College of Engineering, Design and Physical Sciences

The Analytical Modelling of Collective Capability of Human Networks

A thesis submitted for the degree of Doctor of Philosophy

By:

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Abstract

This thesis is an attempt to propose an analytical model for estimating and predicting capability in human networks (i.e. work teams). Capability in this context is the ability to utilise the collective inherent and acquired resources of individuals to complete a given task. The motivation of proposing a method for measuring collective capability of teams is to assist project managers and team builders to allocate and assign *"The most capable teams"* to a project to maximise the likelihood of success.

The review of literature in engineering, human sciences and economics has led to a definition of capability. One of the key findings of this research work is that collective capability can be predicted by:

1. Demographic homophily of members of the team,
2. The diversity of skills that each member brings to the team,
3. The past experience or attainments of the members, and
4. The strength of relationship amongst the members of the team.

The influence of the four predictors of capability is investigated through the design of empirical surveys conducted among postgraduate students over a period of 2 years. The data collected from the surveys are used to assess the correlation between the predictors and the dependent variable using standard statistical methods.

The conclusions of the study confirm that there are positive and significant relationships between the independent predictors and collective capability of project teams. The demographic homophily of the individuals in team and their instrumental (task related)

relationships' strength become the two most effective predictors which have the highest effect on the collective capability of a team as a whole. The skills diversity of the members in a group and their previous level of attainments/experiences in similar projects were also proved to be effective factors (with lower level of effect) in increasing the capability of the whole team in fulfilling the requirements of a pre-defined project.

AUTHOR'S DECLARATION

I confirm that this is work is my own except where references are cited. Once again, I would like to thank Dr Alireza Mousavi for his support and guidance during this project. The conferences and seminars which have achieved as a result of this research are as follows:

CONFERENCES AND SEMINARS

Hosseini, E., Mousavi, A. (2013). On the Capability of Human Networks, 7th *Annual IEEE Systems Conference (SysCon)*

Hosseini, E., Mousavi, A. (2012). The Foundation of Human Networks' Capability Modelling, A poster presented at Brunel University, Graduate School poster Conference and Brunel School of Engineering and Design 5th Research Conference (RESCON 12), June 2012.

Hosseini, E., Mousavi, A. (2010). Organisational Capability Evaluation; A Network Perspective, A poster presented at Brunel University, Graduate School poster Conference and Brunel School of Engineering and Design 3rd Research Conference (RESCON 10), June 2010

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Dedicated to my beloved ones;

Mahmoud Hosseini, Fereshteh Vahid

And Shaghayegh Hosseini

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AAR	After Action Review
APA	American Psychological Association
ARI	Army Research Institute
CAHRS	Centre for Advanced Human Resource Studies
CFI	Comparative Fit Index
CIT	Critical Incident Technique
CMM	Capability Maturity Model
CMMI	Capability Maturity Model Integration
DES	Discrete Event Simulation
EBT	Event Based Training
FCC	Firms Consulting Capability Centre
HRM	Human Resource Management
IFI	Incremental Index of Fit
IOC	Integration Organisation and Cohesion
JIT	Just In Time
KSAOs	knowledge, skills, abilities and other characteristics
LV	Latent Variable
MOD	Ministry of Defence
MSA	Measure of Sampling Adequacy
MV	Measured variable
NFI	Normed Fit Index
OA	Operational Analysis
PCA	Principal Component Analysis
RBV	Resource Based View
RMSEA	Root Mean Square Error of Approximation

SCT	Self-Categorisation Theory
SEM	Structural Equation Modelling
SIT	Social Identity Theory
SMEs	Subject Matter Experts
SMEs	Small or Medium Enterprises
SMM	Shared Mental Model
SPSS	Statistical Package for the Social Sciences
TARGET	Targeted Acceptable Responses to Generated Task
TOM	Teamwork Observation Measure
UPAS	Unit Performance Assessment System
VIF	Variance Inflation Factor
VR	Virtual Reality
WBS	Work Breakdown Structure

Chapter 1

Introduction

1.1 Knowledge Position of Capability Measurement

Although many managers and decision makers believe human resource is the most important asset of their organisation not many organisational decisions reflect this (Barney and Wright, 1998). In other words many crucial decisions, related to resourcing (e.g. recruitment procedures and project team formation) are still based on informal practices such as "word of mouth" or referrals (Carroll et al., 1999). The process of selecting and putting the most capable individuals in a team to perform organisational projects have been one the most widely discussed subjects in management sciences literature. This matter becomes more important since the nature of recruitment both in public and private sector is moving from long term permanent base to short term highly capable project team based (Hosseini and Mousavi, 2013). Therefore fixed term contracts are becoming more common in all organisations regardless of their size and field of industry. Even though the lengths of contracts do not change the fact that improper selection process of employees can be a costly experience for organisations but the impact of bad selection can be different based on the size of the organisation and number of employees (Forth et al., 2006). It's important to realise the fact that inappropriate recruitment can become even more costly for Small or Medium Enterprises (SMEs) as they have less opportunity to replace hired employees within their organisation. As a result it has been the case that some SMEs are forced to substitute their newly recruited staff or continue with workforce.

