0.3}{2} + |1.33-1.47| \times \frac{0.2+0.3}{2} + |1.43-1.33| \times \frac{0.2+0.3}{2}}{\frac{3(3-1)}{2}}\right)$. Meanwhile, we can use the same way to calculate AWPSG value for other projects in the Type1. After that, according to Equation (3.12) to release Total Average Weighted Pair Satisfaction Gap (TAWPSG) value for all the 2 same highest sum of AWTSL value of multi-project combinations (Type1 and Type2 in Figure 5.28). The result of TAWPSG values for all the 2 types can be seen as Figure 5.30 (to get the result of TAWPSG we can also tap the button “Select” in the table “Project Selection Analysis Result” in Figure 5.26).

Combination Type	Designer 1 Project Name	Designer 2 Project Name	Designer 3 Project Name	Designer 4 Project Name	Designer 5 Project Name	TAWPSG value
Type1	Project2	Project1	Project1	Project1	Project2	0.03
Type2	Project1	Project1	Project1	Project2	Project2	0.01

Figure 5.30 - TAWPSG values for all the 2 highest value types in Figure 5.28

In the Figure 5.30 we can find that even though the sum of AWTSL values are the same between the 2 types in Figure 5.28, the TAWPSG values are different. Meanwhile, the Type2 multi-project combination (Project1 for Designer1, Project1 for Designer2, Project1 for Designer3, Designer2 and Designer4, and Project2 for Designer5) get the smallest value of TAWPSG (0.01). Therefore, the project manager should select multi-project to the designer depending on the Type2 in Figure 5.30.

5.4 Risk management process simulation and verification

5.4.1 Risk Assessment simulation and verification

For the risk assessment, we should analyze the risk of the hidden errors in the different error existing designers. In here, we define that 3 candidate designers (Designer1,

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Designer2 and Designer3) have hidden errors (project manager can brainstorm the errors, and release the corresponding effect like **Erreur ! Source du renvoi introuvable.**). To add risk existing designer errors, we have to tap the button “Input” for “Input Risk Existing Designers” in the table “Input risk evaluation parameters” in Figure 5.5. The risk existing designers and corresponding errors can be seen as Figure 5.31.

Designer Name	Error of the Designer
Designer 1	failure of structural design. misused design software
Designer 2	abuse of product specifications. failure of structural design
Designer 3	abuse of product specifications. communication conflict. misused design software

Figure 5.31 - Risk existing designers and corresponding errors

After that depending on the Table 4.1 to Table 4.3, project manager can define the severity, detection and occurrence of the errors in risk existing designers as Figure 5.32 (to input these parameters, we have to tap “Input” for “Input severity, detection, occurrence criteria for designer” in the table “Input risk evaluation parameters” in Figure 5.5).

Designer Name	Designer Error	Severity	Detection	Occurrence
Designer 1	failure of structural design	3	5	3
Designer 1	misused design software	3	5	5
Designer 2	abuse of product specifications	3	5	5
Designer 2	failure of structural design	1	4	5
Designer 3	abuse of product specifications	3	5	5
Designer 3	communication conflict	3	4	3
Designer 3	misused design software	2	5	4

Figure 5.32 - Severity, Detection and Occurrence rank for risk existing designers

After that, project manager can calculate TPRPN for all the risk exiting designers (Figure 5.33) depending on Figure 5.32, Eqs (4.2) and Equation (4.3) (to get the TPRPN result, we can tap the button “RiskManagement” in Figure 5.5).

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Designer Name	TPRPN(Total Personal Risk Priority Number)
Designer 1	120
Designer 2	95
Designer 3	151

Figure 5.33 - TPRPN for risk existing designers

After that, project manager should define the valued position matrix for Actors × Errors (2MAO for errors) (Figure 5.34) (to input these parameters, we have to tap “Input” for “Input levels of errors in designer” in the table “Input risk evaluation parameters” in Figure 5.5).

