ABSTRACT

Title of Document: A COMPLEXITY-BASED APPROACH TO INTRA-ORGANIZATIONAL TEAM SELECTION

Shu-Chien Hsu, 2013

Directed By: Qingbin Cui, Assistant Professor, Department of Civil & Environmental Engineering

Miroslaw Skibniewski, Professor, Department of Civil & Environmental Engineering

Early studies recognized the significance of team's work capacity and suggested the selection of team members based on individual skills and performance in alignment with task characteristics. The equitable team selection method, for example, assigns people to different tasks with even skill distributions for the best overall performance. Recent advancement in organization science also identifies the importance of contextual skills. However, work teams are complex adaptive systems with interdependence between workers and social environment, and exhibit surprising, nonlinear behavior. Optimizing individual stages without taking organizational complexity into account is unlikely to yield a high performing new combination of teams. The objectives of this study can be stated as: a) Utilizing complex system theory to better understand the processes of team selection including forming teams with considering worker's interdependence and replacing the unsuitable members through a time frame; b) Comparing different team selection methods, including random selection, equity method, using knowledge of interdependence in different economic conditions through simulation; c) Comparing different policies of replacing members of teams. This study utilizes a computational model to understand the complexity of project team selection and to examine how diversity of capability and interdependence between workers to effect team performance in different economic conditions. The NK model, a widely used theory for complex systems is utilized here to illustrate the worker's interdependence and fed into an Agent-Based Model. This study uses a small design firm as a case implementation to examine the performance of a variety of team selection approaches and replacement policies. Project data, task assignment, and individual and team performance information were collected for the period of 2009-2011. The simulation results show that while the equity selection method can increase the diversity of capabilities of teams, the net performance is often worse than optimizing worker interdependencies. This study suggests that managers should protect their higher-performing workers with minimal interdependence disruption when they considered team selection. Thus taking the advantages and disadvantages of all three policies into account, transferring low contributors or least supported members are recommended to be enacted before hiring new workers to avoid this last policy's especially large additional costs.

Keyword: Team Selection, Complexity Theory, Agent-Based Modeling, Team Performance

A COMPLEXITY-BASED APPROACH TO INTRA-ORGANIZATIONAL TEAM SELECTION

By

Shu-Chien Hsu

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Advisory Committee:
Assistant Professor Qingbin Cui, Co-Chair
Professor Miroslaw Skibniewski, Co-Chair
Professor Gregory Baecher
Professor Hui Liao
Assistant Professor William Rand

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Chapter 1: Introduction

1.1 Research Background

Businesses are using teams with greater frequency because teams have high potential, high motivation, and the problem-solving ability and flexibility which are important work structures for business life (Gordon 1992; Lawler et al. 1995; Gerard 1995; Baykasoglu et al. 2007). A team is typically defined as a small group of people working in an interactive manner toward a common goal. The success of these project teams is highly dependent upon the people on the team. This makes project team selection an important factor for project success. While the literature has focused on other methods for improving team performance, such as training and feedback, managers usually utilize team selection and replacing team members when other methods do not achieve the desired results (Solow et al. 2002). Project team selection can be defined as selecting the right team members, who together will perform a particular project/task within a given deadline. Teams are a popular participative management tool and there is considerable agreement that team structure will play an increasingly prominent role in organizations. Given the important role of team composition, a variety of predictors for individual performance in teams has been proposed and researched.

During the 1980s and 1990s, several researchers focused on selecting team members based on their personality (Barry & Stewart 1997; Driskell et al. 1987; Hogan & Hogan 1989; Hogan et al. 1988; Smith-Jentsch et al. 1996). Specific research using the Big Five personality traits has been especially promising in predicting teamwork performance. Neuman & Wright (1999) investigated team members for over a year and found that the personality traits of agreeableness and conscientiousness predicted both team performance and individual performance on the team. Moreover, the self-efficacy for teamwork and self-monitoring has proposed the potential to impact team effectiveness (Thomas et al. 1996) although relations with individual team performance behaviors have not yet been investigated (McClough & Rogelberg 2003). These articles have demonstrated that personality-based selection is useful in general; however ability-based selection strategies have historically been more successful in predicting performance (Hunter 1986; Gooding et al. 1984). One example application of this approach is the Virtual Design Team (VDT), which was developed based on contingency theory (Jin & Levitt, 1996). They theorized that there is no best way to organize a project team to lead a project, or to make decisions. Instead, the optimal course of action is dependent upon the internal and external situation. The VDT method addresses coordination needs due to activity interdependency, and provides a simulation based team selection approach that matches the individual's capacity to handle all tasks, from direct work to coordination and institutional efforts. These historical team selection studies focused on how managers could select potential workers based on individual characteristics consistent with individual performance.

Although it is simpler to study team performance as an accumulation of individual contributions and assuming each person's contribution is independent of others, many researchers have realized the importance of interdependence and non-additive contributions (Salas et al. 1992; Hinds et al. 2000). For instance, as Tziner and Eden (1985) discovered in their study of military tank crews, highly skilled teams far outperformed the levels predicted from summing their skill levels, and low-skilled teams performed well below the predicted levels of their summed skills. They used these observations about synergistic performance to offer detailed recommendations for building three-man tank crews from the existing candidate pool. They also noted that switching operators between crews was not a zero-sum game in which one team lost what the other gained. Instead, some combinations of players performed disproportionately better or worse than others.

In an effort to explore the specific knowledge and skills that affect individual-level performance in teams, Stevens and Campion (1994) reviewed relevant team research and outlined fourteen probable individual-level knowledge, skill, and ability (KSA) requirements for teamwork. This research did not focus on the technical KSAs required by jobs. It focused more on KSAs required or made more salient by the distinctive nature of teamwork situations, such as increased social and interpersonal requirements. Therefore, while work on personnel selection has previously focused on the abilities of individuals rather than the relationships among individuals, the focus is shifting to skills related to working well together. Recent research on personnel selection for teams emphasizes the importance of individuals having contextual skills as well as task skills (Borman & Motowidlo 1997; Morgeson 2005). Compared to task performance, contextual performance is particularly important in team settings. Task performance reflects activities that are formally recognized as part of the job, support the organization's technical core, and directly impact organizational goal accomplishment. This has been the focus in traditional, individually oriented selection systems. Contextual performance reflects activities that support the organizational, social, and psychological environment, thereby facilitating effective team functioning. For example, the interpersonal helping, job dedication, and initiative manifested during contextual performance helps make teams work in organizational settings. Without this kind of contextual performance, the development and maintenance of teams will not be successful. Contextual skills encompass all of the organizational, social, and psychological support work performed to help coordinate and sustain interdependent work; task skills are generally defined as skills required for executing specific tasks related to work outcomes. Although these individual attributes are crucial inputs in team design and point to the crucial role of support work in performance, they do not encompass all the ways people act interdependently and thus are limited in their ability to predict how well people will work together.

However, work teams are complex, adaptive systems (Ilgen et al. 2005; McGrath et al. 2000), and exhibit surprising, nonlinear behavior (Anderson 1999). Dealing with complexity is far from straightforward because problem solvers cannot optimize each part individually (Baumann & Siggelkow 2012). Consider, for instance, the challenge faced by managers who need to understand how a change to a firm's set of activities at one stage of the value chain may affect other parts of the value chain and require further adjustments there as well. Thus, optimizing individual stages without taking interdependencies into account is unlikely to yield a high performing new combination of activity choices. Similarly, consider a program manager who selects teams to work together to complete concurrent projects. If the manager wants to create a high-performing program, he cannot optimize the project teams individually, but needs to pay attention to the entire organization in different environmental conditions. As documented by a large body of research, problem solvers often do not deal with complexity by calculating optimal solutions, but rather engage in an adaptive search for satisfactory ones (Nelson & Winter 1982; Baumann & Siggelkow 2012).

It is important to note that even the word “complexity” is difficult to understand. Geraldi (2008) states that mastering complexity is not a new challenge but an old challenge that is being recognized and accepted increasingly. While projects and project organization are associated with complexity, many have difficulty understanding the concept and, as such, do not look upon a project team as a complex system, resulting in very negative consequences. Projects are complex because they represent something unique. Because they are unique, they have an element of uncertainty with regard to their execution that often results in re-work and added time and costs. Often there is insufficient time to make decisions, and it is easy to become involved in the details, losing sight of the overall goals and objectives. This need for timely decision making may lead to mistakes, especially if the goals are not explicit, the team has not worked together before, and there are a large number of stakeholders struggling to comprehend a significant amount of information.

Work on complexity originated during the mid-1980s at New Mexico’s Santa Fe Institute. Distinguished professionals in the fields of particle physics, microbiology, archaeology, astrophysics, paleontology, zoology, botany, and economics came together with similar questions to study and debate the concept of complexity in the life, physical, and social sciences. Their groundbreaking work, as well as the substantive research that followed, offered a definition of complexity theory as the study of how order, structural patterns, and novelty arise from extremely complicated, apparently chaotic systems, and conversely, how complex behavior and structure emerge from simple underlying rules. However, transferring this knowledge from the scientific arena to management theory has been slow at best. Relevant and key concepts associated with complex theory include the following: Nonlinearity, Self-Organization and Emergence, and Complex Adaptive Systems (CAS).

Nonlinearity is a state in which there is an interaction between two or more elements in a system that could not have been predicted at the time the system was designed (Ivory and Alderman 2005). It has been noted that a physical, biological, or social system, such as a project organization, has a distinct tendency, when left undisturbed, to organize in ways that are often unpredictable. Such spontaneous behavior often gives rise to new patterns of behavior. The CAS concept is central to understanding complexity and ways to deal with it. A CAS arises from a self-organizing system, noting that such a system has the capacity to learn from experience. It is this ability to adapt to its surroundings that ensures its survival in the face of a changing environment. Additionally, it consists of a number of independent agents guided by their own rules of behavior and a scheme shared with other groups; CASs are thus spontaneous and self-organizing. As is described in the brief literature review in the next chapter, complexity, the complex system theory seems to be a complementary method for traditional team selection approaches, and can address this knowledge gap between team selection and the context of interdependence.

1.2 Problem Statement

Previous studies have accumulated considerable information on team selection and design, and have focused on how to select individuals to form a team based on their availability, skills (Barry & Stewart 1997; Diskell et al. 1987; Hogan & Hogan 1989; Hogan et al. 1988), knowledge, and abilities (Smith-Jentsch et al. 1996; Hunter 1986; Gooding et al. 1984; Jin

& Levitt, 1996; Salas et al. 1992). However, there is limited research on how complexity, i.e. the interdependence between workers and environmental context, influence and interact with team selection and impact team performance.

Moreover, most team selection research focuses on methods for choosing among candidates for a particular job. However, little guidance is provided as to how to identify the incumbent who needs to be replaced to optimize team performance (Solow et al. 2002; Baykasoglu et al. 2007). Millhiser et al. (2011) also argue that team design with a fixed cast of workers, without the option of better replacement, is more common in a real work situation. Deciding which workers should be transferred to another team, or replaced by hiring new ones, remains a big challenge for managers.

There are several limits on a manager's ability to construct an optimal team. There are time and dollar costs associated with interviewing potential new members. Each new hire requires training time from the manager and the rest of the team. Qualified individuals may not be available or the cost of hiring them may be excessive in the current labor market. Biases can arise in assessing and comparing the performance of a current employee with the potential performance of a job candidate. Furthermore, it is particularly challenging to make replacement decisions in a team setting because of the interdependence among different members of the team. The replacement of a team member can change the team performance level because the remaining members cannot always rely on the new member for information or support that was provided by their former teammate.

The problems addressed by previous research were confirmed by interviews conducted for this study with senior managers in industry to see which kind of problems they met in team selection. A senior program manager at a software company that contracts with the United States (US) Army also indicated that team selection is one of the hardest things he does. With over 20 years of experience, including supervision of over 20 project managers and around 250 team members and coordination with around 100 subcontractors in the software industry, he indicated that his company tried to choose the right people based on their skills, but some projects still did not perform as well as expected. Two major reasons for not achieved desired performance that he identified were, one, that some workers' personalities may not be team players, and two, sometimes select a subcontractors were selected that the company never worked together with before. Another problem he discussed is it is hard to quantify their individual performance due to team members' interdependence. Misjudging individual performance can cause serious problems, such as firing the wrong person, giving unreasonable bonuses to workers, etc.

Other evidence can be found in the construction industry. A senior vice president for a top 10 construction contractor in the US also confirmed that it is very difficult to select the right people for particular jobs. He mentioned that most of the time, teams are put together for specific projects and members may be pulled from the main office, another division, or another region. He found this to be one of the most challenging things his company must do because of the difficulty of getting the team and other parties to the job at the right time when you need them. He said that projects may also get delayed due to permit challenges, awards not made when predicted, other projects not completed on time, people quitting, and more. He affirmed that forming an efficient team remains a challenge for his company.

Based on the literature review and the industrial interviews, the problem statement guiding this research is as follows:

a. There remains a lack of an integrated method for examining team selection – team selection processes should not only focus on forming teams, but also consider the adaptive behavior – transferring or replacing the team members.
b. Although significant knowledge has been accumulated on team selection, there is little research comparing different team selection methods, such as random selection, an equitable selection method, or especially a method that incorporates complexity, i.e. consideration for workers' interdependency and interaction in an economic context. It is useful for managers to know when and how those selection methods should be used, and under what conditions. For example, how should managers determine which workers should be fired and which should be retained to keep the company alive during an economic depression? The problem is not as simple as just firing the lower performing workers, because other workers may also be influenced due to interdependence.
c. While previous research provided useful knowledge on managerial polices for team selection, little knowledge is available on comparing different policies on replacing team members. Under what conditions should a manager re-construct a team or replace team members by hiring new ones?

1.3 Objectives of the Research

This study aims to advance our understanding of team selection with due consideration to interdependent worker productivity and through the lens of teams as dynamic adaptive systems. Will an integrated team selection framework, with roots in the theory of complexity, lead to better decision making in team selection processes?

Obtaining empirical data about the effects of different team selection methods and different replacement policies on team performance can require a prohibitive time commitment. A few months might be required for a new team member to settle in before team performance stabilizes and the need for an additional replacement can be assessed. Tracking even one team through the process of replacing several different members in an organization could require years. To obtain comparable data from a large number of teams would require comparable performance measures for teams with varying responsibilities that account for the impact of exogenous factors during the time frame of the replacements.

Therefore, this study instead utilizes a computational model to understand the complexity of project team selection and to maximize performance across workers and teams in different contexts. This model can simulate the team performance of four different team selection methods and different replacement policies. In order to fill the knowledge gap as described in the above problem statement, the objectives of this study can be stated as follows:

a. To utilize complex system theory to better understand the processes of team selection, including forming teams (selecting right members) in the beginning, and replacing the unsuitable members (adaptive behavior of organizations) through a time frame.
b. To compare different team selection methods, including random selection based, equity method, using knowledge of members' interdependency, and using knowledge of social context interdependency in an agent-based model. An ABM also can demonstrate the interactions between workers and the environment, which is a more realistic set of conditions compared to previous team selection

research. It is useful for managers to know when and how those selection methods should be used, and under what conditions. The proposed model also provides an easier way for managers to understand how to use the knowledge of interdependence between workers and the environment to improve team performance.

c. To compare different policies of replacing members of a team. It can provide a decision support tool to help managers to decide that they should reconstruct the team or replace the team members by hiring new members, and under what conditions. Different scenarios are also considered in the simulation environment.

1.4 Methodology of the Study

The methodology of the study is depicted in Figure 1. This research first reviewed the relevant literature both in project management and organization science, with a focus on three major areas: complexity, team building and selection, and simulation methods. The project complexity framework for project management is then developed through comprehensive reviews. After proving that project team selection has characteristics as a complex adaptive system, the investigation is carried out using complex systems theory. Complex systems are composed of a large number of interacting components, and the interaction leads to interesting and rich system behaviors. Obtaining empirical data about the effects of different team selection methods and different replacement policies on team performance can require a prohibitive time commitment. Therefore, this study utilizes a computational model to understand the complexity of project team selection and to

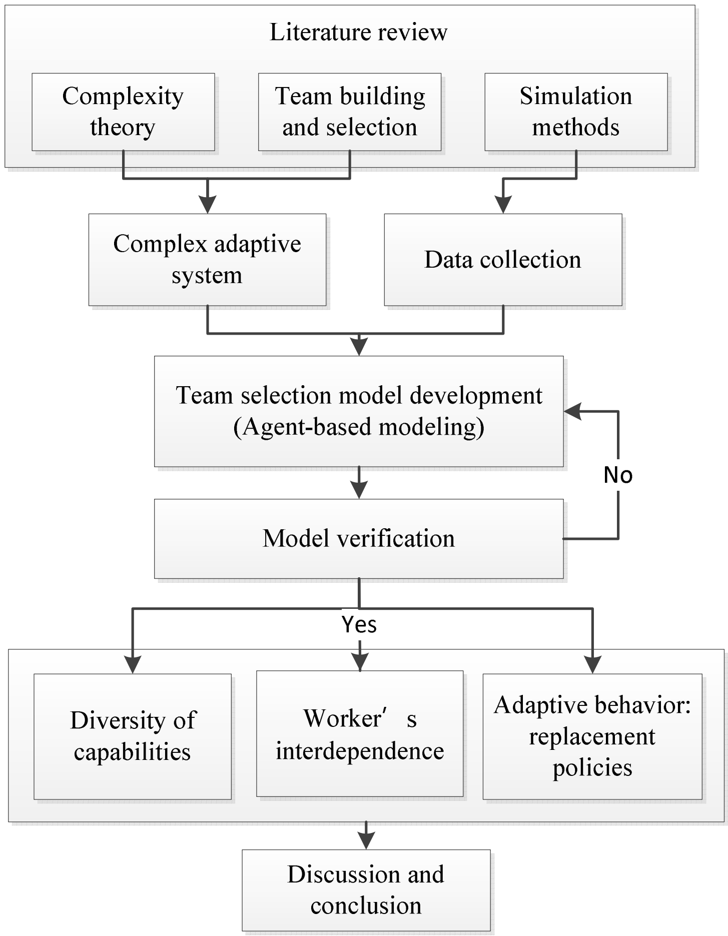


Figure 1. Methodology of the study

maximize the performance across workers and teams in different context situations. The NK model (Kauffman 1993) a widely used model for complex systems, is used here. The NK model provides a "landscape" that represents the performance of a system as a function of the state of the components comprising the system. The worker's interdependence can be captured and measured by the NK model through three components: individual contribution, contributing to others, and receiving from others.

Agent-based modeling was selected to develop this study's model for team selection because it especially designed to model interactions between agents and environments. This study uses a small design firm to examine the performance of a variety of team selection approaches. Project data, task assignment, and team performance information were collected for the period of 2009-2011 and used to verify the developed ABM team selection model. With the use of ABM and simulation, together with insights derived from CAS, this study then illustrates that ABM provides a suitable platform for the creation of robust and accurate "what-if" scenarios within team selection settings. This approach can simulate multiple alternative configurations of teams to predict and evaluate their performance, and then improve the tactical and operational decision-making of construction project team building. Four team selection methods are evaluated under various scenarios to test the general hypotheses. Simulation results and detailed hypotheses testing will be discussed and reported in the later chapters.

1.5 Structure of the Research

Chapter 1 is the introduction of the study and defines the research background and problem statements. The three major objectives of the study and the methodology design for attaining the goals were also described. The next chapter provides an introductory description of project complexity and team building, selection, and design. The ABM is then introduced as a method to operationalize the CAS perspective in construction team organization. Why CAS and ABM are appropriate methods for the study are also discussed. The theory development and detailed hypotheses are then described in chapter 3. In chapter 4, an integrated complexity theory based ABM model for simulating different team selection methods is developed. The details of model development and model implementation – compare the simulation result and a real system are also discussed. with the model verified, the hypotheses can be tested. Chapter 5 examines the diversity of capabilities in teams in different economic contexts. Chapter 6 demonstrates the effect of worker's interdependence on team performance. Chapter 7 compares different team member replacement policies in different scenarios. Finally, chapter 8 summarizes the contributions, potential real-world applications, and limitations of this research.

Chapter 2: Literature Review

The literature review will cover four major areas. The first discusses project-based organization and contains a historical review of team selection. Teams are highly dynamic and exhibit nonlinear behaviors, and thus qualify as complex systems. Therefore, the literature on complexity is the next area covered in the review. Based on the review of the literature, a project's complexity is categorized into two parts: technical and organizational. The following parts are to review the theory, complex adaptive system (CAS) and simulation method, Agent-based modeling (ABM) that is used to develop the decision making model for comparing the different team selection methods in different context.

2.1 Project-based Organization

Project-based organization theory revolves around the concept that a group of individuals or firms join together with the explicit purpose of producing a tangible set of outputs that can be physical, logical or social. The concept, formalized at the peak of the aerospace and military build-ups during the 1950s, emphasized the optimization of project resources to produce the given scope of outputs within given budget and schedule constraints (Chinowsky 2011). In contrast to the long-term, market-centered focus espoused by strategy advocates, project management advocates emphasize the role that projects play in achieving longer-term strategic objectives and the need to re-evaluate organization structure (Morgan et al. 2008). According to this perspective, the optimization of short-term objectives to complete projects should have priority over long-term strategic positioning. The reasoning for this optimization being that the failure to successfully complete a project severely inhibits the opportunity to achieve longer-term goals.

Figure 2 illustrates these themes by dividing types of organizations along a spectrum from continuous-process to project-focused. As illustrated, continuous-process organizations are ones that are based on providing consistent services over an extended period of time with minimal changes to the product or service. Hospitality and consumer products share this end of the spectrum as each emphasizes market share growth through experiential or marketing-based efforts. At the opposite end of the spectrum, we see organizations that center on unique, large project delivery. Engineering and construction companies anchor this end of the spectrum with an emphasis on individual projects where the identity of organization members may be tied more to a specific project than to the overall organization. At the project-focused end of the spectrum, the pursuit of innovative processes to support the optimization of project resources dominates the thinking behind much of the engineering literature, the stated objectives of professional engineering enterprises, and engineering academic curricula. The continuous reinforcement of these objectives by academic and professional entities is arguably driving a broader wedge between the industries residing at the opposing ends of the spectrum.

Project-Based Organizations		Large Project Organizations		Continuous Process Organizations
Construction Engineering	Aerospace	Aircraft & Movies & Software	Automotive	Hospitality & Retail

Figure 2. Organization categories and examples (Chinowsky 2011)

However the assumption that the engineering industry uniquely operates from this perspective is not true. Project management continues to be a key approach in defense and aerospace industries in completing multi-year, multi-billion dollar contracts. Flying the Airbus A380 and the managing the International Space Station require a large-scale coordination of resources over multiple organizations and countries to successfully deploy complex activities. Similarly, organizations traditionally perceived as utilizing projects as a means to achieve strategic market goals are adopting project-based management in part to mitigate the liability of individual efforts that may threaten to bankrupt an organization (Cooke-Davies et al. 2009). Examples of this movement include the film industry, the pharmaceutical industry and even healthcare (Pinto 2002). These industries share a common realization that single projects place the overall organization in danger as the level of resource commitment grows in relation to overall resource reserves.

The innovative management practices of the past decade have demonstrated that the best way to benefit from cooperative human dynamics is through team-based organizational strategies that reduce centralization and functional divisions. The results of decentralized, team-based approaches empower employees by building trust and accountability, which leads to high levels of commitment, enthusiasm, self-motivation, and productivity, as well as feelings of appreciation and self-worth (Spatz 2000). Teamwork had proven so successful in business that by the 1980s management consultants began to emphasize the importance of teams and teamwork ability in order to improve output and overall company performance. Then by the 1990s, the management literature burgeoned with teamwork approaches and leadership styles that are others-oriented. During this time team implementation also had begun to dominate management approaches, and team-based organizations began to replace hierarchical corporate structures. The current objective of management architects is to design leaner organizations that are decentralized, defunctionalized, cooperative, united, and committed to improvement (Spatz 2000).

While a successful project manager must be a good leader, other members of the project team must also learn to work together, whether they are assembled from different divisions of the same organization or even from different organizations. Some problems of interaction may arise initially when the team members are unfamiliar with their own roles in the project team, particularly for a large and complex project. These problems must be resolved quickly in order to develop an effective, functioning team.

Many of the major issues in construction projects require effective interventions by individuals, groups and organizations. The fundamental challenge is to enhance communication among individuals, groups and organizations so that obstacles in the way of improving interpersonal relations may be removed. Some behavior science concepts are helpful in overcoming communication difficulties that block cooperation and coordination. In very large projects, professional behavior scientists may be necessary in diagnosing the problems and advising the personnel working on the project. The power of the organization should be used judiciously in resolving conflicts.

The major symptoms of interpersonal behavior problems can be detected by experienced observers, and these problems are often the source of serious communication difficulties among participants in a project. For example, members of a project team may avoid each other and withdraw from active interactions about differences that need to be dealt with. They may attempt to criticize and blame other individuals or groups when things go wrong. They may resent suggestions for improvement, and become defensive to minimize culpability rather than take the initiative to maximize achievements. All these actions are detrimental to the project organization.

While these symptoms can occur in individuals at any organization, they are compounded if the project team consists of individuals who are put together from different organizations. Invariably, different organizations have different cultures or modes of operation. Individuals from different groups may not have a common loyalty and may prefer to expand their energy in directions most advantageous to themselves instead of to the project team. Therefore, no one should take for granted that a project team will work together harmoniously just because its members are placed physically together in one location. On the contrary, it must be assumed that good communication can be achieved only through the deliberate effort of the top management of each organization contributing to the joint venture (Hendrickson 1998)..

2.2 Team Building and Selection

Businesses are using teams with great frequency (Gordon 1992, Lawler et al. 1995, Gerard 1995), creating a pressing demand for understanding effective team design. Although plans and project management techniques are necessary, it is the people, the project managers and the project team members, who are the key to project success. The success of these teams is highly dependent upon the people involved in the project team. This makes project team selection an important factor in project success. Project team selection can be defined as selecting the right team members, who together will perform a particular project/task within a given deadline. Teams are a popular participative management tool and there is considerable agreement that team structure will play an increasingly prominent role in organizations. Given the important role of team composition, a variety of predictors for individual performance in teams have been proposed and researched.

2.2.1 Personality-based Selection

During the 1980s and 1990s, several researchers focused on selecting team members based on their personality (Barry & Stewart 1997; Driskell et al. 1987; Hogan & Hogan 1989; Hogan et al. 1988; Smith-Jentsch et al. 1996). Specific research with the Big Five personality traits has been especially promising in predicting teamwork performance. In psychology, the Big Five personality traits are five broad domains or dimensions of personality that are used to describe human personality. The theory based on the Big Five factors is called the Five Factor Model (FFM) (Stevens and Campion 1994). The Big Five factors are:

a. Openness to experience: An appreciation for art, emotion, adventure, unusual ideas, curiosity, and variety of experience. Openness reflects the degree of intellectual curiosity, creativity and a preference for novelty and variety. Some disagreement remains about how to interpret the openness factor, which is sometimes called "intellect" rather than openness to experience.

b. Conscientiousness: A tendency to show self-discipline, act dutifully, and aim for achievement. A tendency for planned rather than spontaneous behavior. Being organized and dependable.

c. Extraversion: Exhibiting energy, positive emotions, surgency, assertiveness, sociability and the tendency to seek stimulation in the company of others, and talkativeness.

d. Agreeableness: A tendency to be compassionate and cooperative rather than suspicious and antagonistic towards others.

e. Neuroticism: The tendency to experience unpleasant emotions easily, such as anger, anxiety, depression, or vulnerability. Neuroticism also refers to a person's degree of emotional stability and impulse control, and is sometimes referred by its low pole – "emotional stability".

The Big Five model is a comprehensive, empirical, data-driven research finding. Identifying the traits and structure of human personality has been one of the most fundamental goals of psychology. The five broad factors were discovered and defined by several independent sets of researchers. These researchers began by studying known personality traits and then factor-analyzing hundreds of measures of these traits (in self-report and questionnaire data, peer ratings, and objective measures from experimental settings) in order to find the underlying factors of personality.

Neuman & Wright (1999) investigated team members for over a year and found that the personality traits of agreeableness and conscientiousness predicted both team and individual team performance. Thomas et al. (1996) have proposed that the self-efficacy of teamwork and self-monitoring can impact team effectiveness, although individual team performance behaviors have not yet been investigated (McClough & Rogelberg 2003). These studies have demonstrated that personality-based selection is useful in general; however ability-based selection strategies have historically been more successful in predicting performance (Hunter 1986; Gooding et al. 1984).

2.2.2 Ability-based Selection

In an effort to explore the specific knowledge and skills that affect individual-level performance in teams, there are two major areas that previous research focused on: technical skills and social and interpersonal skills. One example is Virtual Team Design (VDT), which was developed based on contingency theory (Jin & Levitt, 1996). They provided the thinking that there is no best way to organize a project team to lead a project, or to make decisions. Instead, the optimal course of action is dependent upon the internal and external situation. The VDT method addresses coordination needs, due to activity interdependency, and provides a simulation based team selection approach that matches the individual's capacity to handle all tasks, from direct work to coordination and institutional efforts. These historical team selection studies focused on how managers could select potential workers based on individual characteristics consistent with individual performance. An input/output model of how VDT works is shown in Figure 3.

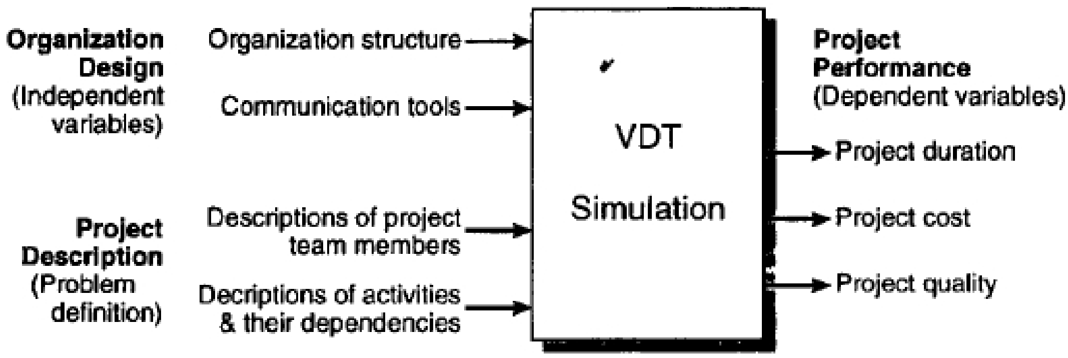


Figure 3. Input and Output of VDT simulations (Jin & Levitt 1996)

VDT takes into consideration the relative match between the complexity of each task versus the skills/experience of the assigned actor to determine the time it would take for the actor to perform the task, and the probability of exceptions, i.e. the likelihood of taking more time to executive task by the assigned actor. Actors are more likely to generate exceptions when confronted with a task for which they do not possess the requisite skills or experience. VDT models exception handling processes to deal with any exceptions that have been generated. Exceptions take time to resolve and result in coordination costs. Actors may be required to partially or completely rework activities that generate exceptions. Further, actors need to attend to communications from other actors and may need to attend scheduled meetings. These communications and meetings generate coordination work and thus increase the amount of total work that must be done to complete a project. Failure to attend to communications or go to meetings increases the probability of errors, thus leading to the possibility of increased downstream coordination and rework costs. VDT has been calibrated to make accurate predictions of participant backlogs arising from the combination of direct Production Work and emergent Coordination Work, and of the resulting schedule and quality risks for a given project organization.

Other than considering technical skills for team selection, Stevens and Campion (1994) reviewed relevant team research and outlined fourteen probable individual-level knowledge, skill, and ability (KSA) requirements for teamwork. This research did not focus on the technical KSAs required by jobs. It focused more on KSAs which are required or made more salient by the distinctive nature of teamwork situations, such as increased social and interpersonal requirements. The authors focused on formal teams that have specific tasks, with the expectation that the teamwork requirements would be especially applicable to semi-autonomous or self-managing teams. They also focused on the KSAs which are unique to the team-oriented situation itself, regardless of the specific team task, and on knowledge of appropriate behaviors rather than personality or dispositions for teamwork.

Possible teamwork KSAs were identified through a review of literature on groups from a variety of fields, including organizational psychology, social psychology, socio-technical theory, and industrial engineering (Stevens & Champion 1994). The proposed teamwork KSAs fell under two main categories - Interpersonal and Self-management, with five subcategories and 14 specific factors. Interpersonal KSAs include the subcategories of Conflict Resolution, Collaborative Problem Solving, and Communication. Self-management KSAs include the subcategories of Goal Setting and Performance Management and Planning & Task Coordination. Interpersonal KSAs (10 out of the 14 KSAs) were generally defined as the skills necessary to maintain healthy working relationships and to react to others with respect for ideas, emotions, and differing viewpoints. Less emphasis was placed upon self-management KSAs (4 out of the 14 KSAs), which encompassed the abilities team members must possess to perform essential management activities such as goal setting and planning. In the same article, the authors presented a multiple choice test designed to assess knowledge of the 14 teamwork KSAs. Item development employed standard test construction procedures including writing situational questions based upon the teamwork KSA content domain, pilot testing the instrument, and eliminating or revising items based on difficulty and discriminability. The test contains 35 situational judgment items and uses a multiple-choice testing format. Examinees are presented with hypothetical team situations and asked to indicate how they would respond to each situation by selecting among the alternatives given. After developing the teamwork KSA test, two validation studies were conducted using supervisor and peer ratings of job performance as the criteria (Stevens and Champion 1999).

There is substantial evidence that selecting people who can work well together is crucial to performance. Studies support the importance of cohesion (Beal et al. 2003, Gully et al. 1995), collective efficacy (Gully et al. 2002), effective team conflict (De Dreu and Weingart 2003), and functional transactive memory (Liang et al. 1995, Moreland et al. 1996) to team performance. Beal et al. (2003) examined issues relevant to applied researchers by providing a more detailed analysis of the criterion domain. They investigated the role of components of cohesion using meta-analytic methods and in light of different types of performance criteria. The results revealed stronger correlations between cohesion and performance when performance was defined as behavior, when it was assessed with efficiency measures and as patterns of team workflow. Gully et al. (2002) utilized meta-analytic techniques to examine level of analysis and interdependence as moderators of observed relationships between task-specific team-efficacy, generalized potency, and performance. 67 empirical studies yielding 256 effect sizes were identified and meta-analyzed. Their results demonstrated that relationships are moderated by level of analysis, and that team-efficacy and potency are positively related to team performance. De Dreu and Weingart (2003) proposed a study to provide a meta-analysis of research on the interrelationships between relationship conflict, task conflict, team performance, and team member satisfaction. They affirmed that the results of their study consistent with past theorizing and revealed strong and negative correlations between relationship conflict, team performance, and team performance. In contrast to what has been suggested in both academic research and introductory textbooks, however, their results also revealed strong negative correlations between task conflict, team performance, and team member satisfaction. Moreover, their research proved that conflict had stronger negative correlations with team performance in more highly complex tasks. Task conflict was less negatively related to team performance when task conflict and relationship conflict were weakly, rather than strongly, correlated.

In highly interdependent teams, task and contextual skills may be so tightly intertwined as to be almost indistinguishable (LePine et al. 2001, Morgeson et al. 2005). Research indicates that an individual's teamwork knowledge and social skills are stronger predictors of contextual performance (i.e., building social networks and support) than are any of the Big Five personality traits (Morgeson et al. 2005). Although these individual attributes are crucial inputs in team design and point to the crucial role of support work to performance, they do not encompass all the ways people act interdependently and thus are limited in their ability to predict how well people will work together.

2.2.3 The Evolution of Team Selection

As mentioned in the literature review, personnel selection research focused on how managers could select potential workers based on individual characteristics consistent with individual performance. Although it is simpler to study team performance as a an accumulation of individual contributions and assuming each person's contribution is independent of others, many researchers have realized the importance of interdependence and nonadditive contributions (Hinds et al. 2000, Tziner and Eden 1985, Salas et al. 1992).

Management researchers have most commonly studied task interdependence as an input of team work (Thompson 1967; Jin & Levitt 1996), but interdependence encompasses four components (Pennings 1974):

a. Task: the flow of work between members;

b. Role: the positions of team members with respect to each other;

c. Social elements: the mutual needs or goals of members; and

d. Knowledge: the differentiated expertise of the members.

Thus, individual team players depend on each other in many ways. They depend on teammates for expertise, organizing skills, sharing of the workload, emotional support, communication, boundary management, and numerous other activities. A consequence of this multidimensional interdependence is that performance is unlikely to be an additive function of the actions of independent individuals. As Tziner and Eden (1985) discovered, highly skilled teams far outperformed the levels predicted from summing their skill levels, and low-skilled teams underperformed the predicted level of their summed skills in the study of military tank crews. Tziner and Eden used these observations about synergistic performance to offer detailed recommendations for building three-man tank crews from the existing candidate pool. They noted that switching operators between crews was not a zero-sum game in which one team lost what the other gained. Instead, some combinations of players performed better or worse than others. Therefore, they recommended that organizing a few teams with only high-ability members and many somewhat-low ability teams to maximize performance across teams. They also found that this mixture better maximized the sum performance of multiple teams than just spreading the talent around.

Sports teams have faced similar challenges. To create expansion teams in 1997-2000, the National Hockey League (NHL) recognized the importance of interdependence on the performance of existing teams and allowed each team to protect a core group of players from being chosen when new teams were being formed. In the expansion drafts between 1997 and 2000, each team could protect up to five defense-men, nine forwards, and one goaltender, or up to three defensemen, seven forwards, and two goaltenders. The NHL allowed new franchises to select one player from among the unprotected players in each existing franchise to create a team. Even though the best available player typically ranked around or above the average in performance for their original teams, the new franchises consistently ranked lowest in their divisions for the first five years after formation. The NHL corrected slightly by lowering the size of the protected core, thus increasing the average skill level of available players. There was no change in the performance of newly formed franchises no matter how individually capable, rarely had any history of working interdependently with new teammates. The expansion teams' lower performance during their initial years highlights the importance of interdependence on team performance. There are many similar cases in sports teams, such as the New York Yankees in Major League Baseball (MLB) in 2008, the Miami Heats in the National Basketball Association (NBA) in 2011, and the Los Angeles Lakers in the NBA in 2013.

These illustrations exemplify the situation many managers face. Managers have a fixed group of workers who must be arrayed into functioning teams. Including a person in one team may prevent that person from helping members of another team. If the evidence suggests that when interdependencies exist among workers, team performance is not additive (i.e., Hinds et al. 2000, Tziner & Eden 1985, Tannenbaun et al. 1992), then moving a person from one team can help that team more than it hurts the receiving team, or vice versa. There is little work on how managers should ideally create teams out of interdependent workers, but there are empirical observations on how individual workers select work partners and how these preferences affect productivity. When given the choice, workers choose others who, among other traits, are highly effective at working interdependently with them. There is consistent evidence that workers will construct their own work teams by choosing to work with others with whom they are personally most effective.

Although previous research has extensively studied team selection based on numerous characteristics including personal skills, contextual skills, and even workers' interdependency, work teams are complex, adaptive systems (Ilgen et al. 2005; McGrath et al. 2000). Personnel selection practices have focused on individual knowledge, skills, abilities, but have largely ignored the complexity of team selection. Dealing with complexity is far from straightforward because problem solvers cannot optimize each part individually (Baumann & Siggelkow 2012). Consider, for instance, the challenge faced by managers who need to understand how a change to a firm's set of activities at one stage of the value chain may affect other parts of the value chain and require further adjustments there as well. Thus, optimizing individual stages without taking interdependencies into account is unlikely to yield a high performing new combination of activity choices. Similarly, consider a program manager who selects teams to work together to complete concurrent projects. If the manager wants to create a high-performing program, he/she cannot optimize the project teams individually, but needs to pay attention to the entire organization in different environmental conditions. As documented by a large body of research, problem solvers often do not deal with complexity by calculating optimal solutions, but rather engage in an adaptive search for satisfactory ones (Nelson & Winter 1982; Baumann & Siggelkow 2012).

MaGrath et al. (2000) argued that the study of groups needs to be regrounded in the reality of group life as it occurs in the world. They suggested that future research should acknowledge and study groups as embedded not only within a hierarchy of levels, from the individual to the interpersonal to the embedding contexts of organizations, networks, and institutions, but also within the passage of time. Groups are bounded, structured entities that emerge from the purposive, interdependent actions of individuals. Groups bring together individuals who carry their pasts with them, and groups create their own history, guided by members' sense of the future, as they operate in time.

In the same article, MaGrath et al. (2000) proposed that groups are complex adaptive systems. They are not simple, isolated nor static. Instead groups are complex entities embedded in a hierarchy of levels and characterized by multiple, bidirectional, and nonlinear causal relations. They are intricately embedded within, and have continual mutual adaption with, a number of embedding contexts. They are inherently dynamic systems, operating via processes that unfold over time, and that are dependent on both the group's past history and anticipated future. Groups develop as systems over time, and change as a function of changing conditions over time. Studying groups as complex adaptive systems Arrow et al. (2000) draw on concepts from general systems theory and from complexity and chaos theory. They then discussed the implications of this theory for conducting research and described a combination of research strategies that together hold promise for studying groups in a way that views complexity, adaptation, and dynamic cross-level interaction as essential characteristic of groups.

They also regarded groups as open and complex systems that interact with the smaller systems (i.e. the members) embedded within them and the larger systems (e.g. organizations, communities) within which they are embedded. Groups have fuzzy boundaries that both distinguish them from and connect them to their members and their embedding contexts. Throughout a group's life, three levels of causal dynamics continually shape the group. Local dynamics involve the activity of a group's constituent elements: members engaged in tasks using tools and resources. Local dynamics give rise to group-level or global dynamics. Global dynamics involve the behavior of system-level variables- such as norms and status structures, group identity and group cohesiveness, leadership, conflict, and task performance effectiveness that emerge from and subsequently shape and constrain local dynamics. Contextual dynamics refer to the impact of system-level parameters that affect the overall trajectory of global group dynamics over time, and whose values are determined in part by the group's embedding context. Levels of organizational support, the supply of potential members, the demand for group outputs, and other extrinsic factors shape and constrain the local and global dynamics of a group.

All groups act in the service of two generic functions: (a) to complete group projects and (b) to fulfill member needs. A group's success in pursuing these two functions affects the viability and integrity of the group as a system. Thus, system integrity becomes a third generic group function, emergent from the other two. A group's system integrity in turn affects its ability to function effectively in completing group projects and fulfilling member needs, and to adapt to changes in demands and opportunities presented by the environment and by the group members. Groups include three types of elements: (a) the people who become a group's members, (b) the intentions that are embodied in group projects, and (c) the resources that comprise the group's technologies. Group members vary in what they bring to the group in terms of skills, values, attitudes, personalities, and cognitive styles. They also differ in demographic attributes, and in the needs they seek to fulfill via group membership. Group projects vary in the opportunities for and requirements imposed on members for various kinds of activities. Technologies, which include the "software" tools of norms and procedures as well as "hardware" tools (e.g., hammers, computers, trucks, and musical instruments) differ in what kinds of activity and instrumental functions they facilitate.

Groups pursue their functions by creating and enacting a coordinated pattern of member-task-tool relations that are called the coordination network. The full coordination network includes six component networks: (a) the member network (member-member relationships such as friendship, hostility, and influence); (b) the task network (task-task relations such as their sequencing relations); (c) the tool network (tool-tool relations, such as the need for clustering particular hardware and software tools); (d) the labor network (member-task relations, which specify who is to do what); (e) the role network (member-tool relations, which specify how members will do their tasks); and (f) the job network (task-tool relations, such as what tools are required to complete particular tasks effectively). The life course of a group can be characterized by three logically ordered modes that are conceptually distinct but have fuzzy temporal boundaries: formation, operation, and metamorphosis. As a group forms, people, intentions, and resources become organized into an initial coordination network of relations among members, projects, and technology that demarcates that group as a bounded social entity. As a group operates in the service of group projects and member needs, its members elaborate, enact, monitor, and modify the coordination network established during formation. Groups both learn from their own experience and adapt to events occurring in their embedding contexts. If and when a group undergoes metamorphosis, it dissolves or is transformed into a different social entity. All three levels of causal dynamics simultaneously and continuously operate in all three modes of a group's life. Local dynamics are manifested in a group's coordination processes, global dynamics reflect a group's developmental processes, and contextual dynamics underlie a group's adaptation processes (McGrath et al. 2000).

In sum, the team selection processes should not only consider individual ability, but also the whole complex system including its interdependencies. The evolution of team selection is shown in Figure 4. Interdependence has many components. Management researchers have most commonly studied task interdependence (Jin & Levitt 1996; Thompson 1967), but interdependence encompasses four components: task (the flow of work between members), role (the positions of the team members relative to each other), social elements (the mutual needs or goals of members), and knowledge (the differentiated expertise of the members) (Pennings 1974; Millhiser et al. 2011). Therefore, in order to fully understand the complexity of the team selection processes in project-based organization I will review what factors of project complexity need to be considered.

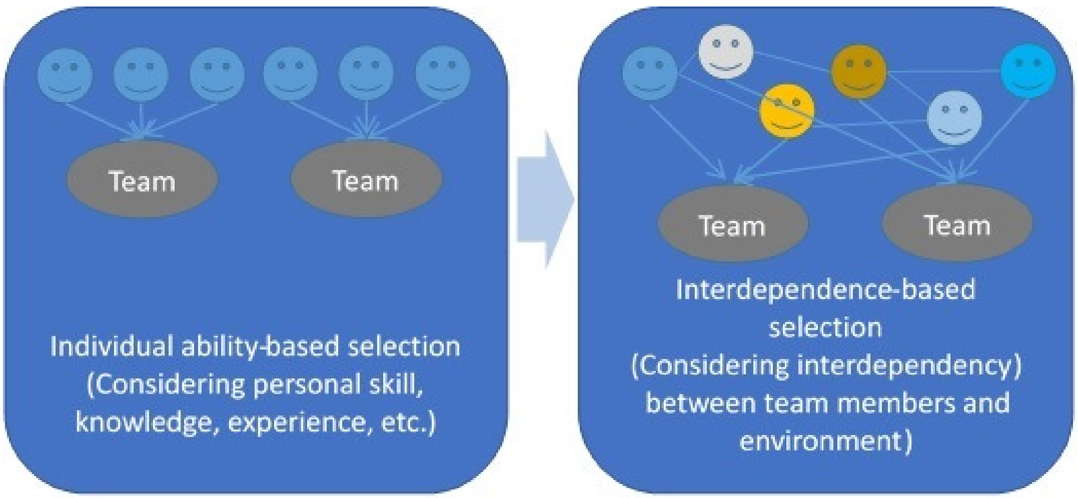


Figure 4. Evolution of Team Selection

2.3 Project Complexity

It is important to note that even the word "complexity" is difficult to understand. Geraldi (2008) states that mastering complexity is not a new challenge but an old one that is being increasingly recognized and accepted. While projects and project management are associated with complexity, many have difficulty understanding the concept and do not regard a project as a complex system, which leads to very negative consequences. Projects are complex in part because they represent something unique. And because they are unique, they have an element of uncertainty with regard to their execution that often results in re-work and added time and costs. Often there is insufficient time to make decisions, and it is easy to become involved in the details, losing sight of the overall goals and objectives. Time pressures on decision-making can lead to mistakes, especially if the goals are not explicit, the team has not worked together before, and there is a large number of stakeholders struggling to comprehend a significant amount of information.