Although as the size of organisations grows the process of selecting individuals has turned out to be more professional (Atkinson and Meager, 1994) but among SMEs who form the largest portion of private sector employment (59.4 Percent according to Office of National Statistics, 2009) is highly unlikely that staff selection procedure follow a professional or systematic method (Carroll et al. 1999).

As all organisations are trying to implement the staff selection procedures to predict the future success of people in specific jobs (projects), the ideal situation is when the selected individual(s) can make positive contribution in the job or tasks related to them, as they are happy with their given job. The purpose of this study is to investigate a systematic and analytic approach to measure the collective capability (team level capability) of the working teams in current business environment which all organisations are shifting their recruitments practices from long term permanent employment to short terms project based employment. This analytical approach should be based on a scientific aspect of *Human Networks* and individuals' relationships within the work groups, rather than relying on subjective measurement factors. The proposed analytical method should look at the concept of capability from a perspective which can cover both individual team member's characteristics and their team level interactions when measuring the collective capability.

This thesis examines what is meant to have a capable working team when two or more individuals have been put together to perform a pre-defined project. The argument in this thesis is that collective capability of more than two individuals who work in a team are results into sharing inherent and acquired skills when they dynamically interact with committed and responsive professional relationships.

The research done to date by the author indicates a lack of existence of any analytical and quantitative method to measure or predict a group of individuals' collective capability. In recent years various industrial disciplines have tried to utilise their physical resources (i.e. machinery and technology) however, there is little evidence that minimum effort has been deployed to manage the capability of *Human Networks*. Being specific and looking at academic literature, the author has not confronted a universal analytical method to maximise the work groups' collective capability in organisations. The reason for that is that human nature is a lot more complicated compared to other resources such as machinery, equipment and manufacturing process. This has led the managers and decision makers to rely on subjective and informal methods when trying to form their work groups and/or make any improvement in terms of capability or performance of those work groups.

1.2 The Aim and Objectives of the Thesis

This thesis aims at finding a quantitative approach for measurement and prediction of collective capability of individuals who are working as a team to fulfil the requirement of a group project. In other words this thesis intends to measurement and prediction of *Human Networks* collective capability by highlighting the effective capability factors and also by examining the effect of each capacity factor (e.g. individuals' relationships within a network) on the team's collective capability as a whole. In doing so, several objectives should be met as discussed below:

- To review and summarise the current body of literature on the two important concepts related to this research: ***Capability*** and ***human networks***.

- To conduct a critical analysis of any existing method that explains formation of networks wither by choice or by design.

- An investigation on existence of any analytical or mathematical method for measuring or predicting the collective capability of more than two individual in a working group.

- Design and propose an improved conceptual model for measuring the collective capability of a group of individuals. This model should be designed in a way that it encompasses and focuses on the capability factors which by nature come from the two main areas of this research (Capability and Human Networks).

- Design and conduct empirical surveys to collect the required quantitative data to test the proposed conceptual model.

- Finally to statistically validate the proposed model.

The motivation for the proposed research is that the nature of recruitment both in public and private sector is moving from long term permanent base to short term highly capable project team based (Hosseini and Mousavi, 2013). Therefore it's very important for managers and decision makers to have a scientific tool in hand which can assist them in measuring and predicting the collective capability of their proposed teams. The outlook in this research is that the findings of this thesis will have implications for managers and decision makers in different disciplines to maximise the collective capability of their proposed work groups (Networks). Measure of capability proposed in this thesis can in future be used to predict working teams' performance or success within a context of a given assignment.

In this study capability is defined as the application of a set of inherent and acquired resources and the level of their utilisation to complete a pre-defined project. These resources include team members' demographic homophily, skills diversity, their past attainments and their dynamic instrumental (project related) relationships within their team. The collective capability is therefore inferred from the interrelationship between the members with respect to their skills diversity, demographic homophily, and their similar past experiences. This research work is a first attempt in measuring the collective capability of human-based systems within the context of dynamics of social-work networks. The networks that are formed either by choice or by necessity.

In more detail this research can contribute to the current body of knowledge by:

a) Providing a comprehensive comparison of concept of capability in different disciplines;

b) Analysing capability concept from both individuals' level and network level simultaneously;

c) Providing a novel algorithm to measure the values of four capability factors among work teams; and finally

d) Providing an analytical model for measurement of collective capability among human work teams.

The analytical model introduced in this research enables managers and decision makers to measure and compare different group formations with respect to their collective capability and use this capability model as a predictor of future performance. Companies and project managers will be able to predict the effect of their interventions in the dynamics of project groups and the constituent resources to achieve better outcomes. The final results achieved

from this research can be used as a tool by managers to gather most suitable individuals in a group with the aim of having most capable work teams.