Designer Name	teamwork conflict	misused design software	failure of structural design	abuse of product specifications	communication conflict
Designer 1	0 ▾	3 ▾	3 ▾	0 ▾	0 ▾
Designer 2	0 ▾	0 ▾	1 ▾	3 ▾	0 ▾
Designer 3	0 ▾	2 ▾	0 ▾	3 ▾	3 ▾

Figure 5.34 - Valued position matrix for Actors × Errors (2MAO for errors)

In the Figure 5.34, we can find that Designer1, Designer2 and Designer3 have different rank of errors, which just match the severity of the errors for existing actor in Figure 5.32.

At the same time, project manager should create the Matrix of direct influence MID (Figure 5.35) and release the Matrix of direct and indirect influence MIDI to calculate the power relationship coefficient (r_i) for all these candidate actors (to input direct influence parameters, we have to tap “Input” for “Input direct influence parameters between designers” in the table “Input risk evaluation parameters” in Figure 5.5).

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Direct Influence Parameters

Designer Name	Designer 1	Designer 2	Designer 3	Designer 4	Designer 5	Designer 6	Designer 7	Designer 8	Designer 9	Designer 10
Designer 1	0	4	2	3	0	4	2	1	0	3
Designer 2	1	0	1	3	1	0	0	3	0	0
Designer 3	2	4	0	2	1	1	3	0	1	2
Designer 4	2	0	2	0	1	1	3	3	2	0
Designer 5	3	1	0	3	0	2	1	0	1	1
Designer 6	3	2	0	1	2	0	2	3	0	2
Designer 7	0	3	3	3	2	1	0	1	1	0
Designer 8	2	0	3	0	1	2	2	0	2	0
Designer 9	1	1	2	2	0	0	0	2	0	0
Designer 10	0	0	1	1	1	0	1	1	1	0

Figure 5.35 - Matrix of direct influence MID

Depending on the MID in Figure 5.35 and the equations from the Equation (4.6) to Equation (4.9), we can calculate power relationship coefficient r_i (Table 5.6) for all the candidate actors.

Table 5.6–Power coefficient value R_i for all candidate designers

Actors	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10
R_i	1.30	0.69	1.14	1.01	1.23	1.23	0.95	1.07	0.73	0.65

Note. A1 = Actor1. A2 = Actor2. A3 = Actor3. A4 = Actor4. A5 = Actor5. A6 = Actor6. A7 = Actor7. A8 = Actor8. A9 = Actor9. A10 = Actor10.

Afterwards, depending on the Equation (4.10) and the 2MAO (Figure 5.32) to release the 3CAA and 3 DAA matrix, and depending on the combination of convergence and divergence matrix, we can release MCDV (matrix of convergences and divergences of the actors for the error). After that, depending on the matrix of MCDV, we can calculate the IRPNn in the equation (4.5). Hereafter, depending on the equation (4.1) to calculate Total RPN for all the error existing actors. The result TRPN for all 3 error designers can be seen as the Figure 5.36 (to get the result of TRPN, we have to tap the button “RiskManagement” in Figure 5.5).

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Designer ID	Designer Name	TPRPN(Total Personal Risk Priority Number)	TIRPN(Total Interdependent Risk Priority Number)	TRPN(Total Risk Priority Number)
2	Designer 1	120	176.40	296.40
3	Designer 2	95	82.65	177.65
4	Designer 3	151	249.15	400.15

Figure 5.36 - Total RPN result for all the hidden risk existing designers

In the Figure 5.36, we can find that the priority order for action designer is Designer 3 (400.15), Designer1 (296.40), Designer 2(177.65). The higher value of Total RPN the actor contains, the more priority level for the actor has. Project manager can depend on this order to take action (training, course, education and etc) to reduce the risk for the error designers. After that, if the risk is still not tolerable, the error designer will be eliminated.

5.4.2 Risk Treatment simulation and verification

After we define the risk evaluation criteria for 3 risk existing designers, we have to make the risk response strategies, which will mitigate these errors. To input the parameters of risk response strategies, we have to tap the button “RiskManagement” in Figure 5.5, and we can get the “Input Risk Response Strategy Parameters” table (Figure 5.38).

Input Risk Response Strategy parameters

Input Risk Response Strategies	Input Budget
Input	Input

Figure 5.37 Input Risk Rspnse Strategy Parameters table

In this design project, the project manager has defined the risk response strategies budget as 200 € (to input the budget, we have to tap the button “input” for “Input Budget” in Figure 5.37). Meanwhile, designers who make errors and project manager have proposed 5 risk response strategies to deal with risks. The risk response strategies and the corresponding effect to the error can be seen as Figure 5.38 (to input risk response strategies, we can tap the button “Input” for “Input Risk Response Strategies” in Figure 5.37).