One of the strongest claims of the scientific revolution is that science provides a more objective and better description of the natural world compared to other ways of knowing. However, the 'real-world' of human affairs seems to us to be different than the world simplified by science - we experience it as complex, or more complex than the world and the issues that are usually addressed in 'normal' science and its methods. Broadly we can say that in some explanations, complexity has been understood as an intrinsic property of a certain kind of system, or as occurring in certain kinds of natural and social phenomena. The kind of complexity emerging from this understanding can be called 'descriptive complexity'. All the attempts that have been made to quantify it or to achieve a quantitative measure of complexity might be included in this category. In other explanations, complexity has been understood as the result of a distinction resulting from a particular perception of a situation (of complexity) made by an observer, what can be denominated as perceived complexity (Schlindwein & Ison 2004). In the following sections, the review of project complexity is divided into two parts as descriptive complexity and perceived complexity to discuss.

2.3.1 Descriptive Complexity

In recent years, the study of complex systems in a unified framework has been recognized as a new scientific discipline, the ultimate in interdisciplinary fields (Bar-Yam 2003). Koch and Laurent (1999) stated that complexity is a useful framework for better understanding the most complex system – the brain. Weng et al. (1999) developed approaches that combined simulation techniques and Monte Carlo methods to analyse complex signalling networks in biological research. Chemistry has emphasized the approximation of complex nonlinear processes by simpler linear ones. Complexity has also been described as a profitable approach not only in chemistry but also for a wide range of problems, especially in the life sciences (Whitesides & Ismagilow 1999). The development of artificial neural networks (ANNs) is one example of a successful transfer of information about a complex biological system to nonbiological applications (Binder, 2008).

Advanced technologies and biology have extremely different physical implementations, but they are far more alike in system-level organization than is widely appreciated. Recently, engineering systems have begun to reach almost biological levels of complexity. The components of a Boeing 777, for example, consist of 150,000 different subsystem modules, organized via elaborate protocols into complex control systems and networks, including roughly 1,000 computers that automate all vehicle functions. Commercial aircraft are not the only systems undergoing such acceleration in complexity as a result of advanced control and embedded networking; all technologies are evolving similarly (Csete & Doyle 2002).

Additionally, complexity theory has been broadly applied in the social sciences, including economics, psychology, and organizational science. Complexity portrays the economy not as deterministic, predictable, and mechanistic, but as process-dependent, organic, and always evolving. The major difference between complexity in economics and complexity in science is that economic elements react with strategy and foresight by considering outcomes that might result as a consequence of behavior they might undertake (Arthur 1999). Human behavior adds a level of complication to economics that is not experienced in the natural sciences. Previous research in psychology indicates that language and culture are two salient aspects that need to be considered in measuring complexity scores in communications (Suedfeld & Leighton 2002). Complex information processing demands more time, energy, emotion, and material resources. Although the result may be a better understanding of the problems and possible solutions, it may also produce information overload, internal contradiction, and confusion (Suedfeld & Leighton 2002). In organizational science, researchers use nonlinear methods to describe complex systems whose behavior cannot be explained by breaking down the system into its component parts (Svyantek & Brown 2000).

The concept of complexity has expanded into the area of project management in recent years. As one of the first investigators, Baccarini (1996) proposed that the definition of project complexity be "consisting of many varied interrelated parts" and be calibrated in terms of differentiation and interdependency in construction project management.. After that, there followed several works on the concept of complexity (Thomas & Mengel 2008; Vidal & Marle 2008; Geraldi 2009; Bosch-Rekveldt et al. 2010). There is, however, a lack of consensus on what constitutes project complexity (Vidal & Marle, 2010). Based on some previous research (Baccarini 1996; Austin et al. 2002; Vidal & Marle 2008), Vidal et al. (2010) propose this definition for complexity of a project: “the property of a project that makes it difficult to understand, foresee and keep under control its overall behaviour, even when given reasonably complete information about the project system.” Previous research developed various ways to classify project complexity. The most broadly used classifications of project complexity are divided into two primary areas – technical and organizational (Baccarini 1996; Vidal & Marle 2008; Boushaala 2010)

2.3.1.1 Technical Complexity

The technical aspects are the degree of difficulty in building the project, whereas the business scope, such as schedule, cost, risk, and communications, represent organizational complexity (Malzio et al. 1988; Schilindwein & Ison 2004). The technical aspect of a project and service may be viewed as the development of specifications that lead to a design that meets the client’s needs. Some characteristics such as the number of pieces, parts, components, subassemblies, and assemblies of the project, the number of technologies involved may represent technical complexity while items may be related to the industry, type of project, and discipline rather than a general listing of items that can cause complexity as well as the degree of complexity.

2.3.1.2 Organizational Complexity

The organizational complexity of a project includes the business aspects of the project, the staff working on it, the relationships between the project and other project, to name a few. There are many variables that can add complexity to the management of a project. Some characteristics such as financial arrangements that provide a smooth flow of cash to fund the project as the need for dollar resources occur. The simplest arrangement is to have an available fund to tap as the project's needs are realized. The most complicated or complex arrangement might be funding from several different sources without specific time commitments as to when the funds will be available. The design of the management structure should be straight forward with only the necessary managers involved for simplicity.

Project partnerships between two or more organizations increase the complexity and can cause delays in making important decisions needed to move the project forward. A steering committee may be appointed to make decisions on major projects, which may or may not add complexity. Schedules that lack sufficient detail to guide the project can add complexity without any derived benefit. A schedule that is too detailed can create an environment whereby staff excessively rely on it to guide their actions without properly thinking through consequences. On the other hand, a schedule that is too general may not provide critical guidance. Complexity can arise from either too much detail or not enough detail. Staffing a project with the proper skills and the proper number of individuals at the right time is the simplest solution. Complexity increases when the right skills are not available at the required number at the required time. In some instances, it may be that only a few critical skills are needed for a specified period of time. The lack of these skills hampers work from meeting proper performance standards. Organizational complexity increases as the design changes during the course of the project work and new staff is assigned. Whereas there will be changes to staff for a variety of reasons, new functions and arbitrary changes compromise the efficiency of the organization. Organizational interfaces add to complexity when the number exceeds three external parties. As a matter of fact and based on the presented scenario of complexity aspects, both technical and organizational complexity have great influence on whether a project successfully fulfills its objectives (Boushaala 2010).

Using technical and organizational categories, Vidal and Marle (2008) presented a detailed project complexity framework and integrated four components that included project size, project variety, project interdependence, and project context for software systems. Moreover, Bosch-Rekveldt et al. (2010) indicated that the current project complexity framework should add environmental elements as an essential component of the model. Their new project complexity framework would then be comprised of technical, organizational, and environmental (TOE) categories. In addition to the definition and classification framework, some researchers have tried to develop models for managing project complexity (Gidado 1996; Pich et al. 2002; Sommer & Loch 2004). A great number of project-complexity-related studies have been conducted that demonstrate the importance of complexity. Certain project characteristics provide a basis for determining the appropriate managerial actions required to complete a project successfully. Complexity is one such critical project dimension. Practitioners frequently describe their projects as simple or complex when they are discussing management issues. This indicates a practical acceptance that complexity makes a difference to the management of projects. It is not surprising that complex projects demand an exceptional level of management and that the application of conventional systems developed for ordinary projects have been found to be inappropriate for complex projects.

2.3.2 Perceived Complexity

Casti (1995) recognized the role of the observer in the acknowledgement of complexity. He defined that complexity is an inherently subjective concept; what is complex depends upon how people look. In contrast to 'descriptive complexity', the epistemological assumptions of 'perceived complexity' are related to epistemologies based on the assumption that reality results from distinctions made by an observer. According to these epistemologies, the explanations we make about the world are not independent of us as explainers. However, this kind of epistemology has been associated with subjectivism, which, according to mainstream scientific thinking, is opposed to objectivism, and therefore very often has been considered non-scientific, since objectivism is one of the core assumptions of classical scientific thought.

The epistemological problem of complexity raises some fundamental cognitive issues on how human beings know about the complexity of the world they live in. For instance, from the perspective of descriptive complexity, and considering the strong influence of objectivity in science, the verification of whether the behavior of a (natural) system is linear or non-linear frequently has been used as a criterion to validate its complexity. However, we are not keen to provide an externalist explanation of complexity. Instead, we assume here that none of us share a common experiential world. All we have at our disposal is our ability to communicate about our worlds of experience and, sometimes, a history of living in a common culture, including language, over a period of time. The sharing of a common culture allows us to appreciate the apparent paradox between our individual and unique cognitive histories and our experience that {{collectively we do not experience the world in relative or subjective (meaning here the lack of regularities) ways. And it is this unique cognitive history we each have as human beings that is denied when only an objective explanation of complexity is pursued and accepted as scientifically valid.

A different cognitive approach can be found in Rescher (1998). He dedicates considerable space to discuss the cognitive aspects of complexity - or how human beings can know about the complexity of their world. In the development of knowledge, progress is always a matter of complexification, since nature is ontologically complex. He also claims the ontological simplicity of the real is somewhere between the hyperbolic and absurd, and the commitment of scientific method to simplicity is nothing more than a procedural principle of least effort. However, to assume that the commitment to simplicity results from the procedural principle of least effort is not only simplistic itself but also seems to deny any epistemology behind this approach. Furthermore, this kind of thinking reveals an epistemological commitment to objectivity, which is the basis of descriptive complexity. In other words, our cognitive limitations regarding complexity might be overcome by technology. This seems to miss the point. {{Your argument in these past few sentences is unclear.}}

To admit human experience as key to our understanding of complexity does not mean that everything said or done is valid or even that we will find as many perceptions of complexity as living human beings. Although the number of possible perceptions of complexity may appear to be infinite, the diversity of these perceptions will be constrained through human community life, the sharing of culture and history, and through collective interests and preferences. The contrary is nothing more than a fallacy frequently used by those who adopt an objectivist epistemology to make explanations about the world, and deny any other approach as plausible. The claim being made here about complexity is, therefore, that its recognition is a cognitive process prescribed by the biological structure of human beings, rather than as already existing in the objects of the world and which can be identified and measured. It is therefore of great interest to investigate the interrelationship between biology and epistemology, and how to address the epistemological problem of complexity from the perspective of the biology of cognition, because we must be aware that the extent to which we as human beings can know about the complexity of the world is constrained by our cognitive limitations.

Perceived complexity is therefore necessarily related to complexity thinking. Complexity thinking is based on the assumption that subject and object, although not the same, are not radically separate. A complete separation would make knowledge impossible (Schlindwein & Ison 2004). As claimed by Casti (1995), complexity resides as much in the eye of the beholder as it does in the structure and behavior of a system itself. And for Morin (1983) the kind of complex thinking he is suggesting requires the reintegration of the observer with his observation (Schlindwein & Ison 2004). In Morin's opinion, whereas traditional epistemologies are characterized by disjunction and fragmentation, complexity thinking is a kind of thinking capable of rejoining, or contextualizing knowledge (Morin 1999; Schlindwein & Ison 2004). To some extent the epistemological problem of complexity can be considered a particular case of the more general epistemological problem of how we human beings know about the world, and what constitutes evidence about that world.

In summation, there are several characteristics of project complexity:

a. Project complexity helps determine planning, coordination and control requirements.
b. Complexity is an important criterion in the selection of an appropriate project organization form.
c. Project complexity influences the selection of project inputs, such as the expertise and experience requirements of management personnel.
d. Complexity is used as a criterion in the selection of a suitable project procurement arrangement.
e. Complexity affects objectives of time, cost and quality.
f. Project complexity should be evaluated by the standards of both descriptive and perceived complexity (objective and subjective aspects).

In recent years, governments have focused on environmental issues, so they may add new carbon policies to limit emissions from operating projects. Additionally, this kind of action will significantly increase project complexity (Hsu & Cui 2011). Increasing project complexity will impact the project life cycle and also increase the cost and schedule of projects. Broadly, the higher the project complexity the greater the time and cost is. Therefore, understanding the complexity of a project is an urgent issue for the construction industry.

2.3.3 Project Complexity Framework

In order to attend the first goal of this research – to better understand project complexity, a construction project complexity framework (shown in table 1) based on a descriptive complexity perspective is developed through literature reviews in this chapter. Whatever the vision of complexity one has, a project system can be considered as a complex system. Understanding a complex system requires understanding the historical processes and interactions that led to the development of consistent patterns of behavior across time (Svyantek & Brown 2000).

Table 1. Elements of Project Complexity

	Project System Size	Project System Variety	Interdependencies Within the Project System	Context
Technical Complexity	Number and quantity of resources Number of data exchanges	Variety of technologies Variety of resources Variety of technological skills Type of data exchange	Interdependence among the components of the project Resource and raw material interdependencies Technological processes dependencies	Technological innovation Interactions with the environment
Organizational complexity	Size of capital investment Number of activities Number of decisions to be made Number of objectives Staff size Number of investors Number of stakeholders Number of structure/groups/ teams/ to be coordinated Number of deliverables Number of projects sharing resources	Diversity of staff Variety of financial resources Variety of organizational skills Variety of organizational interdependencies Variety of managerial scope and methods	Resources sharing at program level Interdependence of objectives Processes interdependence Interdependence among project entities and stakeholders Project team cooperation/disagreement Customer satisfaction Subcontractor relationships Dynamic team structure	Organizational innovation Organizational culture Community involvement Public communication

Construction projects have major challenges that other projects may not have to the same degree, such as larger project sizes, longer durations, and greater unknown risks, including labor safety, government policy change, environmental constraints and more. Hsu and Cui (2011) provide a project complexity framework on construction project characteristics. The construction project complexity factors can be classified into two primary categories, technological complexity and organizational complexity. These in turn can be viewed through four aspects. The first aspect is project size. The size of the project system appears to be a necessary condition for project complexity. Corbett et al. (2002) indicated that an organizational system should meet a minimum critical size to be considered a complex system. The second aspect is project variety. Diversity relates closely to the number of emergent properties and is a necessary condition for project complexity. The third aspect encompasses the interdependencies within the project system.

Previous research shows that interdependencies are likely to be the greatest drivers of project complexity. Rodrigues and Bowers (1996) suggested that traditional project management tools are not sufficient to encompass the reality of interdependence. Calinescu (1998) proposed that each element depends on and influences the others. In construction project processes, numerous kinds of technologies and trades use varying methods and tools. Each requires access, space, and time to carry out its objectives, and they often overlap. The number of roles involved in each of the different technologies may vary and are quite often interdependent on one another in a number of ways, depending on the time and location in which they are carried out on site. Finally, the fourth one deals with context-dependent project complexity (Gidado, 1996; Baccarini, 1996; Sinha et al., 2001; Laurikkala et al., 2001; Vidal & Marle., 2008). Context is considered the common denominator of any complex system (Chu et al., 2003). Consequently, project complexity can neither be analyzed nor managed without considering the implications of the project context.

This descriptive complexity framework aims to be a reference for project managers to identify and characterize some aspects of project complexity. They can understand a project's complexity more efficiently through this framework. Even though the framework was developed through a comprehensive literature review, some other project complexity factors could be added to the framework, especially since project complexity research is still at an early stage.

This research focuses on exploring how to utilize complexity theory to examine team selection processes. We know that individual team members depend on each other in many ways. They depend on teammates for expertise, organizing skills, sharing of the work load, emotional support, communication, boundary management, and numerous other activities. A consequence of this multidimensional interdependence is that performance is unlikely to be an additive function of the actions of independent individuals. Thus, we would like to utilize complex system theory and agent-based modeling to model team selection and demonstrate the interaction between workers and the environment.

2.4 Complex Adaptive Systems

The complexity paradigm is a new approach and a useful perspective for understanding complex phenomena in industries (Choi et al. 2001; McCarthy 2003). Recent research has shown that phenomena consisting of many constraints and conflicting demands, i.e.

complex systems, can be studied and evaluated by models and methods derived from a complexity perspective. The complexity paradigm has been used to facilitate understanding in other fields such as knowledge management (McElroy 2000; Stacey 2000), organization science (Anderson 1999), strategy (Beinhocker 1999; Pascale et al. 2000; Tasaka 1999), and construction (Brown et al. 2012), to name a few.

A CAS is a special kind of complex system since it has the property of adaptation, meaning that it has the "ability to consciously alter its system configuration and influence its current and future survival" (McCarthy 2003). "Complex" implies diversity – a wide variety of elements. "Adaptive" suggests the capacity to alter or change – the ability to learn from experience. A "system" is a set of connected or interdependent things. An agent may be a person, a molecule, a species or an organization, among many others. These agents act based on local or surrounding knowledge and conditions. A central body, master neuron, or a project manager does not control the agent's individual moves. A CAS has a densely connected web of interacting agents, each operating from its own schema or local knowledge. In a construction project context this means that the entities in the system are responsive, flexible, reactive and often deliberately proactive to inputs from other entities which affect them. In the subsequent discussion, we will present and discuss four properties which characterize CAS:

a. CAS is represented by open dynamic systems which continually exchange information and energy with the surrounding environment (Beinhocker, 1997; Gell-Mann 1994).
b. A CAS consists of several agents which dynamically act in correlation and interdependence on each other (Bar-Yam 2003). The agents act according to

certain organizational policies and in response to other agents, creating non-linearity in the system (Beinhocker 1997; Pascale 1999; Stacey 2000).

c. The type of systems that CAS represents exhibit a common feature - emergence (Beinhocker 1997; Choi et al. 2001; Stacey 2000). Emergence could be described as the outcome of collective behavior, i.e. interactions among agents (elements, individuals, etc.) performing something individually, or together, which creates some kind of pattern or behavior which the agents themselves cannot produce (Bar-Yam 2003; Gell-Mann 1994; Goodwin 2000; Lissack 1999). Epstein (1999) gives an illustrative example of emergent properties; "people can have happy memories of childhood while, presumably, individual neurons cannot". This means that the behavior of a CAS is unpredictable and often counter-intuitive (Bonabeau 2002) and contributes to a co-evolutionary process among the agents. It also means that new opportunities are always being created by the system. Moreover, as Bonabeau (2002) claims, the only way to analyze and understand emergent phenomena is to model them from the bottom up.

d. It is through the interaction between entities that emergence occurs in the process of self-organization. This process of self-organization can only be successful in open systems because of the need for energy. However, even though CAS never reaches states of equilibrium, order still emerges. As described by Anderson (1999), "order arises in complex adaptive systems because their components are partially, not fully, connected". Systems in which every element is connected to each other in a feedback loop are hopelessly unstable (Simon 2002).

When the scope of business issues is widened, the characteristics of business processes and phenomena become increasingly non-linear, self-organizing, changing and rationally bounded. This happens when the interplay among different business functions and processes is to be considered. These characteristics are even more apparent when customers as well as suppliers are included in the analysis. Hence, the characteristics of CAS are very evident in a business context.

However, while insights from CAS can improve our understanding of project complexity and provides a helpful framework for modeling, some kind of method is needed in order to apply this approach and achieve tangible and understandable results, particularly from a management perspective. The rationale behind such a method is that this research has brought out that managers need to be able to test and evaluate different "what-if" scenarios, simulate policy changes or changes in behavior in order for them to understand and evaluate new ways of thinking and approaches to construction team building issues. In this regard, one modeling and simulation approach influenced by the complexity paradigm is ABM, derived partly from object-oriented programming and distributed artificial intelligence (Jennings et al. 1998), and partly from insights from the science of complexity (Axelrod 1997; Kauffman 1995). ABM provides a useful modeling and simulation approach for applying a complex adaptive system framework to create tangible, understandable results for managers.

2.5 Agent-based Modeling

Historically, the complexity of scientific models was often limited by mathematical tractability: when differential calculus was the only approach we had for modeling, we had to keep models simple enough to solve mathematically and so, unfortunately, we were often limited to modeling only simple problems. With computer simulation, the limitation of mathematical tractability is removed so we can start addressing problems that require models that are less simplified and include more characteristics of real systems. ABMs are less simplified in one specific and important way: they represent a system's individual components and their behaviors. Instead of describing a system only with variables representing the state of the whole system, we model its individual agents.

ABM represents a new paradigm in the modeling and simulation of dynamic systems distributed in time and space (Jennings et al. 1998; Lim and Zhang 2003). ABM enables the application of CAS approaches to address the behavior of each of the participants within a complex system (North et al. 2005). Since construction operations are characterized by distributed activities as well as decision-making, in both time and space, and can be regarded as complex, ABM is highly appropriate for these types of systems. There is a growing interest in using ABM in several business-related areas, such as manufacturing (Chun et al. 2003; Kotak et al. 2003; Lim & Zhang 2003; Zhou et al. 2003), and in logistics and supply chain management (Gerber et al. 2003; Kaihara 2003; Santos et al. 2003). ABM is considered important for developing industrial systems (Davidsson and Wernstedt 2002; Fox et al. 2000; Karageorgos et al. 2003) and it provides a pragmatic approach for the evaluation of management alternatives (Swaminathan et al. 1998), but just a few in construction- related industries (Watkins et al. 2009; Kim & Kim 2010).

In ABM, the focus is on agents and their relationships with other agents or entities (Axelrod 1997; Cicirello & Smith 2004; d'Inverno & Luck 2001; Jennings et al. 1998). Since the field of ABM is fairly new, no general agreement on the term agent has yet been established (Tripathi et al. 2005). Parunak et al. (1998) define an agent as being a software entity with its own thread of control able to execute operations without being externally invoked, while Jennings et al. (1998) define an agent as a self-contained, problem-solving entity. In this paper, agents are defined as real-life components identified in the context of interest, characterized by varying degrees of autonomy (i.e. execution ability and self-control), and with characteristics based on policies, behaviors, states, and constraints.

An organization is a collection of agents that interact and produce some form of output. Formal organizations, such as corporations and governments, are typically constructed for an explicit purpose, though this purpose need not be shared by all organizational members. An entrepreneur who creates a firm may do so in order to generate personal wealth but the worker she hires may have very different goals. As opposed to more amorphous collections of agents, such as friendship networks and societies at large, organizations have a formal structure to them with the prototypical example being a corporation's organizational chart. This structure serves to define lines of communication and the distribution of decision-making. Organizations are also distinguished by their well-defined boundaries as reflected in a clear delineation as to who is and who is not a member. This boundary serves to make the organization a natural unit of selection. For example, corporations are formed and liquidated, though they can also morph into something different through activities like mergers.

The primary task of organization theory is to understand how organizations behave and to identify and describe the determinants of organization performance. To take an agent-based approach means not having to assign an objective to an organization, and instead modelling the agents that comprise it with explicit attention to how decisions are made and how the interactions of these decisions produce organization output. The smallest decision-making unit is then required to be smaller than the organization itself. The anthropomorphic view associated with the theory of the firm – firms are profit-maximizers – is not an ABM. Though neoclassical economics has many ABMs of organizations, including agency theory and team theory, these models are generally quite restrictive in terms of the assumptions placed on agent behavior, the number and heterogeneity of agents, the richness of the interaction among agents, and the features of the environment. These restrictions are forced upon scholars by virtue of the limited power of analytical methods. To derive universal results requires limiting the size of one's universe. While some structures are relatively simple in their real form, organizations are inherently complex; they are their own brand of society, plagued with conflicting interests while dealing with multi-faced problems amidst a coevolving environment. Proving universal results is only achieved at the cost of severely restricting the richness of the setting.

A computational ABM uses the power of computing to create a robust model. A model is written down, parameter values are specified, random variables are realized, and, according to the agents' behavioral rules, agent output is produced. Organization output comes from the specified mapping from the environment and agents' actions into the output space.

2.5.1 The Bottom-up Approach

The core concept of ABM is the bottom-up approach by which an ABM model is constructed. Previous research provides a comparison of conventional top-down -oriented methodologies and agent-based bottom-up ones (Nilsson & Darley 2006). The comparison can be shown in Figure 5. The top-down methodologies are based on the assumption that knowledge is outside the system and someone can measure and analyze the observable phenomenon of interest and from that decompose it correctly to different sub-units where the sub-problems are solved separately. Then, at the end, the partial solutions are put together in a single overall solution (Kreipl & Pinedo 2004). While the top-down approach enables operation processes to be translated into mathematical equations for correct analytic solutions, it does not emphasize the relationships and dynamics in reality (Parunak et al. 1998). This is especially the case when the target modeling context is widened to include several dispersed functions or processes within a project or a company. Models which are constructed by global performance measures cannot cope with the dynamics of their constituent parts, since the observables are constructed of the aggregated behaviors of the whole system (Swaminathan et al. 1998). This top-down assumption is inherited from the positivistic paradigm, hence built on mechanistic assumptions and reductionism.

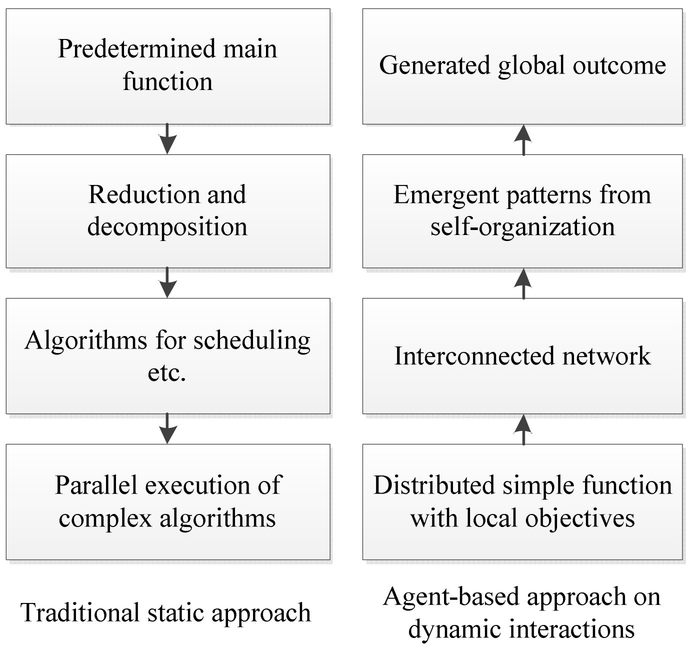


Figure 5. A comparison of top-down and bottom-up approaches (Nilsson & Darley 2006)

Bottom-up methodologies are instead based on a synthesizing philosophy, where the user presumes that he/she cannot understand the whole phenomenon of interest but can observe, on a micro level, specific activities and processes, and tries to understand their behavior and their objectives. These agents interact and communicate with other agents and they join to form a coherent whole on the macro level (d'Inverno & Luck 2001). Each agent's ability to make decisions based on information-processing rules creates the internal dynamics which form the behavior of the organization. The emergent behaviors cannot be predicted in advance. According to this regard, other researchers indicated that the user first needs to understand the concept of emergent phenomena in order to understand ABM (Jenning et al. 1998). Emergent phenomena are fundamental in complex adaptive systems. Global patterns emerge from the interacting and interrelated networks of agents. ABM is ideally suited to representing problems that have multiple perspectives and multiple problem solving entities (Jenning et al. 1998). Therefore, a bottom-up approach might seem to be advantageous in pragmatic research with empirical bounding. This means that, when it comes to modeling and simulation, there is no need to consider the whole phenomenon at once. The phenomenon should be constructed and developed in the process of building the model. Then focus can be placed on the local and distributed parts since they have their own working principles, behaviors, states, and constraints. With the use of simulations, emergent behavior can often be identified and understood.

2.5.2 Agents

There are many definitions of an agent in the ABM literature. An agent is said to be purposeful, autonomous, adaptive, and so on. While these terms serve to convey a sense of what the researcher is after, they only shift the question of "what is an agent?" In almost all models of organizations, an agent represents a human (Chang & Harrington 2005). Being purposeful may mean adjusting behavior to improve some measure of well-being; being autonomous may mean choosing actions even if they are in conflict with an organizational goal; being adaptive may mean modifying behavior in response to past experiences. Though the terms are vague, the way in which they are implemented has substantive consequences. There are differences between agents and objects although they seem similar in nature. Wooldridge (2002) indicates that an agent embodies a stronger notion of autonomy than objects. Jennings et al. (1998) explains autonomy as "objects do it for free; agents do it for money". Another distinction between an object and agent system is with respect to the notion of flexible, autonomous behavior. In general, objects are passive. They need, for example, to receive a message or something similar in order to become active. However, agents have internal mechanism for that. A third difference is that ABMs are considered to have their own thread of control, whereas in the standard object model, there is a single thread of control (Jennings & Bussmann 2003).

Typically, an agent is endowed with a utility function and, {{given beliefs over that which is unknown to the agent--}}, acts to maximize expected utility or, in an inter-temporal setting, the expectation of the discounted sum of utility. When an agent is making choices in a multi-agent context, and what is best depends on what others do (and this certainly describes an organization), ABM is augmented with the equilibrium assumption that each agent understands how other agents behave. This does not necessarily mean that agents know exactly what others will do, but they do know other agents' decision rules –

how private information maps into actions. Agents have complete understanding though may lack complete information.

In contrast to the assumption of a hyper-rational agent, it is standard in the computational ABM to assume agents are boundedly rational. The most concise statement of this modeling approach is that agents engage in adaptive searches that are subject to various cognitive constraints. These models may {{contribute to deploy the optimization framework --}}though assuming myopic optimization and the beliefs are empirically-based rather than the product of understanding what is optimal behavior for others. Agents observe but do not necessarily theorize. With this bounded rationality framework in place, models often provide a parameter by which one can "tune" the cognitive skills of an agent. When rules adapt to experience, a key parameter is how much experience an agent has as well as the size of its memory. In the context of information dissemination, the likelihood that an agent observes an innovation reflects a level of skill (DeCanio & Watkins 1998). For hill-climbing algorithms, agents may only evaluate alternatives imperfectly, where less skilled agents may have noisier evaluation or are constrained in the set of alternatives available to them, while more skilled agents are able to consider options in a wider neighborhood around their current practices (Kollman et al. 2000). A novel and promising approach is to assume that an agent has a "model" of how actions map onto performance, though the model is of lower dimensionality than reality.

2.5.3 Organizations

An organization is comprised of multiple agents, and indeed one common question in the literature is how the number of agents influences organization performance. But more than pure numbers is relevant, especially when agents are heterogeneous. There is an architecture to organizations, which we will elaborate upon momentarily, which raises questions of how agents are distributed across various units and how agents are matched to tasks. We include four dimension in our rubric of organization structure:

a. Allocation of information: This refers to how information moves between the environment and the organization. For example, agents receive data from the environment and the data moves within the organization. This may have a fairly stable component to it, as might be described by the rules of communication laid out in an organizational chart. However, information can flow outside of mandated channels.

b. Allocation of authority: This dimension describes who makes the decisions, and is characterized by two main facets: modularity and decentralization. For example, an organization may have to perform many sub-tasks in solving a problem and a key structural issue is how these sub-tasks are combined into distinct modules which are then reintegrated to produce an organizational solution. The degree to which a problem can be efficaciously modularized depends on the nature of the task. Two classic structures that represent alternative modular forms are the M-form (all of the sub-tasks associated with a particular product line are combined) and the U-form (all similar sub-tasks are combined). With the allocation of tasks, there is still an issue of which agent ultimately make the decision. Aghion and Tirole (1997) argued that if an agent with decision-making authority relies heavily on information provided by other agents, then the real authority may lie with those providing the information. The allocation of information and real authority are thus interwined.

c. Organizational norms and culture: As defined by Sathe (1985), "culture is a set of shared assumptions regarding how the world works and what ideals are desirable." Agent behavior is influenced by an organization's past and this past is embodied in what is called norms or culture. Norms can be determined by past behavior, can influence current behavior, and can then serve to define future norms (Chang & Harrington 2005).
d. Agent motivation: Agents may be modelled as having preferences. They may desire income and dislike exerting effort. This kind of agent behavior can be translated to the ABM depends on an organization's incentive scheme for rewarding and punishing. The compensation scheme for corporate managers may drive them to seek higher organization profit while the scheme for division managers may be tied to division profit, which can then create a conflict of interests. Conflict may also arise when an organization uses promotions or bonuses based on relative performance to encourage effort. Traditional artificial intelligence (AI) models process this kind of problem with the assumption that agents have coherence of goals. ABM is more realistic and can recognize that conflicts of interest are an endemic feature of actual organizations.

Organizations have output and deliver some measure of performance. Performance may be measured by profit or may involve specifying a particular target and then measuring performance by the frequency with which organizations reach their targets. Although most organizations are designed with a particular objective, it does not follow that organization behavior is consistent with that. The members of an organization may have different goals than those of the entrepreneur. An ABM can let organization behavior emerge from the interaction of agents amongst themselves and with the environment.

2.5.4 Environments

An organization resides in an environment and is faced with problems and constraints to be faced in trying to solve it. The problem may be producing and selling a product if it is a manufacturing firm. The problem may be searching projects and earn profits from the projects to keep the company operation. Problems vary in terms of their difficulty. The problems may be more difficult due to several reasons, such as it requires more information, there are interactions between various choice variables, or directed search is infeasible and ineffective. Even if there is a metric, the relationship between performance and actions may not be well-behaved in that the components of the gradient may quickly change signs and admit many optima. This means that hill-climbing algorithms can get stuck on lousy local optima and it is not clear where to look for better ones.

Organization issues may also have dynamic components. Unlike traditional equation-based methods, ABMs can solve the problems in real time, which is the best solution because it may evolve with changes in the environment. A less stable environment makes the problem more difficult as the organization is pursuing a moving target. As long as the problems retain some similarity, the solution to one will provide clues for another, thereby creating opportunity to learn. Moreover, there may be a pool of organizations coevolving (like teams in a firm). Other organizations may influence an organization's current performance or influence future performance when they can learn from each other (Miller

2001) or exchange personnel (Axtell 1999). In providing an endogenous source of change in an organization's environment, coevolution can provide rich and non-trivial dynamics.

2.5.5 Team Simulation Using Agent-Based Modeling

The simulation of teams has been undertaken by several researchers, reflecting the large number of team-based activities available (Fan & Yan 2004). The kinds of teams that have been simulated range from those in the military, using the STEAM framework (Tambe 1997), to robotic football teams (Candea et al. 2000). The fundamental aspect of a team that distinguishes them from a mere group of interacting agents is that they share common goals, as in a project team. A project process typically involves considerable innovation, concurrency, and iteration. Such processes are difficult to model, due to the inherent uncertainties and interdependencies between the different technical and social aspects. However, the project process has consistent repeatable structure, through experience, and furthermore is facilitated by such structure.

Agent technology has much to offer to the understanding, modeling and simulation for designing task, particularly as a tool for comparing alternative team configurations and compositions to support managerial decision making. Indeed, the key characteristics of ABMs – 1) each agent has incomplete information or different capabilities for problem solving, 2) decentralized date, and 3) asynchronous computation – mirror those of employees in large organization. As such, ABMs are therefore both a metaphor for human behavior in organizations, and a potential method for studying them. It has been argued that multi-agent systems offer strong models for representing real-world environments with an appropriate degree of complexity and dynamism (Luck et al 2004). The characteristics of ABMs make them ideal for simulating human behavior, particularly of a social nature such as team work. For example, ABMs have been used to support members of human teams given a time-critical task involving the aggregation of information from their peers about other members' actions (Payne et al. 2000). Social dynamics have been studied through modeling human and group behavior using ABMs as well (Tsvetovat & Carley 2004).

2.5.6 Summary of ABM

There are four major advantages of ABM. Each advantage is described as follows: (Nilsson & Darley 2006):

a. Realism (Jennings et al. 1998; Bonabeau 2002; Valluri & Croson 2003): The parameters of ABM are set to characterize an authentic situation of interest. Each agent can be made directly comparable to machines, vehicles, products or groups found in real-life contexts and easily facilitates validation of simulation runs. The results and graphic output of the model are easy to understand for the people involved and there is no requirement for them to understand ABM.
b. Heterogeneity (Bonabeau (2002): In reality, construction activities are not homogeneous at the construction level. ABM can incorporate the heterogeneity in these systems because there is no need to aggregate different agents' behavior into average variables.
c. Bounded rationality (Valluri & Croson 2003): The individuals in organizations often have their own goals and their own policies. ABMs can explicitly build

bounded rationality into agent design rather than either imprecisely modeling it or assuming it away entirely because agents do not possess global information.

d. Scalability and Flexibility (Tripathi et al. 2005): The agents can be developed separately and systems can be built up in several stages until the system one wishes to investigate is covered. This means that adding another sub-system is fairly easy. This additive ability is important in building systems for construction projects since the organization structure of a construction project often involve several sub-teams.

There will never be any one method or tool that can flawlessly handle all scenarios, including ABM. The first disadvantage of ABM is that there are relatively high costs in time and effort compared to equation-based models. Additionally, ABM models require more data than many other approaches (Gacia 2005). Due to the high demand for data, it is difficult to detect whether the results produced are the result of a programming error or a groundbreaking insight. Another drawback is that customized models are often specific to modeled context and have limited re-use, thus generalizing the results is difficult (Leombruni & Richiardi 2005). In order to overcome these drawbacks, making theoretical and assumptive generalizations is must to have in model development. Understanding the characteristics of a phenomena under investigation at the lowest appropriate level of description is also important to ABM. Furthermore, the models need to be updated on a regular basis with new polices, rules, states, and other types of data. This will help the model continue to provide valuable and useful results. Finally, ABM will only be as accurate as the assumptions and data that go into it. Given these various characteristics, researchers then see ABM as an ideal research tool for examining team selection in a project organization domain.

Chapter 3: Theory Development and Hypotheses

Although previous studies have extensively investigated team selection, little research has been done examining those selection methods through complex system theory. The major objective of this research is to examine those selection methods using agent-based modeling which is developed based on complex adaptive system theory. This model can simulate the interactions between different team selection methods in different environment settings. Four selection methods will be tested in the following sections and the detailed hypotheses are described as following in this chapter.

3.1 Team vs. Individual

There is a large body of research indicating that the use of teams as a firm's basic structure has many advantages. Teamwork continues to be a key topic in organization research and has been extensively studied across many disciplines such as psychology, management, engineering, and computer science (Fleming & Koppelman 1996; Ilgen et al. 2005; Crowder et al. 2012). Pinchot and Pinchot (1993) hold that empowered teams are such a powerful force of integration and productivity that they form the basic building block of any intelligent organization. Ulrich (1996) said that leaders of the future will have to master the art of forming teams. They will have to master teamwork and work with and through others because no one person can possibly master all the divergent sources of information necessary to make good decisions. Teams also bring together complementary skills and experience that exceed those of any individual on the team. Teams are more effective in problem solving and can provide a unique social dimension that enhances productivity, motivation, and faster peer pressure and internal accountability (Katzenbach & Smith 1993).

Indeed, teams have been shown to offer organizations many advantages over individual work, and effective teamwork is related to a number of desirable outcomes such as organization efficiency and improved quality. Fundamentally, teams can link and network in ways that individuals cannot, enabling organizations to develop high quality ideas and products efficiently and effectively. A team can make better decisions, solve more complex problems and projects, and do more to enhance creativity and build skills than an individual working alone. They have become the vehicle for moving organizations into the future (Blanchard 2007). Using teams can increase capacity when team members work together rather than in isolation (Patterson et al. 2008). I expect to see that using teams can yield better performance than letting members work individually.

Hypothesis I. Using teams can yield better performance than let employees work individually.

3.2 Equity Approach vs. Random Selection

Traditional project organizations consider a worker's availability as the first criterion for choosing team members. However, the best people for a team are typically the least available. In contrast, if a manager chooses a team member just based on the potential member's availability, the manager may select unsuitable people for the team.

Anecdotally, it seems that common division practices include evenly allocating strong and weak members across teams, or assigning people from different functions with even skill distributions, in efforts to achieve equity. Research on how teachers assign students to teams reveals a mixture of methods. In a study of 40 instructors, Decker (1995) found that 52% of teachers deferred to students, allowing them to select their own teams like the workers in the Van Zelst studies (1952), 18% assigned them by equally allocating people by diversity indicators including majors and demographic characteristics, 10% used random distribution and the final 20% employed a variety of other approaches. Allocating by skill or assigning randomly achieves the most evenly performing teams. Achieving equity in inputs plays a strong role in what we know about the team assignment approaches of managers and teachers. Teachers often want to protect every student from a poor experience, and generally want to provide a chance for equal performance by all teams (Bacon 2001).

Managers, in contrast, are likely more concerned about maximizing performance across multiple teams. In reality, business or sports teams still utilize equity selection to build their teams, but that is not because the business wants to split their employees evenly, but because one of the biggest concerns of a business is “cost.” The best people tend to cost more. In project organization, project performance can be evaluated by three major attributes: cost, schedule, and quality. If the progress of a progress is on schedule and the project also meets quality requirements, the lower cost of the project means the better performance. That is one of the major reasons why managers want to use an equity approach in building their teams. In software projects for example, the team usually includes a project manager, senior software developers, and junior or fresh developers. It is rare to see a team with all talents working together.

Another reason an equity approach may be chosen to build a team is because there is evidence that the best teams are not always made up of the best individuals. What makes teams good can make them difficult too. The qualities that make individuals useful for high performance teams – drive, focus, perfectionism, high expectation and above-average intelligence – can make them difficult for others to work with. For example, self-confidence can aid one member's decision-making but can alienate others when member comes across as domineering. A superior intellect can help you get your head around complex problems but can also lead you to too easily dismiss the contributions of others. High expectations lead to setting ambitious goals but sometimes can leave others feeling unable to satisfy them.

More examples can be found in team sports, law, and investment banking. Individual star players can find it difficult to replicate their superior performance when they move from one team to another. It takes NBA basketball players an average of 21 games with a new team to recover their pre-transfer performance. 46% of a sample of 1,052 investment analysts, all star performers, were unable to replicate their outstanding performance when they moved to a different investment bank, even after five years. One explanation is that the success of an individual star performer is rarely the result of raw talent alone but also builds on the support structure around them (Millhiser et al. 2011). Which means that if the firm replacing someone in the support structure of the star performer, his or her performance may be influenced. The best individuals do not always make up the best teams. Real Madrid famously spent over 400 million euros acquiring star players only to see their investment return the worst sequence of short-term results in the club's history, between 2004 and 2006. The total annual salaries for the players of the Los Angeles Lakers in the NBA in 2013 is 10 million – the most expensive team ever in the NBA, but only rank No.7 in the in west conference of the NBA. Yet the team was swept away by the San Antonio Spurs in first round of playoffs. On the other hand, the Oakland Athletics spent less on their payroll and won more baseball games than almost any other club between 2000 and 2006. Why is it that a technically suboptimal team can outperform an all-star cast? Team managers often answer in terms of personalities, pointing out that a socially gifted colleague can smooth the edge of those at the top of the food chain who are oblivious to the emotional harm they inflict on others. The tradeoff between competence and sociability raises thorny issues for team selection. It is impossible to justify someone who is, by any objective measure, technically superior to someone who is merely good enough, yet expected to gel a team socially.

Hypothesis II: Using equity approach to select team members can yield better set of teams than using random selection method.

3.3 Interdependence-based Selection vs. Equity Approach

While previous research has extensively studied team selection in practice by considering the members' expertise, capacity, availability (Morgeson et al. 2005), a team's performance is not simply a sum of its individual member's performance (Millhiser et al. 2011). Team selection also needs to consider interdependence – both interdependence within the team and interaction with the environment. Individual performance can be seen as contributing to others and receiving from others. Each team member must know what his job is, who depends on him, and whom he depends on (Young et al. 1992). Determining how to create teams out of cohorts of people who have worked together must take into consideration the ability of each member to work with other particular individuals in addition to the individual's expected contribution. Taking interdependence into account, three components of the selection process, not all observable by managers or peers, comprise member's contributions to their team: their individual contributions, their contributions to others' performance, and changes in their own performances derived from the contribution of others. Like the military officers in Tziner and Eden's study of tank crews, managers must decide between spreading the talent around to create average teams, creating a combination of low and high performing teams, or electing some other variant (Tziner & Eden 1985).

There is little research on how managers divide cohorts of people to form effective teams. Unlike an equity approach, a complexity-based selection method for building teams considers how well specific people work together. In this research, we utilized three policies developed by Millhiser et al. (2011) that managers might use to allocate interdependent people to teams. They evaluate how team-assignment policies that respect how well people work together might improve on simple equitable-allocation methods. The three polices are (1) the clusters of support policy, (2) the removing low contributors policy, and (3) the removing the least supported policy. The first policy they created is to explore splitting the workers into similarly performing clusters. It works by separating people who are least supportive of each other and allowing cohorts of interdependent high-performers to stay together. Under the second policy, they create a core of strong mutual supporters by assigning workers who appear to contribute least to an alternate team. In the third scenario, a core of the top performers by assigning individuals to a separated team is created. The workers in the core do not support. In the latter two policies, workers who are put on the alternate team do not necessarily have low skill levels but rather work poorly with the strongest core. They have a chance of being highly contributing members if they are assigned teammates with whom they can work better by being moved away from the strongest core. In this scenario, those workers may contribute more and create a possibility of improved performance across two teams. In complex system thinking, team selection processes need to consider those interdependences – from forming the team to replacing team members. I would like to see if using knowledge of complex systems for team selection can improve team performance.

Hypothesis III: Using interdependence-based selection can yield set of teams with better performance than equity approach.

Chapter 4: Development of Agent-Based Model for Team Selection

4.1 Why using Agent-Based Modeling?

ABMs are models where individuals or agents are described as unique and autonomous entities that usually interact with other local entities and with their local environment. Agents can be organisms, humans, businesses, institutions, and any other entity that pursues a certain goal. Being unique implies that agents usually are different from each other in such characteristics as size, location, resource reserves, and history. Interacting locally means that agents usually do not interact with all other agents but only with their neighbors- in geographic space or in some other kind of space such as a network. Being autonomous implies that agents act independently of each other and pursue their own objectives. Organisms strive to survive and reproduce; traders in the stock market try to make money; businesses have goals such as meeting profit targets and staying in business; regulatory authorities want to enforce laws and provide public well-being. Agents therefore use adaptive behavior: they adjust their behavior to the current state of themselves, other agents, and their environment.

Using ABMs let us address problems that concern emergence: system dynamics that arise from how the system's individual components interact with and respond to each other and their environment. Hence, with ABMs researchers can study questions of how a system's behavior arises from, and is linked to, the characteristics and behaviors of its individual components. There are several kinds of questions that may use ABMs to solve. Here are the examples:

How can researchers manage tropical forests in a suitable way, maintaining both economic used and biodiversity level critical for forests' stability properties (Huth et al. 2004)? What causes the complex and seemingly unpredictable dynamics of a stock market? Are market fluctuations caused by the dynamic behavior of traders, variation in stock value, or simply the market's trading rules (LeBaron 2001, Duffy 2006)?