The novelty of this research firstly is because of the fact that it's the first attempt to mathematically measure and predict the collective capability of work teams. No other researchers previously (to the best of author's knowledge) have modelled the collective capability mathematically in a way that is done in this research. The majority of previous researchers have limited their work to analyse the concept of capability rather than mathematically model the concept. Secondly the unique perspective of this research which takes into accounts both: individual members' characteristics (such as skills and abilities) and their team level dynamics in measuring the collective capability is a unique approach.

1.3 Key Questions to be answered

Within the context of the thesis, the three key questions that this thesis intends to address are:

1) What are the effective capability factors on collective capability of human networks?
2) Can we provide a general model which can measure the collective capability of human networks?
3) What are the direct and indirect relationships between nominated capability factors (if any) and the collective capability of individuals within a project team?

The first question posed in the research is answered by a combination of literature review (Chapters 2, 3, 4, 5 and 6) where definition of capacity from different perspectives and in different disciplines is presented. Furthermore by reviewing other researchers' findings in this area, four capability factors are nominated in this research as effective capability factors on team level collective capability. The true effects of the four nominated capability factors are

tested through designing empirical survey and collecting statistical data in further chapters in the thesis.

The second question posed in this research is addressed in chapters 6 by proposing a conceptual capability model for measurement of the collective capability of human teams.

Finally to answer the third question of the thesis an empirical survey has been designed and the proposed conceptual model is statically tested and proved in chapter 7.

1.4 The Structure of the Thesis

To give a clear overview of the structure of this thesis Figure 1-1 shows the sequence of the 8 chapters which constitute this research.