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Strategy Name	Strategy Cost / Person(€)	Affect Error	The amount of Severity reduction	The amount of Detection reduction	The amount of Occurrence reduction
Communication training	12	communication conflict	2	2	2
Knowledge course	2	abuse of product specifications	2	1	1
Knowledge course	2	communication conflict	2	2	1
Quality training	12	communication conflict	1	1	2
Skill training	2	communication conflict	1	2	2
Technical and technology training	2	failure of structural design	2	1	2
Technical and technology training	2	misused design software	1	1	1

Figure 5.38 - Risk response strategies and the corresponding effect to the error

In the Figure 5.38, we can find that every risk response strategy has different risk response implementation cost. Meanwhile, these risk response strategies influence different errors (communication conflict, abuse of product specifications and etc.) with the corresponding degree of affected Severity, Detection and Occurrence.

After that we can use Equation (4.11) to Equation (4.15) and Table 4.10 to release the $\Delta TRPN$ for every response strategy to every actor. The $\Delta TRPN$ result for every response strategy to every actor can be seen as Table 5.7.

Table 5.7–Power coefficient value R_i for all candidate designers

Risk response strategy	Designer	$\Delta TRPN$
ST (G1)	Designer3	90.10
KC(G2)	Designer2	110.33
	Designer3	241.15
CT(G3)	Designer3	79.50
QT(G4)	Designer3	84.80
TTT(G5)	Designer1	207.48
	Designer2	54.23
	Designer3	74.20

Note. ST: Skill Training. KC: Knowledge Course. CT: Communication Training. QT: Quality Training. TTT: Technical and Technology Training.

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In the Table 5.7, the $\Delta TRPN$ is the combination result if the $\Delta TIRPN$ and $\Delta TPRPN$ value. For instance, for the ST (G1) to the Designer3, the 90.10 ($\Delta TRPN$) is the combination of the value 32.0 ($\Delta TPRPN$) and the value 52.80 ($\Delta TIRPN$). With result of TRPN for the 3 risk existing designers and Equation (4.23), we can calculate the weight W_k (Table 5.8).

Table 5.8–Weight W_k for 5 risk existing actors

	Designer1	Designer2	Designer3
W_k	0.34	0.20	0.46

In the Table 5.8, depending on the Equation (4.23), for example, we can get the weight value for Designer1 is 0.34 $\left(\frac{296.40}{(296.40+177.65+400.15)}\right)$.

From then on, we can use the optimization model (Equation (4.16) through Equation (4.19)) to evaluate expected utility of risk response strategy and select the highest expected utility strategies while the implementation cost for strategies must lower than the budget. The evaluation result of relationship between risk response strategy implementation cost and expected utility function with in the budget (to input the budget, we can tap the button “Input” for “Input Budget” in Figure 5.37) can be seen as Figure 5.39 (to get the result of expected utility function table, we can tap “RiskManagement” in Figure 5.5).

Chapter 5 Simulation and verification

Combination type	Risk Response Strategy	Affected Designer Name	Expected Utility Function Result(F(x))
Combination1	Communication training	Designer 3	2.8276
	Knowledge course	Designer 2	
	Knowledge course	Designer 3	
	Quality training	Designer 3	
	Skill training	Designer 3	
	Technical and technology training	Designer 1	
	Technical and technology training	Designer 2	
	Technical and technology training	Designer 3	
Combination2	Communication training	Designer 3	2.6643
	Knowledge course	Designer 2	
	Knowledge course	Designer 3	
	Quality training	Designer 3	
	Skill training	Designer 3	
	Technical and technology training	Designer 1	
	Technical and technology training	Designer 3	
Combination3	Communication training	Designer 3	2.4193
	Knowledge course	Designer 2	
	Knowledge course	Designer 3	
	Quality training	Designer 3	
	Skill training	Designer 3	
	Technical and technology training	Designer 1	
	Technical and technology training	Designer 2	

Figure 5.39 - Top 3 Expected Utility Function Result (F(x)) for all the risk response strategy combinations

In the Figure 5.39, we can find that within the budget, risk response strategy combination type 1 (Combination1) gets the highest Expected Utility Result (2.8276). Therefore, project manager should select Communication Training for Designer3, Knowledge course for Designer2, Knowledge course for Designer3, Quality training for Designer3, Skill training for Designer3, Technical and Technology training for Designer1, Technical and Technology training for Designer2 and Technical and Technology training for Designer3.