ABMs are useful for problems of emergence because they are across-level models. Traditionally, some scientists have studied only systems, modeling them using approaches such as differential equations that represent how the whole system changes. Other scientists have studied only what we call agents: how plants and animals, people, organizations, etc. change and adapt to external conditions. ABMs are different because they are concerned with two or even more levels and their interactions: we use them to both look at what happens to the system because of what its individuals do and what happens to the individuals because of what the system does. So throughout this course there will be a focus on modeling behavior of agents and, at the same time, observing and understanding the behavior of the system made by the agents.

ABMs are also often different from traditional models in being "unsimplified" in other ways, such as representing how individuals, and the environmental variables that affect them, vary over space, time, or other dimensions. ABMs often include processes that we know to be important but are too complex to include in simpler models.

The ability of ABMs to address complex, multilevel problems comes at a cost, of course. Traditional modeling requires mathematical skills, especially differential calculus and statistics. But to use simulation modeling researchers need additional skills. Railsback and Grimm (2012) addressed three important skills for using ABMs:

a. A new language for thinking about and describing models. Because people cannot define ABMs concisely or accurately in the languages of differential equations or statistics, researchers need a standard set of concepts (e.g. emergence, adaptive behavior, interaction, sensing) that describe the important elements of ABMs.
b. The software skills to implement models on computers and to observe, test, control, and analyze the models. Producing useful software is more complex for ABMs than for most other kinds of models.
c. Strategies for designing and analyzing models. There is almost to limit to how complex a computer simulation model can be, but if a model is too complex it quickly becomes too hard to parameterize, validate, or analyze. Researchers need a way to determine what entities, variables, and processes should and should not be in a model, and researchers need methods for analyzing a model, after it is built, to learn about the real system.

Full-fledged ABMs assume that agents are different from each other; that they interact with only some, not all other agents; that they change over time; that they can have different life cycle or stages they progress through, possibly including birth and death; and that they make autonomous adaptive decisions to pursue their objectives. However, as with any model assumption, assuming that these individual-level characteristics are important is experimental. It might turn out that for many questions we do not explicitly need all, or even any, of these characteristics. And, in fact, full-fledge ABMs are quite rare. In ecology, for example, many useful ABMs include only one individual-level characteristics, local interactions. Thus, although ABMs are defined by the assumption that agents are represented in some way, we still have to make many choices about what type of agent to represent and in what detail. Rand & Rust (2011) also provide a guideline to explain which kind of model is appropriate to use ABMs to build.

ABM is not the appropriate tool to use when a system is composed of only one or two agents or the number of agents is very large. If the system is only composed of two agents, game theory often provides a better modeling tool; if the number of agents is very large then the agents can be modeled as a representative agent by statistical regression. Medium numbers is a shorthand way of saying that though the system has a population of agents, this population can be affected by a few important individual interactions. The team selection model in this research does exhibit the medium numbers property because most of teams feature a group of workers that substantially affects the overall organization performance.

ABM becomes more useful as the interactions between individuals become more complex and local (Casti 1995). Local information and complex interactions can be modeled using game theory, but it is hard to use game theory to deal with the complex interactions when the number of agents reaches above a small set (Rand & Rust 2011). At this point, ABM becomes an appropriate framework to consider.

One of advantages of ABM is that each individual can be modeled as differently from other individuals as necessary. For example, agents can have different levels of expertise, salary, capacity, and demographic properties. Beyond different values, the agents can be of different types, such as workers, managers, and projects. Types can even be divided into different types of organizations. In contrast, if a system contains many homogeneous agents, system dynamics modeling may be more useful because it efficiently tracks populations of identical agents and examines how they change over time. In team selection processes, most workers have different properties and different interdependent partners, which almost requires the use of an ABM approach.

ABM facilitates the representation of rich and dynamic environments. These environments can be as simple as two-dimensional abstract spaces or as realistic as a space derived from data contained in a geographic information system (GIS; Brown et al. 2005) or a network-based space derived with data from social network analysis (Carley 2002). The team selection model is designed based on a local dynamic project market environment.

ABM is a technique for modeling processes and is well suited for examining how complex systems change over time. Therefore, temporal aspects are almost necessary condition for the ABM approach. Many modeling approaches allow users to examine the equilibrium states of dynamic games, but ABM is one of the few that allows users to examine the dynamics that give rise to those equilibria. It is often necessary to observe the performance of a company with a certain time period, especially my research will examine the effects of different team selection methods. The temporal nature of the process is central to the research question.

ABM has ability to include adaptive agents within simulations. If an agent takes an action that produces a negative result, then that agent may try other actions in the future. ABM can embed a machine learning approach within each agent that allows that agent to dynamically adopt the rules under which it operates. For instance, in my model, the agents will be transferred or replaced by different worker replacement policies based on their performance. There are few modeling techniques besides ABM that are able to robustly represent adaption.

Because most model assumptions are experimental, researchers need to test our model: researchers must implement the model and analyze its assumptions. For the complex systems we usually deal with in science, just thinking is not sufficient to rigorously deduce the consequences of our simplifying assumptions: researchers have to let the computer show us what happens. Researchers thus have to iterate through the modeling cycle.

4.2 The ODD Protocol for Team Selection

One way to make ABM more understandable and wieldy is standardization. To bring the benefits of standardization to ABMs, a large group of experienced modelers (Grimm et al. 2006; Grimm and Railsback 2005) developed the Overview, Design concepts, and Details (ODD) protocol for describing ABMs. ODD is designed to create factual model descriptions that are complete, quick and easy to grasp, and organized to present information in a consistent order. ODD is now gaining widespread acceptance in the ecological and social science literature (Pohill et al. 2008), and there is a newly updated guide for using ODD (Grimm et al. 2010).

ODD is the protocol that is very useful for formulating ABMs as well as for its original purpose of just describes them. Just as differential equations provide a way to think about mathematical modeling problems, and frequentist and Bayesian theory provide ways to think about statistical modeling problems, ODD provides a way to both think about and describe agent-based modeling problems.

ODD protocol starts with three elements: Overview, Design concepts, and Details that provide an overview of what the model is about and how it is designed, followed by an element of design concepts that depict the ABM's essential characteristics, and it ends with three elements that provide necessary to make the description complete. The ODD described the seven elements which are shown in Table 2.

Table 2. Overview of the ODD protocol for describing ABMs (Grimm et al. 2010)

	Elements of the ODD protocol
Overview	1. Purpose
	2. Entities, state variables, and scales
	3. Process overview and scheduling
Design concepts	4. Design concepts * Basic principles * Emergence * Adaption * Objectives * Learning * Prediction * Sensing * Interaction * Stochasticity * Collectives * Observation
Details	5. Initialization
	6. Input data
	7. Submodels

4.2.1 Overview of Team Selection Model

Purpose

The first element of ODD is a clear and concise statement of the question or problem addressed by the model: what system we are modeling, and what we are trying to learn about it. Knowing a model's purpose is like having a roadmap to the rest of the model description.

The purpose of my model is to examine and compare different team selection methods in different contexts. First, it is necessary to establish what is meant by team performance.

Although it has been defined in numerous ways, three key performance variables have emerged: the quality of a team's output, the amount of time taken to deliver this output, and the cost of doing so. Within engineering and project management fields, these three variables – quality, time, and cost – are often collectively referred to as the triangle for evaluating performance. However, in this model, we assume that the quality of all projects meet the requirements, which means the selected teams can perform well on the projects without quality issues. The assigned teams are assumed to complete the projects within the planned project duration. The criterion of team performance evaluation here is profit earned from the team. Profit was chosen as the criterion because it can easily show the teams' outcome and can clearly demonstrate the difference when comparing those team selection methods.

An agent-based model environment is developed for a virtual project-based company, a small construction design firm, to test the hypotheses. There are two major reasons why I chose a small design firm. First is because I would like to simplify the economical context. Small firms usually target local markets. It is easier to create a reasonable scope of environment for a small firm rather than for large companies. For example, an international design firm may have projects around the world, which makes it more difficult to set the boundary of the market. Second is because I would like to simplify the interdependence of workers. Although one of the objectives of my research is to see if using knowledge of worker's interdependence can improve project performance, it is very hard to define the interdependence matrix for a team or an organization with complex working relationships.

In the modern industrialized world, construction usually involves the translation of designs into reality. A formal design team may be assembled to plan the physical proceedings, and to integrate those proceedings with the other parts. The design usually consists of drawings and specifications, usually prepared by a design team including surveyors, civil engineers, cost engineers (or quantity surveyors), mechanical engineers, electrical engineers, structural engineers, fire protection engineers, planning consultants, architectural consultants, and archaeological consultants. The design team is most commonly employed by (i.e. in contract with) the property owner. Under this system, once the design is completed by the design team, a number of construction companies or construction management companies may then be asked to make a bid for the work, either based directly on the design, or on the basis of drawings and a bill of quantities provided by a quantity surveyor. Following the evaluation of bids, the owner will typically award a contract to the most cost efficient bidder.

The modern trend in design is toward integration of previously separated specialties, especially among large firms. In the past, architects, interior designers, engineers, developers, construction managers, and general contractors were more likely to be entirely separate companies, even in the larger firms. Presently, a firm that is nominally an "architecture" or "construction management" firm may have experts from all related fields as employees, or to have an associated company that provides each necessary skill. Thus, each such firm may offer itself as "one-stop shopping" for a construction project, from beginning to end. This is designated as a "design build" contract where the contractor is given a performance specification and must undertake the project from design to construction, while adhering to the performance specifications.

Several project structures can assist the owner in this integration, including design-build, partnering and construction management. In general, each of these project structures allows the owner to integrate the services of architects, interior designers, engineers and constructors throughout design and construction. In response, many companies are growing beyond traditional offerings of design or construction services alone and are placing more emphasis on establishing relationships with other necessary participants through the design-build process.

To explore how interdependence-based team selection improves performance compared with skills-based assignments, three components associated with a worker's contribution need to be quantified: individual contribution, contributions to others, and contributions from others. The developed model follows a number of agent-based simulation models that study complex interdependencies in organizations (Sorenson 2002; Chang and Harrington 2006).

To begin, consider how dividing a cohort into two project teams affects interdependencies. If the employees work independently within but not across the resulting team, either because of physical or organizational barriers, then some who had previously worked well together will be separated. Suppose a worker, when placed on a team, loses connection with one co-worker who previously affected that worker's performance. For example, the transferred employee could be a consultant put on a new project without the support of a familiar colleague with particular information technology skills. If the original interdependencies were necessary for the consultant to deliver projects, then the consultant will naturally seek to form a new relationship with someone on the new team with similar information technology expertise.

Exchanging an established relationship with a new connection can be thought of as replacing a supportive colleague on whom a worker was interdependent with another who may or may not be supportive. Given the interdependencies among workers, it is reasonable to assume that losing co-workers influences, either positively or negatively, the individual and collective performances of those who remain – the larger the number of losses, the greater the variance in performance. Therefore, when team selection occurs, we can assume that a worker's performance changes in an uncertain manner, with the potential for individual and team change increasing with each disrupted interdependency.

Considering the complex nature of interaction in interdependent groups, assessing individual and team level performance can be challenging in practice (Solow et al. 2002; Millhiser et al. 2011). Many organizations document observed employee performance through periodic appraisals. However, managers are unable to see how these workers contribute to others or what portion of their performance is attributable to help from others. We utilized the NK model and Decision Support Matrix (DSM) to capture these three components: individual contributions, giving to others, and receiving from others that affect a worker's total contribution to a team. The detailed processes of different team selection methods and how to utilize ABM to compare them will be discussed in the design concept of ODD protocol.

Entities, State Variables, and Scales

ABMs usually have the following types of entities: one or more types of agents; the environment in which the agents live and interact, which is often broken into local units or patches; and the global environment that affects all agents. These model entities are characterized by their state variables, which is how the model specifies their state at any time. An agent's state is defined by its properties and attributes, such as size, age, opinion, etc. and often by its behavioral strategy, such as searching behavior, bidding strategy, etc. Some state variables are static and do not change, for example the sex and species of an animal and the location of immobile agents such as plants and cities. These variables are still different among agents. State variables can be deduced or calculated from the state of the agent and its environment.

Many ABMs are spatially explicit: they represent where agents are in a space or environment, and the space is often heterogeneous. The environment can be represented continuously, but much more often space is represented discretely by cells or patches, usually on a square grid. The advantage of this discrete structure is that spatial effects within the patches are ignored, greatly reducing the amount of data and calculation required to simulate spatial processes. Patches may be characterized by one-to-many state variables, including the coordinates defining where they are in space.

Although psychology research has greatly enhanced the understanding of team building and selection, it has tended to focus on a team's composition and social interactions, and neglected the influence of structural factors, such as those related to the nature of the work task itself. This indicates a potential serious gap in the research that doesn't sufficiently consider the technical aspects of socio-technical systems in which teams operate, where both the social and technical elements are crucial for the successful performance of work tasks. In this model, the variables of entities are defined as follows.

Agent (Worker)

Education: The worker's education is divided into three major categories: graduate, college, and high school.

Working experience: The experience that a worker gained while working in a specific field or occupation.

Expertise: The worker's skill or knowledge in a particular area. Since the case study in this research is a design firm that focuses on designing road construction projects, the expertise of workers include five major areas - pavement, geographical, hydraulic, structural, and environmental design.

License: The license means to give permission. A licensor may grant a license under intellectual property laws to authorize the use of the IP. A professional engineer (PE) license is a requirement for project managers in our setting.

Salary: A salary is a form of remuneration paid periodically by an employer to an employee, the amount and frequency of which may be specified in an employment contract. In our setting, the workers' salaries are correlated with their education, working experience, expertise, and license.

Availability: The definition of availability can be defined as the proportion of time a system is in a functional condition. Here we assume that the workers spend 8 hours per day, 22 days a month on their jobs.

Capacity: In economics, management and engineering, capacity refers to the maximum possible output of a system. A worker's capacity is defined as the amount of work he can do. The expected capacity of workers is based on the salary. The higher the salary, the larger the capacity that is expected. In reality, the expected capacity of workers ranges from 1.6 to 2.5 times of each of their salaries.

Interdependence with other workers: The interdependence is measured and captured by the concept of NK model and DSM. This model utilize the DSM to capture three components of performance – individual contributions, giving to others, and receiving from others – that affect a worker's total contribution to a team. The initial setting of worker's interdependence is K=3.

Patch (Project) - Immobile

Project scope: The work that needs to be accomplished to deliver a product, service, or result with the specified feature and functions (PMBok Guide 2008).

Project budget: A prediction of the costs associated with a particular project. These costs include labor, materials, and other related expenses. The project budget is often broken down into specific tasks, with task budgets assigned to each. A cost estimate is used to establish a project budget.

Rate of profit: In finance, rate of return (ROR), also known as return on investment (ROI), rate of profit or sometimes just return, is the ration of money gained or lost on an investment relative to the amount of money invested.

Duration: The duration of a project's terminal element is the number of calendar periods it takes from the time the execution of element starts to the moment it is completed.

Global environment

The global environment, finally, refers to variables that vary in time, but not necessarily in space. An example might be weather variables such as temperature, the frequency with which some kind of system-wide disturbance occurs, or tax rates. These environmental variables are typically external: provided by data or submodel that are not affected by the ABM's entities. The global environment variable we set here is the economic situation. The economic situation setting is directly related to the number of projects available on the market. In order to simplify the model, the economic situation is set as a range from zero to one. In the normal situation, the economic situation is set as 0.5. If the number is set as lower than 0.5, that means the economic situation is in a depression. In contrast, there is economic growth if the number is set higher than 0.5.

Temporal and spatial scales

The model's temporal and spatial scales need to be specified here. Temporal scales refer to how time is represented. Most ABMs represent time using discrete time steps of, for example, a day, a week, or a year. The use of time steps means that all the processes and changes that occur in less time than a time step are only summarized and represented by how they make state variables jump from one time step to the next.

In our model, the temporal scale is set as days because most of time project duration is counted by calendar days. A tick in this ABM means a day. The new projects are also announced by project owners (i.e. government) every day. The agents' jobs not only considered as working on the projects, but also on preparing, evaluating, and bidding on projects.

The temporal extent of a model refers to the typical length of a simulation: how much time is simulated? This depends on what observations or model outputs researchers are interested in and the time scales at which they occur. The temporal extent is usually determined by system-level phenomena produced by the model, whereas temporal resolution is usually determined by the agent-level phenomena driving the model internally. Since the target of simulated team selection are for small groups (less than 20 workers), this model sets the simulation time as 3 year because the duration of most projects in the small construction design field range from 1 month to 1 year, and simulating 3 years can properly encompass the typical operations of a project-based organization

If the model is spatially explicit, then the total size, or extent, of the space must be described. If grid cells or patches are used to represent variation over space, then their size – the spatial resolution – must also be specified. As with temporal resolution, the right spatial resolution of an ABM depends on key behaviors, interactions, and phenomena. Spatial relationships and effects within a grid are ignored; only spatial effects among cells are represented.

Process Overview and Scheduling

With the elements of ODD now laid out, this section will address model dynamics, i.e. the processes that change the state variables of model entities. Every process describes the behavior of the model's entities. If the model is extremely simple, it can be described completely here. Here processes are treated as "sub-models," representing them only by a self-explanatory name – mating, selling, buying etc. – with further details provided in the final part of the ODD description.

The processes of events that agents act in our model can be showed in Table 3. The goal of the simulation is to explore the relative effects of different team selection methods on firm performance in a context. The computational model consists of agents and a schedule of events. The agents in the model are teams and projects, and the schedule of

Table 3. Schedule of events

Build the firm	
	1. Create a population of projects representing opportunities
	2. Give project a return and a cost
	3. Create workers
	4. Create project teams (based on different selection methods)
	5. Give each team an initial of capabilities
	6. Give each team a capacity
Team assignment	
	7. A team is randomly chosen to select a project
	8. The team eliminates projects it cannot afford given its capacity
	9. Once a project is selected, it is removed from the main choice set
	10. The firm earns a return on the project it selected
	11. The team's capacity is replenished
	12. Replace poor performers (based on different replacement policies)
	13. Repeat events 7-9 until all teams' capacities are full

events governs the interactions among the agents. Model parameters are discussed in the previous selection. I built a simulation model of a project organization with a limited number of relevant capabilities based on employees' expertise. The market has a population of projects. These projects represent opportunities for the firm to make investments in capabilities.

Workers are selected into teams based on different team selection methods. They can work on multiple projects, but the total workload cannot surpass their capacity. What we are interested in is comparing different team selection methods and demonstrating why taking into account complexity to form a team can yield better overall team performance. I am assuming workers have no ability to sense information about other patches, so it is reasonable to simply assume they choose a new project randomly. The next step is bidding and assigning the project. Workers have possibilities to win the bid based on relationships with project owners if the team still has available capacity. Workers will keep searching and bidding on projects until the team's capacity is full. The team's capacity will be replenished and the team will earn the expected profit when the project is completed. These processes will repeat in our model and the profit earning will be accumulated as emergence. I also consider team member replacement policies. Individual performance will be examined every 6 months. The poor performers will be transferred to another team or be replaced by hiring new ones based on different replacement policies and different environmental conditions. Managers traditionally replace lower performers according to their low abilities (i.e. lower technical skills or personality – who may not be work as a team player). However this study explores whether using knowledge of complex systems to replace workers can yield better performance than ability-based replacement.

The only processes that are not linked to one of the model's entities are observer processes: the creators of the model want to observe and record what the model entities do, and why and when they do it. Therefore, researchers need to specify observation processes that do things like display the model's status on graphical displays and plots and write statistical summaries to output files. The ODD protocol includes description of observer processes because the way researchers observe a model – the kind of data they collect from it and how they look at those data – can strongly affect how they interpret the model and what they learn from it.

The observer process in this study is simple: to show the profit earned from the teams. This model already set up the decision rule for assigning workers – workers cannot be assigned over their maximum capacity – that means the project can be insured to operate to meet the quality requirement and should be accomplished within the expected duration.

Although there are many other factors (i.e. unpredictable risks) that may cause projects to fail or delay, these variables are not considered in the model this time.

Some ABMs have schedules simple enough that they can be specified completely by simply listing the model processes in this part of ODD in the order they are executed, adding any needed detail on the order in which individual agent execute. In many ABMs, though, scheduling is rather complicated and hard to accurately describe accurately in words. Some researchers suggest that the creators can use of pseudo-code to describe the schedule (pseudo-code is a logic structure of computer programs) (Railsback & Grimm 2012).

4.2.2 Design Concepts – NK model and Design Support Matrix

This section of the ODD protocol describes how the model implements a set of basic concepts that are important for designing ABMs. The key concepts are listed in Table 2. These design concepts provide a standardized way to think about very important characteristics of ABMs that cannot be described well using other conceptual frameworks such as differential equations. For example, what model outcomes emerge from what characteristics of the agents and their environment? Conventional models typically produce only one outcome, which is calculated directly from equations, but ABMs can produce many kinds of results that arise in complex, unpredictable ways. In the ODD protocol there are eleven different concepts listed in Table 2. The table is like using a checklist to ensure that important design decisions are made consciously. However, not all of the concepts are important for all ABMs; some ABMs are simple enough that researchers need to address only a few design concepts in detail. It is important to consider the full list of design concepts and show what common characteristics of ABMs researchers choose not to employ.

Basic Principles

The design principles of this model are based on comparing different hypotheses for team selection. This section describes how the overall performance of a project based organization is defined and evaluated in this study. What I would like to explain here is to define how I evaluate the overall performance for a project based organization. The details of three selection methods I want to compare and the definition and performance evaluation criteria are discussed in the following sections.

Individual isolation

Based on the agent setting of this model, the workers each have their own capacity. In the individual isolation condition, the average performance of a company is assumed to be 0.5.

Random selection method

Based on the agent setting of this model, each worker has their own capacity. In the random selection condition, the average performance of teams in a company is assumed as 0.5, but each team has their own team capacity. Project managers and workers are randomly selected into different teams based on their availability.

Equity-based selection method

Consider how real organizations form teams from cohorts when a managers knows individual performance levels but not who works best together. Anecdotal evidence suggests that a reasonable practice is to divide talent fairly. For example, children or adults set up sports teams by choosing leaders who take turns selecting players. Mangers sometimes use similar processes. They may allocate the most creative people evenly between teams, then the best analysts, the best salespeople, and so forth. Such a policy is thought to result in roughly equally capable, albeit average, teams. I call this allocation based on putting the members of matched sets of people on different teams an equity approach. In our model, assigning many teams by group equity yields average team and multiple team performances of 0.5 because dividing talent fairly tends to divide performance evenly.

Interdependence-based selection method

This research utilized the concept of NK model and Design Structure Matrix (DSM) tool and modified the concept that proposed by (Millhiser et al. 2011) to measure and capture the three components of performance – individual contributions, giving to others, and receiving from others – that affect a worker's total contribution to a team.

Even though the *NK* model was initially conceived by Kauffman (1993) for understanding biological systems, it has been extensively applied in many other domains including computational organization theory. An organization is conceptualized as a system of activities. It makes decisions concerning N activities where each activity can take on two states, 0 or 1, so that, referring back to the general model, $A = \{0, 1\}N$. A particular configuration of activity is then described by a binary vector of length N. The distance between two such vectors, $x \equiv (x_1, \ldots, x_N)$ and $y \equiv (y_1, \ldots, y_N)$, is captured by the Hamming distance:

$$d(x, y) = \sum_{i=1}^{N} |x_i - y_i| \qquad (4\text{-}1)$$

that is, the number of dimensions for which the vectors differ. As part of the *NK* model, the mapping *v* from the activity vector to the level of performance is a primitive. *v* is set to depend on the performance contributions that these activities make individually, where the contribution of each activity depends on the interactions among a subset of activities. The degree of interdependence among activities is captured by a parameter *K* which is the number of other activities that directly affect the contribution of a given activity. In its original formulation, these *K* activities are randomly selected from *S* for each activity. To be more concrete, let $vi(x_i, x_i^1, \ldots, x_i^k)$ denote the contribution of activity *i* to the organization's performance where its dependence on activity *i*, *xi* , and the *K* activities to which it is coupled, $(x_i^1, \ldots, x_i^k)$, is made explicit. It is common to assume that the value attached to *vi* is randomly drawn from [0, 1] according to a uniform distribution for each possible vector $(x_i, x_i^1, \ldots, x_i^k)$. The overall organizational performance is then

$$v(x) = \left(\frac{1}{N}\right) \sum_{i=1}^{N} v_i \left(x_i, x_i^1, \ldots\ldots, x_i^k\right) \qquad (4\text{-}2)$$

Normalization by N enables performance comparisons when N is changed. The interaction parameter, K, controls the difficulty of the search problem by making the value contribution of an activity dependent upon K other activities. When K = 0, the activities are completely independent so that changing the state of one activity does not affect the performance contribution of the remaining N-1 activities. The landscape is then single-peaked so the globally optimal vector of activities is also the unique local optimum. That is, improving *vi* by changing xi must raise the organization's performance since the contribution of the other activities is unaffected by xi. The other extreme is when K=N-1 so that a change in the state of an activity changes the performance contributions of all other activities. This typically results in numerous local optima for v due to the complementarity among activities. That is, changing any one of a collection of activities could lower v but simultaneously changing all activities could raise v.

Kauffman (1993) shows that the number of local optima increases in K. Rather than specify the coupled or interacting activities to be randomly selected, many organizational models using the NK framework choose the interaction pattern so as to explore how different architectures influence performance. For those purposes, it is convenient to capture the interdependencies in an adjacency matrix (Ghemawat and Levinthal, 2000). Figure 6 shows four such matrices for N = 6 in which the degree of interdependence as well as the exact structure of the interdependence differ. If the performance contribution of the j th activity (row j) is affected by the chosen activity in the ith activity (column i) then the element in the matrix corresponding to row j and column i has an 'x'. This is always true of the principal diagonal as the contribution of an activity depends upon the practice chosen for that activity. Figure 6(a) is an adjacency matrix for an organization in which K = 0 so that the activities are completely independent. Figure 6(b) is when K = 5 and each activity is influenced by every other activity in S. Figure 6(c) captures a special case of K = 2, where the interdependencies are restricted to non-overlapping strict subsets of S; the activities in {1, 2, 3} influence one another, while those in {4, 5, 6} influence one another. Figure 6(d) is another case of K = 2, though there is no obvious systematic structure in

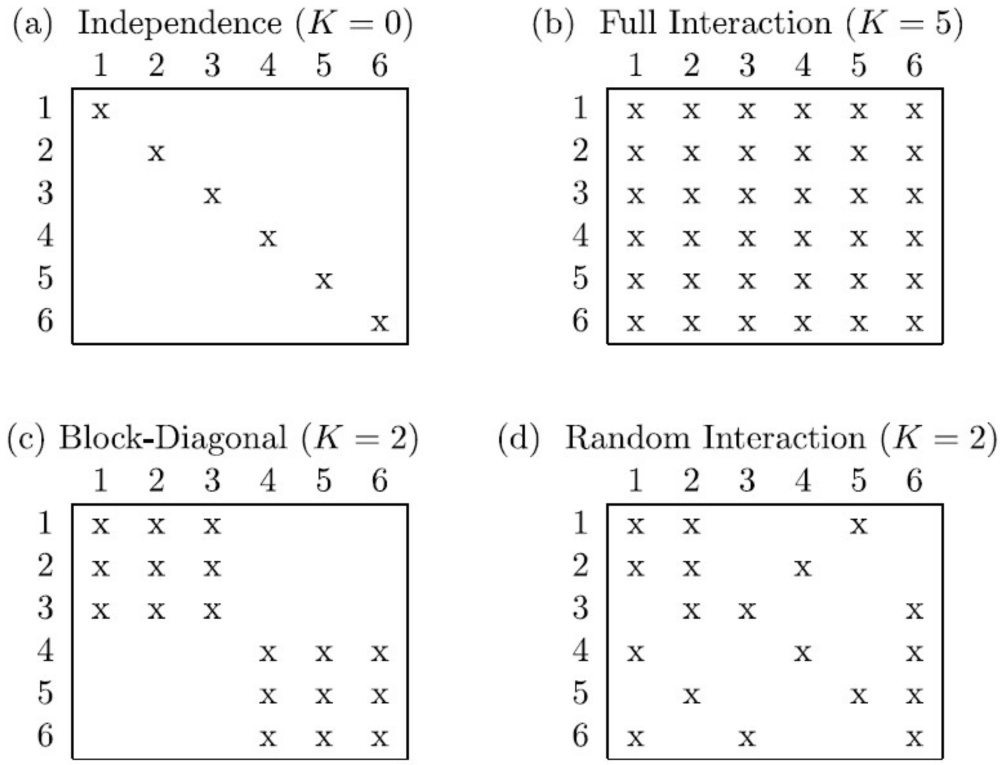


Figure 6. Example of measuring interdependence by NK model

comparison to the other matrices. This is what would be typical if the interactions were random.

Observed performance usually reflects an individual's contribution together with the results of whatever contributions others make to that person, but does not capture the contribution of that individual to others. What is needed is a measure of how much interdependence a worker has. Assuming for sake of generality that there are N workers in the original cohort, I refer to a particular job as worker i (where i indicates the worker's number from 1 to N). Because each worker "depends on" others to accomplish tasks, I assume that a worker is interdependent on K others, ranging from complete self-reliance (K = 0) to dependence on everyone else (K = N-1).

To distinguish between the two types of interdependence, the colleagues who support a worker, those represented by an x in that worker's column are called contributing partners; those who rely on a worker (represented by xs in that worker's column) are called dependent partners. In addition to these partners, I assume every worker relies on him or herself, as depicted by xs along the diagonal. For example, Figure 6(c) row 1 indicates that worker 1's performance depends on himself and support from contributing partners 2 and 3; column 1 further specifies that worker 1 contributes to dependent partner 2 and 3 also. In Figure 6(d), row 1 indicates that worker 1's performance depends on himself and support from contributing partners 2 and 5; column 1 further specifies that worker 1 contributes to dependent partner 2, 4, and 6. Taking Figure 6(d) as example, I can assume that the row 1 indicates that worker 1 has previous experience working with project owner 2 and 5; column 1 specifies that project owner 1 has previous experience working with worker 1, 2, 4, and 6.

Given a worker and that worker's contributing partners, a worker's performance can be attributed to the worker and and the support for that worker from the K partners who influence the worker (Millhiser et al. 2011). To simulate a cohort with some history of working together, the performance of the worker is modeled as a number generated randomly between 0 and 1, with values closer to 1 indicating better performance and values closer to 0.5 indicating average performance (the random distribution assures that 0.5 is the average of worker's performance across project teams).

When a worker is assigned to a team with all the original contributing partners from the cohort, I assume that the performance of that worker is unaffected. Although there are other considerations which may affect worker's performance, I only focus on the role of interdependence on team performance. In contrast, the worker's performance will vary widely, perhaps as low as 0 or as high as 1 if all contributing co-workers are assigned elsewhere because the worker need to establish the new relationships with other team members to accomplish the project. When contact with some new, but not all, contributing partners occurs, the new performance is assumed to vary proportionally to the number of disrupted interdependencies. The new performance will be widely set between 0 and 1 based on how many disruptions of the original number of co-workers.

If worker i's initial performance in the cohort is p_i and if team selection disrupts d_i of the worker's K interdependences, the worker's new performance is called p_i', which is generated by choosing a random number between some new lower and upper performance limits. The upper limit u_i is assumed to be the proportion d_i/K of the potential improvement from the current performance p_i up to m_i (maximum capacity). The lower limit l_i is the proportion d_i/K of the possible performance loss form p_i down to 0. The equations of l_i and u_i are:

$$l_i = p_i - \left(\frac{d_i}{K}\right) p_i \qquad (4\text{-}3)$$

$$u_i = p_i - \left(\frac{d_i}{K}\right) (m_i - p_i) \qquad (4\text{-}4)$$

In other words, if a worker loses one of three partners, the upper limit is one-third of the distance from current performance to 100% of potential performance and the lower limit is one-third the distance from current performance to zero.

In order to simply the model, I assume there are no second-order effects. For example, consider the team shown in Figure 6(d). If worker 1 is assigned to another team away from interdependent co-workers, I make an assumption that the only performance change for dependent workers 2, 4, and 6 is their interdependent behavior related to worker 1 and that everything is the same between workers 2, 4, and 6 after the departure of worker 1. Even if actions of workers 2, 4, and 6 are different because of the absence of worker 1, this does not influence worker 2, 4, and 6's contributions to others. Although that could be second-order effects from each change (i.e. the contribution from worker 2 to worker 4 may become lower due to worker 1's leave), I do not consider this kind of effects here.

Managers may not always seek equality in performance across all teams. For example, they may want to send a group they can trust to perform well together to their best customer or to a customer with the greatest potential of generating substantial new business. If the teams are working on internal processes, managers may be able to accept varying levels of performance across teams, as long as they can identify the better performing teams to place on more critical problems and can more closely supervise lower performing teams. In these cases, they need a process of building the teams for varied tasks while maintaining the highest total performance across all teams.

Because sorting people into separate teams may require upsetting current interdependencies, a manager might take advantage of natural breakpoints by attempting to keep together those who work well together. To keep these people together, the manager should be to divide the workers so that there is minimal interdependence disruption for higher-performing workers (Millhiser et al. 2011). The total disruption performance (TDP) can be measured as:

$$\text{TDP} = d_1 p_1 + d_2 p_2 + d_3 p_3 + \cdots + d_N p_N \qquad (4\text{-}5)$$

Although a visual inspection of a sorted matrix may allow us to identify the best clustering, this type of visual pattern-finding becomes increasing challenging in larger or more interdependence teams. This formula helps decision maker identify splits that disconnect fewer workers and disconnect lower-performing workers. This implicitly benefits weak performers and protects strong performers (Millhiser et al. 2011). For example by sorted cohort depicted in Figure 6(d) and the observable individual performance is shown in Table 4, if we divided the workers 1, 2, and 3 into the first team, and the rest workers are in second team, the measure becomes

TDP = $1p_1 + 1p_2 + 1p_3 + 0p_4 + 1p_5 + 2p_6 = 0.53 + 0.80 + 0.22 + 0 + 0.82 + 0.72 = 3.09$

An alternative division places workers 1, 2, and 4 in the first team with

TDP = $1p_1 + 0p_2 + 1p_3 + 1p_4 + 1p_5 + 1p_6 = 0.52 + 0 + 0.22 + 0.30 + 0.82 + 0.36 = 2.22$

The latter division is preferred to the first because it disrupts fewer interdependencies, as predicted by the lower TDP. The major reason why I would like to minimize the TDP is because disrupt higher performers' interdependence could be more costly. The policy of protecting relationships between higher performers and their supporters is utilized in this study's interdependence-based selection method.

Emergence

The most important and unique characteristic of ABMs is that complex, often unexpected, system dynamics emerge from how we model underlying processes (Railsback & Grimm 2012). Emergence, therefore, is the most basic concept of the system and what model outcomes emerge – arise in relatively complex and unpredictable ways – from what behaviors of the agents and what characteristics of their environment?

Although many companies are profit-driven with annual targets, in reality, the profit earned should be an emergence from employees completed their work (i.e. how many products sale to customers; how many projects that a construction company completed within a period). It is hard to use traditional methods, i.e. regression analysis to predict the profit earned for a project-based company. Based on the team selection rule I defined – the workers cannot be assigned to projects over their capacity, I assume that the quality of all projects meet to the requirements, which means the selected teams can perform well for the projects without quality issues. The assigned teams are assumed to complete the projects within the planned project duration. The criterion for evaluating team performance is the profit earned from the team's completed projects. Profit was chosen as the criterion because its generation can be clearly attributed to specific teams and it can clearly differentiate team outcomes when comparing those team selection methods.

Adaption

The adaption here is defined as team member replacement. While the literature has focused on other methods for improving team performance, managers can intentionally replace team members when other methods do not achieve the desired results. In practice, few managers have the luxury of hiring all new employees with ideal characteristics when they need to form teams. In most cases, managers must form teams from existing cohorts of workers who have histories of working together. There are two primary options when executing team replacement, namely replacing members by hiring new ones (Solow et al. 2002) or transferring current members onto other teams (Millhiser et al. 2011). While Millhiser et al. (2011) argue that it is more common during team design to work with a fixed cast of workers without the option of better replacement, managers may be interested in seeing how their organization may evolve if they adopt the replacement rule of fixed cast of workers or replace the lower performers by hiring the new ones, and know which adaption rule is better. In our model, we do not only compare the team selection methods from forming teams, but also consider the different adaption rules because team working is complex adaptive system.

People who are poor performers may have low skills, but the group itself may be limiting a member's success for some reasons, such as scapegoating, bullying, or stereotyping. Some literature on diversity and minority influence (Cox 1993) documents the type of rejection faced by people who differ from the majority. We would like to test different team replacement rules which have been proposed by Solow et al. (2002) and Millhiser et al. (2011). Solow et al. (2002) examined the process of deciding how to replace members of a team using an optimization model based on NK model concepts. There are several limits on a manager's ability to construct an optimal team. There are time and dollar costs associated with interviewing potential new members. Each new hire requires training time from the manager and the rest of the team. Qualified individuals may not be available or the cost of hiring them may be excessive in the current labor market. Biases can arise in assessing and comparing the performance of a current employee with the potential performance of a job candidate. Furthermore, teams are a particularly challenging setting in which to make replacement decisions because of the interdependence among different members of the team. The replacement of a team member affects morale for other team members and can actually change the team performance level because the remaining members cannot always rely on the new member for information or support that was provided by their former teammate.

Policy 1: Hiring new ones

Therefore, the first replacement police is to replace the poor performer by hiring a new one to maximize the expected performance of the team with the selected candidate. I also follow the assumption articulated by Solow et al. (2002) that there are two qualified individuals available for the position. This model can generate these data of individual randomly. This assumption is reasonable because in practice managers do not know who will actually apply for the position. The better option of candidate is expected to have higher capacity and perform better than the replaced one, but the better candidate also cost more.

Millhiser et al. (2011) captured the aspect of human performance in that disrupting a poor performer's interdependencies is, on average, likely to improve that person's performance. This study differs from the study by Solow et al. (2002) study mentioned above is that Millhiser et al. focus on team design with a fixed cast of workers without the option of better replacement. Their model does not increase the skills of an apparently low performer, but it could remove disruptive interdependencies. In parallel, the performance of stronger employees is harmed when dividing a cohort because of the resulting loss of support from interdependencies with key supporters. Upon any disruption of a worker's contributing partnership, establishing a new output of performance between some new lower and upper limits suggests that across enough workers, the expected value of the resulting individual performance is the average of the limits. If the performance of the worker was below average, then the new performance is expected to be an improvement.

If the performance was above average, then the new performance is expected to decline. In other words, on average, upsetting both helpful and disruptive influences moves a worker toward average performance.

One goal of management is to find team selections from the original cohort that yield improved performance of all teams added together. We assume the overall team performance of the multiple teams remains the average of all the worker contributions after the workers are assigned to teams. What changes is each member's performance caused by lost and new interdependencies. Two policies suggested by Millhiser et al. (2011) to improve multiple team performance are described below.

Policy 2: Transferring low contributors

This strategy seeks to identify workers who contribute least to top performers. Reassigning a worker who influences others negatively will have a beneficial impact on the collective performance of the remaining workers and quite possibly of those reassigned, too. Because policy 2 moves anyone who diminishes the performance of others, it disrupts the poor relationship equally on low-skilled and high-skilled teams.

Millhiser et al. (2011) inferred that a worker impacts others negatively by averaging the performances of that worker and all the worker's dependent partners, referred to as the worker's collective contribution. This policy identify who depends on whom; if group that depends on the same person is performing poorly, then perhaps it would benefit if that person were reassigned. One thing need to be noted here is that the individuals who are poor performer not necessarily to blame because they may be helpful to a different group of members. For example, consider a 6-member team with interdependence shown in Figure 4-1d and the following individual and collective contributions.

In Table 4, worker 2's collective contribution is the average performance of worker 2 and dependent partners 1, 3, and 5 [(0.53 + 0.80 + 0.22 + 0.82)/4 = 0.59]. Then, the worker 3 and worker 6 are moved to another team because their collective contributions are smallest and less than average (0.5).

Table 4. Example of collective contribution

Worker (i)	1	2	3	4	5	6
Observable individual performance	0.53	0.80	0.22	0.30	0.82	0.36
Collective contribution	0.50	0.59	0.29	0.55	0.68	0.43

Policy 3: Transferring the least supported members

Because policy 2 is based on identifying individuals who provide the least help to their dependent partners, Millhiser et al. (2011) considered another policy where they identified individuals who receive little support from their contributing partners.

A worker receiving poor support is reflected in the individual performance measure. If a worker exhibits low performance (less than average), then this is partly due to poor support from that worker's K contributing partners. Policy 3 identifies the workers with the lowest individual performances under the assumption that their reassignment allows new connections.

Returning to the 6-person cohort used in the earlier example, worker 3 has the lowest performance, indicating that contributing partner 6 may not be supportive; reassigning worker 3 improves the chances of finding new support. Similarly, workers 4 and 6 would be reassigned because of their low performances. This example demonstrates two recurring trade-offs. First, like the removing low contributor policy, as more workers are assigned to another team, it is more difficult to break free of unsupportive partners. For instance, when assigning workers 3, 4, and 6 to another team, worker 1 will continue to depend on worker 2. Second, the assignment of a low-performing worker indicates poor support from contributing partners but says nothing about that worker's potentially useful contribution to dependent partners. For example, the reassignment of worker 3, 4, and 6 to another team may improve their performance, but worker 1 loses support from workers 4 and 6 and worker 2 loses support from worker 3.

Objectives

The complexity based ABM model presented here has two types of agents. The first type is the project manager. Project managers usually have more responsibilities than general workers. The objective of project managers are set as "meet the annual target of profit." In practice, the annual target of profit for project managers is often set between 1.6 to 2.5 times their annual salaries. The primary objective set for workers is simply to "complete the work." Although there are other factors, such as motivation and engagement, that may affect the objectives of workers, we assume that the objective workers is to just complete their assigned work and keep their jobs in the company.

Learning

Workers in our model do not have specific learning functions. This model simply used "rise in salary" to show a worker's learning process. For example, I assume that the annual salary of workers increases based on their previous year's performance. Workers also gained work experience. When the salary rise that means the workers' expected capacity increased too.

Prediction and sensing

Prediction is fundamental to decision-making. Prediction is a particularly fascinating part of modeling behavior because a prediction is itself a model: researchers predict the outcomes of our actions by modeling those actions and their consequences. The use of prediction in modeling behavior is quite common. Many models use tacit prediction (Holland 1995).

For example, Railsback and Harvey (2002) provide a model called the Business Investor model. The objective function uses explicit prediction: investors rate alternative business opportunities by their expected wealth at the end of a future time horizon, which they calculate by predicting that the annual profit and failure risk at each patch will be constant over a selected time horizon. The simulation results showed that people out to make a quick buck make different decisions than people making a long-term investment; they would expect a short time horizon to cause investors to seek higher incomes but suffer random failures more often. The results also confirm the expectation that investors take fewer risks and suffer fewer failures when they base decisions on longer-term predictions.

One general approach to modeling decisions when nothing is known about the alternative is to assume agents make changes (move, change investment, etc.) more frequently when their objective is not being met well, and change less frequently when their objective is being met. For example, when ecologists model how animals move in search of food, they sometimes use klinokinesis – moving faster when food intake is low and moving slower when it is high, and orthokinesis – turning less when food intake is low and more when intake is high. A simple version of this approach is to assume agents make a change when their objective function is below a satisficing threshold: if conditions are not good enough to eventually meet one's goal, then one tries something else.

A similar concept is used in my research. Let's assume that workers cannot sense the profit or the failure risk at any patch except their own. Instead, let's assume the workers have a satisficing threshold that is a specific amount of profit, and they abandon their patch (after completed that work) if it provides the amount of profit less than that threshold. They need to keep finding enough amount of profit to alive in the company. Since we are now assuming workers have no ability to sense information about other patches, so it is reasonable to simply assume they choose a new patch randomly.

Interaction

Local interaction is one of the defining characteristics of ABMs. The term interaction refers to how agents communicate with or affect each other, such as exchanging information, competing for resources, helping or fighting each other, or conducting business. Researchers also use interaction for how agents affect, and are affected by their environment; environmental interactions such as consuming and producing resources are very important in many ABMs (Railsback & Grimm 2012). System-level models, in contrast to ABMs, must use the same equations and parameters to present the effects of interaction on all members of the system. In an ABM we can explicitly model interactions as ways that individual agents affect each other and their environment. Consequently, the effects of interactions, and even the kinds of interaction, can depend on the states of the agents and on their environment. Interactions simulated in ABMs are often local – each agent affects only a few nearby others and only its local environment – whereas interactions in system-level models are global: all members of the system affect all other members. Interaction can be modeled as direct interaction, in which an agent directly affects another by exchanging information or resources. But ABMs also often represent mediated interaction. Competition for a shared resource, or signaling by producing or using something, are examples of mediated interactions.

In our model, the interaction between agents is described in the design principles section. The interdependence of workers can be captured and measured by DSM. However, it is not enough for managers to measure team performance based on workers' abilities and interdependence because teams also interacted with the environment. The ABM for team selection here also provides an environment of available projects in the market. This research specially design to demonstrate the interaction between agents and environment. It is useful for managers to see the emergent result (earned profit). Unlike previous research, this study provides a set of more realistic conditions and shows the resulting emergence from the interactions between workers and the environment to enable managers identify which team selection methods and replacement policies can yield better performance.

Stochasticity

In modeling, stochastic describes processes that are at least partly based on random numbers or events. Stochastic processes therefore produce different results each time a model executes because the random events or numbers are different each time. I apply stochasticity concept in many ways in the model.

One of most common uses of stochasticity is to assign initial values to variables, especially when initializing a model. For example, we set workers as agents, with each worker having a variable for salary. When the model starts, we need to give each agent a unique but realistic salary. Data collected from construction design firms in Taiwan indicate that the annual salary of a fresh engineer follows a normal distribution with a mean of $25,000 and a standard deviation of $5,000. We could initialize the model by giving each agent a salary drawn randomly from a normal distribution with this mean and standard deviation. This kind of concept also applies to other variables, such as the salaries of senior engineers or project managers, the project budget, etc.

Collectives

ABMs represent a system by modeling its individual agents, but surprisingly many systems include intermediate levels of organization between the agents and the system. Agents of many kinds organize themselves into what we call collectives: groups that strongly affect both the agents and the overall system. In our model, we already divided the agents by different team selection methods based on literature reviews. Thus, there are no collectives in our model.