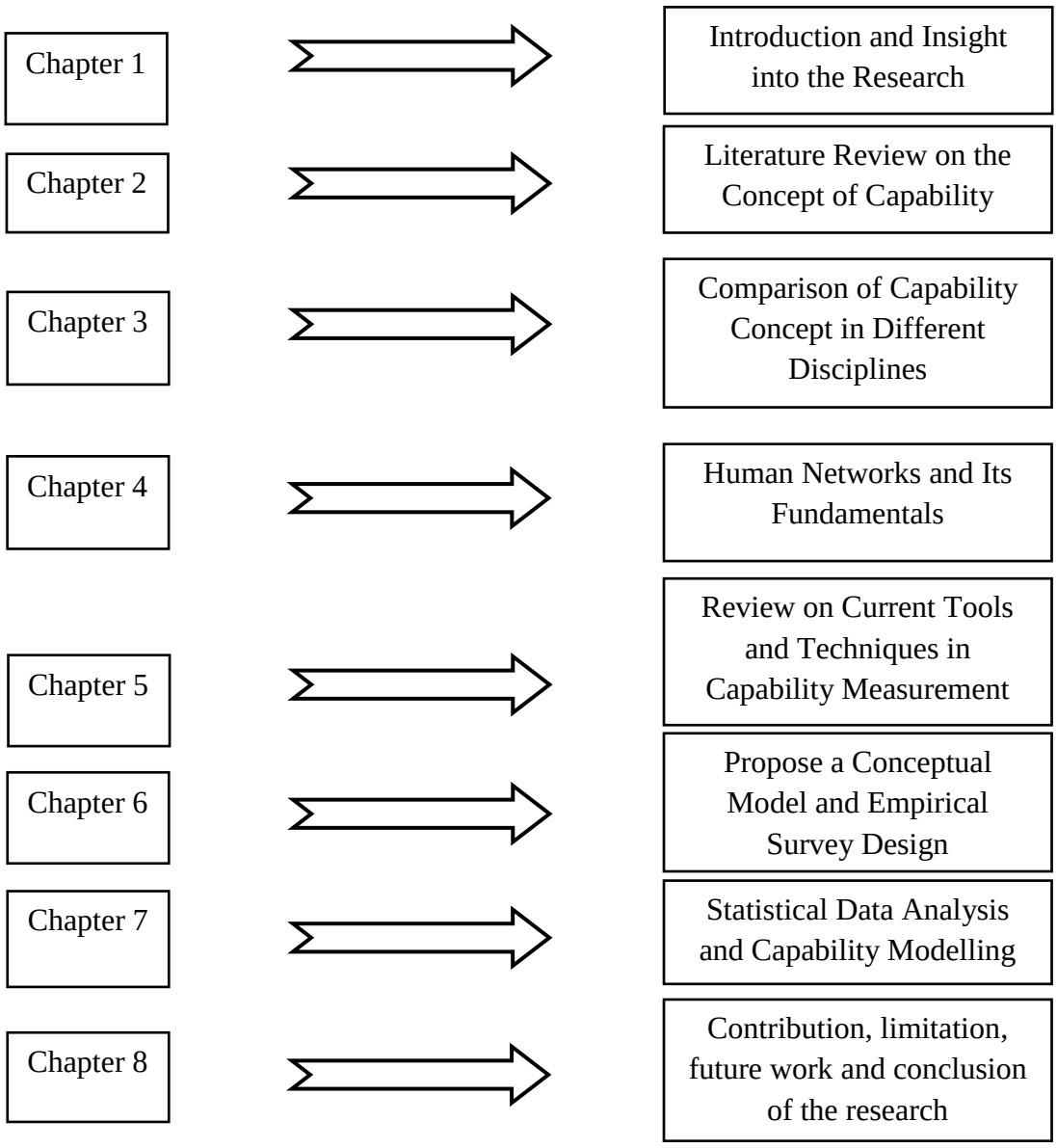


Figure1-1 the structure of the thesis

Chapter 2

A Review of Existing Literature of Capability Concept

The literature review in this research is set on diverse perspectives and dimensions of the capability concept and human networks. According to Anand et al., (2009) the concept of networking is not a new concept in many fields of learning and practical applications. In general, networking is a way of connecting and relating with others by reaching out.

The Centre for Advanced Human Resource Studies (CAHRS) (2012) concurs with Anand's (2010) view on social networks. It adds that in social networks, people share information; gain social recognition in diverse ways from being in such groups (utilitarian definition) and others just want to have a sense of belonging. CAHRS (2012) expounds by indicating that while the term, '*social networking'* has gained popularity in different disciplines, its roots are in social sciences. In social science, networking was, and still is, described as the 'web' of relationships in a community or society of people. This is supported by Harris (2007) who argues that the concept of networking extends not just to the fabric of every society and community but also in organisations. He adds that it forms an identity for each individual in a network.

Anand et al. (2010) and CAHRS (2012) express that in a business organisation environment; there are diverse aspects or concepts forming the core of the social/ human networks. These are capability and human networks and how they relate with each other. In the first review of relevant literatures, the concept of capabilities of people in social networks and work groups are studied.

2.1 The Definition of Capability

The aim of this chapter is to review the existing literatures with regards to definitions and application of Capability concept in different disciplines. The studied disciplines include philosophy, industrial sector, computer sciences, social sciences and human resources.

Harris (2007) believes that the term capability has been one of the most studied and discussed concepts in various fields of study and disciplines. However, according to him definitions provided are relatively opaque and not well understood. Comim et al., (2008) adds that diverse disciplines such as social science, computer science, economics and military have their own interpretation of capability. A cross-referencing among above mentioned disciplines expresses the fact that even though each discipline has got its own definition and practices of capability there are some major commonalities in all disciplines. In studies related to capability it might first seem that social networks are often the main business environment which focuses on the capability of human networks, but according to Alkire (2002) other unique disciplines outside the boundaries of social networks have also begun to understand and view this concept as increasingly related to their success. In a study conducted by the United States Army (2010) an intricate assessment of the concept of capability was undertaken. As a result of this study it became clear that army's ability to leverage cyberspace can be achievable if they accept that required capabilities to fulfil the most difficult tasks can be obtained from training the individuals in the army and also through focusing on relationships among the team members. To do this, the Army must possess the required skills and capabilities across domains and provide them (training) to combatant commanders and Army operators. In other words the United States army's study in this case showed that capability and competitive advantage (even in the very crucial

environment such as army) can be achieved through forming appropriate working teams (Human Networks) and support them with required training and development.

Reviewing different literature by the author about the definition of capability either at an individual or group level gave the impression that capability is an attribute that can be enhanced. Based on the deductions of United States Army (2010) about training and development as an enhancing tool, capability is perceived as a trait that is acquired and not born within an individual. However, as the subsequent discussions shall show, this is the point of departure where lack of consensus seems to emanate from.

Becker et al., (2008) expresses that different disciplines have different views on what capability is and how it can be enhanced to bring organisational strength. In Becker et al., (2008) study, organisation is not limited to a formal structure of a firm, but it is rather working groups either formal or informal and by extension any social human network are organisations.

According to Stewart (2013), it is inevitable for individuals to form social networks whether formally structured or passively perceived. In a paper by him, he argues that individuals cannot exist in a vacuum and alone environment. He explains that belonging to a given network is necessary for development of the individual or organisation. Consequently, individual capabilities and overly the capabilities of the whole network are important. In the following sections we review different views of capability across different disciplines.

2.1.1 The Philosophical Views of Capability

Regarding the philosophy of capability Robeyns (2011) presents an intricate study of network capability based on a philosophical perspective. According to Robeyns (2011) within a political and moral philosophy, the concept of capability has been widely studied. Similar

arguments have been presented by Rothaermel and Hess (2007) who believed that capability concept can be traced to studies of Aristotle, Karl Marx and Adam Smith who were all well-known philosophers of eighteenth and nineteenth centuries. In addition, Rothaermel and Hess (2007) express the fact that true literature on capability of people (within philosophical boundaries) was presented by Amartya Sen who is an Indian economics and Philosopher and has been considered by many researchers as the pioneer scholar of this concept.