Conclusion

In this chapter, we make the simulation and verification for human resource allocation, project selection and risk management methodology. We propose an illustrative case and implement a web application to simulate and verify the methodologies. In the human resource allocation part, through the calculation result of TAVG (Total Average Gap), GPA (Group Personality Ability) and GAWT (Group' s Ability to Work Together) value, project manager can find most communicative and collaborative group for the design project. In the project selection part, through the result of Sum of AWTSL (Average Weighted Total Satisfaction Level) value, project manager can select most designer satisfactory multi-projects and positioned these projects to them. And for the risk management part, the result of TPRN (Total Risk Priority Number) can help project manager to find risky designers. Meanwhile, project manager can use the calculation result of Expected Utility Function ($F(x)$) for all the risk response strategy combinations to select most effective risk response strategies for the risk existing designers.

CONCLUSION AND FUTURE WORK

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Main conclusions

In this paper, we proposed three methodologies to approach the human resource allocation, project selection, risk management problem. In the multi-project human resources allocation methodology, we have considered about the horizontal and collaboration ability, personality ability and group's ability to work together for the design process in the factory of the future.

For the horizontal and collaboration ability, we use the AHP (Analytic Hierarchy Process) method to define the weight of horizontal ability properties, and we use the horizontal properties gap between two actors to calculate the collaboration ability between them. In the personality ability, we use the NEO-PI-R personality inventory to release the score of five personality factors and use the Pentagonal spider chart to calculate the personality ability of the designer. And for the group's ability to work together is to use years, projects and satisfactions with each other between two collaborated designers to calculate the group's ability. The reason to analysis the three abilities are to find the most effective communication and collaboration group for the design project.

In the project selection methodology, we propose the factors and sub-factors of design project which can affect the satisfaction of designer. After that we analyze the designers' satisfaction to the candidate multi-projects to find the most satisfactory multi-project to the designer. After that we analyze the collaboration ability of these designers in the different candidate multi-projects. The target to analyze this collaboration ability is to help designer to find most harmonic and comfortable collaboration environment in candidate project.

In the risk management methodology, we have approach the designer error risk management problem with the consideration of personal and interdependent affect. In the risk assessment part, we use ISO 31000 (International standard of organization in design process) to define the whole risk management process, and use FMEA (Failure Mode and Effect Analysis) method to calculate the personal risk, and use MACTOR (Matrix of Alliances and Conflicts: Tactics, Objectives and Recommendations) method to approach the direct and indirect affected risk problem. After that, in the risk

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treatment part, we propose a method to select risk response strategies to reduce the risk in error designers.

In the human resource allocation part, the analysis of project urgency level and horizontal ability both use the spider web chart presenting for the analysis result, and trying to evaluate the criticality and horizontal ability on basis of the area under the plot. There are many other methodologies also considers a spider chart under multiple performance evaluation objectives. 7Ts (Seven Influencing Measures of Competitive Engineering) (Dwivedi and Prasad (2001)) is a spider web chart, which consider about 7 influencing factors (talents, tasks, teamwork, techniques, technology, time, tools), to measure the competitive engineering. In here, they also consider about different rank in every factor, and then combine them to consider about the domain of influence in competitive engineering. However, the spider web chart does not have a detailed description of the rank in every influence factor. Meanwhile, there is no levels of overall influencing (in our paper, the urgency level of project can be divided as four levels from low to critical). Apart from that, there is no description of the influence is based on the area under the plot. Another spider web chart (Prasad (2001), Prasad (2002)) uses the 8 performance indicators to measuring enterprise competitiveness, and four indicators that need to be maximized and four that need to be minimized. Meanwhile, in the spider web chart, the sum of the Petals Areas can represent the competitiveness of enterprise. However, there is no rank for every performance indicator (in our paper, both project urgency level and horizontal ability contains different rank in every performance indicator). Meanwhile, there is also no levels for overall influencing (in this paper, the urgency level of project can be divided as four levels from low to critical).