4.2.3 Details

Initialization

This step refers to how we set up the model at the beginning of the simulation, because the results of a model often depend on these initial conditions. Examples of initial conditions includes are the number of agents created, the initial values given to the state variables (location, size, etc.) of the agents, and the initial values set for environment variables. It is important to make a model and its results reproducible, so we have to specify the initial state of all the state variables of all entities in the model.

In our model, the major purpose is to observe differences in team performance resulting from different team selection methods. Since the interdependence matrix is hard to create for a large company, a small project based firm better serves as a case study. The detailed model parameters, assumptions, and initial settings are based on the data that we collected from a company from 2009 to 2011. More detailed descriptions of the settings are provided in the next chapter.

Input Data

Models often include environmental variables like temperature or market price that change over time and are read into, instead of simulated within, the model. These inputs are usually read in from data files as the model executes. The input data does not refer to parameter values or initialization data, which are also sometimes read in from files at the start of a simulation. The input data I set in the model is the economic situation. The data range is from 0 to 1. The average condition is set as 0.5. This data will be changed based on the economic prediction.

Sub-models

All the major processes in the model are considered sub-models. The sub-model can be as a model of one process in the ABM; sub-models are often almost completely independent of each other and can be designed and tested independently. The sub-models are listed in the schedule, and to make the ABM reproducible, all equations, logical rules, and algorithms that constitute the sub-models must be described. Even more importantly, rationales behind how the sub-models were formulated is also documented here. This includes what literature was used, what assumptions were made, how parameter values were derived, how the sub-model was tested and calibrated, and under what conditions the sub-model proved to be more or less reliable.

Our ABM can be divided into several sub-models and be categorized into two groups, the team selection processes and the team selection methods. The sub-models of the team selection processes include: assigning, forming, and replacing members. The details of processes have been already discussed in the previous section of process overview and scheduling. Each team selection method chosen for comparison were built as different sub-models. The details of those selection methods have been demonstrated in the section of principle of design concept in the ODD protocol. These sub-models are all supported in previous research.

Summary of ODD review

Describing a model on paper is perhaps the most important part of modeling. Very few benefits from modeling can be achieved without it. It is especially important to use standard concepts and formats to describe and design ABMs. These models are complex, so clear, standard ways to think and write about them are necessary. The standard languages of equations and statistical modeling cannot describe ABMs, so instead the ODD protocol and its design concepts are now used and accepted widely by researchers in different fields. ODD is generic and hierarchical. Generic means that ODD can be used to describe any

ABM in any field of application or discipline. Hierarchical means that ODD starts with an overview of a model's structure, scales, processes, and scheduling, so researchers can understand the model's basics, before presenting the details needed to understand how processes are actually represented.

Previous studies also show it is very clear how to translate the ODD format into a NetLogo program, which is the software that is used to develop the model in this study. Further details on the close correspondence between ODD and NetLogo and why NetLogo was chosen for this study are discussed in the following section.

4.3 Data Collection and Analysis

The collected data are the sources of inputs of the ABM model for team selection. According to the characteristics of ABM and the purpose of team selection model, the target company of the data collection needs to meet three requirements: 1) whole project data from the company in a certain period (a few years); 2) the detailed information of employees including their expertise, working experience, salary, etc. 3) the company take project in a certain boundary area. The data of projects and employees were collected from a small construction design firm- Yi-Hsin Engineering Design Consulting (YHEDC) at New Taipei City in Taiwan from 2009 to 2011. The detailed list of project data can be referred to the appendix II.

The YHEDC is a construction design firm established in 1991 and focus on the areas of road construction design, bridge design, hydraulic system design, geotechnical design, environmental design i.e., parks and sidewalks, and rehabilitated construction design projects. The scope of the work involve basic site investigation, pre-planning, basic and detailed design, bid assisting, and construction supervision. The company has completed hundreds of projects at 29 districts in New Taipei City in Taiwan. In 2008, this company received the "Best quality design award" that is the highest level award for a construction design firm in Taiwan. The numbers of employees are around fifteen to twenty. The team structure consists of three project managers (with professional engineer license) and the others are half of senior engineers and half of junior or fresh engineers.

The project data are collected from the 116 project proposals and contracts during 2009-2011. I spent 2 months during the end of 2012 in YHEDC in person to review all the project proposals and contracts. The collected data include the items of project location, project owner, project type, start and finish time, duration, service fee, project team (who responds to do the project) and the sample form of data is shown in Table 5.

Table 5. Sample Data Collection for Projects

Title	**Sanduo Road Construction Design**
Location	Shulin District, New Taipei City 238
Description	Road construction design for connecting Zhongzheng Road in Shulin District to Xinzhuang District
Type	Road (new construction)
Construction Duration	5/1/2009~9/30/2009
Design Duration	Basic: 30 days Detail: 40 days
Service Fee (Budget)	4,230,000 NTD (around 141,000 USD)
Service Fee (Actual)	4,000,000 NTD (around 133,000 USD)
Owner	Shulin District, New Taipei City Government
Project Manager	C. K. Chen
Engineers	B. Y. Liu, F. Y. Liu, C. B. Huang, and Z. J. Chu

The fifteen employee data include working experience, expertise, and salary. The sample form of data collection for employee is shown as Table 6.

Table 6. Sample Data Collection for Employees

Name	Z. P. Chen
Education	Master of Science Department of Civil Engineering, Taiwan Tech
Expertise	Hydraulic Engineering, Transportation Engineering, Landscape and Environmental Design, Construction Engineering and Management
License	Professional Engineer
Working Experience	26 years
Salary (per month)	100,000 NTD / 3,500 USD

	Employers	Title
1	Yi-Hsin Engineering Design Consulting	Project Manager
2	Taiwan Arbitration Association	Arbitrator
3	Construction and Planning Agency, Ministry of the Interior	Chief Construction Engineer
4	Construction and Planning Agency, Ministry of the Interior	Director
5	Construction and Planning Agency, Ministry of the Interior	Senior Transportation Engineer

The interdependence matrix (shown in Table 7.) was filled out by the project managers of YHEDC with face-to-face interview. This matrix lists the relationships including who contributes to who, and who get supports from who between all workers in YHEDC.

Table 7. Workers Interdependence Matrix of YHEDC

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	x			x			x				x				
2		x			x	x			x						
3			x					x				x	x		
4				x					x					x	x
5			x		x					x			x		
6		x				x	x								x
7	x				x		x				x				
8		x						x							
9			x			x			x			x			
10				x				x		x					x
11	x										x		x	x	
12		x	x				x					x			
13					x				x				x		x
14	x					x					x	x		x	
15		x		x						x					x

After collected the data from 116 projects, the descriptive analyses are used to overview the scope of data. The domains of descriptive analyses include project types, project design service fees, employees' working experience, and the structure of salaries. The five major project types that YHEDC works on are road construction design, bridge design, hydraulic system design, geotechnical design, and landscape and environmental design. The distribution of these five project types is shown in Figure 7. Road and bridge design are two major project types that YHEDC focus on – more than 50% of the total projects are in these two types. Although hydraulic system design and geotechnical design cover 36% of total projects, most of these design work are associated with road and bridge design projects.

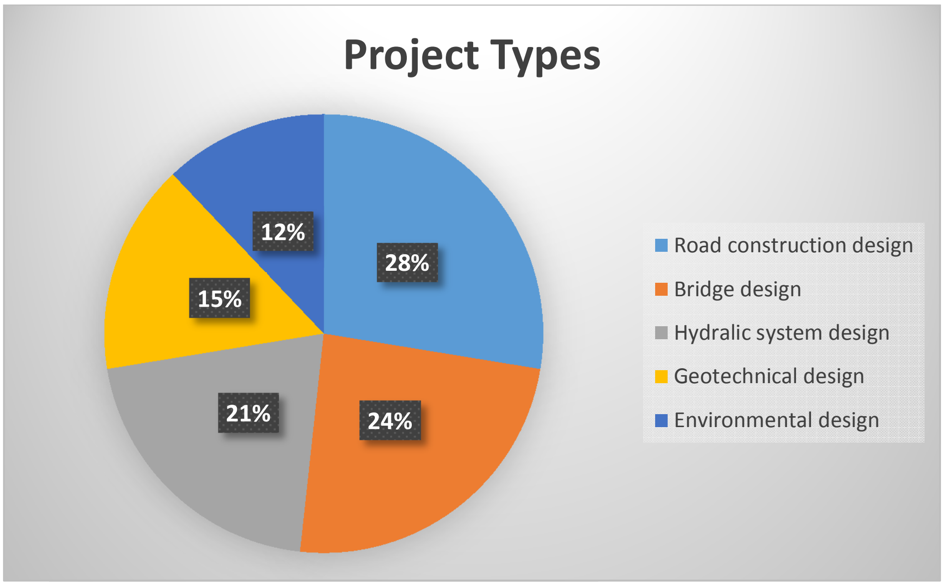


Figure 7. Distribution of Project Types of YHEDC

In Figure 8, the over 50% of project design service fees are in the range from $10,000 to $50,000. This shows that YEHDC focus on taking small design projects. Only 4% of projects have service fees higher than $100,000 and around 20% of projects have service fees from $50,000 to $100,000. The rest of 21% project service fees are less than $10,000. Considering YEHDC is a small design firm with around 15 employees and the average project design duration is 20 days, the distribution of project service fees is reasonable.

The distribution of employees' working experience is shown in Figure 9. There are three project managers in YHEDC and around 27% of employees have more than 20 years working experience. There are 46% of employees who have working experience in the range from 10 to 20 years. More than 70% of employees are senior level engineers and only 27% of employees are in entry and junior level. This shows that the project teams of YHEDC have rich experience in their professional areas. The structure of salaries also reflects that (shown in Figure 10). Although the salaries looks fairly low compared to the

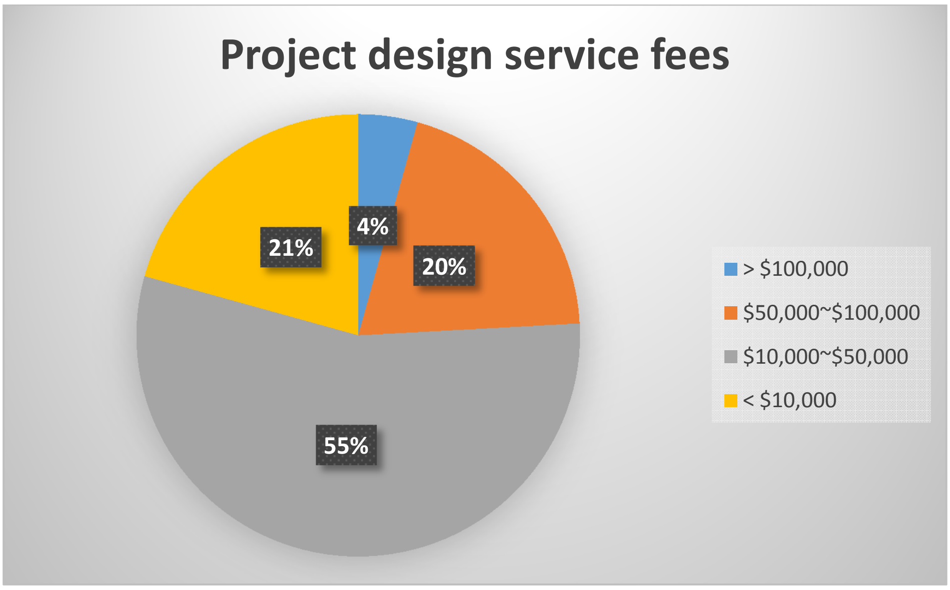


Figure 8. Distribution of Project Design Service Fees of YHEDC

salaries of civil engineer in United States, the salaries are competitive in the construction related industries in Taiwan.

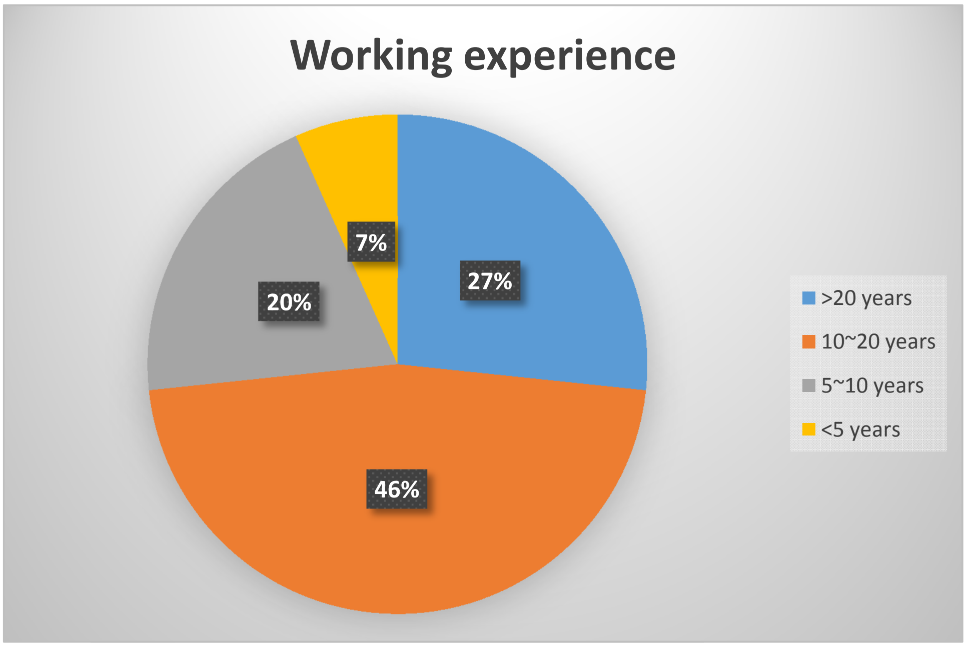


Figure 9. Distribution of Employees' Working Experience in YHEDC

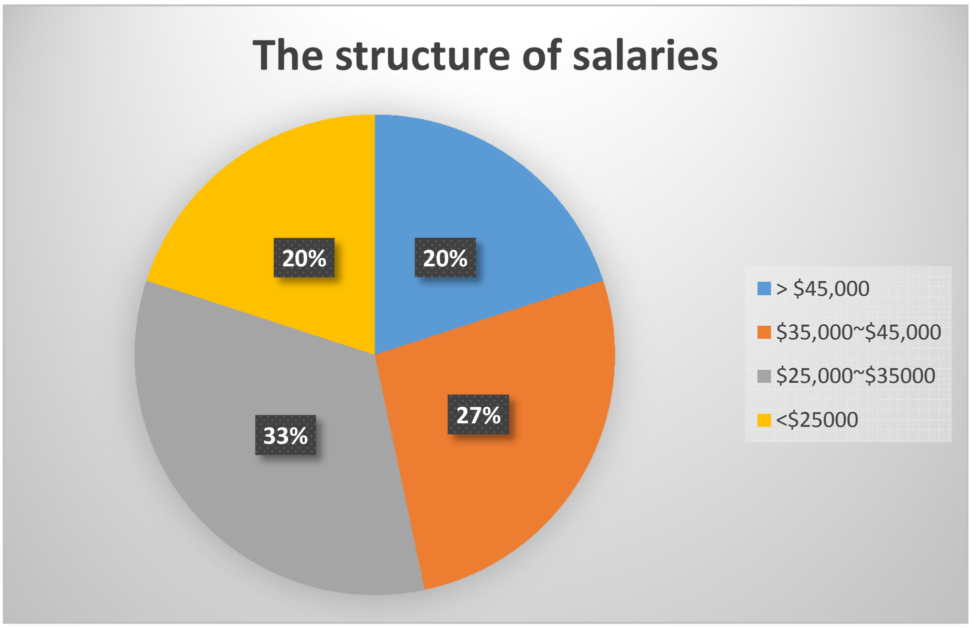


Figure 10. Distribution of Employees' Salaries in YHEDC

Other than the data collected from YHEDC, the available projects information are collected from the government bidding system in New Taipei City in Taiwan because YHEDC only did projects in New Taipei City. This can keep the ABM model as simple as possible because it has clear boundary of project market. According to the collected data from the YHEDC and the government bidding system in New Taipei City in Taiwan, the inputs of model parameters and assumptions are then listed as Table 8.

Table 8. Model parameters and assumptions

Parameter	Value	Comments
Number of projects initially available	10	
Number of capabilities valuable	5, randomly assigned portions of capabilities to projects	Limited number of capabilities. The sum of portions is equal to 1.

Number of projects available each day	1~5, based on economic situation prediction. Set 3 as initial setting.	Collected data from the government bidding system in New Taipei City in Taiwan. The average number of projects available each day is around 3 in general economic conditions.
Project cost	30~7000, randomly assigned	Collected data from government bidding system in New Taipei City in Taiwan. The cost of available design projects is a range from 30k to 7000k for small firms.
Project duration	(94.245 + 1.334 * 10 ^ (-6) * project cost) / 10) * 10	Based on a regression analysis of project cost and project duration.
Expected project return	0.047~0.061, randomly assigned to project with cost from 3000k to 7000k 0.061~0.072, randomly assigned to project with cost from 800k to 3000k 0.072~0.083, randomly assigned to project with cost from 200k to 800k 0.083~0.094, randomly assigned to project with cost less than 200k	Collected data from the government bidding system in New Taipei City in Taiwan. The expected project return is based on the project cost. The larger the project, the lower the expected return.
Number of teams	1~10, set 3 as initial setting.	Small groups
Worker's salary	Normal distribution with a mean of $25,000 and a standard deviation of $5,000 for a fresh engineer. Normal distribution with a mean of $ 35,000 and a standard deviation of $5,000 for a senior engineer. Normal distribution with a mean of $45,000 and a standard deviation of $5,000 for a project manager (PE)	Collected data based on interviews with some small design firms in New Taipei City in Taiwan.
Worker's expertise	5, randomly assigned portion of expertise to workers	Limited number of expertise. The sum of portions is equal to 1.

Initial capacity of individuals	1.6~2.5 times of salary of workers	Based on the overhead of the firm. In practice, the larger the firm, the larger the overhead.
Initial capacity of each team	Sum of individual capacity in the team	
Capacity renewal each time step		Return earned contributes to next period capacity

4.4 Team Selection Model Development

This section describes the team selection model developed for this study (shown in Figure 11). The team selection model was built using the software, NetLogo. NetLogo is a programmable modeling environment for simulating natural and social phenomena.

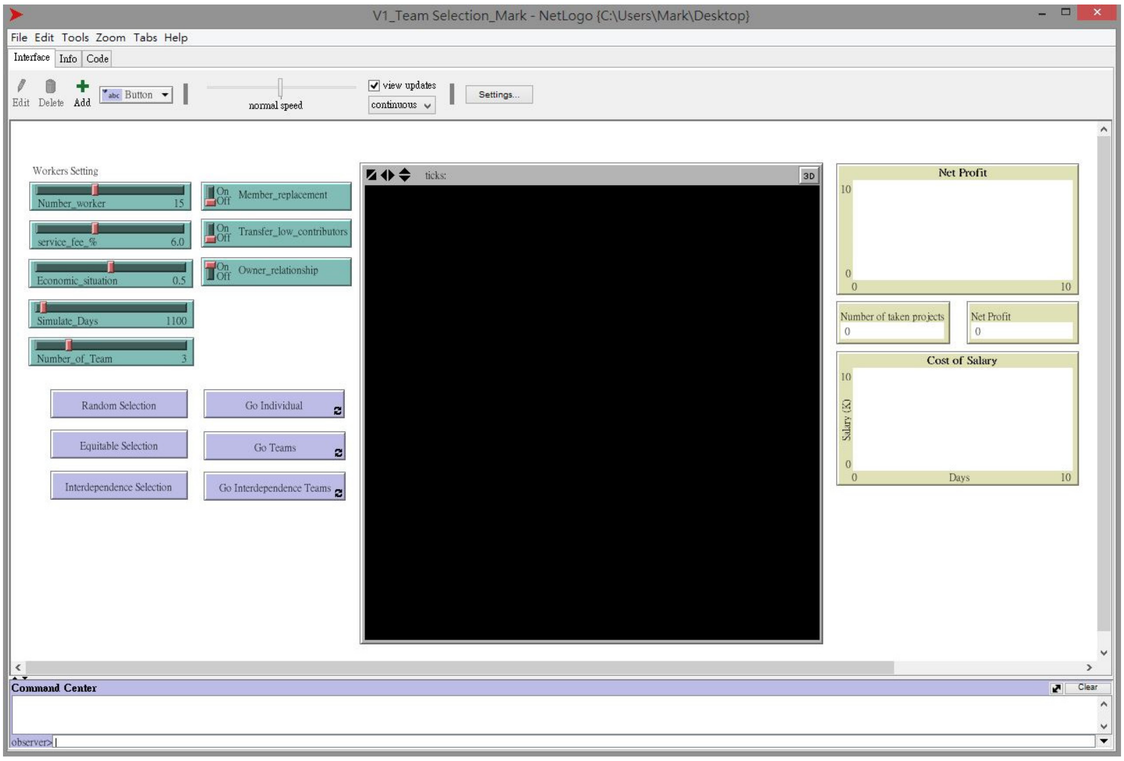


Figure 11. Project Team Selection Model

It was authored by Uri Wilensky (1999) and has been in continuous development ever since at the Center for Connected Learning and Computer-Based Modeling in Northwestern University. NetLogo is particularly well suited for modeling complex systems that develop over time. Modelers can give instructions to hundreds or thousands of agents all operating independently. This makes it possible to explore the connection between the micro-level behavior of individuals and the macro-level patterns that emerge from their interaction.

There are four types of agents in NetLogo:

1. Mobile agent - NetLogo are refers to these as turtles. In this study turtles represent workers.
2. Patches - These are square cells that represent space. The patches in this paper's model represent available projects in the market.
3. Links - Each link connects two turtles and provides a way to represent relationships among turtles such as networks. The color of agents are used to more clearly show these linkages.
4. The observer - This agent can be thought of as an overall controller of a model and its displays. The observer does things such as create other agents and contain global variables. The observer in this study's model is a program manager who makes decisions on forming teams and replacing team members.

The agents here are a little different from how they are typically used by ABMs. When talking about ABMs instead of NetLogo, the "agents" refer to the individuals in a model that make up the population or system we are modeling, not to things like patches, links, and the observer. Each of these types of agents has certain variables and commands that it uses. The NetLogo Dictionary is where these variables and commands are defined. There are several important built-in variables for each agent type, which users can find in the dictionary. These built-in variables represent things like location and color, which are used in almost all models. Variables belonging to the observer are automatically "global" variables, which means that all agents can read and change their value. Global variables are often used to represent general environmental characteristics that affect all agents and to represent model parameters. A primitive is one of NetLogo's built-in procedures or commands for telling agents what to do; these primitives are extremely important because they do much of the programming work for users. For example, the primitive *move-to* tells a turtle to move to the location of a patch or other turtle. The code environment is shown in Figure 12. The detailed NetLogo code for the team selection model is provided in the appendix and the pseudocode of my model is as follow:

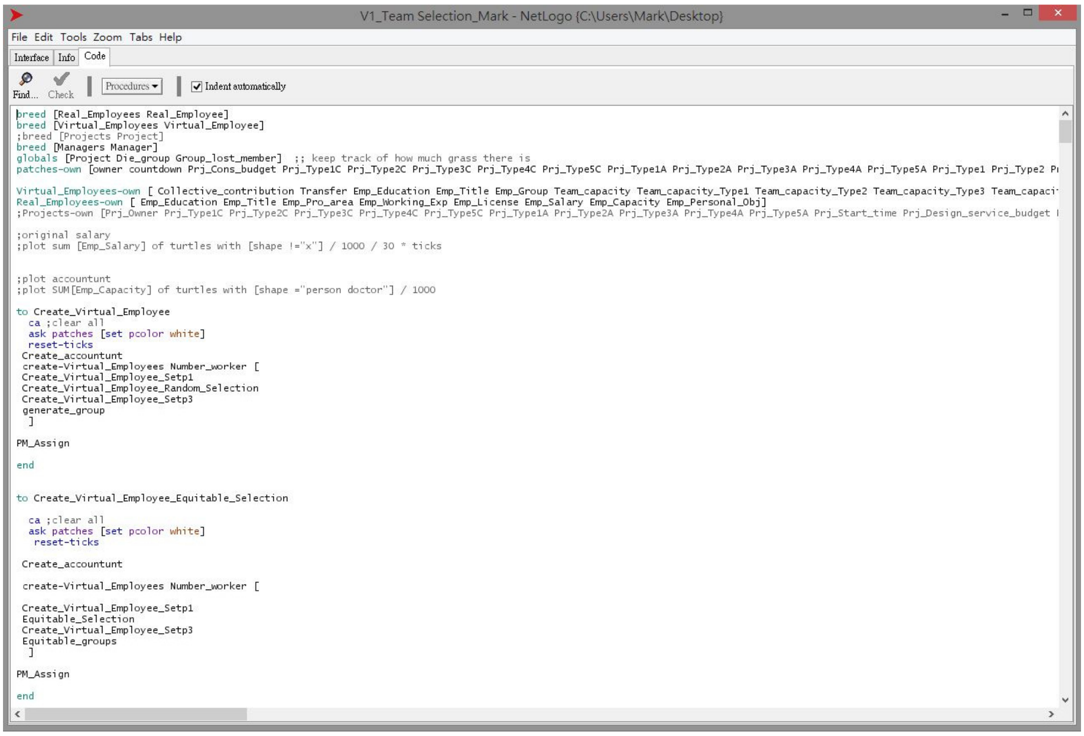


Figure 12. Code of environment in NetLogo

Team Selection Model Pseudocode

```
to setup
   create m workers
   for all workers
      set salary random ($25,000~$50,000)
      set expertise random (1~5)
      set individual capacity (salary * random (1.6~2.5))
      set location random
      set collective contribution random (0.6~1.3)
      set number of teams (1~10) based on user input

   create n projects (initial available on patches)
   for all projects
      set type random (1~5)
      set cost random (range with collected data)
      set duration (range with collected data)
      set profit rate (range with collected data)
      set location random
end
```

Perform team selection based on user input to

1) Random
2) Equity
3) Interdependence

```
   to team selection (random)
      set at least one worker in each team
      set randomly assign workers to teams
   end

   to team selection (equity)
      set number of workers / number of teams based on user input
      set capacities of capabilities of each team are equilibrium (dividing workers based
          on functional diversity)
   end
```

```
  to team selection (interdependence)
    set number of workers / number of teams based on user input
    minimize TDP (refer to page in dissertation)
  end

to go
  ask workers move random in the market
    when workers met projects
      if team capability match project type and team capacity > project cost
        team has random (0.2~0.5) possibility to take project
      if team take the project, then team earned profit from the project and project was
        eliminated in the market
  ask projects reproduce (based on collected data)
  ask workers replenish capacity (after project completed)
    if workers' profit taken is lower than expected p
      they will be
        1) fired
        2) transferred (based on collective contribution)
  states program profit (sum revenue of completed projects – workers' salaries)
end
```

Figure 13 shows the functions of the Project Team Selection Model divided into four areas: A) global variables input, B) different team selection settings, C) a model demonstration display, and D) a set of result displays. The One of the global variables is the number of workers, which was given an initial setting of 15. Another global variable is economic situation, defined as a prediction about market growth or depression. A value close to 1 means that the market is better; in contrast, a value close to 0 means that the market is poor.

The initial setting of 0.5 indicates an average economic situation. The number of simulation days can be set according to a user's target. The initial setting is 3 years, which is around 1100 days. The initial number of teams was set at 3. There are three switches:

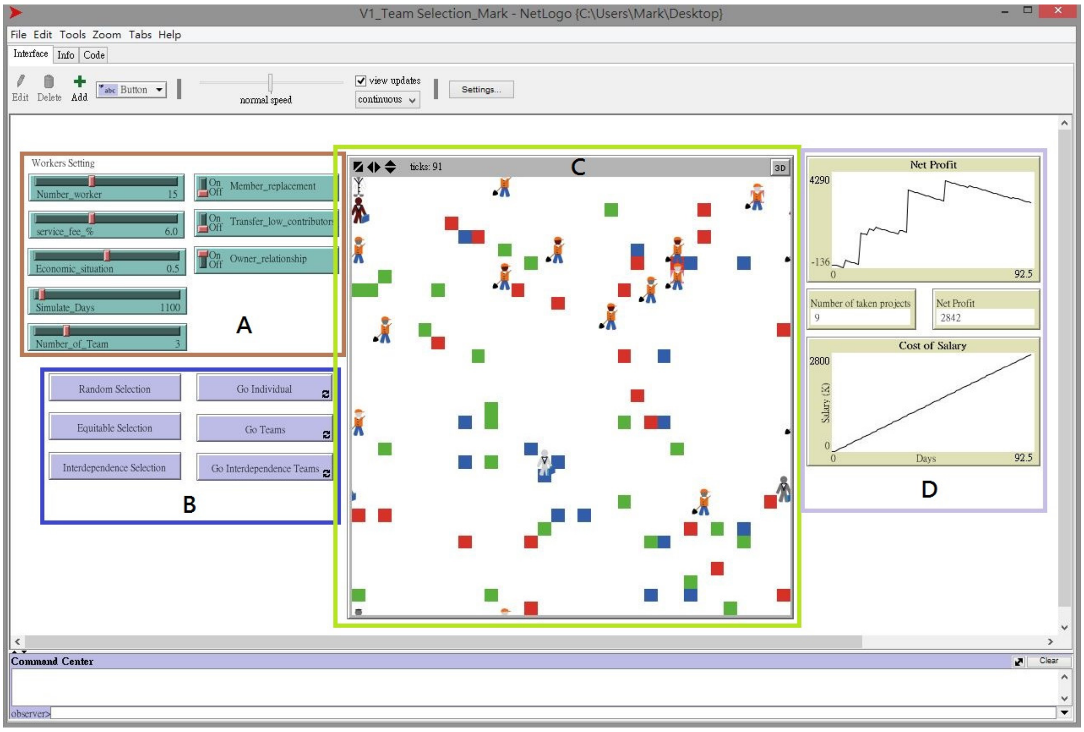


Figure 13. Functions of Project Team Selection Model

replace poor performers, remove low contributors, and remove the least supported members. Users can decide which switch they want to test to influence the overall multiple team performance.

Below the global variables on the user interface are buttons related different settings related team selection methods. The “Go Individual” button sets employees to work individually Second is to divide the workers into different teams by random selection. The “Equitable Selection” means that the manager (observer) divided the talents and the workers with different expertise (function-based) evenly to different teams. The final selection method is interdependence-based selection. The detailed theory of this selection method has been discussed in previous section at 4.2.2. The manager is assumed to know who works well together with whom and split them into different teams with minimal interdependence disruption.

Part C is a visual market I created for the firm. The model can display interactions between turtles and patches. The turtles here are employees (in the shape of human workers with shovels) and project managers (which appear with briefcases). Different colors of workers mean that they are in different teams. Workers with same color faces are on the same team. The small squares on the patches are available projects in the visual market. The different colors of the projects indicate different project costs. When workers are assigned to a project, the project color changes to pink and the workers cannot move. After the project is completed, the workers can move and search for new projects on the market.

The plots in area D shows the emergent results, including the profit earned from the model. The major function of this area is to provide an easier way to compare the differences in performance resulting from different team selection methods. Simple static analysis methods assess the profitability of an investment for a time span of one period. Unless otherwise specified, the term "profitability" is used here to indicate the achievement of positive or higher economic returns from a project (GoEtze et al. 2008 (Investment appraisal)). However, it should not be confused with the concept of "accounting profit," which includes non-cash items and accounting adjustments and is not always consistent with economic, wealth-maximizing decision objectives. The profitability considered here can be thought of in two ways – in absolute terms or in relative terms. Absolute profitability means that making an investment is better than rejecting it. Relative profitability means that investing in project A is better than investing in project B. In using financial analysis to assess an investment's absolute or relative profitability, specific assumptions are made:

a. The model's data and linkages are known with certainty.

b. All relevant effects can be isolated, allocated to a given investment project, and forecasted in the form of revenues and costs or cash inflows and outflows.

c. No relationship exists between the alternative investment projects being analyzed, apart from their mutual exclusivity.

d. Other decisions, such as financing or production decisions, are made before the investment decision.

e. The economic life of the investment projects is specified.

The profit comparison method (PCM) is used to compare the relative profitability of different team selection methods for a small design firm. As the name suggests, the profit comparison method differs from the cost comparison method because it considers both the cost and revenues of investment projects. The target measure is the average profit, which is determined as the difference between revenues and costs. Apart from this difference, all of the other assumptions made in the PCM are the same as shown previously. As applied in this study, relative profitability is achieved by a team selection method when it leads to a higher profit than other team selection methods. Each team selection method is run through the simulation 25 times. The outcomes of the simulations are then compared to identify differences in profit earned according to each of the team selection methods. There are two major comparisons – different team selection methods with sensitive analyses for diversity of team capabilities and workers' interdependence within different economic condition settings, and different team member replacement methods. The detailed simulation results analyses are presented in the following sections.

4.5 Model Verification and Validation

I follow the guidelines of Rand and Rust (2011) for an agent-based model verification and validation. Verification is the process of making sure that the implemented model corresponds to the conceptual model, while validation is the process of making sure that the implemented model correspond to the real world.

There are three steps for model verification: Documentation, Programmatic Testing and Test Cases and Scenarios. The conceptual design of model is described in section 4.2.2. The implemented Netlogo model itself also contains inline documentation. In terms of programmatic testing, extensive unit testing was carried out to confirm that each component of the model produced desired outputs. In addition, both code walkthrough and debugging walkthrough were used. Corner cases were explored extensively to make sure that there were no bugs at the extreme ends in the code with regards to test cases and scenarios. Finally, several specific scenarios were generated which were easily predictable, to make sure that the model behaved as expected. For example, the model was tested by the sets of scenarios including: 1) using teams can outperform employees working individually; 2) using teams can improve the possibility of taking projects; 3) using teams can take larger projects than working isolation. In each case the model presented in my research performed as expected and so to that extent the model is verified.

Models are used to predict or compare the future performance of a new system, a modified system, or an existing system under new conditions. When models are used for comparison purposes, the comparison is usually made to a baseline model representing an existing system, to someone's conception of how a new or modified system will work (i.e., to a baseline design), or to current real-world system performance (Carson 2002). In any of these cases we want to know that the model has sufficient accuracy. Sufficient accuracy means that the model can be used as a substitute for the real system for the purposes of experimentation and analysis (assuming that it were possible to experiment with the actual system). Thus it is important to validate any simulation by comparing its results to a real system (Naylor & Finger 1967; Carson 2002; Sargent 2011). This section describes the simulation results based on the initial settings of the model. The simulation results are then compared to project data that was collected from the small design firm, YHEDC from 2009 to 2011.

Working Individually

First the simulation was run with employees set to work individually. No teamwork occurs according to this setting. The simulation results are shown in Figure 14. The results show that the firm experienced an average of $325,209 (with a standard deviation of $55,068) loss under these conditions (shown in Figure 15). This is because the projects in the market are more complex than individual skills typically can manage. There are just a few projects that can be completed by one person with relatively high skills.

Random selection

Next the simulation results of random selection teams are shown in Figure 16. The average profit is $946,169 (with a standard deviation of $264.931) shown in Figure 17, which is a $1,271,405 profit increase from working in isolation. This clearly shows why teams are used more frequently in today's business environment. Teams can increase capacity and capability when team members work together rather than in isolation.

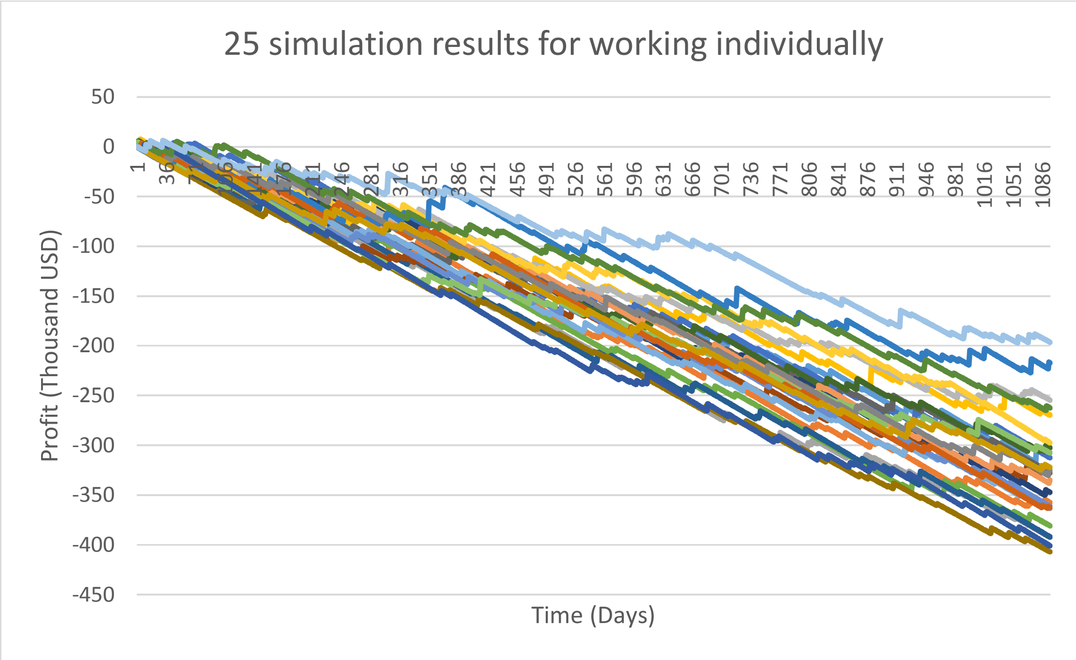


Figure 14. 25 simulation results for working individually

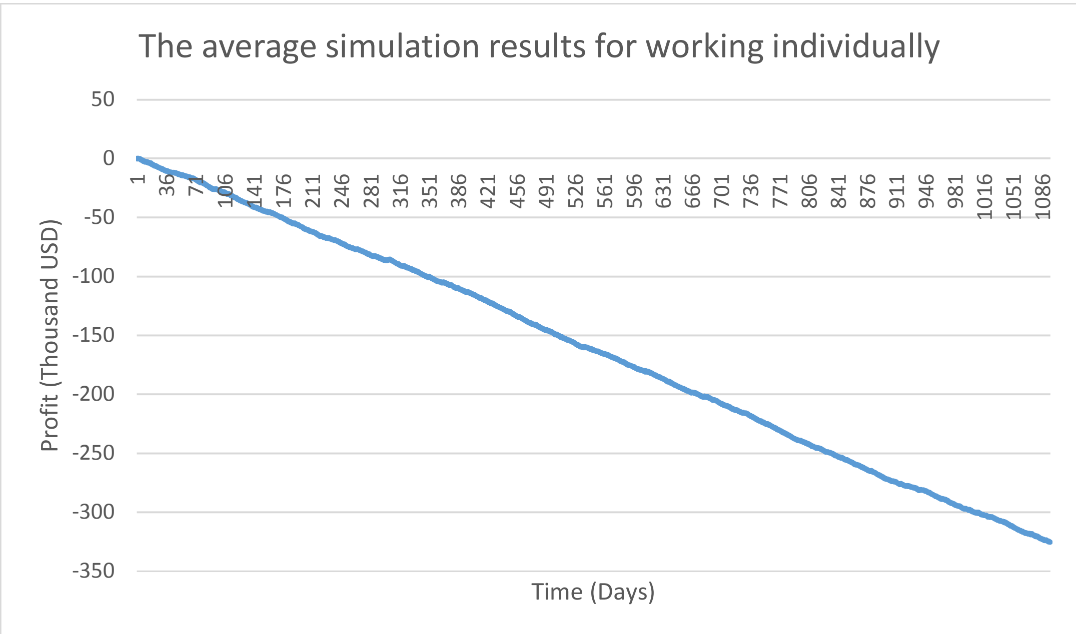


Figure 15. The average simulation results for working individually

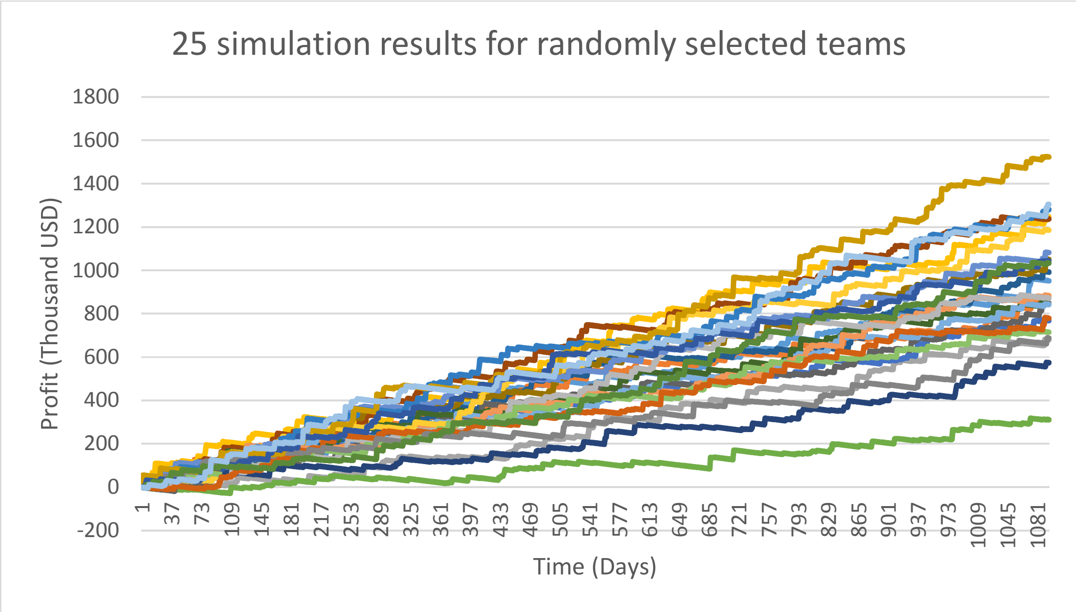


Figure 16. 25 simulation results for randomly selected teams

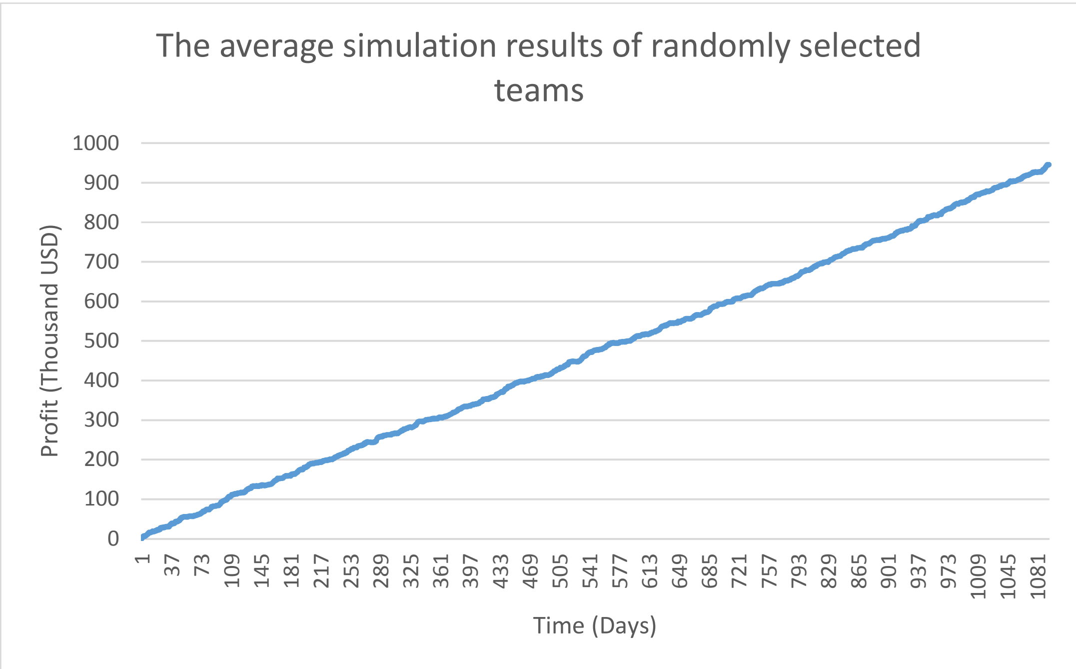


Figure 17. The average simulation results of randomly selected teams

Equity selection

The equity method is used very often in today's business. The simulation results are shown in Figure 18. The average profit earned is $1,039,159 shown in Figure 19 (with a standard deviation of $159,969), which is more than $92,990 profit earned compared to the random selection method. The equity method may be better than random selection because equity selection increases the diversity of team members – the teams have more diverse capabilities (worker's skills) to respond to complex projects in the markets. Therefore, even the same people are in a pool of employees, the overall multiple team performance will be increased if a firm uses an equity method to assign their employees to teams rather than random selection.