Knowing what has been researched around the concept of capability and focus more on the definition of capability, Rothaermel and Hess (2007) and Robeyns (2011) both define capability as the ability of people for being able to do or perform a given task effectively. This definition is also upheld by Pogge (2002), Phillips (2004), Pierik and Robeyns (2007) who synonymously indicate that the concept of capability is directly related to the competences, skills and abilities of people. There is a one point of agreement among all these researchers' work, they all agree that capability is concerned with an individual's wellbeing, social arrangement and social change within society or network that he/ she is a member of.

However, Stewart (2013) indicates that the contribution of Sen in late 1990s to the topic of capability approach indicate that capability is the core underpinning of human development. Human development in Stewart's sense is concerned with individual freedoms or capabilities where the objective is to expand the capabilities. Pogge (2002) and Steward (2013) further indicate that individuals are able to make choices of being able to do a process known as functioning by Robeyns (2011). According to Pettit (2001), the philosophical arguments of Sen are observed on face value. He indicates that many scholars have contraindicated on Sen's observations as Pettit (2001) argues. Pettit (2001) elaborates that Sen equates capability to personal freedom but does not specify in detail the nature of freedom that he is referring to. This is the bone of contention that scholars like Cohen (1993, cited in Pettit, 2001) had with

the arguments of Amartya Sen. However, Sen's equation of freedom and capabilities has been misunderstood in most cases as he acknowledges (Pettit, 2001; Robeyns, 2011; Pierik and Robeyns, 2007). This is because there are diverse kinds of freedoms which may be valuable, trivial or detrimental and hence may mean differently to different people. Therefore, the concerns of Cohen in Pettit (2001) are true as Sen acknowledges but in summary, freedom and by extension capabilities in philosophy involve decisive preferences and not decisive choices only. However, decisive preference should be independent and effective. Relying on Sen's arguments, Pettit (2001) argues that the philosophy of capabilities should be assessed through functioning (which will be addressed later in this section).

2.1.2 Capabilities in the Industrial Sector

In industrial fields, Blomqvist and Levy (2006) argue that the concept of capability approach and framework has diverse definitions and levels of significance. They further postulate that capability of people and work groups is perceived differently depending on the impact of capability on the objectives that are guiding each industry. For instance in manufacturing industries McGrath (2008) explains the relational capability as a result of a gradual process which two or more individuals (company) broaden their relationships to improve their competitive position in the market.

Blomqvist and Levy (2006) add that productivity and quality in manufacturing industry depends on how effective team/ work group capabilities are coordinated. They elaborate by indicating that coordination of capabilities is collaboration between group diversity and individual diversities within particular group. The aspect of group and capability diversity shall be explored in detail in the next chapter which is assesses human or work group networks.

Looking into the concept of capability form a lower layer the definition of a capable worker in Blackwood, et al (2006), is the ability of the worker to effectively deliver services to the team and the organisation by extension. It is also expressed in CAHRS (2012), Anand et al (2010), Harris (2007) and Comim et al., (2008) research that capabilities of people is the ability to do (doing) or be (being). While the philosophical approach by scholars and authors such as Harris (2007) based on arguments of Amartya Sen equate capabilities to freedoms. The definition of capabilities in some industrial fields such as manufacturing industry is rather simple. Blackwood et al (2006) clearly identifies that capabilities can either be attributes and habits or abilities of individual workers and teams/ work groups.

Comim et al., (2008) expound the above deductions and indicate that capabilities manifest in form of habits or attributes including: reliability, self- discipline, timeliness, honesty and consistent behaviour. On the other hand, capability in the form of abilities (which is conformant with the philosophical definition of capabilities) entails aspects such as organisational skills, problem solving abilities, communication abilities and capability to recognise opportunities and weaknesses.

Reference to the capabilities definition in manufacturing industries, having a high capable firm enhances efficacy, reliability and quality of process and output (Williamson, 2000; Eisernhardt and Martin, 2000). Peppard and Ward (2004) elaborate these observations by indicating that quality management literatures have identified that manufacturing organisations which assign work to workers and teams based on their capabilities have achieved significant efficacy. Peppard and Ward (2004) identify firms such as Toyota which have used employee capabilities through innovative quality management models such as Just in Time (JIT) to achieve excellent work place performance. This is supported by Firms consulting Capability Centre (FCC) (2012). According to FCC (2012), some manufacturing

firms have diverse processes that are supplementary to each other. In other words increasing capability of one facet of whole end to end process will result in increasing the capability of other processes in the whole chain and ensures that their output is of highest quality. According to Gasper (2002) collaborating output from other sub-systems or teams, the whole organisation becomes effective and holistically reliable.

The other industry in which the concept of capability has been viewed critically is the defence industry. This is supported by the United States Army (2010) and Carey (2010) who indicate that the army is a good organisation where human networks and work teams are explicit. They explain that teams and companies in the military are established based on the individual capabilities which have been amalgamated in a way that capabilities of each individual augment others' capabilities to form a formidable team. In line with this explanation, Sleap et al., (2008) development of individual and team capabilities bridges the capability gap to form an effective operational use. However, as illustrated in figure 2-1(in the next page), this takes time.