Research contributions

The first contribution of this article is to approach the human resource allocation problem in factory of the future, especially for the collaboration and communication problem in candidate design groups. With the result of TAVG (Total Average Gap), GPA (Group Personality Ability) and GAWT (Group' s Ability to Work Together), project manager can select most effective communication and collaboration designer

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group to the design project. Meanwhile, the results also contribute to an understanding of individual collaboration harmonious environment degree in the team context.

The second contribution is to help the project manager to select the design projects depending on the satisfaction of the designer. For the satisfaction of designer to the design projects, we have consider about five main factors (Satisfaction of the Personal responsibility, Satisfaction of the constraints in design project, Satisfaction of work environment, Satisfaction of Salary and welfare, and Satisfaction Personal Aspirations), which consist of different sub-factors respectively, that influence the designer. Then, through the result of AWTSL (Average Weighted Total Satisfaction Level), project manager can find the most satisfactory combination of design projects for designers. After that, if the AWTSL values are the same among different combination projects, we can analysis collaboration ability of designer in the different combination projects to identify them. In here, through the result of TAWPSG (Total Average Weighted Pair Satisfaction Gap) value, project manager can find and select smallest value of the multi-project combination type the designers.

The third contribution of this research is to manage the risk for error designer in future design process. In here, when we calculate the risk of the error designer, we are not only considering about the personal risk in error designer but also thinking about the interdependent risk in collaborated designers. After that we propose an optimization model which considering the risk response strategy implementation cost, constraints of the budget and interdependent response effect. Project manager can use this optimization model result to find the most desirable risk response strategies, and implement these strategies to the error designers.

Compared with previous studies, our methods consider the communication and collaboration relationship between designers to confront future point-to-point collaborative design organization relationship. Hence, the human resource allocation, project selection and risk management methodology can let the P-P-O (Product-Process-Organization) system adapts the factory of the future.

Limitation and future work

Although all the results above are consistent with our objectives, there are still limitations and difficulties. In the human resource allocation part, we illustrate about the global view of the personality ability for the designer. The creation knowledge of the personality ability is inspired from the personality result of successful team and unsuccessful team. However, the successful and unsuccessful team global view of the personality not only affects the communication and collaboration ability but also affects the creativity and exceptional performance of designer. Therefore, it is also very important to exactly identify that which kinds of personality traits will mainly affect the creative and exceptional performance of designer, and which kinds of personality traits will mainly affect the communication and collaboration ability. Project managers can be more precise distinction about the personality and depended of the design project (one step of design process) to make further screening of candidate designers. Apart from that in the experience working ability, we only consider about the three properties (Years of Experience, projects of experience and Satisfaction) while there also have many other attributes (the experienced project performance, mutual exchanged information/knowledge cognitive ability and so on) affect the group's ability to work together. For the limitation in project selection part, we analysed the designer's satisfaction with the design project. However, it is difficult for us to understand how to improve the different factors and sub-factors in design project to increase the satisfaction of the designer to the design project. Apart from that in the collaboration ability, we only consider about the two properties (individual perception of strength of relationship (ST) and Weighted Total Satisfaction Level (WTSL)) while there also have many other attributes (the experienced project performance, mutual exchanged information/knowledge cognitive ability and so on) affect the collaboration ability. For the limitation in risk management part, the selection of the risk response strategies not only concern about the factors of the risk in the actor but also relate to the personal preference for the strategies, which will influence the effectiveness of the risk response strategy implementation. Future research should aim to overcome this limitation and integrating risk response strategy preference to the risk response strategy selection method.

Conclusion and future work

Further studies will focus on an analysis of influence of the personality traits to exactly identify that which kinds of personality traits will mainly affect the creativity, exceptional performance, and the communication and collaboration ability of designer. Also, the studies keep on to analysis other attributes when define the group's ability to work together. Meanwhile, further studies will also focus on the limitations and difficulties in project selection and risk management process which has been mentioned above.

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