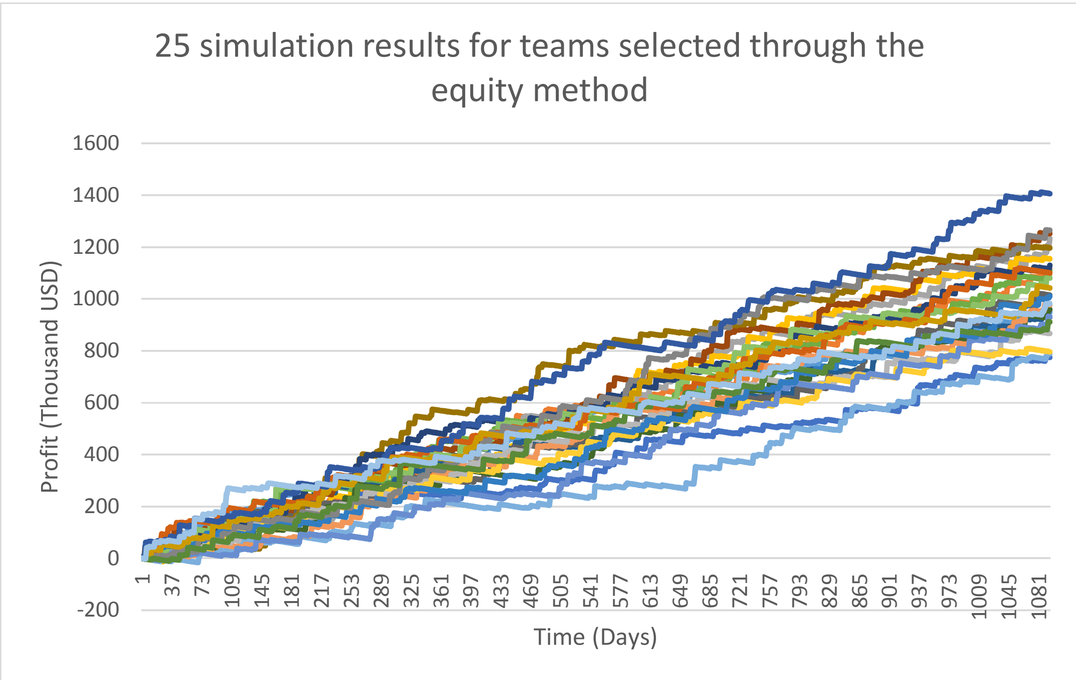


Figure 18. 25 simulation results for teams selected through the equity method

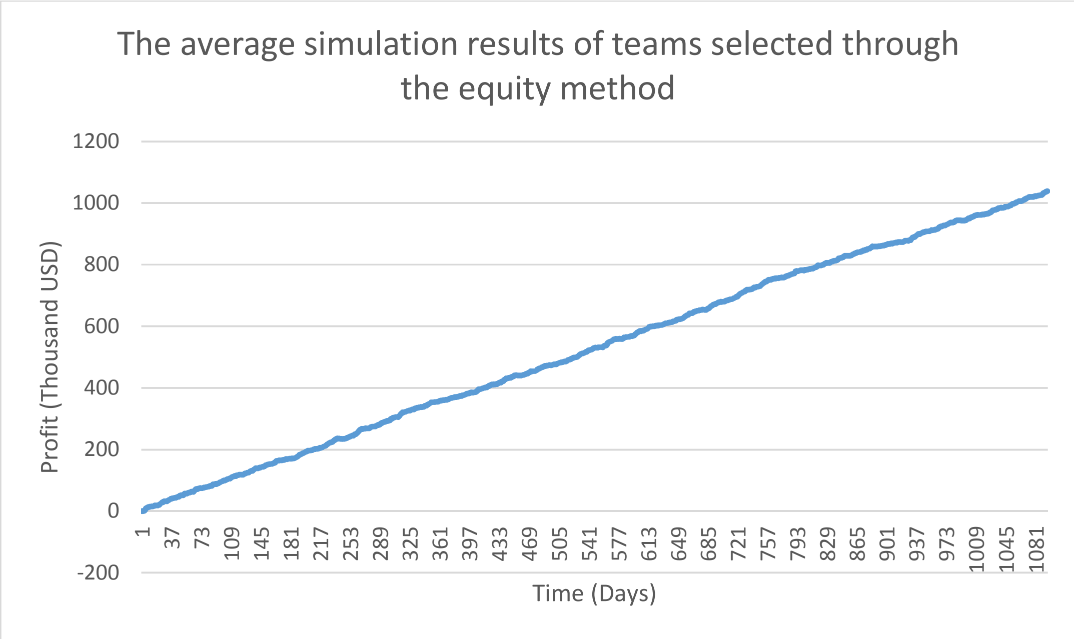


Figure 19. The average simulation results of teams selected through the equity method

Interdependence-based selection

As discussed in literature review, while previous studies have greatly enhanced our knowledge about team selection, there is little research on how to use knowledge of worker's interdependence to improve the team performance. The simulation of this study is a step toward closing this gap in the research. The simulation results for applying complexity-based team selection are shown in Figure 16. The average profit earned is $1,258,616 shown in Figure 17 (with a standard deviation of $191,374). The profit improved by $219,457 compared to the equity selection approach.

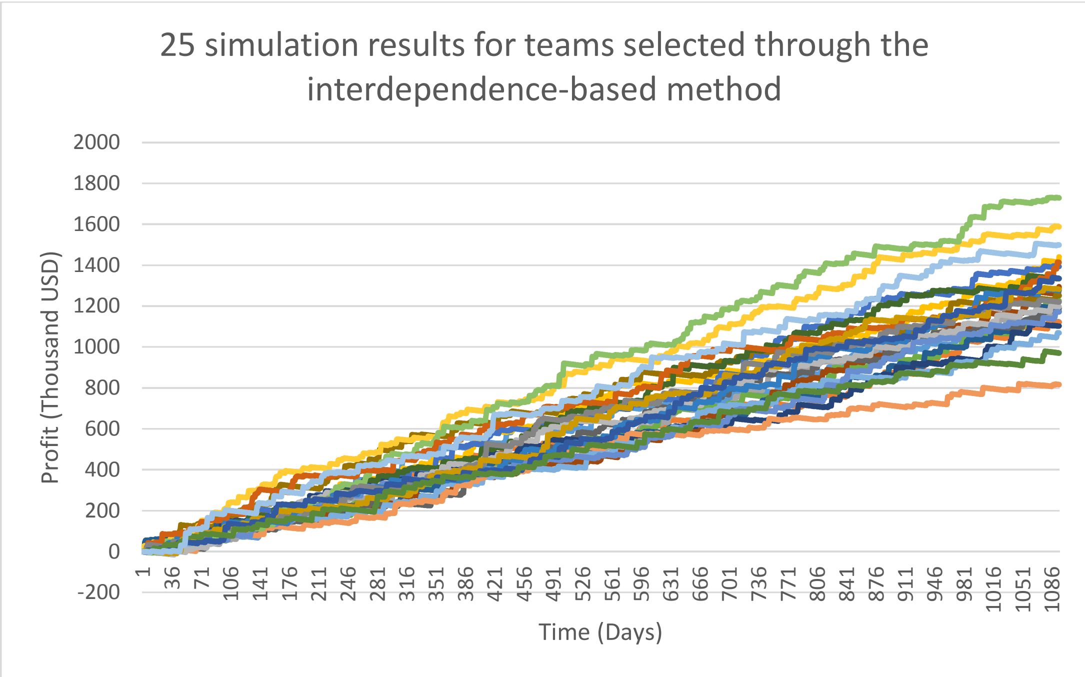


Figure 20. 25 simulation results for teams selected through the interdependence-based method

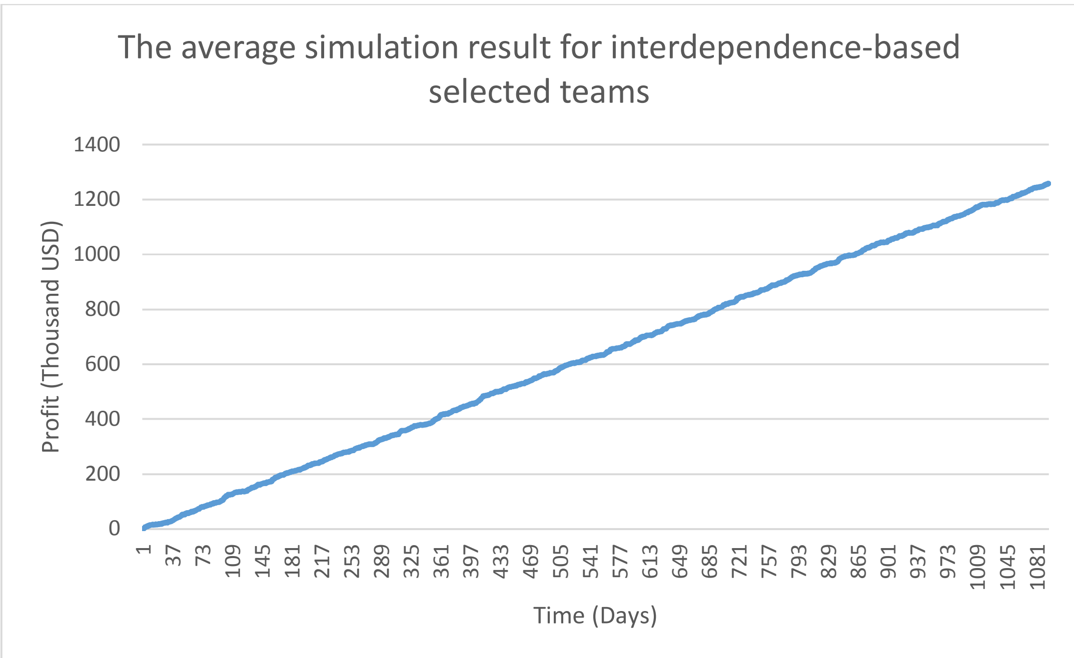


Figure 21. The average simulation result for interdependence-based selected teams

Comparison of different selection methods

The profit earned for each of the studied team selection methods is shown in Figure 22. The interdependence-based selection method is 21% better than the equity method, 33% better than random selection, and 4.87 times better than letting employees work in isolation.

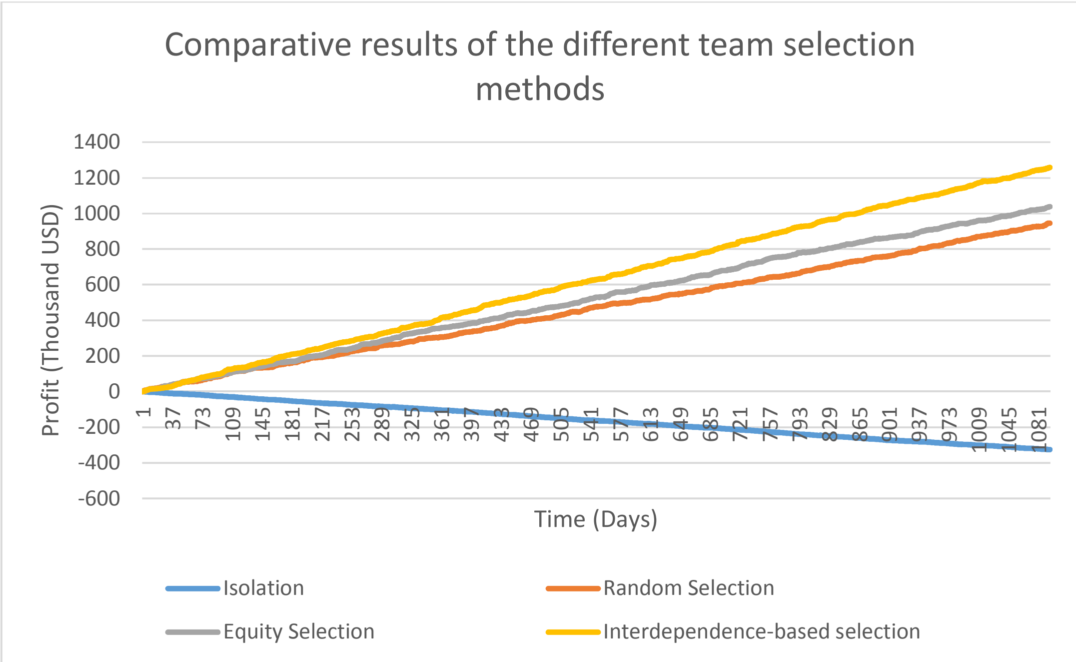


Figure 22. Comparative results of the different team selection methods

One-way analysis of variance, ANOVA, and the Least Significant Difference (LSD) test are useful tools for evaluating the significance of the simulation results of different team selection methods. The results from these analyses are shown in Tables 9 and 10, respectively. The analyzed results show that there are significant differences between these team selection methods. However, the difference between the random selection method and the equity method is not significant. Nonetheless the mean value of profit earned from the equity method is $92,990 higher than random selection.

Table 9. ANOVA for profit earned from each team selection method

ANOVA

Profit

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	3.838E7	3	1.279E7	377.847	.000
Within Groups	3250436.386	96	33858.712		
Total	4.163E7	99			

Table 10. Mutiple comparisons of team selection methods

Multiple Comparisons

Profit

LSD

(I) Selection	(J) Selection	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1	2	-1271.37827*	52.04514	.000	-1374.6871	-1168.0695
	3	-1364.36824*	52.04514	.000	-1467.6770	-1261.0594
	4	-1583.82450*	52.04514	.000	-1687.1333	-1480.5157
2	1	1271.37827*	52.04514	.000	1168.0695	1374.6871
	3	-92.98997	52.04514	.077	-196.2988	10.3188
	4	-312.44623*	52.04514	.000	-415.7550	-209.1374
3	1	1364.36824*	52.04514	.000	1261.0594	1467.6770
	2	92.98997	52.04514	.077	-10.3188	196.2988
	4	-219.45627*	52.04514	.000	-322.7651	-116.1475
4	1	1583.82450*	52.04514	.000	1480.5157	1687.1333
	2	312.44623*	52.04514	.000	209.1374	415.7550
	3	219.45627*	52.04514	.000	116.1475	322.7651

*. The mean difference is significant at the 0.05 level.

Model validation with real cases

The resulting profit earned and the numbers of projects taken in the simulation also quite well match the data collected from the small design firm in New Taipei City in Taiwan. The data covered 116 projects completed for the Taiwanese government between 2009 and 2011. The project data information included the project size, return rate, project duration, project scope, etc. Data on 15 employees was also collected, including their educational background, experience, expertise, etc. The average annual profit of the company from 2009 to 2011 was $338,144. The average profit earned on the projects was $8,745. A comparison of the profits earned according to the simulation and to real data is shown in Figure 19 and summarized in Table 8. The average profit earned is $346,386 with a standard deviation of $53,323. The average number of projects completed per year in the simulation are 37.4 (as compared to 35.3 from the real data). The average size of the projects in the simulation is $9,262.

A curve estimation of linear regression was used to examine the fitness between the simulation results and the collected data. A summary of the model, the ANOVA, and the coefficients are shown in Table 11. The value of R Square (0.985) indicates that the simulation results have a significant and positive correlation with the collected data (shown in Figure 23 and 24). According to these comparisons, the model demonstrates validity in simulating team selection. The simulation results also support the hypotheses that I proposed in this research. It remains interesting to see that the equity method doesn’t generate substantially better results than the random selection method. A sensitive analysis was conducted to examine if this apparently insignificant difference in performance between the random and equity methods holds under different economic conditions.

Table 11. Comparison of collected data and simulation result

Compared variables	Collected data	Simulation
Annual profit	$338,144	$346,386 (stdev: $53,323)
Annual numbers of project completed	35.3	37.4
Average size of projects	$8,745	$9,262

Table 12. Model summary of regression fitness of simulation validation

Model Summary

R	R Square	Adjusted R Square	Std. Error of the Estimate
.992	.985	.985	37.071

The independent variable is Data.

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Regression	9.780E7	1	9.780E7	7.117E4	.000
Residual	1502064.999	1093	1374.259		
Total	9.930E7	1094			

The independent variable is Data.

Coefficients

	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
Data	1.026	.004	.992	266.769	.000
(Constant)	55.600	2.096		26.526	.000

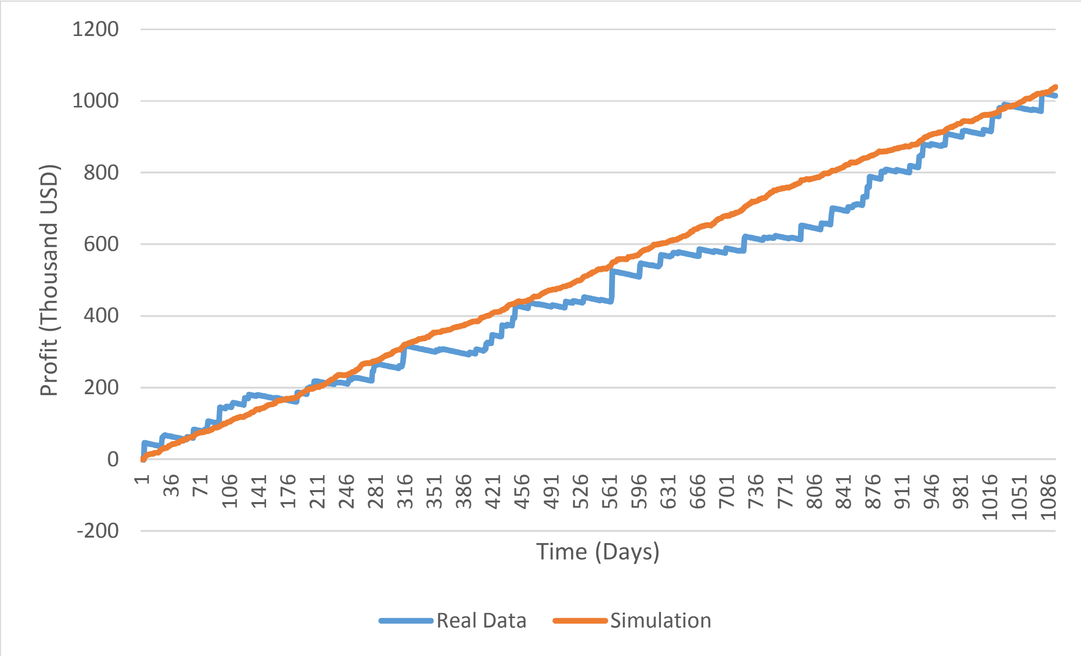


Figure 23. Profit comparison between the real data and the simulation results

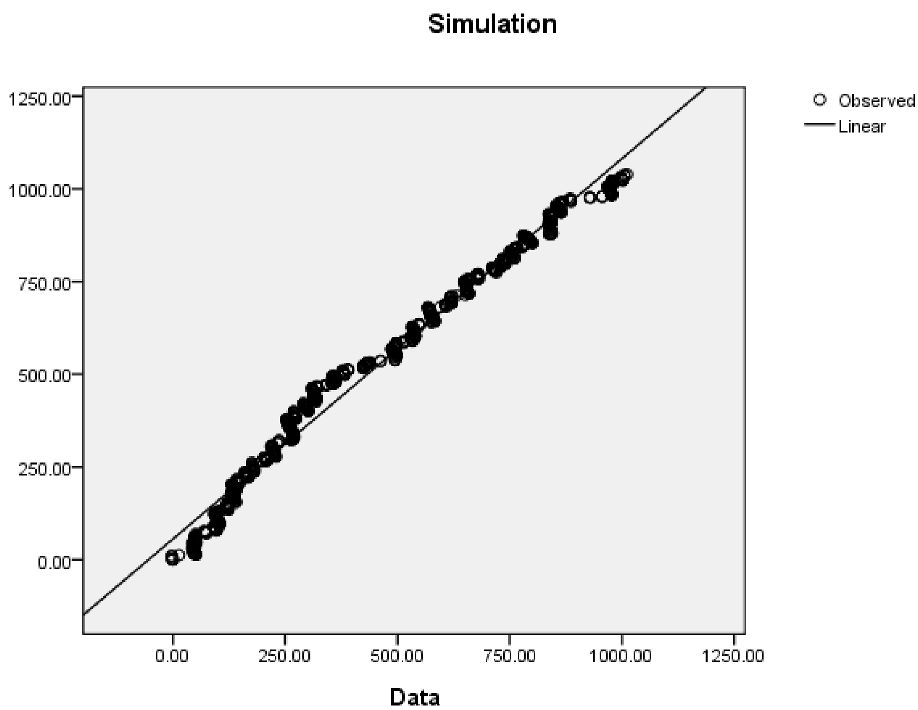


Figure 24. Curve estimation of the collected data and the simulation results

Chapter 5: Diversity of Team Capabilities

The equity method is characterized by dividing talents evenly across teams, which enhances the diversity of capabilities on each team more than randomly assigning workers onto each team. This chapter provides a more detailed comparison of the performance differences between the equity method and random selection, particular under different economic conditions.

5.1 Diversity and Complexity

Diversity has many roles and effects. Diversity can provide insurance, improve productivity, spur innovation, enhance robustness, produce collective knowledge, and, perhaps most important light of these other effects, sustain further diversity. But diversity also can contribute to collapse, conflict, and incomprehensible mangles (Page 2011).

Complex phenomena are hard to describe, explain, or predict- like the weather or the economy. To get a feel for complex phenomena, researchers also need to understand the systems that produce them. Complex systems are collections of diverse, connected, interdependent entities whose behavior is determined by rules, which may adapt, but need not. The interactions of these entities often produce phenomena that are more than the parts. These phenomena are called emergent. Given this characterization, the brain would count as a complex system, so would a forest, and so would the city. Each contains diverse, connected entities that interact. Each produces outcomes that exceed the capacities of its component parts. Neurons are simple. Brains are complex.

In other examples, a calculus exam and a blender would not be complex, though for different reasons. The parts of a calculus exam – the questions – don't interact. It is a fixed set of problems, so it may be difficult but it won't be complex (Page 2008). The blender won't be complex either, but for different reason – it cannot adapt. A blender has diverse parts, and those parts follow rules don't allow it to respond to the environment. As a result, a blender, like most machines, it therefore complicated. Another example is Boeing 787 airplane, which uses flight guidance software, as complex. Others might see it as complicated.

Most complex systems are not predictable. Owing to the interdependence of actions, complex systems can be predicted only in the very short run. For example economics are all complex and not easily forecast even with abundant data (Orrell 2007). Complexity creates problems for analysis. In systems that produce static equilibria, we can gauge the effect of changing levels of diversity by performing comparative static analysis. Researchers can measure how the equilibrium changes when diversity increased or decreased, and can quantify the effect.

In previous studies, diversity has isolatable, direct effects prove rare. And any foray into scholarly research on the impact of diversity in complex systems proves a humbling experience (Page 2011). Some broad general claims do appear to hold across contexts. First diversity often enhances the robustness of complex systems. Systems that lack diversity can lose functionality. Second, diversity drives innovation and productivity. In economies, variation and experimentation also lead to innovation and recombination (Arthur 2009). Greater diversity for the most part correlates with greater productivity. For example, cities that are more diverse are more productive and more innovative (Page 2011). There are three types of diversity:

a. Diversity within a type, or variation. This refers to differences in the amount of some attribute or characteristic.
b. Diversity of types and kinds, or species in biological systems. This refers to differences in kind, such as the different types of personality of employees in an organization.
c. Diversity of composition. This refers to differences in how the types are arranged.

A diverse society creates problems and opportunities. In the past, much of the public interest in diversity has focused on issues of fairness and representation. More recently, there has been a rising interest in the benefits of diversity. In the common understanding, diversity in a group of people refers to differences in their demographic characteristics, cultural identities and ethnicity, and training and expertise. Advocates of diversity in problem-solving groups claim a linkage among these sorts of diversity and what we might call functional diversity, differences in how people represent problems and how they go about solving them. Given that linkage, they conclude that, because of their greater functional diversity, identity-diverse groups can outperform homogeneous groups (Nisbett & Ross 1980; Robbins 1994; Thomas & Ely 1996; Hong & Page 2004).

The conclusion that identity-diverse groups can outperform homogeneous groups due to their greater functional diversity rests upon an accepted claim that if agents across groups have equal ability, functionally diverse groups outperform homogeneous groups. It has also been shown that functionally diverse group tend to outperform the best individual agents, provided that agents in the group are nearly as good (Huberman 1990). These results still leave open an important question: Can a functionally diverse group whose members have less ability outperform a group of people with high ability who may themselves be diverse? Hong and Page (2004) introduce a framework for modeling functionally diverse problem-solving agents. They found that when selecting a problem-solving team from a diverse population of intelligent agents, a team of randomly selected agents outperform a team comprised of the best-performing agents. The results relies on the intuition that, as the initial pool of problem solvers becomes large the best-performing agents becomes similar in the space of problem solvers. Their relatively greater ability is more than offset by their lack of problem-solving diversity. The result also provides insights into the trade-off between diversity and ability. An ideal group would contain high-ability problem solvers who are diverse. But, as the result, when the pool of problem solvers grows larger, the very best problem solvers cannot be diverse. The result also relies on the size of the random group becoming large. If not, the individual members of the random group may still have substantial overlap in their local optima and not perform well. The result suggests that diversity in perspective and heuristic space should be encouraged. Organizations should do more than just exploit the existing diversity. They may be encouraged even greater functional diversity, given its advantages.

Although previous research concluded the benefits of diversity in a group, there is a few studies focus on interaction between diversity and social context. The research questions are: Can diversity benefit an organization in different social context conditions? Under what condition diversity can truly contribute the organization performance?

5.2 Sensitive Analysis of Random Selection

A sensitive analysis of random selection was conducted by altering the settings of the economic conditions. The economic conditions were divided into a five-part scale: 1 = Very bad, 2 = bad, 3 = neutral, 4 = good, and 5 = very good. For the purpose of this model, the settings for economic conditions correspond to the number of available projects on the market. According to the data collected from the government bidding system in Taiwan, the average available projects are three per day in a neutral economic situation. Thus for the model, setting 1 = one new project available per day in the market; 2 = two new projects available per day; 3 = three new projects available projects per day; 4 = four new projects available per day; and 5 = five new projects available per day. The other settings remained the same. The simulation results are shown in Figure 25. The ANOVA and LSD test results are shown in Table 13 and Table 14. The test results indicate that the differences in profit earned are significant in different economic contexts.

Table 13. ANOVA for random selection in different economic contexts

ANOVA

Profit

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	3.835E7	4	9588199.772	210.345	.000
Within Groups	5469982.862	120	45583.191		
Total	4.382E7	124			

Table 14. Multiple comparisons of profit earned based on random selection in different economic contexts

Multiple Comparisons

Profit

LSD

(I) Economic	(J) Economic	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
0.1	0.3	-545.90764*	60.38754	.000	-665.4708	-426.3445
	0.5	-1028.03527*	60.38754	.000	-1147.5984	-908.4721
	0.7	-1323.31826*	60.38754	.000	-1442.8814	-1203.7551
	0.9	-1535.64110*	60.38754	.000	-1655.2042	-1416.0780
0.3	0.1	545.90764*	60.38754	.000	426.3445	665.4708
	0.5	-482.12763*	60.38754	.000	-601.6908	-362.5645
	0.7	-777.41062*	60.38754	.000	-896.9737	-657.8475
	0.9	-989.73346*	60.38754	.000	-1109.2966	-870.1703
0.5	0.1	1028.03527*	60.38754	.000	908.4721	1147.5984
	0.3	482.12763*	60.38754	.000	362.5645	601.6908
	0.7	-295.28299*	60.38754	.000	-414.8461	-175.7199
	0.9	-507.60583*	60.38754	.000	-627.1690	-388.0427
0.7	0.1	1323.31826*	60.38754	.000	1203.7551	1442.8814
	0.3	777.41062*	60.38754	.000	657.8475	896.9737
	0.5	295.28299*	60.38754	.000	175.7199	414.8461
	0.9	-212.32284*	60.38754	.001	-331.8860	-92.7597
0.9	0.1	1535.64110*	60.38754	.000	1416.0780	1655.2042
	0.3	989.73346*	60.38754	.000	870.1703	1109.2966
	0.5	507.60583*	60.38754	.000	388.0427	627.1690
	0.7	212.32284*	60.38754	.001	92.7597	331.8860

*. The mean difference is significant at the 0.05 level.

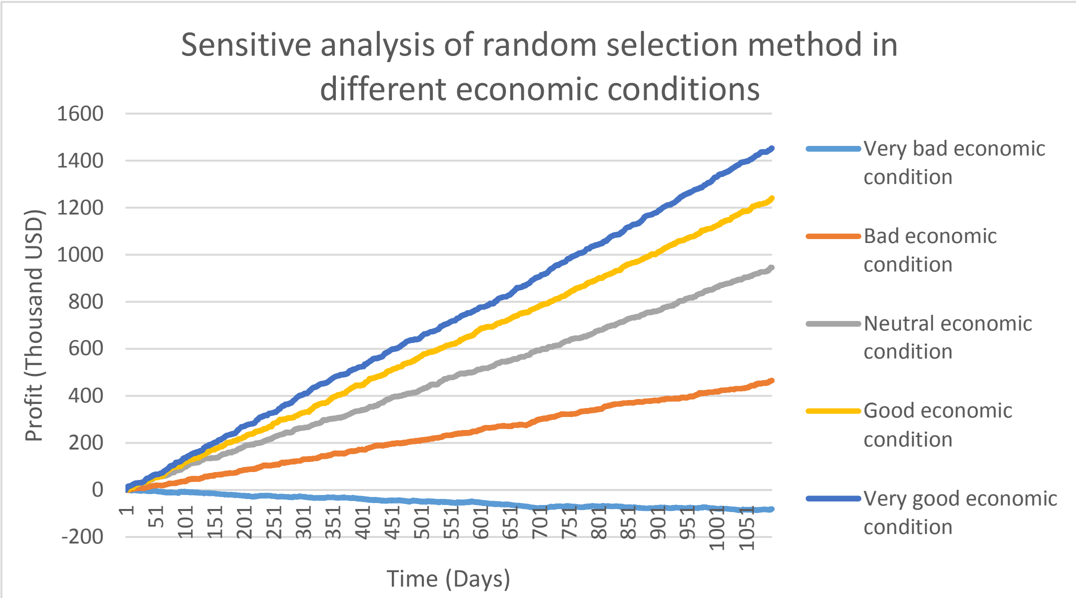


Figure 25. Sensitive analysis of random selection method in different economic conditions

5.3 Sensitive Analysis of Equity Method

The settings for conducting a sensitive analysis of the equity method are the same as those used for the random selection method. The results are shown in Figure 26. The ANOVA and LSD test results are shown in Table 15 and 16.

Table 15. ANOVA for equity method in different economic conditions

ANOVA

Profit

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	4.530E7	4	1.132E7	322.883	.000
Within Groups	4208740.365	120	35072.836		
Total	4.951E7	124			

Table 16. Multiple comparisons of profit earned based on the equity method under different economic conditions

Multiple Comparisons

(I) Economic	(J) Economic	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
0.1	0.3	-695.23614*	52.97006	.000	-800.1132	-590.3591
	0.5	-1107.34686*	52.97006	.000	-1212.2239	-1002.4698
	0.7	-1488.14256*	52.97006	.000	-1593.0196	-1383.2655
	0.9	-1685.08365*	52.97006	.000	-1789.9607	-1580.2066
0.3	0.1	695.23614*	52.97006	.000	590.3591	800.1132
	0.5	-412.11072*	52.97006	.000	-516.9877	-307.2337
	0.7	-792.90643*	52.97006	.000	-897.7835	-688.0294
	0.9	-989.84752*	52.97006	.000	-1094.7245	-884.9705
0.5	0.1	1107.34686*	52.97006	.000	1002.4698	1212.2239
	0.3	412.11072*	52.97006	.000	307.2337	516.9877
	0.7	-380.79570*	52.97006	.000	-485.6727	-275.9187
	0.9	-577.73679*	52.97006	.000	-682.6138	-472.8598
0.7	0.1	1488.14256*	52.97006	.000	1383.2655	1593.0196
	0.3	792.90643*	52.97006	.000	688.0294	897.7835
	0.5	380.79570*	52.97006	.000	275.9187	485.6727
	0.9	-196.94109*	52.97006	.000	-301.8181	-92.0641
0.9	0.1	1685.08365*	52.97006	.000	1580.2066	1789.9607
	0.3	989.84752*	52.97006	.000	884.9705	1094.7245
	0.5	577.73679*	52.97006	.000	472.8598	682.6138
	0.7	196.94109*	52.97006	.000	92.0641	301.8181

*. The mean difference is significant at the 0.05 level.

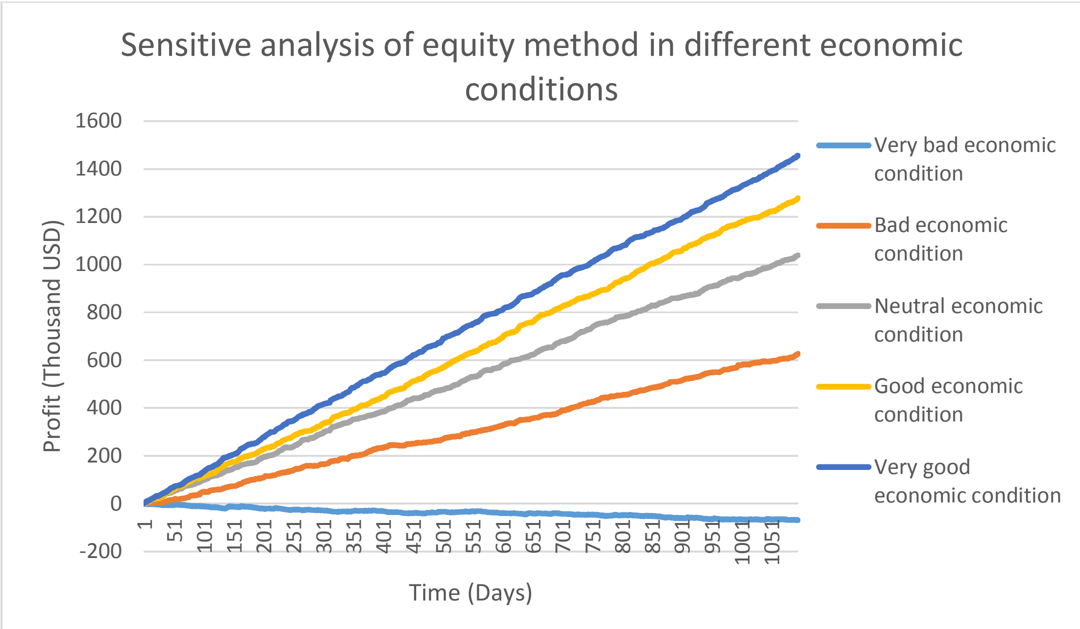


Figure 26. Sensitive analysis of equity method in different economic conditions

5.4 Comparison of Random Selection and Equity Method

The objective of this chapter is to compare the difference of profit earned from random selection and equity method. The results are shown in Figure 27. In this figure, while the simulation results indicate that the difference in profit earned from random selection and equity method is not significant, the equity method can yield better performance when the economy is in a depression. The differences in performance are relatively close in extremely bad or very good conditions. The ANOVA and LSD test results are shown in Table 17 and 18 respectively.

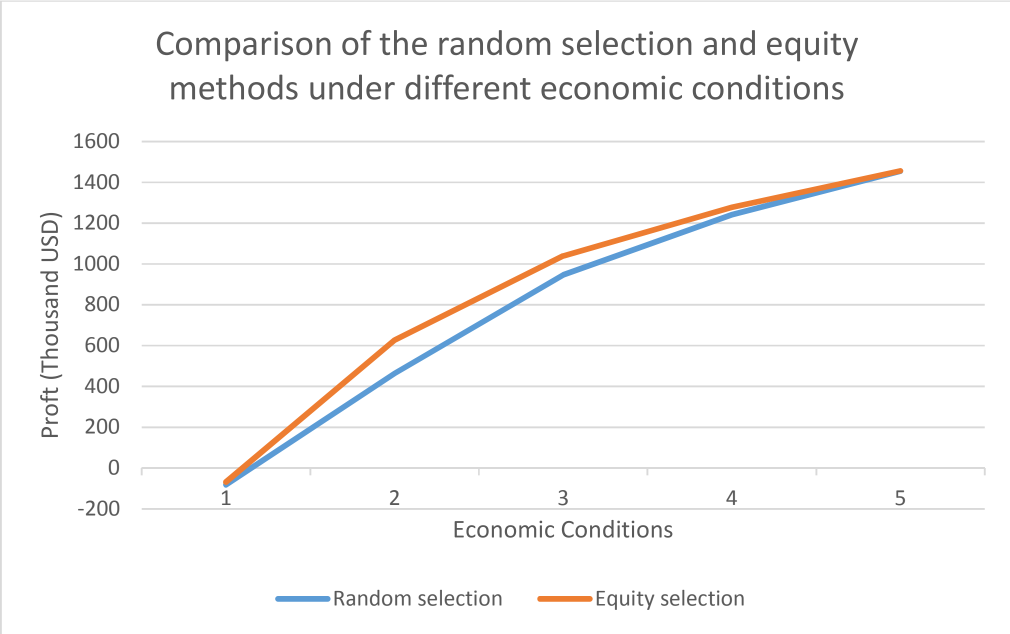


Figure 27. Comparison of the random selection and equity methods under different economic conditions

Table 17. ANOVA comparing the random selection and equity methods under different economic conditions

ANOVA

Profit

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	7.551E7	9	8389548.700	221.533	.000
Within Groups	9088894.338	240	37870.393		
Total	8.459E7	249			

Table 18. Multiple comparison of random selection and equity method under different economic conditions

Multiple Comparisons

(I) Economic	(J) Economic	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1	2	-545.90764*	55.04209	.000	-654.3349	-437.4804
	3	-1028.03527*	55.04209	.000	-1136.4625	-919.6080
	4	-1323.31826*	55.04209	.000	-1431.7455	-1214.8910
	5	-1535.64110*	55.04209	.000	-1644.0684	-1427.2138
	6	-13.67837	55.04209	.804	-122.1056	94.7489
	7	-708.91451*	55.04209	.000	-817.3418	-600.4872
	8	-1121.02523*	55.04209	.000	-1229.4525	-1012.5980
	9	-1359.82543*	55.04209	.000	-1468.2527	-1251.3982
	10	-1537.07241*	55.04209	.000	-1645.4997	-1428.6451
2	1	545.90764*	55.04209	.000	437.4804	654.3349
	3	-482.12763*	55.04209	.000	-590.5549	-373.7003
	4	-777.41062*	55.04209	.000	-885.8379	-668.9833
	5	-989.73346*	55.04209	.000	-1098.1607	-881.3062
	6	532.22927*	55.04209	.000	423.8020	640.6565
	7	-163.00687*	55.04209	.003	-271.4341	-54.5796
	8	-575.11759*	55.04209	.000	-683.5449	-466.6903
	9	-813.91779*	55.04209	.000	-922.3451	-705.4905
	10	-991.16477*	55.04209	.000	-1099.5921	-882.7375
3	1	1028.03527*	55.04209	.000	919.6080	1136.4625
	2	482.12763*	55.04209	.000	373.7003	590.5549
	4	-295.28299*	55.04209	.000	-403.7103	-186.8557
	5	-507.60583*	55.04209	.000	-616.0331	-399.1786

	6	1014.35690*	55.04209	.000	905.9296	1122.7842
	7	319.12076*	55.04209	.000	210.6935	427.5480
	8	-92.98997	55.04209	.092	-201.4172	15.4373
	9	-331.79016*	55.04209	.000	-440.2174	-223.3629
	10	-509.03715*	55.04209	.000	-617.4644	-400.6099
4	1	1323.31826*	55.04209	.000	1214.8910	1431.7455
	2	777.41062*	55.04209	.000	668.9833	885.8379
	3	295.28299*	55.04209	.000	186.8557	403.7103
	5	-212.32284*	55.04209	.000	-320.7501	-103.8956
	6	1309.63989*	55.04209	.000	1201.2126	1418.0672
	7	614.40375*	55.04209	.000	505.9765	722.8310
	8	202.29302*	55.04209	.000	93.8657	310.7203
	9	-36.50717	55.04209	.508	-144.9345	71.9201
	10	-213.75416*	55.04209	.000	-322.1814	-105.3269
5	1	1535.64110*	55.04209	.000	1427.2138	1644.0684
	2	989.73346*	55.04209	.000	881.3062	1098.1607
	3	507.60583*	55.04209	.000	399.1786	616.0331
	4	212.32284*	55.04209	.000	103.8956	320.7501
	6	1521.96273*	55.04209	.000	1413.5355	1630.3900
	7	826.72659*	55.04209	.000	718.2993	935.1539
	8	414.61587*	55.04209	.000	306.1886	523.0431
	9	175.81567*	55.04209	.002	67.3884	284.2429
	10	-1.43131	55.04209	.979	-109.8586	106.9960
6	1	13.67837	55.04209	.804	-94.7489	122.1056
	2	-532.22927*	55.04209	.000	-640.6565	-423.8020
	3	-1014.35690*	55.04209	.000	-1122.7842	-905.9296
	4	-1309.63989*	55.04209	.000	-1418.0672	-1201.2126
	5	-1521.96273*	55.04209	.000	-1630.3900	-1413.5355
	7	-695.23614*	55.04209	.000	-803.6634	-586.8089

	8	-1107.34686*	55.04209	.000	-1215.7741	-998.9196
	9	-1346.14706*	55.04209	.000	-1454.5743	-1237.7198
	10	-1523.39404*	55.04209	.000	-1631.8213	-1414.9668
7	1	708.91451*	55.04209	.000	600.4872	817.3418
	2	163.00687*	55.04209	.003	54.5796	271.4341
	3	-319.12076*	55.04209	.000	-427.5480	-210.6935
	4	-614.40375*	55.04209	.000	-722.8310	-505.9765
	5	-826.72659*	55.04209	.000	-935.1539	-718.2993
	6	695.23614*	55.04209	.000	586.8089	803.6634
	8	-412.11072*	55.04209	.000	-520.5380	-303.6834
	9	-650.91092*	55.04209	.000	-759.3382	-542.4836
	10	-828.15790*	55.04209	.000	-936.5852	-719.7306
8	1	1121.02523*	55.04209	.000	1012.5980	1229.4525
	2	575.11759*	55.04209	.000	466.6903	683.5449
	3	92.98997	55.04209	.092	-15.4373	201.4172
	4	-202.29302*	55.04209	.000	-310.7203	-93.8657
	5	-414.61587*	55.04209	.000	-523.0431	-306.1886
	6	1107.34686*	55.04209	.000	998.9196	1215.7741
	7	412.11072*	55.04209	.000	303.6834	520.5380
	9	-238.80020*	55.04209	.000	-347.2275	-130.3729
	10	-416.04718*	55.04209	.000	-524.4745	-307.6199
9	1	1359.82543*	55.04209	.000	1251.3982	1468.2527
	2	813.91779*	55.04209	.000	705.4905	922.3451
	3	331.79016*	55.04209	.000	223.3629	440.2174
	4	36.50717	55.04209	.508	-71.9201	144.9345
	5	-175.81567*	55.04209	.002	-284.2429	-67.3884
	6	1346.14706*	55.04209	.000	1237.7198	1454.5743
	7	650.91092*	55.04209	.000	542.4836	759.3382
	8	238.80020*	55.04209	.000	130.3729	347.2275

	10	-177.24698*	55.04209	.001	-285.6743	-68.8197
10	1	1537.07241*	55.04209	.000	1428.6451	1645.4997
	2	991.16477*	55.04209	.000	882.7375	1099.5921
	3	509.03715*	55.04209	.000	400.6099	617.4644
	4	213.75416*	55.04209	.000	105.3269	322.1814
	5	1.43131	55.04209	.979	-106.9960	109.8586
	6	1523.39404*	55.04209	.000	1414.9668	1631.8213
	7	828.15790*	55.04209	.000	719.7306	936.5852
	8	416.04718*	55.04209	.000	307.6199	524.4745
	9	177.24698*	55.04209	.001	68.8197	285.6743

*. The mean difference is significant at the 0.05 level.

The ABM is able to capture the number of projects taken by the teams, and the simulation results show that the equity method can take on 12% more projects than the random selection method can in bad economic conditions. This provides evidence as to the underlying cause for the difference in performance between the two selection methods. The deliberately assigned diversity of capabilities on each team created through the equity method enhances each team's ability to take on a variety of projects available in the market. In contrast, while a random selection of team members can generate more capacity in a certain type of capability on each of the teams, it also limits each team's ability to take on other types of projects.

Creating teams with less diversity of capabilities may mean that each team has a higher capacity in certain types of capabilities. These teams may have a better ability to take on larger projects that require such higher levels of specialization than a team with a higher diversity of capabilities. However, under depressed economic conditions (which corresponds to level 2 of the scale described in section 5.1), fewer new projects requiring specialized expertise are on the market, while more open contracts for just maintaining infrastructure are more common. The scope of these kinds of contracts may include different kinds of work, such as designing how to maintain a public park or designing how to maintain part of a road. These more open contracts more frequently need to equally apply a wide range of capabilities. Thus using an equity method to select teams has shown to be advantageous when economic conditions are somewhat worse than neutral.

The results show that the difference in performance between teams selected by either randomly or through an equity approach become insignificant during both severe depression (level 1 on this model's scale) and intense growth (level 5). At the depressed end of the scale, the insignificance may be explained by the absolute reduction of any projects available for either type of teams to take. While during high growth, the absolute number of available projects is so high both types of teams have an abundance of projects available to take that the differences in having wide or specialized abilities becomes irrelevant.

Although this study's model clearly quantifies the advantages of applying an equity method for team selection, previous research suggest that managers should not only focus on ability-based selection, but also consider worker interdependence (Milliser et al. 2011) because team performance is not the sum of its individual members' performance. The next chapter provides a comparison between the equity method and the interdependence-based method used in this study that incorporates knowledge of worker interdependence to develop an alternative team selection model.

Chapter 6: Interdependence of Workers

Worker interdependence, which is a form of organizational complexity, is an important factor that influences a team's performance. Work contributions from employees should be divided into three kinds: an employee's individual contribution, the employee's contribution to other employee's work, and the contributions that a employee needs from other employees to make the first two kinds of contributions. This chapter investigates how using knowledge of worker's interdependence during team selection can improve a team's overall performance above teams created through an equity method.

6.1 Sensitive Analysis of Interdependence-based Selection

In previous research, Millhiser et al. (2011) have proved that clustering teams with minimum total disruption performance (TDP) is best when interdependence is light. They concluded that when managers consider the initial interdependencies between workers when splitting them into new teams, the new teams perform best when the previous levels of interaction among the workers was light and the new team sizes are even, or when previous levels of interaction were heavy and one new team is much larger than the other new team. Unlike their research, this study did not focus on the effects of degrees of interdependence, but instead investigated how, under different economic conditions, whether using knowledge of worker interdependence for team selection might improve team performance more than the equity method.

The sensitive analysis of interdependence-based selection uses the same settings for different economic conditions as were used in the previous sensitive analyses. Three teams are selected evenly with five workers (one of them is project manager). The K is set at three, which means one worker's performance depends on three other supporters, a realistic number according to the interviews with ten project managers in different small design firms. The simulation results are demonstrated in Figure 28. The ANOVA and LSD test results are shown in Tables 19 and 20 respectively.

The profit earned from interdependence-based selection increased more rapidly than equity selection from very bad to neutral economic conditions, but the differences in profit earned from neutral to good and very good economic conditions only gently increased.

Table 19. ANOVA for sensitive analysis of interdependence-based selection under different economic conditions

ANOVA

Profit

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	4.170E7	4	1.042E7	295.557	.000
Within Groups	4232457.814	120	35270.482		
Total	4.593E7	124			

Table 20. Multiple comparison of sensitive analysis of interdependence-based selection in different economic contexts

Multiple Comparisons

(I) Economic	(J) Economic	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1	2	-763.89039*	53.11910	.000	-869.0625	-658.7183
	3	-1289.15665*	53.11910	.000	-1394.3288	-1183.9845
	4	-1452.27128*	53.11910	.000	-1557.4434	-1347.0992
	5	-1570.21012*	53.11910	.000	-1675.3822	-1465.0380
2	1	763.89039*	53.11910	.000	658.7183	869.0625
	3	-525.26625*	53.11910	.000	-630.4384	-420.0941
	4	-688.38089*	53.11910	.000	-793.5530	-583.2088
	5	-806.31973*	53.11910	.000	-911.4918	-701.1476
3	1	1289.15665*	53.11910	.000	1183.9845	1394.3288
	2	525.26625*	53.11910	.000	420.0941	630.4384
	4	-163.11463*	53.11910	.003	-268.2867	-57.9425
	5	-281.05348*	53.11910	.000	-386.2256	-175.8814
4	1	1452.27128*	53.11910	.000	1347.0992	1557.4434
	2	688.38089*	53.11910	.000	583.2088	793.5530
	3	163.11463*	53.11910	.003	57.9425	268.2867
	5	-117.93884*	53.11910	.028	-223.1110	-12.7667
5	1	1570.21012*	53.11910	.000	1465.0380	1675.3822
	2	806.31973*	53.11910	.000	701.1476	911.4918
	3	281.05348*	53.11910	.000	175.8814	386.2256
	4	117.93884*	53.11910	.028	12.7667	223.1110

*. The mean difference is significant at the 0.05 level.