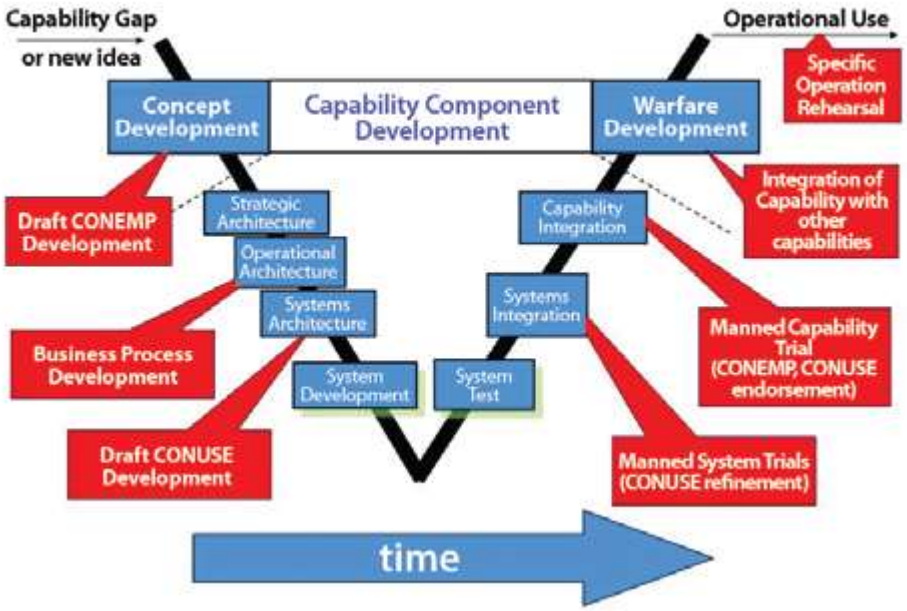


Figure 2-1: capability development in defence industry (Adopted from Sleap, Brooker and Howard, 2008, p. 60)

Carey (2010), Sleap, et al (2008) and United States Army (2010) conclude that the key capabilities in the defence industry entail four basic elements: "organisation (who), main idea (what), environment, parameters, and conditions (where and when), and reason (why)". These four key elements define the efficacy of the defence teams. "US Army Concept Capability Plan for Cyberspace Operations" takes a significant assessment on how future defence industry forces can leverage from defence team capabilities (United States Army (2010, p. 8). It further expounds and elaborates the essence of capabilities in defence networks by indicating that effective capabilities are influenced by psychological contest of wills, strategic engagement and cyber electromagnetic contest.

According to Gombaz (2013), a lack of literature exists in regard to the concept of capability which refers to people/ individuals, institutions and networks and systems. In his literature he

names this type of capabilities as “Humanitarian Capability”. He further argues that “there is no agreement on how to conceptualise the humanitarian capabilities”. The current research hopefully can fill this gap by conceptualising the capability related to human networks.

In his work, organisation and network operations in the military have become one of the most studied area capability application since the 1990s. This is because of the explicit nature of the military or defence industry in regard to human network capability dynamics. The result of his study is a categorisation of humanitarian capability into individual and collective capability and also defining the components of each level of humanitarian capabilities.

Sleap, et al (2008) express that perspectives of capability concept in the defence industry are fostered in computer science aspects. Cyberspace networks have been defined by United States Army (2010), Sleap, et al (2008) and Carey (2010) as a domain in the information systems that have interdependent networks. However, one aspect that has made these literatures a bit more complicated is the facets or domains that make up the cyberspace networks in defence industry. United States Army (2010) expounds that there are three key layers of sub-networks (physical, social and logical) which consist of five components: logical network, physical network, persona, geographical and cyber persona components. This has been intricately illustrated in figure 2-2 in the next page.