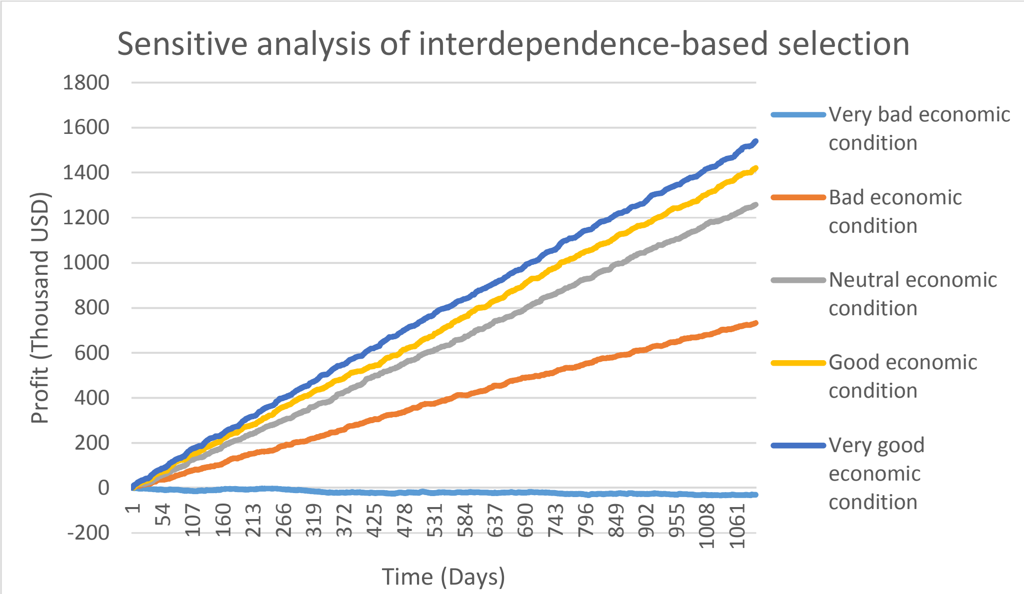


Figure 28. Sensitive analysis of interdependence-based selection

6.2 Comparing Interdependence-based and Equity Team Selection Methods

As demonstrated in the results in Figure 29 and 30, in extremely bad economic conditions (level 1 on this model's scale), the average profit earned from teams created through interdependence-based and equity approaches has no significant difference (ANOVA and LSD analyses are shown in Table 21 and 22).

Table 21. ANOVA for comparison of interdependence-based selection and equity selection

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	7.949E7	9	8832149.028	269.980	.000
Within Groups	7851369.289	240	32714.039		
Total	8.734E7	249			

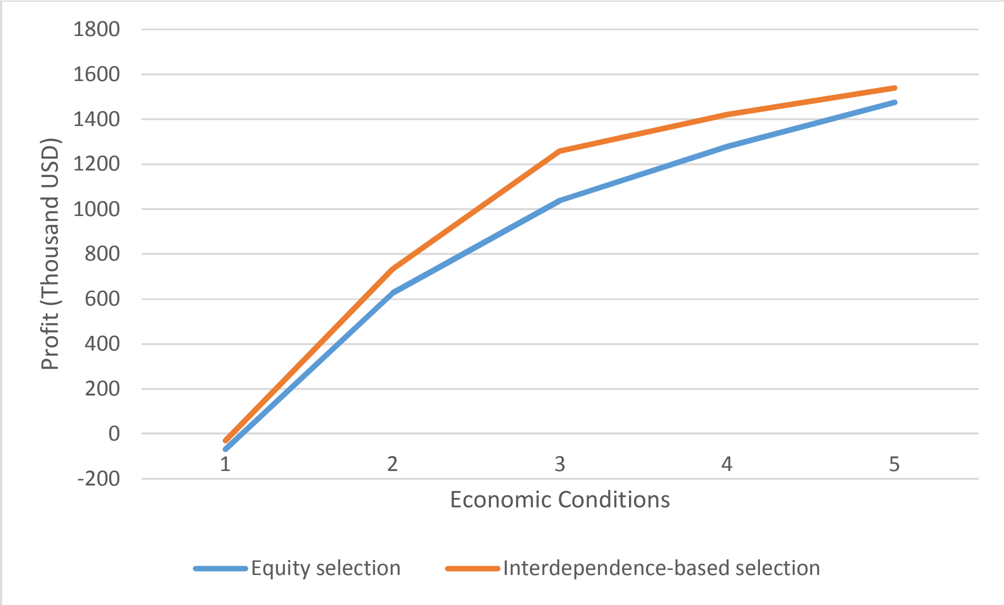


Figure 29. Profit comparison of interdependence-based and equity methods under different economic conditions

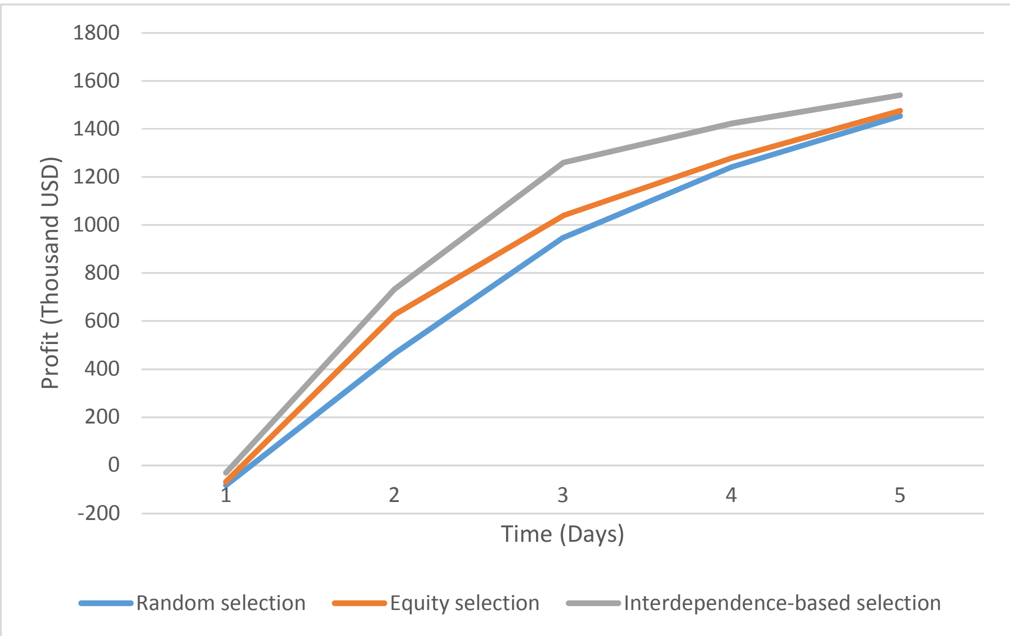


Figure 30. Profit comparison of different team selection methods under different economic conditions

Table 22. Multiple comparisons of interdependence-based and equity team selection methods

Multiple Comparisons

(I) Economic	(J) Economic	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1	2	-763.89039*	51.15783	.000	-864.6661	-663.1147
	3	-1289.15665*	51.15783	.000	-1389.9323	-1188.3810
	4	-1452.27128*	51.15783	.000	-1553.0470	-1351.4956
	5	-1570.21012*	51.15783	.000	-1670.9858	-1469.4344
	6	37.64648	51.15783	.463	-63.1292	138.4222
	7	-657.58965*	51.15783	.000	-758.3653	-556.8140
	8	-1069.70038*	51.15783	.000	-1170.4761	-968.9247
	9	-1308.50058*	51.15783	.000	-1409.2763	-1207.7249
	10	-1485.74756*	51.15783	.000	-1586.5232	-1384.9719
2	1	763.89039*	51.15783	.000	663.1147	864.6661
	3	-525.26625*	51.15783	.000	-626.0419	-424.4906
	4	-688.38089*	51.15783	.000	-789.1566	-587.6052
	5	-806.31973*	51.15783	.000	-907.0954	-705.5440
	6	801.53688*	51.15783	.000	700.7612	902.3126
	7	106.30074*	51.15783	.039	5.5251	207.0764
	8	-305.80998*	51.15783	.000	-406.5857	-205.0343
	9	-544.61018*	51.15783	.000	-645.3859	-443.8345
	10	-721.85716*	51.15783	.000	-822.6328	-621.0815
3	1	1289.15665*	51.15783	.000	1188.3810	1389.9323
	2	525.26625*	51.15783	.000	424.4906	626.0419
	4	-163.11463*	51.15783	.002	-263.8903	-62.3390
	5	-281.05348*	51.15783	.000	-381.8292	-180.2778

	6	1326.80313*	51.15783	.000	1226.0275	1427.5788
	7	631.56699*	51.15783	.000	530.7913	732.3427
	8	219.45627*	51.15783	.000	118.6806	320.2319
	9	-19.34393	51.15783	.706	-120.1196	81.4317
	10	-196.59091*	51.15783	.000	-297.3666	-95.8152
4	1	1452.27128*	51.15783	.000	1351.4956	1553.0470
	2	688.38089*	51.15783	.000	587.6052	789.1566
	3	163.11463*	51.15783	.002	62.3390	263.8903
	5	-117.93884*	51.15783	.022	-218.7145	-17.1632
	6	1489.91776*	51.15783	.000	1389.1421	1590.6934
	7	794.68162*	51.15783	.000	693.9059	895.4573
	8	382.57090*	51.15783	.000	281.7952	483.3466
	9	143.77070*	51.15783	.005	42.9950	244.5464
	10	-33.47628	51.15783	.513	-134.2520	67.2994
5	1	1570.21012*	51.15783	.000	1469.4344	1670.9858
	2	806.31973*	51.15783	.000	705.5440	907.0954
	3	281.05348*	51.15783	.000	180.2778	381.8292
	4	117.93884*	51.15783	.022	17.1632	218.7145
	6	1607.85661*	51.15783	.000	1507.0809	1708.6323
	7	912.62047*	51.15783	.000	811.8448	1013.3961
	8	500.50974*	51.15783	.000	399.7341	601.2854
	9	261.70955*	51.15783	.000	160.9339	362.4852
	10	84.46256	51.15783	.100	-16.3131	185.2382
6	1	-37.64648	51.15783	.463	-138.4222	63.1292
	2	-801.53688*	51.15783	.000	-902.3126	-700.7612
	3	-1326.80313*	51.15783	.000	-1427.5788	-1226.0275
	4	-1489.91776*	51.15783	.000	-1590.6934	-1389.1421
	5	-1607.85661*	51.15783	.000	-1708.6323	-1507.0809
	7	-695.23614*	51.15783	.000	-796.0118	-594.4605

	8	-1107.34686*	51.15783	.000	-1208.1225	-1006.5712
	9	-1346.14706*	51.15783	.000	-1446.9227	-1245.3714
	10	-1523.39404*	51.15783	.000	-1624.1697	-1422.6184
7	1	657.58965*	51.15783	.000	556.8140	758.3653
	2	-106.30074*	51.15783	.039	-207.0764	-5.5251
	3	-631.56699*	51.15783	.000	-732.3427	-530.7913
	4	-794.68162*	51.15783	.000	-895.4573	-693.9059
	5	-912.62047*	51.15783	.000	-1013.3961	-811.8448
	6	695.23614*	51.15783	.000	594.4605	796.0118
	8	-412.11072*	51.15783	.000	-512.8864	-311.3350
	9	-650.91092*	51.15783	.000	-751.6866	-550.1352
	10	-828.15790*	51.15783	.000	-928.9336	-727.3822
8	1	1069.70038*	51.15783	.000	968.9247	1170.4761
	2	305.80998*	51.15783	.000	205.0343	406.5857
	3	-219.45627*	51.15783	.000	-320.2319	-118.6806
	4	-382.57090*	51.15783	.000	-483.3466	-281.7952
	5	-500.50974*	51.15783	.000	-601.2854	-399.7341
	6	1107.34686*	51.15783	.000	1006.5712	1208.1225
	7	412.11072*	51.15783	.000	311.3350	512.8864
	9	-238.80020*	51.15783	.000	-339.5759	-138.0245
	10	-416.04718*	51.15783	.000	-516.8229	-315.2715
9	1	1308.50058*	51.15783	.000	1207.7249	1409.2763
	2	544.61018*	51.15783	.000	443.8345	645.3859
	3	19.34393	51.15783	.706	-81.4317	120.1196
	4	-143.77070*	51.15783	.005	-244.5464	-42.9950
	5	-261.70955*	51.15783	.000	-362.4852	-160.9339
	6	1346.14706*	51.15783	.000	1245.3714	1446.9227
	7	650.91092*	51.15783	.000	550.1352	751.6866
	8	238.80020*	51.15783	.000	138.0245	339.5759

	10	-177.24698*	51.15783	.001	-278.0227	-76.4713
10	1	1485.74756*	51.15783	.000	1384.9719	1586.5232
	2	721.85716*	51.15783	.000	621.0815	822.6328
	3	196.59091*	51.15783	.000	95.8152	297.3666
	4	33.47628	51.15783	.513	-67.2994	134.2520
	5	-84.46256	51.15783	.100	-185.2382	16.3131
	6	1523.39404*	51.15783	.000	1422.6184	1624.1697
	7	828.15790*	51.15783	.000	727.3822	928.9336
	8	416.04718*	51.15783	.000	315.2715	516.8229
	9	177.24698*	51.15783	.001	76.4713	278.0227

*. The mean difference is significant at the 0.05 level.

When economic conditions start to improve, the interdependence-based method increased profit more sharply than the equity method, but not by much, as indicated by the statistically insignificant p value of 0.029. As explained previously, this is likely due to the absolute lack of available projects for any of team types to take during such economic conditions.

The largest gap is in the neutral condition (level 3) – the teams created through the interdependence-based method was able to earn $219,456 more than the teams created through the equity method. The trend of increased profit earned from interdependence-based selection stabilizes when the economic conditions range from good to very good.

This phenomenon indicates that interdependence-based team selection can improve the capacity of teams as this method disrupts worker interdependencies less than traditional selection methods, which in turn helps protect the higher performers. For example, while the equity selection method can increase the diversity of capabilities of teams, the net performance is often worse than optimizing worker interdependencies. These results support the argument made by Millhiser et al. (2011) that considering the interdependence of workers when building teams may be more important than primarily focusing on the individual abilities of workers.

Chapter 7: Team Member Replacement Policies

7.1 Comparison of Replacement Policies

It is not sufficient to only generate and analyze simulation results for the initial creation of teams. It is also crucial to evaluate the effects of different worker replacement policies. A complex adaptive system should involve adaptive behavior, which may require replacing workers. Replacement policies have been discussed in detail in section 4.2.2., and the methodologies and results for testing the performance of different replacement policies are described below.

Hiring new ones

The first replacement policy tested in this study is "hiring new ones." This replacement policy was introduced by Solow et al. (2002). The setting in the model has a regular period (180 days) to appraise the performance of workers. The lowest performer is replaced by hiring a new one. In this situation, it is assumed that the manager does not have knowledge of the specific interdependencies among the workers, but the new workers will affect the performance of current workers with whom the new workers have relationships. The equations for calculating the effect of interdependence disruption are found in section 4.2.2. The simulation results from applying this policy is shown in Figure 31. The average profit is $1,336,269 (with a standard deviation of $348,066). The profit earned was $77,653 more than the profit earned from the interdependence-based method without any replacement mechanism.

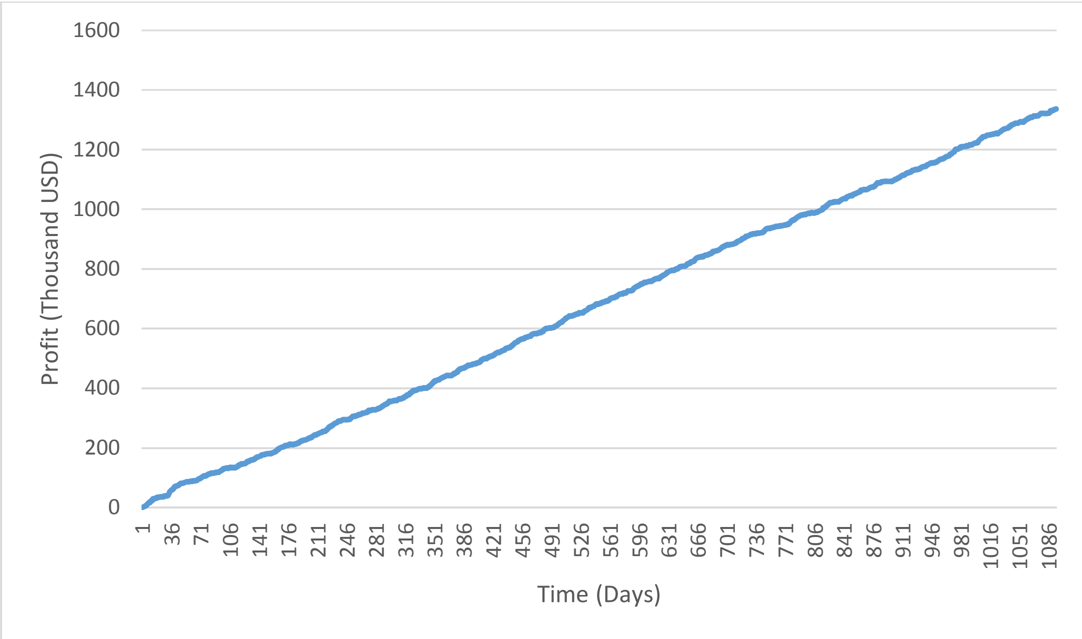


Figure 31. The average simulation results of replacement policy 1

Transferring Low Contributors

This replacement strategy seeks to identify workers who contribute the least to top performers and reassign them. Reassigning a worker who influences others negatively has a beneficial impact on the collective performance of the remaining workers and quite possibly of those reassigned as well (Solow et al. 2002; Millheiser et al. 2011). A detailed description of transferring low contributors policy is found in section 4.2.2. In Figure 32, the simulation of this replacement policy shows that the average profit earned by this firm for 3 years is $1,367,245 (with a standard deviation of $218,667). The profit earned was $108,629 more than from the interdependence-based method without any replacement mechanism.

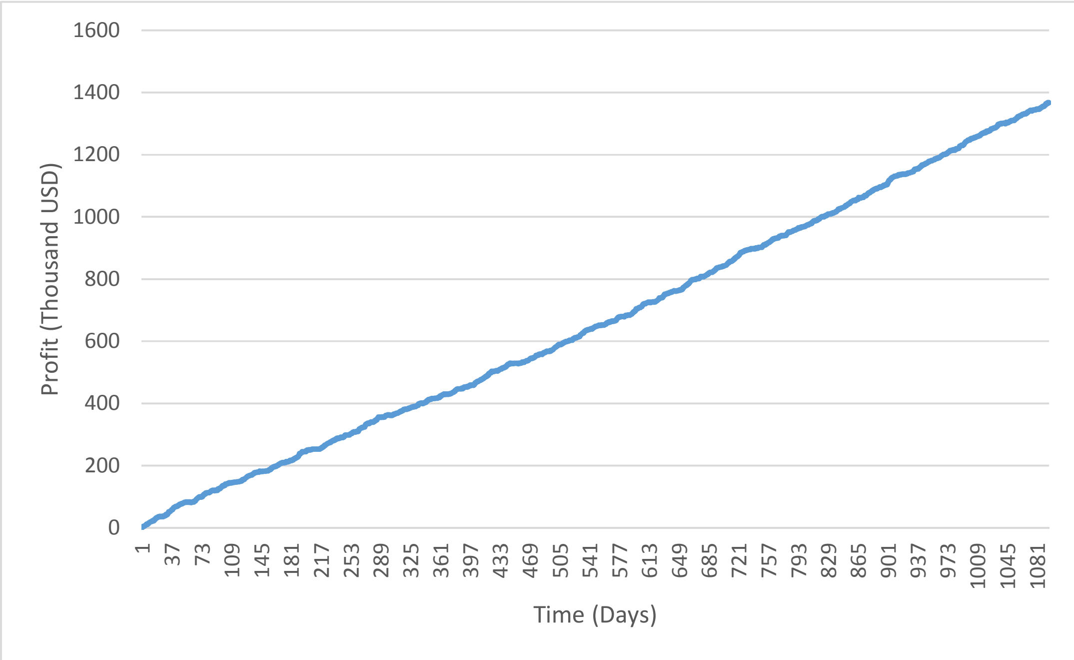


Figure 32. The average simulation results of replacement policy 2

Transferring the Least Supported Members

The simulation results of the "transfer the least supported members" policy are shown in Figure 33. The results show that the average profit earned is $1,293,010 (with a standard deviation of $202,076). This is a $34,394 increase in profit compared to the interdependence-based team selection method without any replacement policies. The comparison results of the three replacement policies are shown in Figure 34.

In summary, the results show that enacting any of the three the replacement policies can slightly improve the profit earned from 2.7% to 8.6% from compared to not enacting any replacement policy. The ANOVA and LSD tests were also used to evaluate the differences between these three replacement policies. The results as shown in Tables 23 and 24 indicate that the three replacement policies have no significant differences.

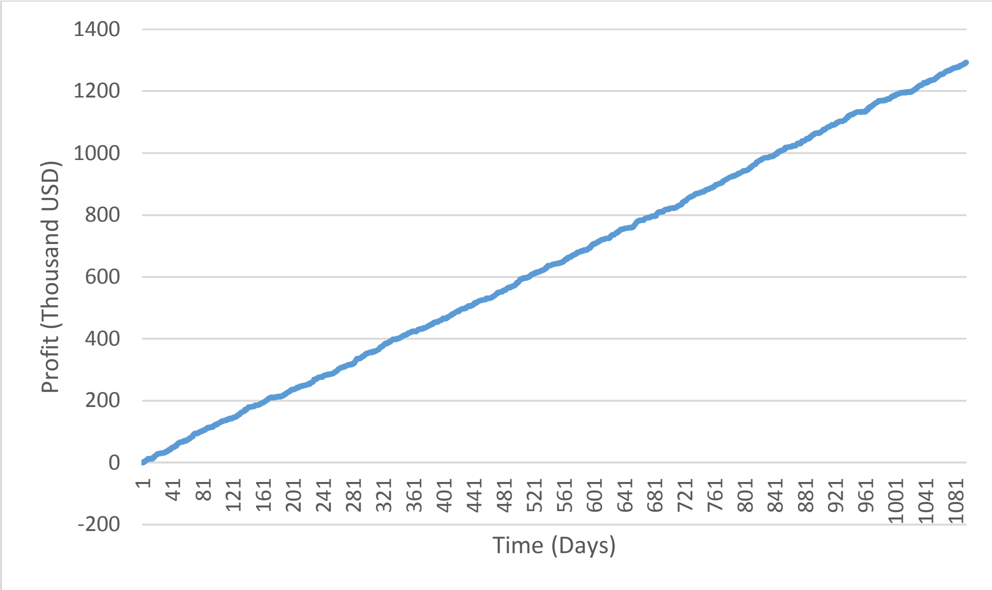


Figure 33. Simulation result of replacement policy 3

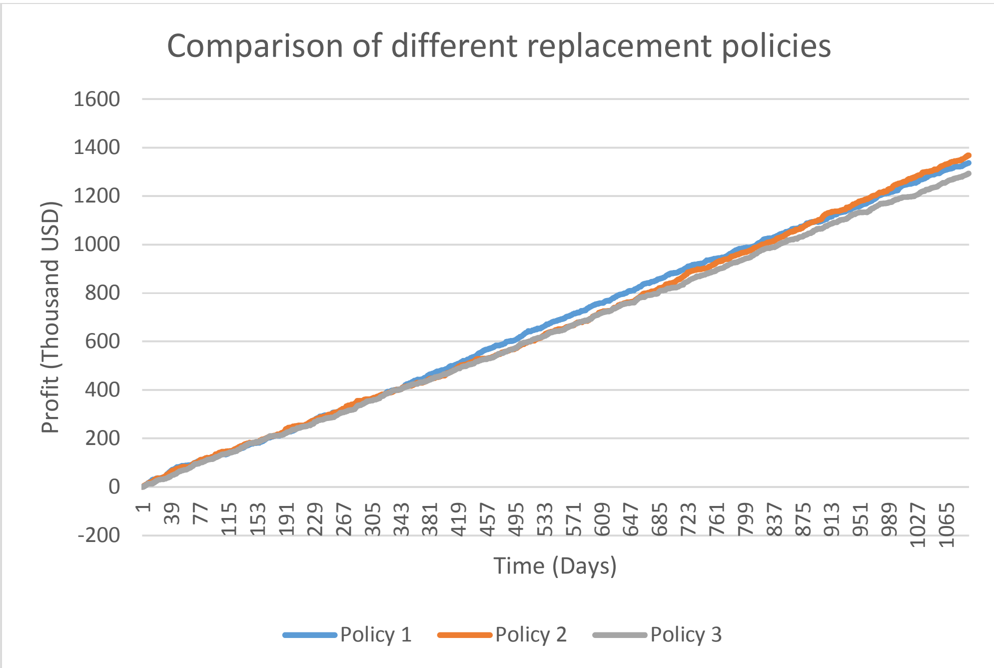


Figure 34. Comparison of different replacement policies

The comparison between different replacement policies in different economic conditions is shown in Figure 35. The results indicate that they have no significant differences neither.

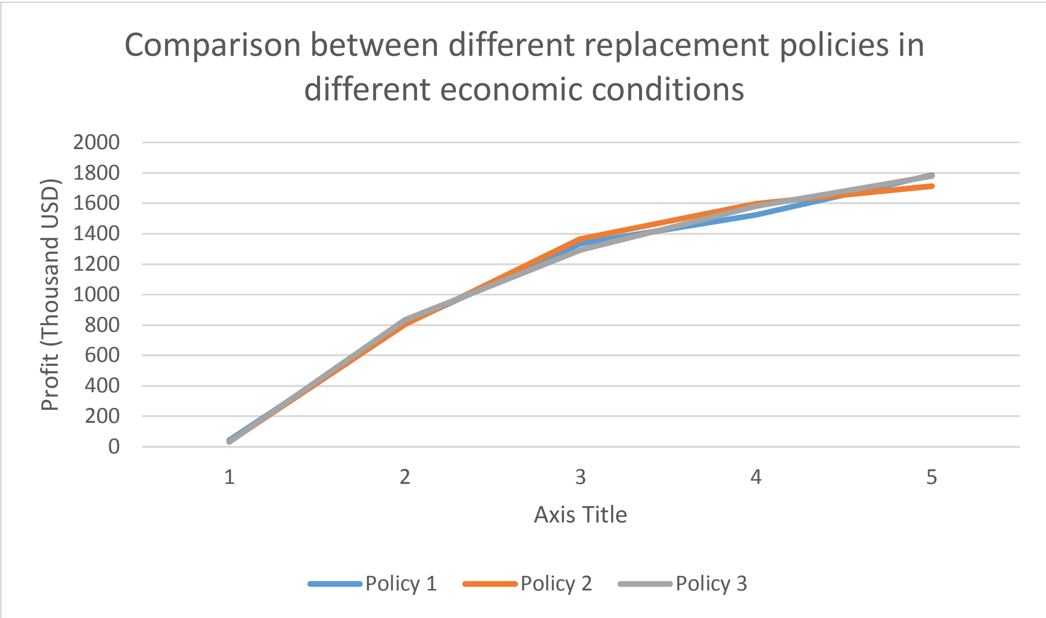


Figure 35. Comparison between different replacement policies in different economic conditions

Table 23. ANOVA for profit earned from different replacement policies

ANOVA

Profit

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	69513.707	2	34756.854	.716	.492
Within Groups	3496148.431	72	48557.617		
Total	3565662.138	74			

Table 24. Multiple comparisons for profit earned from different replacement policies

Multiple Comparisons

(I) Replacement	(J) Replacement	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1	2	-30.97564	62.32663	.621	-155.2215	93.2702
	3	43.25913	62.32663	.490	-80.9867	167.5050
2	1	30.97564	62.32663	.621	-93.2702	155.2215
	3	74.23478	62.32663	.238	-50.0111	198.4807
3	1	-43.25913	62.32663	.490	-167.5050	80.9867
	2	-74.23478	62.32663	.238	-198.4807	50.0111

7.2 Summary and Discussion

The comparative analyses provided above demonstrate that using teams can substantially improve the overall performance of a firm, especially when the available projects on the market are more complex. It is hard for an individual to complete a project by working in isolation. The main concept of the equity method is to evenly divide the talents of workers. The equity method also generates teams with a higher diversity of capabilities. While the equity method is often used in many kinds of organizations, the simulation results in this research indicate that there are no significant differences in performance between the equity method and random selection in neutral economic conditions. However, the equity method can enhance the ability to take projects in bad economic conditions due to the higher diversity of team capabilities. The interdependence-based selection method, which protects high-performing workers by minimizing interdependence disruption, demonstrates better results than either the random selection or equity methods.

The simulation results of the replacement policies show that such policies can improve overall team performance, but the differences between the policies are not significant. The replacement policies have their own advantages and disadvantages. For example, hiring a new worker with better abilities may improve team performance, but better employees usually cost more and are less available on the market. In project management practice, project managers are seeking the "right people." Although they want to improve performance by replacing poor performers, they do not need someone who is overqualified to fill the position. Furthermore, hiring new employees have costs associated with conducting interviews. The interview costs were not incorporated into this model. One advantage of transferring low contributors from one team to a new team is that the contributions of the transferred worker may substantially increase, due to for example better skill or personality matches between that worker and the other members of the new team. One disadvantage, however, is that in the event that the contribution of the worker still remains low in the new team, it remains unknown whether the low contribution is due to a problem resulting from the interaction between that worker and the other new team members, or due to a problem inherent to the individual worker. The advantage and disadvantage of transferring low performing, least supported members to new teams are similar to transferring low contributors. If such transferred members still exhibit low performance, it remains unknown to management whether this lack of change in performance is due to a continued lack of support from members of the new team or due to a shortcoming inherent to the transferred worker.

Thus taking the advantages and disadvantages of all three policies into account, transferring low contributors or least supported members are recommended to be enacted before hiring new workers to avoid this last policy's especially large additional costs.

Chapter 8: Conclusion

8.1 Contributions

This research first reviewed the team selection and project complexity related literature for project organization. Team selection practices have focused on individual knowledge, skills, and abilities but little research has focused on examining the complexity of selection processes. A key conclusion that emerged from assessing the current literature is that project team selection should shift away from ability-based selection to complexity-based selection. The diversity of team capabilities, interdependence between employees, and interaction with the market in different economic contexts are three major factors that affect team selection and team performance. These factors however have not been thoroughly addressed in previous studies. Senior managers in project-based industries also affirm the importance of worker's interdependence when building teams. This study utilizes the NK model and decision support matrix to capture and measure employee interdependence. The employee's performance should be evaluated by individual contributions, giving to others, and receiving from others, which all affect a worker's total contribution to a team.

The ABM developed in this study provides a framework for modeling and comparing different team selection methods by combining agents and the project market environment. The simulation results show that the interdependence-based selection method can yield better performing set of teams than traditional ability-based selection methods. We suggest that managers should protect their higher-performing workers by minimizing interdependence disruption when building teams. Managers should also consider transferring low contributors and least supported members to another team before replacing poor performers by hiring new employees.

This model also offers two key methodological contributions. First, it provides a general framework for modeling team selection by combining agents and their corresponding project market environment. This ABM approach will prove useful for modeling team selection in many different domains. Second, the ABM framework integrates a number of variables of demonstrated importance to team selection, and does so in many cases through the use of regression equations.

While many of these variables will be equally relevant to team selection in different domains, it is likely that the mathematical relationships between these variables will differ. As such, to further develop this model for more accurate and optimal application, researchers are recommended to collect their own data on these similar variables in the specific organizations of interest to them. They can conduct their own analyses and modify the model's equations accordingly. Organizations can then use such further customized ABMs to examine the impact of changing the composition of teams in a risk-free artificial environment and make more informed team selection decisions.

8.2 Limitations and Extensions

While this research provides a novel way to examine team selection processes, there are some limitations. First, the variables that considered in this research may not include all the variables of a complex system that are relevant team selection. Other variables that may affect team selection and team performance include communication, trust, and motivation.

Because the main objective of this research is to compare the effects of different team selection methods, the model should be kept as simple as possible. Other important variables can be added to and tested with this model due to the flexibility provided by ABM.

8.3 Implications for Practice

It may be challenging to implement the complexity theory and policies studied in previous research. This research converts the theory into practice through an agent-based model. This study suggests that managers should be as aware as possible of how interdependent relationships are distributed across a cohort before they do any reorganization. These interdependencies may have as much or more effect on team performance than individual knowledge, skills, and abilities, and yet are often overlooked. The results of this study also indicate that using the equity method for team selection may not improve team performance by much. A manager who has worked closely and for a long time with a cohort of workers may know from observation, experience, and other types of information gathering, who works well with whom. Managers should use knowledge of complexity to protect the interdependencies of the most effective workers, and reshuffle those make below average contributions.

If managers cannot confidently identify who works well together because of unfamiliarity with their worker's relationships, they may adopt self-selection methods of team formation. There is precedence for recommending self-selection (Van Zelst 1952; Katzenbach & Smith 1993; Jin 1993). Voluntarily-formed teams had better performance and higher work motivation than teams whose workers were assigned by management. This study suggests why previous research has demonstrated that worker's performances jumped dramatically, namely because workers knew best who supported their successful performance. By surveying their preferences and allowing managers to sort their partnerships around positive interdependencies, they acted out the kind of sorting analysis we explore. Social psychologists have long observed that people tend to like others with whom they share similarities. There is also evidence that they choose people with whom they work well.

Appendices

The model code for ABM of team selection

```
breed [Real_Employees Real_Employee]
breed [Virtual_Employees Virtual_Employee]
;breed [Projects Project]
breed [Managers Manager]
globals [Project Die_group Group_lost_member]    ;; keep track of how much grass there is
patches-own [owner countdown Prj_Cons_budget Prj_Type1C Prj_Type2C Prj_Type3C Prj_Type4C
Prj_Type5C Prj_Type1A Prj_Type2A Prj_Type3A Prj_Type4A Prj_Type5A Prj_Type1 Prj_Type2
Prj_Type3 Prj_Type4 Prj_Type5 Prj_return_rate Prj_Duration]

Virtual_Employees-own [ Collective_contribution Transfer Emp_Education Emp_Title Emp_Group
Team_capacity Team_capacity_Type1 Team_capacity_Type2 Team_capacity_Type3
Team_capacity_Type4 Team_capacity_Type5 Emp_Pro_area1 Emp_Pro_area2 Emp_Pro_area3
Emp_Pro_area4 Emp_Pro_area5 Emp_Pro_area1C Emp_Pro_area2C Emp_Pro_area3C Emp_Pro_area4C
Emp_Pro_area5C Emp_Pro_area1A Emp_Pro_area2A Emp_Pro_area3A Emp_Pro_area4A
Emp_Pro_area5A Emp_Working_Exp Emp_License Emp_Salary Emp_Capacity Emp_Avaliability
Emp_AvaliabilityC Emp_relation_Owner1 Emp_relation_Owner2 Emp_relation_Owner3
Emp_relation_Owner4 Emp_relation_Owner5 Emp_relation Emp_Personal_Obj Emp_Project_Taken
Emp_Max_Capacity Sum_Prj Sum_Profit Emp_Max_Capacity_Type1 Emp_Max_Capacity_Type2
Emp_Max_Capacity_Type3 Emp_Max_Capacity_Type4 Emp_Max_Capacity_Type5]
Real_Employees-own [ Emp_Education Emp_Title Emp_Pro_area Emp_Working_Exp Emp_License
Emp_Salary Emp_Capacity Emp_Personal_Obj]
;Projects-own [Prj_Owner Prj_Type1C Prj_Type2C Prj_Type3C Prj_Type4C Prj_Type5C Prj_Type1A
Prj_Type2A Prj_Type3A Prj_Type4A Prj_Type5A Prj_Start_time Prj_Design_service_budget
Prj_Cons_budget Prj_Basic_Design Prj_Detailed_Design Prj_return_rate Prj_Role1 Prj_Role2 Prj_Role3
Prj_Role4 Prj_Role5 Prj_Duration Prj_Type1 Prj_Type2 Prj_Type3 Prj_Type4 Prj_Type5 Prj_Capacity]

;original salary
;plot sum [Emp_Salary] of turtles with [shape !="x"] / 1000 / 30 * ticks

;plot accountunt
;plot SUM[Emp_Capacity] of turtles with [shape ="person doctor"] / 1000

to Create_Virtual_Employee
   ca ;clear all
   ask patches [set pcolor white]
   reset-ticks
  Create_accountunt
  create-Virtual_Employees Number_worker [
  Create_Virtual_Employee_Setp1
  Create_Virtual_Employee_Random_Selection
  Create_Virtual_Employee_Setp3
  generate_group
   ]
```

```
PM_Assign

end

to Create_Virtual_Employee_Equitable_Selection

   ca ;clear all
   ask patches [set pcolor white]
     reset-ticks

  Create_accountunt

  create-Virtual_Employees Number_worker [

  Create_Virtual_Employee_Setp1
  Equitable_Selection
  Create_Virtual_Employee_Setp3
  Equitable_groups
   ]

PM_Assign

end

to Interdependence_Selection

     ca ;clear all
   ask patches [set pcolor white]
     reset-ticks

  Create_accountunt

  create-Virtual_Employees Number_worker [

  Create_Virtual_Employee_Setp1
  Equitable_Selection
  Create_Virtual_Employee_Setp3_INT
  Equitable_groups

   ]

PM_Assign

end

to Create_Virtual_Employee_Setp1
     set Sum_Prj 0
     set Sum_Profit 0
     set size 2
     set color blue
     set shape "person construction"
     setxy random 30 - 15 random 30 - 15
     set Emp_Education random 3 / 2 ;0 is High school, 1 is college, 2 is Graduate
     set Emp_Pro_area1 random 11 / 10 ; 0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1
     set Collective_contribution ( random 8 + 6 ) / 10 ;0.6~1.3
```

```
end

to Create_Virtual_Employee_Random_Selection
   set Emp_Pro_area1 random 10 + 1 ;random value of each Prj_Type
   set Emp_Pro_area2 random 10 + 1 ;random value of each Prj_Type
   set Emp_Pro_area3 random 10 + 1 ;random value of each Prj_Type
   set Emp_Pro_area4 random 10 + 1 ;random value of each Prj_Type
   set Emp_Pro_area5 random 10 + 1 ;random value of each Prj_Type
end

to Equitable_Selection

; Dividing team members based on expertise
   set Emp_Pro_area1 random 3 + 4 ;random value of each Prj_Type 4~6
   set Emp_Pro_area2 random 3 + 4 ;random value of each Prj_Type 4~6
   set Emp_Pro_area3 random 3 + 4 ;random value of each Prj_Type 4~6
   set Emp_Pro_area4 random 3 + 4 ;random value of each Prj_Type 4~6
   set Emp_Pro_area5 random 3 + 4 ;random value of each Prj_Type 4~6

end

to Create_Virtual_Employee_Setp3
   set Emp_Pro_area1A round ((Emp_Pro_area1 / (Emp_Pro_area1 + Emp_Pro_area2 + Emp_Pro_area3 +
Emp_Pro_area4 + Emp_Pro_area5)) * 1000) / 1000 ; cal % of each type
   set Emp_Pro_area2A round ((Emp_Pro_area2 / (Emp_Pro_area1 + Emp_Pro_area2 + Emp_Pro_area3 +
Emp_Pro_area4 + Emp_Pro_area5)) * 1000) / 1000 ; cal % of each type
   set Emp_Pro_area3A round ((Emp_Pro_area3 / (Emp_Pro_area1 + Emp_Pro_area2 + Emp_Pro_area3 +
Emp_Pro_area4 + Emp_Pro_area5)) * 1000) / 1000 ; cal % of each type
   set Emp_Pro_area4A round ((Emp_Pro_area4 / (Emp_Pro_area1 + Emp_Pro_area2 + Emp_Pro_area3 +
Emp_Pro_area4 + Emp_Pro_area5)) * 1000) / 1000 ; cal % of each type
   set Emp_Pro_area5A round ((Emp_Pro_area5 / (Emp_Pro_area1 + Emp_Pro_area2 + Emp_Pro_area3 +
Emp_Pro_area4 + Emp_Pro_area5)) * 1000) / 1000 ; cal % of each type

      set Emp_Working_Exp random 35
      set Emp_License "Quality Control Engineer"
      set Emp_Salary round (random-normal 50 10) * 1000

      if Emp_Salary < 50000 [set Emp_Title 0] ;0 is Engineer, 1 is Senior engineer, 2 is Project manager
      if Emp_Salary > 50000 [set Emp_Title 1] ;0 is Engineer, 1 is Senior engineer, 2 is Project manager

      set Emp_AvaliabilityC 1

      ;Initial Emp available %
      ;set Emp_Avaliability random 100 + 1 ;1-100
      ;if Emp_Avaliability > Fraction_Emp_Available [ set Emp_AvaliabilityC 0]    ;0 is not available    1 is
available
      ;if Emp_Avaliability <= Fraction_Emp_Available [ set Emp_AvaliabilityC 1]    ;0 is not available    1
is available

      ;relationship with owner
      set Emp_relation_Owner1 random 6 / 10 + 0.5 ; relationship with owner1
      set Emp_relation_Owner2 random 6 / 10 + 0.5 ; relationship with owner2
      set Emp_relation_Owner3 random 6 / 10 + 0.5 ; relationship with owner3
      set Emp_relation_Owner4 random 6 / 10 + 0.5 ; relationship with owner4
      set Emp_relation_Owner5 random 6 / 10 + 0.5 ; relationship with owner5
```

```
      set Emp_Personal_Obj round (random 5) + 1 ; 1= very engaged 2= engaged 3= neutral 4= not engaged
5= hated

   if Emp_Personal_Obj > 0.5 and Emp_Personal_Obj < 1.5 [ set Emp_Capacity round (Emp_Salary * 14 *
Overhead / service_fee_% * 100 / 1000) * 1000]
   if Emp_Personal_Obj > 1.5 and Emp_Personal_Obj < 2.5 [ set Emp_Capacity round (Emp_Salary * 14 *
Overhead / service_fee_% * 100 * 0.8 / 1000) * 1000]
   if Emp_Personal_Obj > 2.5 and Emp_Personal_Obj < 3.5 [ set Emp_Capacity round (Emp_Salary * 14 *
Overhead / service_fee_% * 100 * 0.6 / 1000) * 1000]
   if Emp_Personal_Obj > 3.5 and Emp_Personal_Obj < 4.5 [ set Emp_Capacity round (Emp_Salary * 14 *
Overhead / service_fee_% * 100 * 0.4 / 1000) * 1000]
   if Emp_Personal_Obj > 4.5 and Emp_Personal_Obj < 5.5 [ set Emp_Capacity round (Emp_Salary * 14 *
Overhead / service_fee_% * 100 * 0.2 / 1000) * 1000]

   set Emp_Max_Capacity Emp_Capacity ;Emp_Max_Capacity = original capacity

; Emp_Pro_area C performance (area * capacity)
   set Emp_Pro_area1C Emp_Pro_area1A * Emp_Capacity
   set Emp_Pro_area2C Emp_Pro_area2A * Emp_Capacity
   set Emp_Pro_area3C Emp_Pro_area3A * Emp_Capacity
   set Emp_Pro_area4C Emp_Pro_area4A * Emp_Capacity
   set Emp_Pro_area5C Emp_Pro_area5A * Emp_Capacity

   set Emp_Max_Capacity_Type1 Emp_Pro_area1C
   set Emp_Max_Capacity_Type2 Emp_Pro_area2C
   set Emp_Max_Capacity_Type3 Emp_Pro_area3C
   set Emp_Max_Capacity_Type4 Emp_Pro_area4C
   set Emp_Max_Capacity_Type5 Emp_Pro_area5C

end

to generate_group

  set Emp_Group round (random Number_of_Team) + 1

;At least one worker in each group

if Number_of_Team = 1 [ask one-of Virtual_Employees with [who = 0] [set Emp_Group 1]]

if Number_of_Team = 2 [ask one-of Virtual_Employees with [who = 0] [set Emp_Group 1]
                        ask one-of Virtual_Employees with [who = 1] [set Emp_Group 2]]

if Number_of_Team = 3 [ask one-of Virtual_Employees with [who = 0] [set Emp_Group 1]
                        ask one-of Virtual_Employees with [who = 1] [set Emp_Group 2]
                        ask one-of Virtual_Employees with [who = 2] [set Emp_Group 3]]

if Number_of_Team = 4 [ask one-of Virtual_Employees with [who = 0] [set Emp_Group 1]
                        ask one-of Virtual_Employees with [who = 1] [set Emp_Group 2]
                        ask one-of Virtual_Employees with [who = 2] [set Emp_Group 3]
                        ask one-of Virtual_Employees with [who = 3] [set Emp_Group 4]]

if Number_of_Team = 5 [ask one-of Virtual_Employees with [who = 0] [set Emp_Group 1]
                        ask one-of Virtual_Employees with [who = 1] [set Emp_Group 2]
                        ask one-of Virtual_Employees with [who = 2] [set Emp_Group 3]
                        ask one-of Virtual_Employees with [who = 3] [set Emp_Group 4]
```

```
                                     ask one-of Virtual_Employees with [who = 4] [set Emp_Group 5]]

if Number_of_Team = 6 [ask one-of Virtual_Employees with [who = 0] [set Emp_Group 1]
                                     ask one-of Virtual_Employees with [who = 1] [set Emp_Group 2]
                                     ask one-of Virtual_Employees with [who = 2] [set Emp_Group 3]
                                     ask one-of Virtual_Employees with [who = 3] [set Emp_Group 4]
                                     ask one-of Virtual_Employees with [who = 4] [set Emp_Group 5]
                                     ask one-of Virtual_Employees with [who = 5] [set Emp_Group 6]]

if Number_of_Team = 7 [ask one-of Virtual_Employees with [who = 0] [set Emp_Group 1]
                                     ask one-of Virtual_Employees with [who = 1] [set Emp_Group 2]
                                     ask one-of Virtual_Employees with [who = 2] [set Emp_Group 3]
                                     ask one-of Virtual_Employees with [who = 3] [set Emp_Group 4]
                                     ask one-of Virtual_Employees with [who = 4] [set Emp_Group 5]
                                     ask one-of Virtual_Employees with [who = 5] [set Emp_Group 6]
                                     ask one-of Virtual_Employees with [who = 6] [set Emp_Group 7]]

if Number_of_Team = 8 [ask one-of Virtual_Employees with [who = 0] [set Emp_Group 1]
                                     ask one-of Virtual_Employees with [who = 1] [set Emp_Group 2]
                                     ask one-of Virtual_Employees with [who = 2] [set Emp_Group 3]
                                     ask one-of Virtual_Employees with [who = 3] [set Emp_Group 4]
                                     ask one-of Virtual_Employees with [who = 4] [set Emp_Group 5]
                                     ask one-of Virtual_Employees with [who = 5] [set Emp_Group 6]
                                     ask one-of Virtual_Employees with [who = 6] [set Emp_Group 7]
                                     ask one-of Virtual_Employees with [who = 7] [set Emp_Group 8]]

if Number_of_Team = 9 [ask one-of Virtual_Employees with [who = 0] [set Emp_Group 1]
                                     ask one-of Virtual_Employees with [who = 1] [set Emp_Group 2]
                                     ask one-of Virtual_Employees with [who = 2] [set Emp_Group 3]
                                     ask one-of Virtual_Employees with [who = 3] [set Emp_Group 4]
                                     ask one-of Virtual_Employees with [who = 4] [set Emp_Group 5]
                                     ask one-of Virtual_Employees with [who = 5] [set Emp_Group 6]
                                     ask one-of Virtual_Employees with [who = 6] [set Emp_Group 7]
                                     ask one-of Virtual_Employees with [who = 7] [set Emp_Group 8]
                                     ask one-of Virtual_Employees with [who = 8] [set Emp_Group 9]]

if Number_of_Team = 10 [ask one-of Virtual_Employees with [who = 0] [set Emp_Group 1]
                                     ask one-of Virtual_Employees with [who = 1] [set Emp_Group 2]
                                     ask one-of Virtual_Employees with [who = 2] [set Emp_Group 3]
                                     ask one-of Virtual_Employees with [who = 3] [set Emp_Group 4]
                                     ask one-of Virtual_Employees with [who = 4] [set Emp_Group 5]
                                     ask one-of Virtual_Employees with [who = 5] [set Emp_Group 6]
                                     ask one-of Virtual_Employees with [who = 6] [set Emp_Group 7]
                                     ask one-of Virtual_Employees with [who = 7] [set Emp_Group 8]
                                     ask one-of Virtual_Employees with [who = 8] [set Emp_Group 9]
                                     ask one-of Virtual_Employees with [who = 9] [set Emp_Group 10]]

end


to Equitable_groups

;Number_worker=30        Number_of_Team=5
```

```
ask Virtual_Employees with [who <= Number_worker / Number_of_Team] [set Emp_Group 1] ;who<=6 -->1,2,3,4,5,6
ask Virtual_Employees with [who > 1 * (Number_worker / Number_of_Team ) and who <= 2 * (Number_worker / Number_of_Team )] [set Emp_Group 2] ;who>6 and who<=12 7,8,9,10,11,12
ask Virtual_Employees with [who > 2 * (Number_worker / Number_of_Team ) and who <= 3 * (Number_worker / Number_of_Team )] [set Emp_Group 3] ;who>10 who<=15    13,14,15,16,17,18
ask Virtual_Employees with [who > 3 * (Number_worker / Number_of_Team ) and who <= 4 * (Number_worker / Number_of_Team )] [set Emp_Group 4]
ask Virtual_Employees with [who > 4 * (Number_worker / Number_of_Team ) and who <= 5 * (Number_worker / Number_of_Team )] [set Emp_Group 5] ;
ask Virtual_Employees with [who > 5 * (Number_worker / Number_of_Team ) and who <= 6 * (Number_worker / Number_of_Team )] [set Emp_Group 6] ;
ask Virtual_Employees with [who > 6 * (Number_worker / Number_of_Team ) and who <= 7 * (Number_worker / Number_of_Team )] [set Emp_Group 7]
ask Virtual_Employees with [who > 7 * (Number_worker / Number_of_Team ) and who <= 8 * (Number_worker / Number_of_Team )] [set Emp_Group 8]
ask Virtual_Employees with [who > 8 * (Number_worker / Number_of_Team ) and who <= 9 * (Number_worker / Number_of_Team )] [set Emp_Group 9]
ask Virtual_Employees with [who > 9 * (Number_worker / Number_of_Team ) and who <= 10 * (Number_worker / Number_of_Team )] [set Emp_Group 10]

end

to PM_Assign

    ;show count turtles

    ;Generate Emp_License
    ;we want to select some of Virtual_Employees as "PE", but even we write "ask n-of 1" it will select more than 1 Virtual_Employees
    ;ask n-of (Fraction_License * count Virtual_Employees) Virtual_Employees [
if Number_of_Team = 1 [ ask one-of Virtual_Employees with [Emp_Group = 1] [PM]]

if Number_of_Team = 2 [ ask one-of Virtual_Employees with [Emp_Group = 1] [PM]
                        ask one-of Virtual_Employees with [Emp_Group = 2] [PM]]

if Number_of_Team = 3 [ ask one-of Virtual_Employees with [Emp_Group = 1] [PM]
                        ask one-of Virtual_Employees with [Emp_Group = 2] [PM]
                        ask one-of Virtual_Employees with [Emp_Group = 3] [PM]]

if Number_of_Team = 4 [ ask one-of Virtual_Employees with [Emp_Group = 1] [PM]
                        ask one-of Virtual_Employees with [Emp_Group = 2] [PM]
                        ask one-of Virtual_Employees with [Emp_Group = 3] [PM]
                        ask one-of Virtual_Employees with [Emp_Group = 4] [PM]]

if Number_of_Team = 5 [ ask one-of Virtual_Employees with [Emp_Group = 1] [PM]
                        ask one-of Virtual_Employees with [Emp_Group = 2] [PM]
                        ask one-of Virtual_Employees with [Emp_Group = 3] [PM]
                        ask one-of Virtual_Employees with [Emp_Group = 4] [PM]
                        ask one-of Virtual_Employees with [Emp_Group = 5] [PM]]

if Number_of_Team = 6 [ ask one-of Virtual_Employees with [Emp_Group = 1] [PM]
                        ask one-of Virtual_Employees with [Emp_Group = 2] [PM]
                        ask one-of Virtual_Employees with [Emp_Group = 3] [PM]
                        ask one-of Virtual_Employees with [Emp_Group = 4] [PM]
```

```
                                        ask one-of Virtual_Employees with [Emp_Group = 5] [PM]
                                        ask one-of Virtual_Employees with [Emp_Group = 6] [PM]]

if Number_of_Team = 7 [ ask one-of Virtual_Employees with [Emp_Group = 1] [PM]
                                        ask one-of Virtual_Employees with [Emp_Group = 2] [PM]
                                        ask one-of Virtual_Employees with [Emp_Group = 3] [PM]
                                        ask one-of Virtual_Employees with [Emp_Group = 4] [PM]
                                        ask one-of Virtual_Employees with [Emp_Group = 5] [PM]
                                        ask one-of Virtual_Employees with [Emp_Group = 6] [PM]
                                        ask one-of Virtual_Employees with [Emp_Group = 7] [PM]]

if Number_of_Team = 8 [ ask one-of Virtual_Employees with [Emp_Group = 1] [PM]
                                        ask one-of Virtual_Employees with [Emp_Group = 2] [PM]
                                        ask one-of Virtual_Employees with [Emp_Group = 3] [PM]
                                        ask one-of Virtual_Employees with [Emp_Group = 4] [PM]
                                        ask one-of Virtual_Employees with [Emp_Group = 5] [PM]
                                        ask one-of Virtual_Employees with [Emp_Group = 6] [PM]
                                        ask one-of Virtual_Employees with [Emp_Group = 7] [PM]
                                        ask one-of Virtual_Employees with [Emp_Group = 8] [PM]]

if Number_of_Team = 9 [ ask one-of Virtual_Employees with [Emp_Group = 1] [PM]
                                        ask one-of Virtual_Employees with [Emp_Group = 2] [PM]
                                        ask one-of Virtual_Employees with [Emp_Group = 3] [PM]
                                        ask one-of Virtual_Employees with [Emp_Group = 4] [PM]
                                        ask one-of Virtual_Employees with [Emp_Group = 5] [PM]
                                        ask one-of Virtual_Employees with [Emp_Group = 6] [PM]
                                        ask one-of Virtual_Employees with [Emp_Group = 7] [PM]
                                        ask one-of Virtual_Employees with [Emp_Group = 8] [PM]
                                        ask one-of Virtual_Employees with [Emp_Group = 9] [PM]]

if Number_of_Team = 10 [ ask one-of Virtual_Employees with [Emp_Group = 1] [PM]
                                        ask one-of Virtual_Employees with [Emp_Group = 2] [PM]
                                        ask one-of Virtual_Employees with [Emp_Group = 3] [PM]
                                        ask one-of Virtual_Employees with [Emp_Group = 4] [PM]
                                        ask one-of Virtual_Employees with [Emp_Group = 5] [PM]
                                        ask one-of Virtual_Employees with [Emp_Group = 6] [PM]
                                        ask one-of Virtual_Employees with [Emp_Group = 7] [PM]
                                        ask one-of Virtual_Employees with [Emp_Group = 8] [PM]
                                        ask one-of Virtual_Employees with [Emp_Group = 9] [PM]
                                        ask one-of Virtual_Employees with [Emp_Group = 10] [PM]]

   ask Virtual_Employees
  [ set color Emp_Group * 4

  ]

SUM_Team_Capacity

end


to SUM_Team_Capacity

if Number_of_Team = 1 [
```

```
ask Virtual_Employees with [Emp_Group = 1] [set Team_capacity sum [Emp_Capacity] of
Virtual_Employees with [Emp_Group = 1]]
ask Virtual_Employees with [Emp_Group = 1] [set Team_capacity_Type1 sum [Emp_Pro_area1C] of
Virtual_Employees with [Emp_Group = 1]]
ask Virtual_Employees with [Emp_Group = 1] [set Team_capacity_Type2 sum [Emp_Pro_area2C] of
Virtual_Employees with [Emp_Group = 1]]
ask Virtual_Employees with [Emp_Group = 1] [set Team_capacity_Type3 sum [Emp_Pro_area3C] of
Virtual_Employees with [Emp_Group = 1]]
ask Virtual_Employees with [Emp_Group = 1] [set Team_capacity_Type4 sum [Emp_Pro_area4C] of
Virtual_Employees with [Emp_Group = 1]]
ask Virtual_Employees with [Emp_Group = 1] [set Team_capacity_Type5 sum [Emp_Pro_area5C] of
Virtual_Employees with [Emp_Group = 1]]
]

if Number_of_Team = 2 [
ask Virtual_Employees with [Emp_Group = 1] [set Team_capacity sum [Emp_Capacity] of
Virtual_Employees with [Emp_Group = 1]]
ask Virtual_Employees with [Emp_Group = 2] [set Team_capacity sum [Emp_Capacity] of
Virtual_Employees with [Emp_Group = 2]]
ask Virtual_Employees with [Emp_Group = 1] [set Team_capacity_Type1 sum [Emp_Pro_area1C] of
Virtual_Employees with [Emp_Group = 1]]
ask Virtual_Employees with [Emp_Group = 1] [set Team_capacity_Type2 sum [Emp_Pro_area2C] of
Virtual_Employees with [Emp_Group = 1]]
ask Virtual_Employees with [Emp_Group = 1] [set Team_capacity_Type3 sum [Emp_Pro_area3C] of
Virtual_Employees with [Emp_Group = 1]]
ask Virtual_Employees with [Emp_Group = 1] [set Team_capacity_Type4 sum [Emp_Pro_area4C] of
Virtual_Employees with [Emp_Group = 1]]
ask Virtual_Employees with [Emp_Group = 1] [set Team_capacity_Type5 sum [Emp_Pro_area5C] of
Virtual_Employees with [Emp_Group = 1]]
ask Virtual_Employees with [Emp_Group = 2] [set Team_capacity_Type1 sum [Emp_Pro_area1C] of
Virtual_Employees with [Emp_Group = 2]]
ask Virtual_Employees with [Emp_Group = 2] [set Team_capacity_Type2 sum [Emp_Pro_area2C] of
Virtual_Employees with [Emp_Group = 2]]
ask Virtual_Employees with [Emp_Group = 2] [set Team_capacity_Type3 sum [Emp_Pro_area3C] of
Virtual_Employees with [Emp_Group = 2]]
ask Virtual_Employees with [Emp_Group = 2] [set Team_capacity_Type4 sum [Emp_Pro_area4C] of
Virtual_Employees with [Emp_Group = 2]]
ask Virtual_Employees with [Emp_Group = 2] [set Team_capacity_Type5 sum [Emp_Pro_area5C] of
Virtual_Employees with [Emp_Group = 2]]
]

if Number_of_Team = 3 [
ask Virtual_Employees with [Emp_Group = 1] [set Team_capacity sum [Emp_Capacity] of
Virtual_Employees with [Emp_Group = 1]]
ask Virtual_Employees with [Emp_Group = 2] [set Team_capacity sum [Emp_Capacity] of
Virtual_Employees with [Emp_Group = 2]]
ask Virtual_Employees with [Emp_Group = 3] [set Team_capacity sum [Emp_Capacity] of
Virtual_Employees with [Emp_Group = 3]]
ask Virtual_Employees with [Emp_Group = 1] [set Team_capacity_Type1 sum [Emp_Pro_area1C] of
Virtual_Employees with [Emp_Group = 1]]
ask Virtual_Employees with [Emp_Group = 1] [set Team_capacity_Type2 sum [Emp_Pro_area2C] of
Virtual_Employees with [Emp_Group = 1]]
ask Virtual_Employees with [Emp_Group = 1] [set Team_capacity_Type3 sum [Emp_Pro_area3C] of
Virtual_Employees with [Emp_Group = 1]]
```

```
ask Virtual_Employees with [Emp_Group = 1] [set Team_capacity_Type4 sum [Emp_Pro_area4C] of
Virtual_Employees with [Emp_Group = 1]]
ask Virtual_Employees with [Emp_Group = 1] [set Team_capacity_Type5 sum [Emp_Pro_area5C] of
Virtual_Employees with [Emp_Group = 1]]
ask Virtual_Employees with [Emp_Group = 2] [set Team_capacity_Type1 sum [Emp_Pro_area1C] of
Virtual_Employees with [Emp_Group = 2]]
ask Virtual_Employees with [Emp_Group = 2] [set Team_capacity_Type2 sum [Emp_Pro_area2C] of
Virtual_Employees with [Emp_Group = 2]]
ask Virtual_Employees with [Emp_Group = 2] [set Team_capacity_Type3 sum [Emp_Pro_area3C] of
Virtual_Employees with [Emp_Group = 2]]
ask Virtual_Employees with [Emp_Group = 2] [set Team_capacity_Type4 sum [Emp_Pro_area4C] of
Virtual_Employees with [Emp_Group = 2]]
ask Virtual_Employees with [Emp_Group = 2] [set Team_capacity_Type5 sum [Emp_Pro_area5C] of
Virtual_Employees with [Emp_Group = 2]]
ask Virtual_Employees with [Emp_Group = 3] [set Team_capacity_Type1 sum [Emp_Pro_area1C] of
Virtual_Employees with [Emp_Group = 3]]
ask Virtual_Employees with [Emp_Group = 3] [set Team_capacity_Type2 sum [Emp_Pro_area2C] of
Virtual_Employees with [Emp_Group = 3]]
ask Virtual_Employees with [Emp_Group = 3] [set Team_capacity_Type3 sum [Emp_Pro_area3C] of
Virtual_Employees with [Emp_Group = 3]]
ask Virtual_Employees with [Emp_Group = 3] [set Team_capacity_Type4 sum [Emp_Pro_area4C] of
Virtual_Employees with [Emp_Group = 3]]
ask Virtual_Employees with [Emp_Group = 3] [set Team_capacity_Type5 sum [Emp_Pro_area5C] of
Virtual_Employees with [Emp_Group = 3]]
]

if Number_of_Team = 4 [
ask Virtual_Employees with [Emp_Group = 1] [set Team_capacity sum [Emp_Capacity] of
Virtual_Employees with [Emp_Group = 1]]
ask Virtual_Employees with [Emp_Group = 2] [set Team_capacity sum [Emp_Capacity] of
Virtual_Employees with [Emp_Group = 2]]
ask Virtual_Employees with [Emp_Group = 3] [set Team_capacity sum [Emp_Capacity] of
Virtual_Employees with [Emp_Group = 3]]
ask Virtual_Employees with [Emp_Group = 4] [set Team_capacity sum [Emp_Capacity] of
Virtual_Employees with [Emp_Group = 4]]
ask Virtual_Employees with [Emp_Group = 1] [set Team_capacity_Type1 sum [Emp_Pro_area1C] of
Virtual_Employees with [Emp_Group = 1]]
ask Virtual_Employees with [Emp_Group = 1] [set Team_capacity_Type2 sum [Emp_Pro_area2C] of
Virtual_Employees with [Emp_Group = 1]]
ask Virtual_Employees with [Emp_Group = 1] [set Team_capacity_Type3 sum [Emp_Pro_area3C] of
Virtual_Employees with [Emp_Group = 1]]
ask Virtual_Employees with [Emp_Group = 1] [set Team_capacity_Type4 sum [Emp_Pro_area4C] of
Virtual_Employees with [Emp_Group = 1]]
ask Virtual_Employees with [Emp_Group = 1] [set Team_capacity_Type5 sum [Emp_Pro_area5C] of
Virtual_Employees with [Emp_Group = 1]]
ask Virtual_Employees with [Emp_Group = 2] [set Team_capacity_Type1 sum [Emp_Pro_area1C] of
Virtual_Employees with [Emp_Group = 2]]
ask Virtual_Employees with [Emp_Group = 2] [set Team_capacity_Type2 sum [Emp_Pro_area2C] of
Virtual_Employees with [Emp_Group = 2]]
ask Virtual_Employees with [Emp_Group = 2] [set Team_capacity_Type3 sum [Emp_Pro_area3C] of
Virtual_Employees with [Emp_Group = 2]]
ask Virtual_Employees with [Emp_Group = 2] [set Team_capacity_Type4 sum [Emp_Pro_area4C] of
Virtual_Employees with [Emp_Group = 2]]
ask Virtual_Employees with [Emp_Group = 2] [set Team_capacity_Type5 sum [Emp_Pro_area5C] of
Virtual_Employees with [Emp_Group = 2]]
```

```
ask Virtual_Employees with [Emp_Group = 3] [set Team_capacity_Type1 sum [Emp_Pro_area1C] of
Virtual_Employees with [Emp_Group = 3]]
ask Virtual_Employees with [Emp_Group = 3] [set Team_capacity_Type2 sum [Emp_Pro_area2C] of
Virtual_Employees with [Emp_Group = 3]]
ask Virtual_Employees with [Emp_Group = 3] [set Team_capacity_Type3 sum [Emp_Pro_area3C] of
Virtual_Employees with [Emp_Group = 3]]
ask Virtual_Employees with [Emp_Group = 3] [set Team_capacity_Type4 sum [Emp_Pro_area4C] of
Virtual_Employees with [Emp_Group = 3]]
ask Virtual_Employees with [Emp_Group = 3] [set Team_capacity_Type5 sum [Emp_Pro_area5C] of
Virtual_Employees with [Emp_Group = 3]]
ask Virtual_Employees with [Emp_Group = 4] [set Team_capacity_Type1 sum [Emp_Pro_area1C] of
Virtual_Employees with [Emp_Group = 4]]
ask Virtual_Employees with [Emp_Group = 4] [set Team_capacity_Type2 sum [Emp_Pro_area2C] of
Virtual_Employees with [Emp_Group = 4]]
ask Virtual_Employees with [Emp_Group = 4] [set Team_capacity_Type3 sum [Emp_Pro_area3C] of
Virtual_Employees with [Emp_Group = 4]]
ask Virtual_Employees with [Emp_Group = 4] [set Team_capacity_Type4 sum [Emp_Pro_area4C] of
Virtual_Employees with [Emp_Group = 4]]
ask Virtual_Employees with [Emp_Group = 4] [set Team_capacity_Type5 sum [Emp_Pro_area5C] of
Virtual_Employees with [Emp_Group = 4]]
]

if Number_of_Team = 5 [
ask Virtual_Employees with [Emp_Group = 1] [set Team_capacity sum [Emp_Capacity] of
Virtual_Employees with [Emp_Group = 1]]
ask Virtual_Employees with [Emp_Group = 2] [set Team_capacity sum [Emp_Capacity] of
Virtual_Employees with [Emp_Group = 2]]
ask Virtual_Employees with [Emp_Group = 3] [set Team_capacity sum [Emp_Capacity] of
Virtual_Employees with [Emp_Group = 3]]
ask Virtual_Employees with [Emp_Group = 4] [set Team_capacity sum [Emp_Capacity] of
Virtual_Employees with [Emp_Group = 4]]
ask Virtual_Employees with [Emp_Group = 5] [set Team_capacity sum [Emp_Capacity] of
Virtual_Employees with [Emp_Group = 5]]
ask Virtual_Employees with [Emp_Group = 1] [set Team_capacity_Type1 sum [Emp_Pro_area1C] of
Virtual_Employees with [Emp_Group = 1]]
ask Virtual_Employees with [Emp_Group = 1] [set Team_capacity_Type2 sum [Emp_Pro_area2C] of
Virtual_Employees with [Emp_Group = 1]]
ask Virtual_Employees with [Emp_Group = 1] [set Team_capacity_Type3 sum [Emp_Pro_area3C] of
Virtual_Employees with [Emp_Group = 1]]
ask Virtual_Employees with [Emp_Group = 1] [set Team_capacity_Type4 sum [Emp_Pro_area4C] of
Virtual_Employees with [Emp_Group = 1]]
ask Virtual_Employees with [Emp_Group = 1] [set Team_capacity_Type5 sum [Emp_Pro_area5C] of
Virtual_Employees with [Emp_Group = 1]]
ask Virtual_Employees with [Emp_Group = 2] [set Team_capacity_Type1 sum [Emp_Pro_area1C] of
Virtual_Employees with [Emp_Group = 2]]
ask Virtual_Employees with [Emp_Group = 2] [set Team_capacity_Type2 sum [Emp_Pro_area2C] of
Virtual_Employees with [Emp_Group = 2]]
ask Virtual_Employees with [Emp_Group = 2] [set Team_capacity_Type3 sum [Emp_Pro_area3C] of
Virtual_Employees with [Emp_Group = 2]]
ask Virtual_Employees with [Emp_Group = 2] [set Team_capacity_Type4 sum [Emp_Pro_area4C] of
Virtual_Employees with [Emp_Group = 2]]
ask Virtual_Employees with [Emp_Group = 2] [set Team_capacity_Type5 sum [Emp_Pro_area5C] of
Virtual_Employees with [Emp_Group = 2]]
ask Virtual_Employees with [Emp_Group = 3] [set Team_capacity_Type1 sum [Emp_Pro_area1C] of
Virtual_Employees with [Emp_Group = 3]]
```

```
ask Virtual_Employees with [Emp_Group = 3] [set Team_capacity_Type2 sum [Emp_Pro_area2C] of
Virtual_Employees with [Emp_Group = 3]]
ask Virtual_Employees with [Emp_Group = 3] [set Team_capacity_Type3 sum [Emp_Pro_area3C] of
Virtual_Employees with [Emp_Group = 3]]
ask Virtual_Employees with [Emp_Group = 3] [set Team_capacity_Type4 sum [Emp_Pro_area4C] of
Virtual_Employees with [Emp_Group = 3]]
ask Virtual_Employees with [Emp_Group = 3] [set Team_capacity_Type5 sum [Emp_Pro_area5C] of
Virtual_Employees with [Emp_Group = 3]]
ask Virtual_Employees with [Emp_Group = 4] [set Team_capacity_Type1 sum [Emp_Pro_area1C] of
Virtual_Employees with [Emp_Group = 4]]
ask Virtual_Employees with [Emp_Group = 4] [set Team_capacity_Type2 sum [Emp_Pro_area2C] of
Virtual_Employees with [Emp_Group = 4]]
ask Virtual_Employees with [Emp_Group = 4] [set Team_capacity_Type3 sum [Emp_Pro_area3C] of
Virtual_Employees with [Emp_Group = 4]]
ask Virtual_Employees with [Emp_Group = 4] [set Team_capacity_Type4 sum [Emp_Pro_area4C] of
Virtual_Employees with [Emp_Group = 4]]
ask Virtual_Employees with [Emp_Group = 4] [set Team_capacity_Type5 sum [Emp_Pro_area5C] of
Virtual_Employees with [Emp_Group = 4]]
ask Virtual_Employees with [Emp_Group = 5] [set Team_capacity_Type1 sum [Emp_Pro_area1C] of
Virtual_Employees with [Emp_Group = 5]]
ask Virtual_Employees with [Emp_Group = 5] [set Team_capacity_Type2 sum [Emp_Pro_area2C] of
Virtual_Employees with [Emp_Group = 5]]
ask Virtual_Employees with [Emp_Group = 5] [set Team_capacity_Type3 sum [Emp_Pro_area3C] of
Virtual_Employees with [Emp_Group = 5]]
ask Virtual_Employees with [Emp_Group = 5] [set Team_capacity_Type4 sum [Emp_Pro_area4C] of
Virtual_Employees with [Emp_Group = 5]]
ask Virtual_Employees with [Emp_Group = 5] [set Team_capacity_Type5 sum [Emp_Pro_area5C] of
Virtual_Employees with [Emp_Group = 5]]
]

if Number_of_Team = 6 [
ask Virtual_Employees with [Emp_Group = 1] [set Team_capacity sum [Emp_Capacity] of
Virtual_Employees with [Emp_Group = 1]]
ask Virtual_Employees with [Emp_Group = 2] [set Team_capacity sum [Emp_Capacity] of
Virtual_Employees with [Emp_Group = 2]]
ask Virtual_Employees with [Emp_Group = 3] [set Team_capacity sum [Emp_Capacity] of
Virtual_Employees with [Emp_Group = 3]]
ask Virtual_Employees with [Emp_Group = 4] [set Team_capacity sum [Emp_Capacity] of
Virtual_Employees with [Emp_Group = 4]]
ask Virtual_Employees with [Emp_Group = 5] [set Team_capacity sum [Emp_Capacity] of
Virtual_Employees with [Emp_Group = 5]]
ask Virtual_Employees with [Emp_Group = 6] [set Team_capacity sum [Emp_Capacity] of
Virtual_Employees with [Emp_Group = 6]]
ask Virtual_Employees with [Emp_Group = 1] [set Team_capacity_Type1 sum [Emp_Pro_area1C] of
Virtual_Employees with [Emp_Group = 1]]
ask Virtual_Employees with [Emp_Group = 1] [set Team_capacity_Type2 sum [Emp_Pro_area2C] of
Virtual_Employees with [Emp_Group = 1]]
ask Virtual_Employees with [Emp_Group = 1] [set Team_capacity_Type3 sum [Emp_Pro_area3C] of
Virtual_Employees with [Emp_Group = 1]]
ask Virtual_Employees with [Emp_Group = 1] [set Team_capacity_Type4 sum [Emp_Pro_area4C] of
Virtual_Employees with [Emp_Group = 1]]
ask Virtual_Employees with [Emp_Group = 1] [set Team_capacity_Type5 sum [Emp_Pro_area5C] of
Virtual_Employees with [Emp_Group = 1]]
ask Virtual_Employees with [Emp_Group = 2] [set Team_capacity_Type1 sum [Emp_Pro_area1C] of
Virtual_Employees with [Emp_Group = 2]]
```

ask Virtual_Employees with [Emp_Group = 2] [set Team_capacity_Type2 sum [Emp_Pro_area2C] of Virtual_Employees with [Emp_Group = 2]]
ask Virtual_Employees with [Emp_Group = 2] [set Team_capacity_Type3 sum [Emp_Pro_area3C] of Virtual_Employees with [Emp_Group = 2]]
ask Virtual_Employees with [Emp_Group = 2] [set Team_capacity_Type4 sum [Emp_Pro_area4C] of Virtual_Employees with [Emp_Group = 2]]
ask Virtual_Employees with [Emp_Group = 2] [set Team_capacity_Type5 sum [Emp_Pro_area5C] of Virtual_Employees with [Emp_Group = 2]]
ask Virtual_Employees with [Emp_Group = 3] [set Team_capacity_Type1 sum [Emp_Pro_area1C] of Virtual_Employees with [Emp_Group = 3]]
ask Virtual_Employees with [Emp_Group = 3] [set Team_capacity_Type2 sum [Emp_Pro_area2C] of Virtual_Employees with [Emp_Group = 3]]
ask Virtual_Employees with [Emp_Group = 3] [set Team_capacity_Type3 sum [Emp_Pro_area3C] of Virtual_Employees with [Emp_Group = 3]]
ask Virtual_Employees with [Emp_Group = 3] [set Team_capacity_Type4 sum [Emp_Pro_area4C] of Virtual_Employees with [Emp_Group = 3]]
ask Virtual_Employees with [Emp_Group = 3] [set Team_capacity_Type5 sum [Emp_Pro_area5C] of Virtual_Employees with [Emp_Group = 3]]
ask Virtual_Employees with [Emp_Group = 4] [set Team_capacity_Type1 sum [Emp_Pro_area1C] of Virtual_Employees with [Emp_Group = 4]]
ask Virtual_Employees with [Emp_Group = 4] [set Team_capacity_Type2 sum [Emp_Pro_area2C] of Virtual_Employees with [Emp_Group = 4]]
ask Virtual_Employees with [Emp_Group = 4] [set Team_capacity_Type3 sum [Emp_Pro_area3C] of Virtual_Employees with [Emp_Group = 4]]
ask Virtual_Employees with [Emp_Group = 4] [set Team_capacity_Type4 sum [Emp_Pro_area4C] of Virtual_Employees with [Emp_Group = 4]]
ask Virtual_Employees with [Emp_Group = 4] [set Team_capacity_Type5 sum [Emp_Pro_area5C] of Virtual_Employees with [Emp_Group = 4]]
ask Virtual_Employees with [Emp_Group = 5] [set Team_capacity_Type1 sum [Emp_Pro_area1C] of Virtual_Employees with [Emp_Group = 5]]
ask Virtual_Employees with [Emp_Group = 5] [set Team_capacity_Type2 sum [Emp_Pro_area2C] of Virtual_Employees with [Emp_Group = 5]]
ask Virtual_Employees with [Emp_Group = 5] [set Team_capacity_Type3 sum [Emp_Pro_area3C] of Virtual_Employees with [Emp_Group = 5]]
ask Virtual_Employees with [Emp_Group = 5] [set Team_capacity_Type4 sum [Emp_Pro_area4C] of Virtual_Employees with [Emp_Group = 5]]
ask Virtual_Employees with [Emp_Group = 5] [set Team_capacity_Type5 sum [Emp_Pro_area5C] of Virtual_Employees with [Emp_Group = 5]]
ask Virtual_Employees with [Emp_Group = 6] [set Team_capacity_Type1 sum [Emp_Pro_area1C] of Virtual_Employees with [Emp_Group = 6]]
ask Virtual_Employees with [Emp_Group = 6] [set Team_capacity_Type2 sum [Emp_Pro_area2C] of Virtual_Employees with [Emp_Group = 6]]
ask Virtual_Employees with [Emp_Group = 6] [set Team_capacity_Type3 sum [Emp_Pro_area3C] of Virtual_Employees with [Emp_Group = 6]]
ask Virtual_Employees with [Emp_Group = 6] [set Team_capacity_Type4 sum [Emp_Pro_area4C] of Virtual_Employees with [Emp_Group = 6]]
ask Virtual_Employees with [Emp_Group = 6] [set Team_capacity_Type5 sum [Emp_Pro_area5C] of Virtual_Employees with [Emp_Group = 6]]
]

if Number_of_Team = 7 [
ask Virtual_Employees with [Emp_Group = 1] [set Team_capacity sum [Emp_Capacity] of Virtual_Employees with [Emp_Group = 1]]
ask Virtual_Employees with [Emp_Group = 2] [set Team_capacity sum [Emp_Capacity] of Virtual_Employees with [Emp_Group = 2]]

```
ask Virtual_Employees with [Emp_Group = 3] [set Team_capacity sum [Emp_Capacity] of
Virtual_Employees with [Emp_Group = 3]]
ask Virtual_Employees with [Emp_Group = 4] [set Team_capacity sum [Emp_Capacity] of
Virtual_Employees with [Emp_Group = 4]]
ask Virtual_Employees with [Emp_Group = 5] [set Team_capacity sum [Emp_Capacity] of
Virtual_Employees with [Emp_Group = 5]]
ask Virtual_Employees with [Emp_Group = 6] [set Team_capacity sum [Emp_Capacity] of
Virtual_Employees with [Emp_Group = 6]]
ask Virtual_Employees with [Emp_Group = 7] [set Team_capacity sum [Emp_Capacity] of
Virtual_Employees with [Emp_Group = 7]]
ask Virtual_Employees with [Emp_Group = 1] [set Team_capacity_Type1 sum [Emp_Pro_area1C] of
Virtual_Employees with [Emp_Group = 1]]
ask Virtual_Employees with [Emp_Group = 1] [set Team_capacity_Type2 sum [Emp_Pro_area2C] of
Virtual_Employees with [Emp_Group = 1]]
ask Virtual_Employees with [Emp_Group = 1] [set Team_capacity_Type3 sum [Emp_Pro_area3C] of
Virtual_Employees with [Emp_Group = 1]]
ask Virtual_Employees with [Emp_Group = 1] [set Team_capacity_Type4 sum [Emp_Pro_area4C] of
Virtual_Employees with [Emp_Group = 1]]
ask Virtual_Employees with [Emp_Group = 1] [set Team_capacity_Type5 sum [Emp_Pro_area5C] of
Virtual_Employees with [Emp_Group = 1]]
ask Virtual_Employees with [Emp_Group = 2] [set Team_capacity_Type1 sum [Emp_Pro_area1C] of
Virtual_Employees with [Emp_Group = 2]]
ask Virtual_Employees with [Emp_Group = 2] [set Team_capacity_Type2 sum [Emp_Pro_area2C] of
Virtual_Employees with [Emp_Group = 2]]
ask Virtual_Employees with [Emp_Group = 2] [set Team_capacity_Type3 sum [Emp_Pro_area3C] of
Virtual_Employees with [Emp_Group = 2]]
ask Virtual_Employees with [Emp_Group = 2] [set Team_capacity_Type4 sum [Emp_Pro_area4C] of
Virtual_Employees with [Emp_Group = 2]]
ask Virtual_Employees with [Emp_Group = 2] [set Team_capacity_Type5 sum [Emp_Pro_area5C] of
Virtual_Employees with [Emp_Group = 2]]
ask Virtual_Employees with [Emp_Group = 3] [set Team_capacity_Type1 sum [Emp_Pro_area1C] of
Virtual_Employees with [Emp_Group = 3]]
ask Virtual_Employees with [Emp_Group = 3] [set Team_capacity_Type2 sum [Emp_Pro_area2C] of
Virtual_Employees with [Emp_Group = 3]]
ask Virtual_Employees with [Emp_Group = 3] [set Team_capacity_Type3 sum [Emp_Pro_area3C] of
Virtual_Employees with [Emp_Group = 3]]
ask Virtual_Employees with [Emp_Group = 3] [set Team_capacity_Type4 sum [Emp_Pro_area4C] of
Virtual_Employees with [Emp_Group = 3]]
ask Virtual_Employees with [Emp_Group = 3] [set Team_capacity_Type5 sum [Emp_Pro_area5C] of
Virtual_Employees with [Emp_Group = 3]]
ask Virtual_Employees with [Emp_Group = 4] [set Team_capacity_Type1 sum [Emp_Pro_area1C] of
Virtual_Employees with [Emp_Group = 4]]
ask Virtual_Employees with [Emp_Group = 4] [set Team_capacity_Type2 sum [Emp_Pro_area2C] of
Virtual_Employees with [Emp_Group = 4]]
ask Virtual_Employees with [Emp_Group = 4] [set Team_capacity_Type3 sum [Emp_Pro_area3C] of
Virtual_Employees with [Emp_Group = 4]]
ask Virtual_Employees with [Emp_Group = 4] [set Team_capacity_Type4 sum [Emp_Pro_area4C] of
Virtual_Employees with [Emp_Group = 4]]
ask Virtual_Employees with [Emp_Group = 4] [set Team_capacity_Type5 sum [Emp_Pro_area5C] of
Virtual_Employees with [Emp_Group = 4]]
ask Virtual_Employees with [Emp_Group = 5] [set Team_capacity_Type1 sum [Emp_Pro_area1C] of
Virtual_Employees with [Emp_Group = 5]]
ask Virtual_Employees with [Emp_Group = 5] [set Team_capacity_Type2 sum [Emp_Pro_area2C] of
Virtual_Employees with [Emp_Group = 5]]
```

```
ask Virtual_Employees with [Emp_Group = 5] [set Team_capacity_Type3 sum [Emp_Pro_area3C] of
Virtual_Employees with [Emp_Group = 5]]
ask Virtual_Employees with [Emp_Group = 5] [set Team_capacity_Type4 sum [Emp_Pro_area4C] of
Virtual_Employees with [Emp_Group = 5]]
ask Virtual_Employees with [Emp_Group = 5] [set Team_capacity_Type5 sum [Emp_Pro_area5C] of
Virtual_Employees with [Emp_Group = 5]]
ask Virtual_Employees with [Emp_Group = 6] [set Team_capacity_Type1 sum [Emp_Pro_area1C] of
Virtual_Employees with [Emp_Group = 6]]
ask Virtual_Employees with [Emp_Group = 6] [set Team_capacity_Type2 sum [Emp_Pro_area2C] of
Virtual_Employees with [Emp_Group = 6]]
ask Virtual_Employees with [Emp_Group = 6] [set Team_capacity_Type3 sum [Emp_Pro_area3C] of
Virtual_Employees with [Emp_Group = 6]]
ask Virtual_Employees with [Emp_Group = 6] [set Team_capacity_Type4 sum [Emp_Pro_area4C] of
Virtual_Employees with [Emp_Group = 6]]
ask Virtual_Employees with [Emp_Group = 6] [set Team_capacity_Type5 sum [Emp_Pro_area5C] of
Virtual_Employees with [Emp_Group = 6]]
ask Virtual_Employees with [Emp_Group = 7] [set Team_capacity_Type1 sum [Emp_Pro_area1C] of
Virtual_Employees with [Emp_Group = 7]]
ask Virtual_Employees with [Emp_Group = 7] [set Team_capacity_Type2 sum [Emp_Pro_area2C] of
Virtual_Employees with [Emp_Group = 7]]
ask Virtual_Employees with [Emp_Group = 7] [set Team_capacity_Type3 sum [Emp_Pro_area3C] of
Virtual_Employees with [Emp_Group = 7]]
ask Virtual_Employees with [Emp_Group = 7] [set Team_capacity_Type4 sum [Emp_Pro_area4C] of
Virtual_Employees with [Emp_Group = 7]]
ask Virtual_Employees with [Emp_Group = 7] [set Team_capacity_Type5 sum [Emp_Pro_area5C] of
Virtual_Employees with [Emp_Group = 7]]
]

if Number_of_Team = 8 [
ask Virtual_Employees with [Emp_Group = 1] [set Team_capacity sum [Emp_Capacity] of
Virtual_Employees with [Emp_Group = 1]]
ask Virtual_Employees with [Emp_Group = 2] [set Team_capacity sum [Emp_Capacity] of
Virtual_Employees with [Emp_Group = 2]]
ask Virtual_Employees with [Emp_Group = 3] [set Team_capacity sum [Emp_Capacity] of
Virtual_Employees with [Emp_Group = 3]]
ask Virtual_Employees with [Emp_Group = 4] [set Team_capacity sum [Emp_Capacity] of
Virtual_Employees with [Emp_Group = 4]]
ask Virtual_Employees with [Emp_Group = 5] [set Team_capacity sum [Emp_Capacity] of
Virtual_Employees with [Emp_Group = 5]]
ask Virtual_Employees with [Emp_Group = 6] [set Team_capacity sum [Emp_Capacity] of
Virtual_Employees with [Emp_Group = 6]]
ask Virtual_Employees with [Emp_Group = 7] [set Team_capacity sum [Emp_Capacity] of
Virtual_Employees with [Emp_Group = 7]]
ask Virtual_Employees with [Emp_Group = 8] [set Team_capacity sum [Emp_Capacity] of
Virtual_Employees with [Emp_Group = 8]]
ask Virtual_Employees with [Emp_Group = 1] [set Team_capacity_Type1 sum [Emp_Pro_area1C] of
Virtual_Employees with [Emp_Group = 1]]
ask Virtual_Employees with [Emp_Group = 1] [set Team_capacity_Type2 sum [Emp_Pro_area2C] of
Virtual_Employees with [Emp_Group = 1]]
ask Virtual_Employees with [Emp_Group = 1] [set Team_capacity_Type3 sum [Emp_Pro_area3C] of
Virtual_Employees with [Emp_Group = 1]]
ask Virtual_Employees with [Emp_Group = 1] [set Team_capacity_Type4 sum [Emp_Pro_area4C] of
Virtual_Employees with [Emp_Group = 1]]
ask Virtual_Employees with [Emp_Group = 1] [set Team_capacity_Type5 sum [Emp_Pro_area5C] of
Virtual_Employees with [Emp_Group = 1]]
```

ask Virtual_Employees with [Emp_Group = 2] [set Team_capacity_Type1 sum [Emp_Pro_area1C] of Virtual_Employees with [Emp_Group = 2]]
ask Virtual_Employees with [Emp_Group = 2] [set Team_capacity_Type2 sum [Emp_Pro_area2C] of Virtual_Employees with [Emp_Group = 2]]
ask Virtual_Employees with [Emp_Group = 2] [set Team_capacity_Type3 sum [Emp_Pro_area3C] of Virtual_Employees with [Emp_Group = 2]]
ask Virtual_Employees with [Emp_Group = 2] [set Team_capacity_Type4 sum [Emp_Pro_area4C] of Virtual_Employees with [Emp_Group = 2]]
ask Virtual_Employees with [Emp_Group = 2] [set Team_capacity_Type5 sum [Emp_Pro_area5C] of Virtual_Employees with [Emp_Group = 2]]
ask Virtual_Employees with [Emp_Group = 3] [set Team_capacity_Type1 sum [Emp_Pro_area1C] of Virtual_Employees with [Emp_Group = 3]]
ask Virtual_Employees with [Emp_Group = 3] [set Team_capacity_Type2 sum [Emp_Pro_area2C] of Virtual_Employees with [Emp_Group = 3]]
ask Virtual_Employees with [Emp_Group = 3] [set Team_capacity_Type3 sum [Emp_Pro_area3C] of Virtual_Employees with [Emp_Group = 3]]
ask Virtual_Employees with [Emp_Group = 3] [set Team_capacity_Type4 sum [Emp_Pro_area4C] of Virtual_Employees with [Emp_Group = 3]]
ask Virtual_Employees with [Emp_Group = 3] [set Team_capacity_Type5 sum [Emp_Pro_area5C] of Virtual_Employees with [Emp_Group = 3]]
ask Virtual_Employees with [Emp_Group = 4] [set Team_capacity_Type1 sum [Emp_Pro_area1C] of Virtual_Employees with [Emp_Group = 4]]
ask Virtual_Employees with [Emp_Group = 4] [set Team_capacity_Type2 sum [Emp_Pro_area2C] of Virtual_Employees with [Emp_Group = 4]]
ask Virtual_Employees with [Emp_Group = 4] [set Team_capacity_Type3 sum [Emp_Pro_area3C] of Virtual_Employees with [Emp_Group = 4]]
ask Virtual_Employees with [Emp_Group = 4] [set Team_capacity_Type4 sum [Emp_Pro_area4C] of Virtual_Employees with [Emp_Group = 4]]
ask Virtual_Employees with [Emp_Group = 4] [set Team_capacity_Type5 sum [Emp_Pro_area5C] of Virtual_Employees with [Emp_Group = 4]]
ask Virtual_Employees with [Emp_Group = 5] [set Team_capacity_Type1 sum [Emp_Pro_area1C] of Virtual_Employees with [Emp_Group = 5]]
ask Virtual_Employees with [Emp_Group = 5] [set Team_capacity_Type2 sum [Emp_Pro_area2C] of Virtual_Employees with [Emp_Group = 5]]
ask Virtual_Employees with [Emp_Group = 5] [set Team_capacity_Type3 sum [Emp_Pro_area3C] of Virtual_Employees with [Emp_Group = 5]]
ask Virtual_Employees with [Emp_Group = 5] [set Team_capacity_Type4 sum [Emp_Pro_area4C] of Virtual_Employees with [Emp_Group = 5]]
ask Virtual_Employees with [Emp_Group = 5] [set Team_capacity_Type5 sum [Emp_Pro_area5C] of Virtual_Employees with [Emp_Group = 5]]
ask Virtual_Employees with [Emp_Group = 6] [set Team_capacity_Type1 sum [Emp_Pro_area1C] of Virtual_Employees with [Emp_Group = 6]]
ask Virtual_Employees with [Emp_Group = 6] [set Team_capacity_Type2 sum [Emp_Pro_area2C] of Virtual_Employees with [Emp_Group = 6]]
ask Virtual_Employees with [Emp_Group = 6] [set Team_capacity_Type3 sum [Emp_Pro_area3C] of Virtual_Employees with [Emp_Group = 6]]
ask Virtual_Employees with [Emp_Group = 6] [set Team_capacity_Type4 sum [Emp_Pro_area4C] of Virtual_Employees with [Emp_Group = 6]]
ask Virtual_Employees with [Emp_Group = 6] [set Team_capacity_Type5 sum [Emp_Pro_area5C] of Virtual_Employees with [Emp_Group = 6]]
ask Virtual_Employees with [Emp_Group = 7] [set Team_capacity_Type1 sum [Emp_Pro_area1C] of Virtual_Employees with [Emp_Group = 7]]
ask Virtual_Employees with [Emp_Group = 7] [set Team_capacity_Type2 sum [Emp_Pro_area2C] of Virtual_Employees with [Emp_Group = 7]]

```
ask Virtual_Employees with [Emp_Group = 7] [set Team_capacity_Type3 sum [Emp_Pro_area3C] of
Virtual_Employees with [Emp_Group = 7]]
ask Virtual_Employees with [Emp_Group = 7] [set Team_capacity_Type4 sum [Emp_Pro_area4C] of
Virtual_Employees with [Emp_Group = 7]]
ask Virtual_Employees with [Emp_Group = 7] [set Team_capacity_Type5 sum [Emp_Pro_area5C] of
Virtual_Employees with [Emp_Group = 7]]
ask Virtual_Employees with [Emp_Group = 8] [set Team_capacity_Type1 sum [Emp_Pro_area1C] of
Virtual_Employees with [Emp_Group = 8]]
ask Virtual_Employees with [Emp_Group = 8] [set Team_capacity_Type2 sum [Emp_Pro_area2C] of
Virtual_Employees with [Emp_Group = 8]]
ask Virtual_Employees with [Emp_Group = 8] [set Team_capacity_Type3 sum [Emp_Pro_area3C] of
Virtual_Employees with [Emp_Group = 8]]
ask Virtual_Employees with [Emp_Group = 8] [set Team_capacity_Type4 sum [Emp_Pro_area4C] of
Virtual_Employees with [Emp_Group = 8]]
ask Virtual_Employees with [Emp_Group = 8] [set Team_capacity_Type5 sum [Emp_Pro_area5C] of
Virtual_Employees with [Emp_Group = 8]]
]

if Number_of_Team = 9 [
ask Virtual_Employees with [Emp_Group = 1] [set Team_capacity sum [Emp_Capacity] of
Virtual_Employees with [Emp_Group = 1]]
ask Virtual_Employees with [Emp_Group = 2] [set Team_capacity sum [Emp_Capacity] of
Virtual_Employees with [Emp_Group = 2]]
ask Virtual_Employees with [Emp_Group = 3] [set Team_capacity sum [Emp_Capacity] of
Virtual_Employees with [Emp_Group = 3]]
ask Virtual_Employees with [Emp_Group = 4] [set Team_capacity sum [Emp_Capacity] of
Virtual_Employees with [Emp_Group = 4]]
ask Virtual_Employees with [Emp_Group = 5] [set Team_capacity sum [Emp_Capacity] of
Virtual_Employees with [Emp_Group = 5]]
ask Virtual_Employees with [Emp_Group = 6] [set Team_capacity sum [Emp_Capacity] of
Virtual_Employees with [Emp_Group = 6]]
ask Virtual_Employees with [Emp_Group = 7] [set Team_capacity sum [Emp_Capacity] of
Virtual_Employees with [Emp_Group = 7]]
ask Virtual_Employees with [Emp_Group = 8] [set Team_capacity sum [Emp_Capacity] of
Virtual_Employees with [Emp_Group = 8]]
ask Virtual_Employees with [Emp_Group = 9] [set Team_capacity sum [Emp_Capacity] of
Virtual_Employees with [Emp_Group = 9]]
ask Virtual_Employees with [Emp_Group = 1] [set Team_capacity_Type1 sum [Emp_Pro_area1C] of
Virtual_Employees with [Emp_Group = 1]]
ask Virtual_Employees with [Emp_Group = 1] [set Team_capacity_Type2 sum [Emp_Pro_area2C] of
Virtual_Employees with [Emp_Group = 1]]
ask Virtual_Employees with [Emp_Group = 1] [set Team_capacity_Type3 sum [Emp_Pro_area3C] of
Virtual_Employees with [Emp_Group = 1]]
ask Virtual_Employees with [Emp_Group = 1] [set Team_capacity_Type4 sum [Emp_Pro_area4C] of
Virtual_Employees with [Emp_Group = 1]]
ask Virtual_Employees with [Emp_Group = 1] [set Team_capacity_Type5 sum [Emp_Pro_area5C] of
Virtual_Employees with [Emp_Group = 1]]
ask Virtual_Employees with [Emp_Group = 2] [set Team_capacity_Type1 sum [Emp_Pro_area1C] of
Virtual_Employees with [Emp_Group = 2]]
ask Virtual_Employees with [Emp_Group = 2] [set Team_capacity_Type2 sum [Emp_Pro_area2C] of
Virtual_Employees with [Emp_Group = 2]]
ask Virtual_Employees with [Emp_Group = 2] [set Team_capacity_Type3 sum [Emp_Pro_area3C] of
Virtual_Employees with [Emp_Group = 2]]
ask Virtual_Employees with [Emp_Group = 2] [set Team_capacity_Type4 sum [Emp_Pro_area4C] of
Virtual_Employees with [Emp_Group = 2]]
```