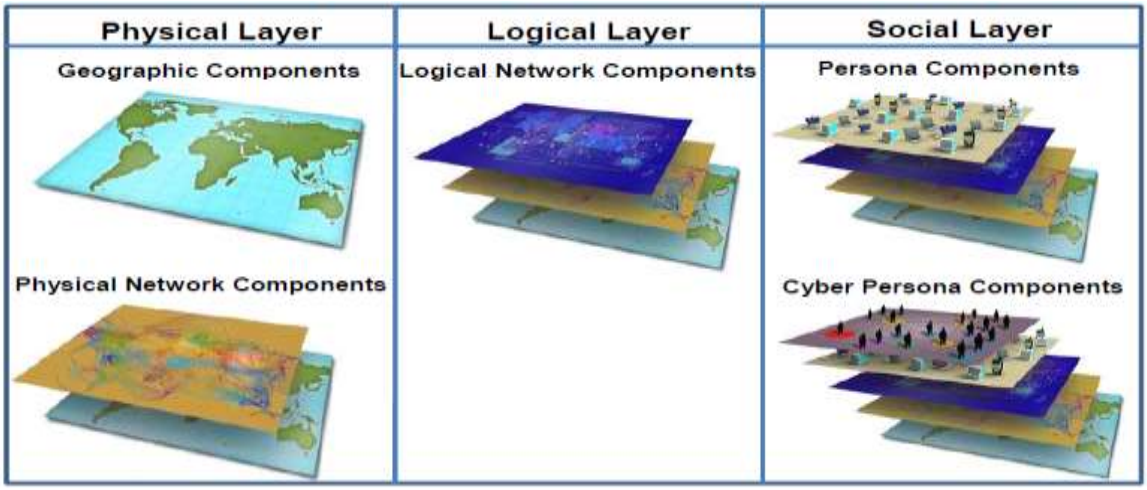


Figure 2-2: the people/persona networks in cyberspace defence networks (Adopted from United States Army, 2010, p. 8)

The significance of this study (presented in figure 2-2) is under the social layer which by extension defines human networks. The capabilities of each domain or facet of the cyberspace network and particularly the social layer has been perceived as very significant in defence industry. Sleap, et al (2008) supports this by indicating that there can be very complex technologies in the warfare and defence industry of a given country, it all boils down to the degree of capabilities of individual soldiers, teams and companies and even different defence agencies such as Air Force, Military, Navy and all the different divisions that each agency has. Summarily, the observations in the manufacturing and defence industry can be elaborated by articles of Fukuda-Parr (2003). He indicates that human capabilities can be development (as illustrated in figure 2-1) in order to enhance effective interrelationships among diverse human networks with even more diverse capabilities.

The automotive industry is one of the examples of how important individual and team capabilities are. This has been extensively and intricately presented in Williamson (2000) who uses NASCAR race team as a case to explain the concept of capability in the auto industry. According to Williamson (2000), the collective capability of a race car driver and

his crew is a vital requirement for success. Arguably, Fukuda-Parr (2003) agrees with Williamson's suggestions and indicates that developing the capabilities of each team member and the collective capability of the team is a good predictor of the performance. In deed looking at how race car teams such as NASCAR or Red Bull coordinates diverse individual capabilities especially on a pit stop during a race exhibits the significance of team coordination and collaboration. Williamson (2000) recaps by indicating that there should be a team that offers services timely, accurately and consistent in order to bolster and foster competitive advantage.

Another industry where the concept of capability has been in focus is the construction industry. According to Construction Excellence (2012), excellence in performance of the construction industry relies significantly on the capability of teams. Construction Excellence (2012) defines construction as an activity that depends on collaboration of teams and individual workers. In other words, by pooling each individual's experiences and knowledge marvellous tasks have been achieved. However, Constructing Excellence (2012) indicates that success in construction industry does not merely depend on grouping or setting up social/ human networks but on the capabilities and contributions that each network/ team member brings to the team. Similar deductions have been proclaimed by Narayanan and Shmatikov (2009). According to Narayanan and Shmatikov (2009) the extent of capability in construction teams and human networks is an intricate example of how overall success depends on the quality and capability of unit elements in human networks. In support of these arguments, Constructing Excellence (2012) observes that there are six dimensions or elements that shape the efficacy of team work: identity of the team, sharing of visions and common objectives, efficacy in communication, participation and collaboration, negotiation

and resolution, self-reflection and assessment are some of the capabilities that build a good construction team.

Similar to any industry, Constructing Excellence (2012) argues that capabilities and human networks are very diverse. Arguably, members of a team or network who have exemplary abilities contribute most to the overall team. However, one key observation of this literature seems surprising; Constructing Excellence (2012) indicates that in order for the team member with the highest abilities to become significant, the other team members should have exemplary capabilities. Therefore, individual technical skills and experiences determine the ability to coordinate actions.

Summarily, team/ human/social groups and network capabilities are significant in all industries in fostering competitive advantage. The United States Army (2010), Carey (2010) and Sleap, et al., (2008) argument in regard to defence industry are explicitly similar to the manufacturing deductions of Blackwood, et al (2006) and postulation of Williamson (2000) in the automotive industry as far as the concept of capability is concerned. The significance of the deductions from the diverse industries as reviewed above to this study is that capability is perceived in a similar manner. However, the researcher has noted some key differences in regard to the degree of significance and perception of the capability concept. For instance, team and individual capabilities in the defence industry are relatively technical compared to the manufacturing and automotive industry. The defence industry seems to take a significant emphasis on the concept of individual and team capability than the other industries. On a reflection, this seems to be highly relevant to the analytical modelling of human networks' capability in this study. In other words, the author believes that when the stakes of the outcome of the human work groups are high like in the defence industry, it is very important to understand and foster capabilities of each individual. In reference to figure 2-2 presented

by United States Army (2010), the capability of social layer and domain of cyberspace determines success of the whole team.