ask Virtual_Employees with [Emp_Group = 2] [set Team_capacity_Type5 sum [Emp_Pro_area5C] of Virtual_Employees with [Emp_Group = 2]]
ask Virtual_Employees with [Emp_Group = 3] [set Team_capacity_Type1 sum [Emp_Pro_area1C] of Virtual_Employees with [Emp_Group = 3]]
ask Virtual_Employees with [Emp_Group = 3] [set Team_capacity_Type2 sum [Emp_Pro_area2C] of Virtual_Employees with [Emp_Group = 3]]
ask Virtual_Employees with [Emp_Group = 3] [set Team_capacity_Type3 sum [Emp_Pro_area3C] of Virtual_Employees with [Emp_Group = 3]]
ask Virtual_Employees with [Emp_Group = 3] [set Team_capacity_Type4 sum [Emp_Pro_area4C] of Virtual_Employees with [Emp_Group = 3]]
ask Virtual_Employees with [Emp_Group = 3] [set Team_capacity_Type5 sum [Emp_Pro_area5C] of Virtual_Employees with [Emp_Group = 3]]
ask Virtual_Employees with [Emp_Group = 4] [set Team_capacity_Type1 sum [Emp_Pro_area1C] of Virtual_Employees with [Emp_Group = 4]]
ask Virtual_Employees with [Emp_Group = 4] [set Team_capacity_Type2 sum [Emp_Pro_area2C] of Virtual_Employees with [Emp_Group = 4]]
ask Virtual_Employees with [Emp_Group = 4] [set Team_capacity_Type3 sum [Emp_Pro_area3C] of Virtual_Employees with [Emp_Group = 4]]
ask Virtual_Employees with [Emp_Group = 4] [set Team_capacity_Type4 sum [Emp_Pro_area4C] of Virtual_Employees with [Emp_Group = 4]]
ask Virtual_Employees with [Emp_Group = 4] [set Team_capacity_Type5 sum [Emp_Pro_area5C] of Virtual_Employees with [Emp_Group = 4]]
ask Virtual_Employees with [Emp_Group = 5] [set Team_capacity_Type1 sum [Emp_Pro_area1C] of Virtual_Employees with [Emp_Group = 5]]
ask Virtual_Employees with [Emp_Group = 5] [set Team_capacity_Type2 sum [Emp_Pro_area2C] of Virtual_Employees with [Emp_Group = 5]]
ask Virtual_Employees with [Emp_Group = 5] [set Team_capacity_Type3 sum [Emp_Pro_area3C] of Virtual_Employees with [Emp_Group = 5]]
ask Virtual_Employees with [Emp_Group = 5] [set Team_capacity_Type4 sum [Emp_Pro_area4C] of Virtual_Employees with [Emp_Group = 5]]
ask Virtual_Employees with [Emp_Group = 5] [set Team_capacity_Type5 sum [Emp_Pro_area5C] of Virtual_Employees with [Emp_Group = 5]]
ask Virtual_Employees with [Emp_Group = 6] [set Team_capacity_Type1 sum [Emp_Pro_area1C] of Virtual_Employees with [Emp_Group = 6]]
ask Virtual_Employees with [Emp_Group = 6] [set Team_capacity_Type2 sum [Emp_Pro_area2C] of Virtual_Employees with [Emp_Group = 6]]
ask Virtual_Employees with [Emp_Group = 6] [set Team_capacity_Type3 sum [Emp_Pro_area3C] of Virtual_Employees with [Emp_Group = 6]]
ask Virtual_Employees with [Emp_Group = 6] [set Team_capacity_Type4 sum [Emp_Pro_area4C] of Virtual_Employees with [Emp_Group = 6]]
ask Virtual_Employees with [Emp_Group = 6] [set Team_capacity_Type5 sum [Emp_Pro_area5C] of Virtual_Employees with [Emp_Group = 6]]
ask Virtual_Employees with [Emp_Group = 7] [set Team_capacity_Type1 sum [Emp_Pro_area1C] of Virtual_Employees with [Emp_Group = 7]]
ask Virtual_Employees with [Emp_Group = 7] [set Team_capacity_Type2 sum [Emp_Pro_area2C] of Virtual_Employees with [Emp_Group = 7]]
ask Virtual_Employees with [Emp_Group = 7] [set Team_capacity_Type3 sum [Emp_Pro_area3C] of Virtual_Employees with [Emp_Group = 7]]
ask Virtual_Employees with [Emp_Group = 7] [set Team_capacity_Type4 sum [Emp_Pro_area4C] of Virtual_Employees with [Emp_Group = 7]]
ask Virtual_Employees with [Emp_Group = 7] [set Team_capacity_Type5 sum [Emp_Pro_area5C] of Virtual_Employees with [Emp_Group = 7]]
ask Virtual_Employees with [Emp_Group = 8] [set Team_capacity_Type1 sum [Emp_Pro_area1C] of Virtual_Employees with [Emp_Group = 8]]

```
ask Virtual_Employees with [Emp_Group = 8] [set Team_capacity_Type2 sum [Emp_Pro_area2C] of
Virtual_Employees with [Emp_Group = 8]]
ask Virtual_Employees with [Emp_Group = 8] [set Team_capacity_Type3 sum [Emp_Pro_area3C] of
Virtual_Employees with [Emp_Group = 8]]
ask Virtual_Employees with [Emp_Group = 8] [set Team_capacity_Type4 sum [Emp_Pro_area4C] of
Virtual_Employees with [Emp_Group = 8]]
ask Virtual_Employees with [Emp_Group = 8] [set Team_capacity_Type5 sum [Emp_Pro_area5C] of
Virtual_Employees with [Emp_Group = 8]]
ask Virtual_Employees with [Emp_Group = 9] [set Team_capacity_Type1 sum [Emp_Pro_area1C] of
Virtual_Employees with [Emp_Group = 9]]
ask Virtual_Employees with [Emp_Group = 9] [set Team_capacity_Type2 sum [Emp_Pro_area2C] of
Virtual_Employees with [Emp_Group = 9]]
ask Virtual_Employees with [Emp_Group = 9] [set Team_capacity_Type3 sum [Emp_Pro_area3C] of
Virtual_Employees with [Emp_Group = 9]]
ask Virtual_Employees with [Emp_Group = 9] [set Team_capacity_Type4 sum [Emp_Pro_area4C] of
Virtual_Employees with [Emp_Group = 9]]
ask Virtual_Employees with [Emp_Group = 9] [set Team_capacity_Type5 sum [Emp_Pro_area5C] of
Virtual_Employees with [Emp_Group = 9]]
]

if Number_of_Team = 10 [
ask Virtual_Employees with [Emp_Group = 1] [set Team_capacity sum [Emp_Capacity] of
Virtual_Employees with [Emp_Group = 1]]
ask Virtual_Employees with [Emp_Group = 2] [set Team_capacity sum [Emp_Capacity] of
Virtual_Employees with [Emp_Group = 2]]
ask Virtual_Employees with [Emp_Group = 3] [set Team_capacity sum [Emp_Capacity] of
Virtual_Employees with [Emp_Group = 3]]
ask Virtual_Employees with [Emp_Group = 4] [set Team_capacity sum [Emp_Capacity] of
Virtual_Employees with [Emp_Group = 4]]
ask Virtual_Employees with [Emp_Group = 5] [set Team_capacity sum [Emp_Capacity] of
Virtual_Employees with [Emp_Group = 5]]
ask Virtual_Employees with [Emp_Group = 6] [set Team_capacity sum [Emp_Capacity] of
Virtual_Employees with [Emp_Group = 6]]
ask Virtual_Employees with [Emp_Group = 7] [set Team_capacity sum [Emp_Capacity] of
Virtual_Employees with [Emp_Group = 7]]
ask Virtual_Employees with [Emp_Group = 8] [set Team_capacity sum [Emp_Capacity] of
Virtual_Employees with [Emp_Group = 8]]
ask Virtual_Employees with [Emp_Group = 9] [set Team_capacity sum [Emp_Capacity] of
Virtual_Employees with [Emp_Group = 9]]
ask Virtual_Employees with [Emp_Group = 10] [set Team_capacity sum [Emp_Capacity] of
Virtual_Employees with [Emp_Group = 10]]
ask Virtual_Employees with [Emp_Group = 1] [set Team_capacity_Type1 sum [Emp_Pro_area1C] of
Virtual_Employees with [Emp_Group = 1]]
ask Virtual_Employees with [Emp_Group = 1] [set Team_capacity_Type2 sum [Emp_Pro_area2C] of
Virtual_Employees with [Emp_Group = 1]]
ask Virtual_Employees with [Emp_Group = 1] [set Team_capacity_Type3 sum [Emp_Pro_area3C] of
Virtual_Employees with [Emp_Group = 1]]
ask Virtual_Employees with [Emp_Group = 1] [set Team_capacity_Type4 sum [Emp_Pro_area4C] of
Virtual_Employees with [Emp_Group = 1]]
ask Virtual_Employees with [Emp_Group = 1] [set Team_capacity_Type5 sum [Emp_Pro_area5C] of
Virtual_Employees with [Emp_Group = 1]]
ask Virtual_Employees with [Emp_Group = 2] [set Team_capacity_Type1 sum [Emp_Pro_area1C] of
Virtual_Employees with [Emp_Group = 2]]
ask Virtual_Employees with [Emp_Group = 2] [set Team_capacity_Type2 sum [Emp_Pro_area2C] of
Virtual_Employees with [Emp_Group = 2]]
```

ask Virtual_Employees with [Emp_Group = 2] [set Team_capacity_Type3 sum [Emp_Pro_area3C] of Virtual_Employees with [Emp_Group = 2]]
ask Virtual_Employees with [Emp_Group = 2] [set Team_capacity_Type4 sum [Emp_Pro_area4C] of Virtual_Employees with [Emp_Group = 2]]
ask Virtual_Employees with [Emp_Group = 2] [set Team_capacity_Type5 sum [Emp_Pro_area5C] of Virtual_Employees with [Emp_Group = 2]]
ask Virtual_Employees with [Emp_Group = 3] [set Team_capacity_Type1 sum [Emp_Pro_area1C] of Virtual_Employees with [Emp_Group = 3]]
ask Virtual_Employees with [Emp_Group = 3] [set Team_capacity_Type2 sum [Emp_Pro_area2C] of Virtual_Employees with [Emp_Group = 3]]
ask Virtual_Employees with [Emp_Group = 3] [set Team_capacity_Type3 sum [Emp_Pro_area3C] of Virtual_Employees with [Emp_Group = 3]]
ask Virtual_Employees with [Emp_Group = 3] [set Team_capacity_Type4 sum [Emp_Pro_area4C] of Virtual_Employees with [Emp_Group = 3]]
ask Virtual_Employees with [Emp_Group = 3] [set Team_capacity_Type5 sum [Emp_Pro_area5C] of Virtual_Employees with [Emp_Group = 3]]
ask Virtual_Employees with [Emp_Group = 4] [set Team_capacity_Type1 sum [Emp_Pro_area1C] of Virtual_Employees with [Emp_Group = 4]]
ask Virtual_Employees with [Emp_Group = 4] [set Team_capacity_Type2 sum [Emp_Pro_area2C] of Virtual_Employees with [Emp_Group = 4]]
ask Virtual_Employees with [Emp_Group = 4] [set Team_capacity_Type3 sum [Emp_Pro_area3C] of Virtual_Employees with [Emp_Group = 4]]
ask Virtual_Employees with [Emp_Group = 4] [set Team_capacity_Type4 sum [Emp_Pro_area4C] of Virtual_Employees with [Emp_Group = 4]]
ask Virtual_Employees with [Emp_Group = 4] [set Team_capacity_Type5 sum [Emp_Pro_area5C] of Virtual_Employees with [Emp_Group = 4]]
ask Virtual_Employees with [Emp_Group = 5] [set Team_capacity_Type1 sum [Emp_Pro_area1C] of Virtual_Employees with [Emp_Group = 5]]
ask Virtual_Employees with [Emp_Group = 5] [set Team_capacity_Type2 sum [Emp_Pro_area2C] of Virtual_Employees with [Emp_Group = 5]]
ask Virtual_Employees with [Emp_Group = 5] [set Team_capacity_Type3 sum [Emp_Pro_area3C] of Virtual_Employees with [Emp_Group = 5]]
ask Virtual_Employees with [Emp_Group = 5] [set Team_capacity_Type4 sum [Emp_Pro_area4C] of Virtual_Employees with [Emp_Group = 5]]
ask Virtual_Employees with [Emp_Group = 5] [set Team_capacity_Type5 sum [Emp_Pro_area5C] of Virtual_Employees with [Emp_Group = 5]]
ask Virtual_Employees with [Emp_Group = 6] [set Team_capacity_Type1 sum [Emp_Pro_area1C] of Virtual_Employees with [Emp_Group = 6]]
ask Virtual_Employees with [Emp_Group = 6] [set Team_capacity_Type2 sum [Emp_Pro_area2C] of Virtual_Employees with [Emp_Group = 6]]
ask Virtual_Employees with [Emp_Group = 6] [set Team_capacity_Type3 sum [Emp_Pro_area3C] of Virtual_Employees with [Emp_Group = 6]]
ask Virtual_Employees with [Emp_Group = 6] [set Team_capacity_Type4 sum [Emp_Pro_area4C] of Virtual_Employees with [Emp_Group = 6]]
ask Virtual_Employees with [Emp_Group = 6] [set Team_capacity_Type5 sum [Emp_Pro_area5C] of Virtual_Employees with [Emp_Group = 6]]
ask Virtual_Employees with [Emp_Group = 7] [set Team_capacity_Type1 sum [Emp_Pro_area1C] of Virtual_Employees with [Emp_Group = 7]]
ask Virtual_Employees with [Emp_Group = 7] [set Team_capacity_Type2 sum [Emp_Pro_area2C] of Virtual_Employees with [Emp_Group = 7]]
ask Virtual_Employees with [Emp_Group = 7] [set Team_capacity_Type3 sum [Emp_Pro_area3C] of Virtual_Employees with [Emp_Group = 7]]
ask Virtual_Employees with [Emp_Group = 7] [set Team_capacity_Type4 sum [Emp_Pro_area4C] of Virtual_Employees with [Emp_Group = 7]]

```
ask Virtual_Employees with [Emp_Group = 7] [set Team_capacity_Type5 sum [Emp_Pro_area5C] of
Virtual_Employees with [Emp_Group = 7]]
ask Virtual_Employees with [Emp_Group = 8] [set Team_capacity_Type1 sum [Emp_Pro_area1C] of
Virtual_Employees with [Emp_Group = 8]]
ask Virtual_Employees with [Emp_Group = 8] [set Team_capacity_Type2 sum [Emp_Pro_area2C] of
Virtual_Employees with [Emp_Group = 8]]
ask Virtual_Employees with [Emp_Group = 8] [set Team_capacity_Type3 sum [Emp_Pro_area3C] of
Virtual_Employees with [Emp_Group = 8]]
ask Virtual_Employees with [Emp_Group = 8] [set Team_capacity_Type4 sum [Emp_Pro_area4C] of
Virtual_Employees with [Emp_Group = 8]]
ask Virtual_Employees with [Emp_Group = 8] [set Team_capacity_Type5 sum [Emp_Pro_area5C] of
Virtual_Employees with [Emp_Group = 8]]
ask Virtual_Employees with [Emp_Group = 9] [set Team_capacity_Type1 sum [Emp_Pro_area1C] of
Virtual_Employees with [Emp_Group = 9]]
ask Virtual_Employees with [Emp_Group = 9] [set Team_capacity_Type2 sum [Emp_Pro_area2C] of
Virtual_Employees with [Emp_Group = 9]]
ask Virtual_Employees with [Emp_Group = 9] [set Team_capacity_Type3 sum [Emp_Pro_area3C] of
Virtual_Employees with [Emp_Group = 9]]
ask Virtual_Employees with [Emp_Group = 9] [set Team_capacity_Type4 sum [Emp_Pro_area4C] of
Virtual_Employees with [Emp_Group = 9]]
ask Virtual_Employees with [Emp_Group = 9] [set Team_capacity_Type5 sum [Emp_Pro_area5C] of
Virtual_Employees with [Emp_Group = 9]]
ask Virtual_Employees with [Emp_Group = 10] [set Team_capacity_Type1 sum [Emp_Pro_area1C] of
Virtual_Employees with [Emp_Group = 10]]
ask Virtual_Employees with [Emp_Group = 10] [set Team_capacity_Type2 sum [Emp_Pro_area2C] of
Virtual_Employees with [Emp_Group = 10]]
ask Virtual_Employees with [Emp_Group = 10] [set Team_capacity_Type3 sum [Emp_Pro_area3C] of
Virtual_Employees with [Emp_Group = 10]]
ask Virtual_Employees with [Emp_Group = 10] [set Team_capacity_Type4 sum [Emp_Pro_area4C] of
Virtual_Employees with [Emp_Group = 10]]
ask Virtual_Employees with [Emp_Group = 10] [set Team_capacity_Type5 sum [Emp_Pro_area5C] of
Virtual_Employees with [Emp_Group = 10]]
]

end

to Reproduce_Projects
;Economic_situation ;0.5==>60 1==>120
if random 1000 < Economic_situation * 120 [ set pcolor red set Prj_Cons_budget random 10 * 100000000]
if random 1000 < Economic_situation * 120 [ set pcolor green set Prj_Cons_budget random 7500 * 10000
+ 25000000]
if random 1000 < Economic_situation * 120 [ set pcolor blue set Prj_Cons_budget random 2000 * 10000 +
5000000]
if random 1000 < Economic_situation * 120 [ set pcolor green set Prj_Cons_budget random 420 * 10000 +
800000]
if random 1000 < 800 [ set pcolor white]
set Prj_Duration 30
set owner round (random 5) + 1

end

to create_Project

ask patches [
```

```
; if pcolor = brown [
;       ifelse countdown <= 0
;           [ set pcolor green
;               set countdown grass-regrowth-time ]
;           [ set countdown countdown - 1 ]

      if pcolor != pink [ ;if project untaken
        ifelse Prj_Duration <= 0    ;judge Prj_Duration <0 or not

        ; yes, then create new project, set Duration=30
    [ Reproduce_Projects ]

;No,
         [ set Prj_Duration Prj_Duration - 1 ]
      ]
]


;project taken
ask patches [
if pcolor = pink [
        if Prj_Duration <= 0 ;if project has not assign duration
            [set Prj_Duration round( (94.245 + 1.334 * 10 ^ (-6) * Prj_Cons_budget ) / 10 ) * 10 ] ;assign
duration from euqation

        ifelse Prj_Duration <= 1 ;if duration has been assigned

            [ set pcolor white ]            ;finished, recreate project

            [ set Prj_Duration Prj_Duration - 1 ] ;not finished, -1 everyday
    ]
]

  ask patches [
    if Prj_Cons_budget < 5000000 [
        set Prj_return_rate (random 11 + 83) / 1000
        ]

    if Prj_Cons_budget > 5000000 and Prj_Cons_budget < 25000000 [
            set Prj_return_rate (random 11 + 72) / 1000
            ]

    if Prj_Cons_budget > 25000000 and Prj_Cons_budget < 100000000 [
            set Prj_return_rate (random 11 + 61) / 1000
            ]

    if Prj_Cons_budget > 100000000 [
        set Prj_return_rate (random 14 + 47) / 1000
        ]

      set Prj_Type1 random 10 + 1 ;random value of each Prj_Type
    set Prj_Type2 random 10 + 1 ;random value of each Prj_Type
    set Prj_Type3 random 10 + 1 ;random value of each Prj_Type
    set Prj_Type4 random 10 + 1 ;random value of each Prj_Type
```

```
    set Prj_Type5 random 10 + 1 ;random value of each Prj_Type
    set Prj_Type1A round ((Prj_Type1 / (Prj_Type1 + Prj_Type2 + Prj_Type3 + Prj_Type4 + Prj_Type5)) *
1000) / 1000; cal % of each type
    set Prj_Type2A round ((Prj_Type2 / (Prj_Type1 + Prj_Type2 + Prj_Type3 + Prj_Type4 + Prj_Type5)) *
1000) / 1000; cal % of each type
    set Prj_Type3A round ((Prj_Type3 / (Prj_Type1 + Prj_Type2 + Prj_Type3 + Prj_Type4 + Prj_Type5)) *
1000) / 1000; cal % of each type
    set Prj_Type4A round ((Prj_Type4 / (Prj_Type1 + Prj_Type2 + Prj_Type3 + Prj_Type4 + Prj_Type5)) *
1000) / 1000; cal % of each type
    set Prj_Type5A round ((Prj_Type5 / (Prj_Type1 + Prj_Type2 + Prj_Type3 + Prj_Type4 + Prj_Type5)) *
1000) / 1000; cal % of each type

  ;set Prj_Cons_budget abs(int(random-normal 59358105 73744275))
    set Prj_Type1C round(Prj_Type1A * Prj_Cons_budget)
    set Prj_Type2C round(Prj_Type2A * Prj_Cons_budget)
    set Prj_Type3C round(Prj_Type3A * Prj_Cons_budget)
    set Prj_Type4C round(Prj_Type4A * Prj_Cons_budget)
    set Prj_Type5C round(Prj_Type5A * Prj_Cons_budget)

    set owner round (random 5) + 1
  ]

end

to GO_BY_TEAM
    tick

    if ticks >= Simulate_Days [ stop ]

    ;Create_Project
    ;Project_Moving

    Create_Project

    Turtle_Move

    Personal_recovery

    Take_Project_Team

    SUM_Team_Capacity

    if Transfer_low_contributors [Transfer_Team]

    if Member_replacement [ Emp_Die ]

    Accounting

    ;hire_Emp

end

to Go_BY_Interdependence

      tick
```

```
    if ticks >= Simulate_Days [ stop ]

    ;Create_Project
    ;Project_Moving

    Create_Project

    Turtle_Move

    Personal_recovery

    Take_Project_Team

    SUM_Team_Capacity

    if Transfer_low_contributors [Transfer_Team]

    if Member_replacement [ Emp_Die_INT ]

    Accounting

    ;hire_Emp

end

to Go_individual

     tick

    if ticks >= Simulate_Days [ stop ]

    ;Create_Project
    ;Project_Moving

    Create_Project

    Turtle_Move

    Personal_recovery

    Take_Project

    ;SUM_Team_Capacity

    if Transfer_low_contributors [Transfer_Team]

    if Member_replacement [ Emp_Die_INT ]

    Accounting

    ;hire_Emp

end
```

```
to Turtle_Move

ask turtles [
   if pcolor != pink and shape !="person doctor" and shape !="x"[
     move-to one-of patches with [not any? turtles-here]
]
   ]

end

to Personal_recovery
;When turtle move (not take any project), emp_capacity = Max
   ask Virtual_Employees[
      if pcolor = white[
   set Emp_Capacity Emp_Max_Capacity
   set Emp_Pro_area1C Emp_Max_Capacity_Type1
   set Emp_Pro_area2C Emp_Max_Capacity_Type2
   set Emp_Pro_area3C Emp_Max_Capacity_Type3
   set Emp_Pro_area4C Emp_Max_Capacity_Type4
   set Emp_Pro_area5C Emp_Max_Capacity_Type5
      ]
   ]

end

to Team_recovery

end

to Take_Project
   ask turtles [
   if shape !="x" and shape !="person doctor" and pcolor != pink and pcolor != white [

      if random 10 < 4 and
           Prj_Type1C < Emp_Pro_area1C and Prj_Type1C > 0 and
           Prj_Type2C < Emp_Pro_area2C and Prj_Type2C > 0 and
           Prj_Type3C < Emp_Pro_area3C and Prj_Type3C > 0 and
           Prj_Type4C < Emp_Pro_area4C and Prj_Type4C > 0 and
           Prj_Type5C < Emp_Pro_area5C and Prj_Type5C > 0[

      set Emp_Pro_area1C Emp_Pro_area1C - Prj_Type1C
      set Emp_Pro_area2C Emp_Pro_area2C - Prj_Type2C
      set Emp_Pro_area3C Emp_Pro_area3C - Prj_Type3C
      set Emp_Pro_area4C Emp_Pro_area4C - Prj_Type4C
      set Emp_Pro_area5C Emp_Pro_area5C - Prj_Type5C

      set pcolor pink
      set Sum_Prj Sum_Prj + 1
      set Sum_Profit Sum_Profit + ( Prj_Cons_budget * Prj_return_rate )
      ;set Prj_Cons_budget 999999999999999

   ]
   ]
   ]
```

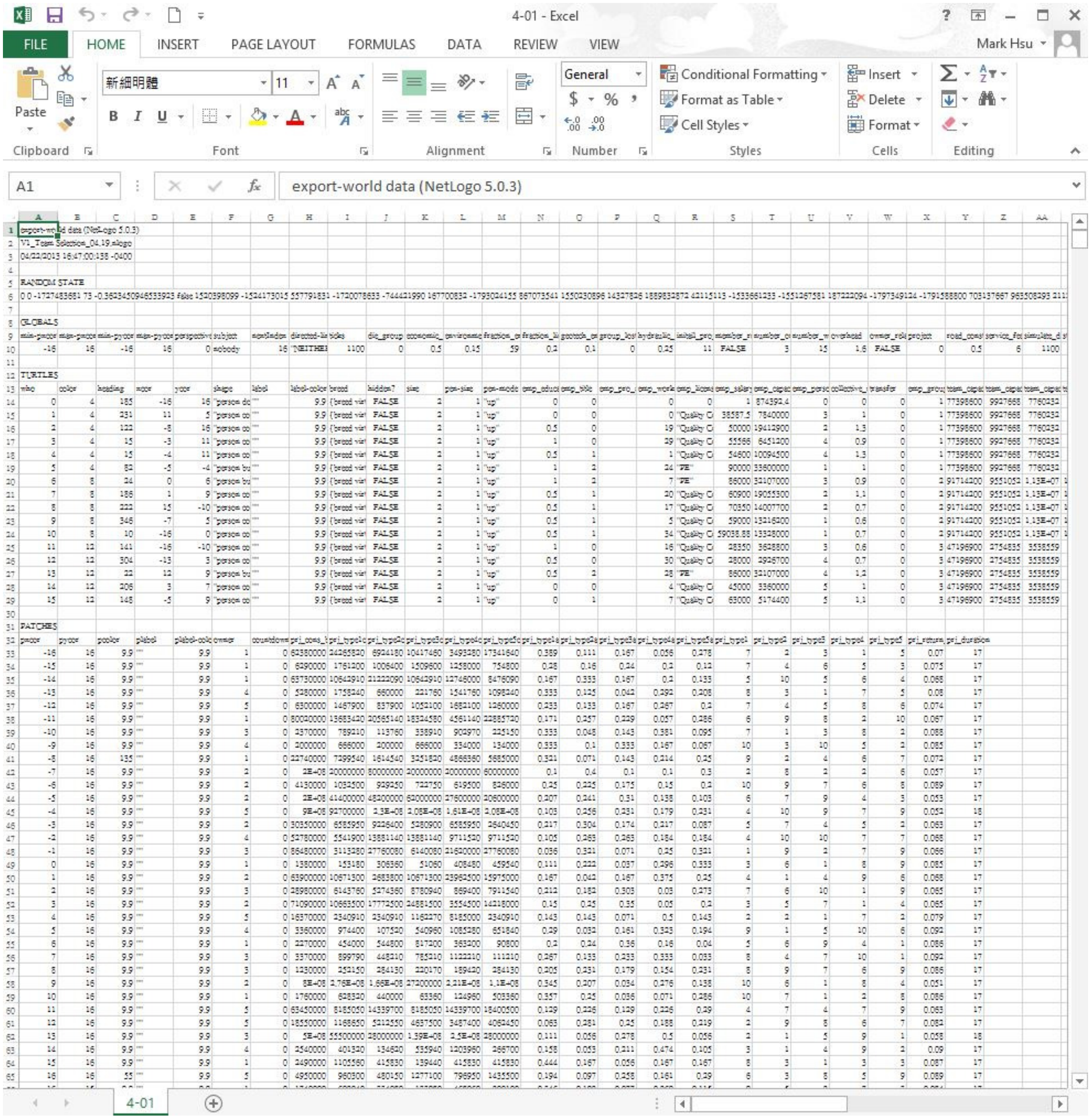
```
end

;Team_capacity_Type1

to Take_Project_Team
   ask turtles [
   if shape !="x" and shape !="person doctor" and pcolor != pink and pcolor != white [

      ;if Prj_Cons_budget < Team_capacity and Prj_Cons_budget > 0[
      ;set Emp_Capacity Emp_Capacity - Prj_Cons_budget

      ;Emp_relation_Owner1

      if random 10    < ( -0.133 * Number_worker + 6) * Emp_relation_Owner1 and ;15-->40% , 30-->25%
           Prj_Type1C < Team_capacity_Type1 and Prj_Type1C > 0 and
           Prj_Type2C < Team_capacity_Type2 and Prj_Type2C > 0 and
           Prj_Type3C < Team_capacity_Type3 and Prj_Type3C > 0 and
           Prj_Type4C < Team_capacity_Type4 and Prj_Type4C > 0 and
           Prj_Type5C < Team_capacity_Type5 and Prj_Type5C > 0[
      set Emp_Pro_area1C Emp_Pro_area1C - Prj_Type1C
      set Emp_Pro_area2C Emp_Pro_area2C - Prj_Type2C
      set Emp_Pro_area3C Emp_Pro_area3C - Prj_Type3C
      set Emp_Pro_area4C Emp_Pro_area4C - Prj_Type4C
      set Emp_Pro_area5C Emp_Pro_area5C - Prj_Type5C

      set pcolor pink
      set Sum_Prj Sum_Prj + 1
      set Sum_Profit Sum_Profit + ( Prj_Cons_budget * Prj_return_rate )
      ;set Prj_Cons_budget 999999999999999
   ]
   ]
   ]

end

to PM

          set Emp_License "PE"
          set shape "person business"
          setxy random 30 - 15 random 30 - 15
          ;set color yellow
          set Emp_Salary round (random-normal 90 10) * 1000
          set Emp_Capacity round (Emp_Salary * 14 * Overhead / service_fee_% * 100 / 1000) * 1000
          set Emp_Max_Capacity Emp_Capacity ;Emp_Max_Capacity = original capacity
          set Emp_Title 2

end

to Transfer_Team

if ticks mod 183 = 0 ;2 times per year

[
ask min-n-of Number_of_Team Virtual_Employees [Sum_Profit][
```

```
set Emp_Group random Number_of_Team + 1
   set Emp_Capacity Emp_Max_Capacity
   set Emp_Pro_area1C Emp_Max_Capacity_Type1
   set Emp_Pro_area2C Emp_Max_Capacity_Type2
   set Emp_Pro_area3C Emp_Max_Capacity_Type3
   set Emp_Pro_area4C Emp_Max_Capacity_Type4
   set Emp_Pro_area5C Emp_Max_Capacity_Type5
   set Transfer Transfer + 1
]
]

end

to Emp_Die

   ask turtles[
     if shape !="person doctor" and ticks > 365 and Sum_Profit / ticks / Emp_Salary * 30 < 3.5 [ set shape
"x" set Emp_Salary 1]
   ]


end

to Emp_Die_INT

if ticks mod 183 = 0
   [
     ask min-n-of 1 Virtual_Employees with [shape !="person doctor" and
shape !="x"][Collective_contribution][
     set shape "x"
     set Emp_Salary 1
     set Die_group Emp_group

     ask n-of 2 Virtual_Employees with [Emp_group = Die_group][
     set Collective_contribution ( random 6 + 8 ) / 10

     ]
   ]

  create-Virtual_Employees 1 [
  Create_Virtual_Employee_Setp1
  Equitable_Selection
  Create_Virtual_Employee_Setp3_INT
  Equitable_groups
  set Emp_group Die_group
   ]
   ]

;     ask min-n-of NO_of_replacement_for_INT Virtual_Employees with [shape !="person doctor" and
shape !="x"][Collective_contribution][
;     set shape "x" set Emp_Salary 1

       ;Collective_contribution
```

```
end

to Accounting
   ;adjust salary
   ask turtles[
     if ticks mod 365 = 0 and Sum_Profit / ticks / Emp_Salary * 30 > 5 [set Emp_Salary Emp_Salary *
1.05 ]
   ]
   ask turtles with [shape ="person doctor"][
   set Emp_Capacity sum [Emp_Salary] of turtles with [shape !="x" and shape !="person doctor"]
   set Emp_Avaliability Emp_Avaliability + Emp_Capacity
   ]

end

to Create_accountunt
create-Virtual_Employees 1 [

       set shape "person doctor"
       setxy -16 16
       set Emp_Salary 1
       set size 2
]

end

to hire_Emp

   if count turtles with [shape !="x"] - 1 < Number_worker [
  create-Virtual_Employees Number_worker - count turtles with [shape !="x"] - 1 [
  Create_Virtual_Employee_Setp1
  Equitable_Selection
  Create_Virtual_Employee_Setp3
  Equitable_groups
   ]
   ]

end

to Create_Virtual_Employee_Setp3_INT

       set Emp_Pro_area1A round ((Emp_Pro_area1 / (Emp_Pro_area1 + Emp_Pro_area2 + Emp_Pro_area3
+ Emp_Pro_area4 + Emp_Pro_area5)) * 1000) / 1000 ; cal % of each type
   set Emp_Pro_area2A round ((Emp_Pro_area2 / (Emp_Pro_area1 + Emp_Pro_area2 + Emp_Pro_area3 +
Emp_Pro_area4 + Emp_Pro_area5)) * 1000) / 1000 ; cal % of each type
   set Emp_Pro_area3A round ((Emp_Pro_area3 / (Emp_Pro_area1 + Emp_Pro_area2 + Emp_Pro_area3 +
Emp_Pro_area4 + Emp_Pro_area5)) * 1000) / 1000 ; cal % of each type
   set Emp_Pro_area4A round ((Emp_Pro_area4 / (Emp_Pro_area1 + Emp_Pro_area2 + Emp_Pro_area3 +
Emp_Pro_area4 + Emp_Pro_area5)) * 1000) / 1000 ; cal % of each type
   set Emp_Pro_area5A round ((Emp_Pro_area5 / (Emp_Pro_area1 + Emp_Pro_area2 + Emp_Pro_area3 +
Emp_Pro_area4 + Emp_Pro_area5)) * 1000) / 1000 ; cal % of each type

       set Emp_Working_Exp random 35
       set Emp_License "Quality Control Engineer"
```

```
	set Emp_Salary round (random-normal 50 10) * 1000

	if Emp_Salary < 50000 [set Emp_Title 0] ;0 is Engineer, 1 is Senior engineer, 2 is Project manager
	if Emp_Salary > 50000 [set Emp_Title 1] ;0 is Engineer, 1 is Senior engineer, 2 is Project manager

	set Emp_AvaliabilityC 1

	;Initial Emp available %
	;set Emp_Avaliability random 100 + 1 ;1-100
	;if Emp_Avaliability > Fraction_Emp_Available [ set Emp_AvaliabilityC 0]    ;0 is not available    1 is
available
	;if Emp_Avaliability <= Fraction_Emp_Available [ set Emp_AvaliabilityC 1]    ;0 is not available    1
is available

	;relationship with owner

	set Emp_relation_Owner1 1
	if Owner_relationship [ set Emp_relation_Owner1 random 6 / 10 + 0.5] ; relationship with owner1
	set Emp_relation_Owner2 random 6 / 10 + 0.5 ; relationship with owner2
	set Emp_relation_Owner3 random 6 / 10 + 0.5 ; relationship with owner3
	set Emp_relation_Owner4 random 6 / 10 + 0.5 ; relationship with owner4
	set Emp_relation_Owner5 random 6 / 10 + 0.5 ; relationship with owner5
	set Emp_Personal_Obj round (random 5) + 1 ; 1= very engaged 2= engaged 3= neutral 4= not engaged
5= hated

   if Emp_Personal_Obj > 0.5 and Emp_Personal_Obj < 1.5 [ set Emp_Capacity round (Emp_Salary * 14 *
Overhead / service_fee_% * 100 / 1000) * 1000 * Collective_contribution]
   if Emp_Personal_Obj > 1.5 and Emp_Personal_Obj < 2.5 [ set Emp_Capacity round (Emp_Salary * 14 *
Overhead / service_fee_% * 100 * 0.8 / 1000) * 1000 * Collective_contribution]
   if Emp_Personal_Obj > 2.5 and Emp_Personal_Obj < 3.5 [ set Emp_Capacity round (Emp_Salary * 14 *
Overhead / service_fee_% * 100 * 0.6 / 1000) * 1000 * Collective_contribution]
   if Emp_Personal_Obj > 3.5 and Emp_Personal_Obj < 4.5 [ set Emp_Capacity round (Emp_Salary * 14 *
Overhead / service_fee_% * 100 * 0.4 / 1000) * 1000 * Collective_contribution]
   if Emp_Personal_Obj > 4.5 and Emp_Personal_Obj < 5.5 [ set Emp_Capacity round (Emp_Salary * 14 *
Overhead / service_fee_% * 100 * 0.2 / 1000) * 1000 * Collective_contribution]

   set Emp_Max_Capacity Emp_Capacity ;Emp_Max_Capacity = original capacity

; Emp_Pro_area C performance (area * capacity)
   set Emp_Pro_area1C Emp_Pro_area1A * Emp_Capacity
   set Emp_Pro_area2C Emp_Pro_area2A * Emp_Capacity
   set Emp_Pro_area3C Emp_Pro_area3A * Emp_Capacity
   set Emp_Pro_area4C Emp_Pro_area4A * Emp_Capacity
   set Emp_Pro_area5C Emp_Pro_area5A * Emp_Capacity

   set Emp_Max_Capacity_Type1 Emp_Pro_area1C
   set Emp_Max_Capacity_Type2 Emp_Pro_area2C
   set Emp_Max_Capacity_Type3 Emp_Pro_area3C
   set Emp_Max_Capacity_Type4 Emp_Pro_area4C
   set Emp_Max_Capacity_Type5 Emp_Pro_area5C

end
```

<u>The sample of simulation data</u>



Examples of collected project data

ID	Owner	District	Type 1	Type 2	Type 3	Start time	Completed time	Design service budget (NTD)	Construction budget (NTD)	Basic Design (Day)	Detailed Design (Day)
A9804	2	T	Hydraulic engineering	Structural		4/27/2009					
T10003	3	H	Road maintenance	Geotech		9/15/2011	5/12/2012	4,000,000	50,000,780	20	20
Z10101	4	L	Environmental engineering	Hydraulic		1/19/2012	4/28/2012	827,820	8,948,000	30	30
A9807	1	L	Road construction	Geotech	Hydraulic	8/1/2009	1/23/2011	12,964,537	210,307,000	70	50
A9902	1	T	Road construction	Geotech	Hydraulic	3/26/2011	1/20/2012	7,679,386	93,727,655	40	50
A9904	1	Y	Road construction	Geotech	Hydraulic	8/26/2010	6/22/2011	284,100	35,402,800	45	45
A9907	1	H	Road construction	Structural	Geotech	12/14/2010	5/13/2011	1,497,380	18,174,929	40	30
A9908	1	ALL	Hydraulic engineering	Renovation	Geotech	12/30/2010	12/30/2011	3,124,242	312,343,434	7	14
A9909-1	1	S	Road maintenance			12/31/2010	12/31/2010	23,123,111	1,232,131,400	20	50
A9909-2	1	C	Environmental design			7/1/2009	12/31/2009	434,234	23,231,231	10	20
A9909-4	1	T	Road maintenance	Hydraulic		4/1/2010	12/31/2010	23,212,556	652,342,432	30	50
A9909-5	1	ALL	Environmental design			4/1/2010	12/31/2010	1,733,588	22,610,197	10	20
A9909-8	1	S	Road maintenance			4/27/2011	5/27/2011	3,231,443	43,423,424	10	20
A10003	1	S	Road construction	Geotech	Environment	6/1/2011	1/30/2012	3,230,000	50,030,000	40	40
A10005	1	Y	Road construction	Environment	Hydraulic	11/1/2011	2/15/2012	1,052,000	11,970,000	20	30

A10009	1	S	Road construction	Geotech	Environment	12/1/2011	5/1/2012	1,991,957	24,209,152	20	30
A10012	1	P	Road construction	Structural	Environment	2/1/2013	6/30/2014	27,153,361	393,255,646	60	75
A10101	1	L	Environment	Road	Hydraulic	2/1/2012	5/10/2012	827,820	8,948,000	30	30
A10102	1	ALL	Disaster management			2/1/2012	5/10/2012	5,093,391	64,135,824	7	14
G9901	4	W	Road maintanance	Hydraulic	Environment	1/1/2011	12/31/2011	9,000,000	125,000,802	14	30
T10003	1	H	Road construction			10/1/2011	1/31/2012	4,000,000	50,000,780	20	20
T10101	2	H	Road maintanance			3/1/2012	6/30/2012	5,232,528	66,170,000	20	20
G9801	3	W	Hydraulic engineering	Structural	Road	7/1/2009	12/31/2009	4,400,000	50,000,000	20	20
Y9801	6	S	Road construction (new)	Hydraulic	Geotech	1/1/2009	12/31/2009	5,460,000	60,000,000	20	30
T9902	2	L	Hydraulic engineering	Road	Geotech	4/1/2010	12/31/2010	5,000,000	57,319,110	14	30
L9802	7	K	Hydraulic engineering			5/1/2009	8/31/2009	2,350,000	35,000,000	20	20
T9801	2	H	Hydraulic engineering	Road	Geotech	4/1/2009	12/31/2009	9,000,000	124,908,023	20	20
T9901	2	H	Road	Hydraulic	Geotech	4/1/2010	12/31/2010	9,000,000	161,070,000	20	20

Examples of employee data

NO	Education	Title	Professional area			Starting date	Working experience (year)	License	Salary (NTD per month)
1	Graduate	Project manager	Civil engineering	Structural engineering		2004	8	PE	90000
2	Graduate	Project manager	Road construction	Tunnel construction	Bridge construction	1999	13	PE	90000
3	Graduate	Project manager	Hydraulic engineering	Water resource engineering	Environmental design	1985	27	PE	90000
4	College	Senior engineer	Road construction	Water resource engineering	Site condition survey	1990	22	FE	75000
5	College	Engineer	Building construction	Road construction		1998	14	FE	60000
6	College	Engineer	Building construction	Road construction		1998	14	FE	60000
7	Graduate	Engineer	Geotech engineering	Construction management		2007	5		42000
8	College	Engineer	Geotech engineering	Archtechtual design		2000	12		51000
9	College	Senior Engineer	Environmetal design	Cost estimating		1995	17	FE	45000
10	College	Engineer	Environmetal design	Archtechtual design		2006	6	FE	45000
11	College	Senior Engineer	Road construction			1981	31	FE	60000
12	College	Engineer	Building construction	Road construction		2001	11	FE	45000
13	College	Engineer	Building construction	Road construction		2001	11	FE	45000
14	College	Senior Engineer	Building construction	Road construction		1989	23	FE	45000
15	College	Engineer	Geotech engineering	Road construction		2006	6	FE	45000

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