Consequently, this study does not assess the concept of capability from one single perspective. It rather makes assessment based on incorporate and diverse viewpoints in order to reduce biased assessment. This approach has been supported by Hartog (2001), Comim etal,. (2008) and Helfat and Liberman (2002) who indicate that in modelling the concepts such as capability what is a vital requirement is a clear, extensive, comprehensive and intricate understanding of the concept. Comim et al., (2008) elaborate further that measuring and applying the concepts and subsequent derivation of models should be applied in any area or field of study. This is the point of significance of this subsection to the overall study of statistical modelling of human networks and capabilities. In the subsequent subsections, a more detailed overview of the concept of capability in diverse disciplines of learning is presented.

2.1.3 An overview of Capability in Human Resource Management Literature

Researchers in Human Resource Management discipline have studied human networks and work groups either formal or informal together with their diverse dynamics extensively (Eisernhardt and Martin, 2000). The resource-based view of the firm (RBV) is an influential theoretical framework which explains how competitive advantage within firms becomes achievable and how those advantages could be sustained over time. Having this framework as the backbone of their research, Eisernhardt and Martin (2000) express the fact that different kind of resources (e.g., specialised equipment, geographic location), and especially human resources “are at the heart of any organisation”. They also believe that being able to achieve to the competitive advantages requires human resource managers to consider training and

development processes for employees who are underperforming. As a broad finding of their research they conclude that long term competitive advantages can be achieved as result of resource configuration.

Some other researchers such as Deneulin and McGregor (2010) have been more focused on human and employment rights in their research around Human Resource Management (HRM) discipline. Their definition of capability has been more in favour of employees, as they indicate that the Employment Rights Act of 1996 of the United Kingdom defines capability of individuals and networks as the ability in reference to amount of skills, degree of good health and aptitude that the network members have. Consequently, lack of adequate capability in employees can arise due to diverse reasons and effects. The Deneulin and McGregor's (2010) view on the capability concept is highly in line with Sen's view on Capability. Their version of capability is highly related to the concept of "living well". Their definition of capability is actually a modified version of Sen's definition, as they believe capability is not only "living well" but it's about "living well together".

Some other researchers in the HRM discipline (Mehta, 2013) have been more focused on the factors which can discourage human capabilities in the workplace. He believes that stress, inappropriate job allocation which is not matched with employees' experiences and skills and even health related issues can prevent human from performing with high capability in their given job. Comim et al., (2008) add that other aspects such as extrinsic circumstances such as new technologies and legislations impede human resource to exhibit their full capabilities. This often occurs when the work force has not acclimatised well with the changed environment

Another key contributor to the concept of capability in this area is Rothaermel and Hess (2007) who indicate that the view of human resource management discipline is resource

based. They express that the dynamics of capability are cantered on a resource based view of an organisation. From this point of view, it can be argued that an organisation's success depends on the ability of the resources to deliver the services or outcome that they were meant to deliver. Consequently, abilities (capabilities) of these resources (including human resource) integrate and reconfigure both the internal and external dimensions of an organisation. Rothaermel and Hess (2007) agree that the dynamics of capabilities enhance not only the ability of firms to adapt to changing operational environment but also help organisations recognise potential technological developments. In order to understand the deductions and findings of Rothaermel and Hess (2007) human network capabilities can be advanced through intellectual human capital management processes. Intellectual human capital management is a human resource management concept that is concerned with the development of capability aspect of people.

Comim et al., (2008) in their book about capability measurement and applications express the fact that capability among human groups can also be achieved as a result of knowledge and skills sharing among individuals in a group. Their view of human capabilities in line with some other researchers express the idea that individuals with high capabilities can share the same capabilities and skills to those with fewer capabilities (Helfat and Peteraf, 2003). For instance, interns allocated to a given team or network in an organisation will learn from their supervisors some capabilities such as skills and experience.

Comim et al., and Stewart (2013) believed that human resource managers can play a vital role on gaining higher capabilities by their employees by focusing and encouraging their employees to improve their capabilities.

Majumdar and Subramanian (2001) explicitly study the concept of capabilities in human resource and observe that human resource within an organisation can be managed

independently. In essence, the term *organisation* has been used here generically to mean any form of grouping whether formal or informal.

Human/ social networks are presumed to be part of organisation whose members or individual member can be developed either independently or collectively. What CAHRS (2012), Comim et al., and Stewart (2013) try to explain here is that there is diversity in skill and abilities (capabilities) and each person has his own degree of a given capability such as skill. Needless to say that individualistic perspective is necessary in enhancing capabilities and hence through synergy of efforts, a holistic development can be achieved. Therefore, a significant effort is to foster individual identity in each network to reduce the inherent barrier of sharing knowledge in the units. Similar observations are also deduced by Woolley et al., (2007) who argue that to improve the comprehension of the concept of capability, especially innovation or technical capabilities, at firm level, it is fair and necessary to enhance individual capabilities within each unit network or organisation. However, Woolley et al (2007) stress that the capability development need to be continuous in order to fit to the dynamic environment of human resource management.

Wang and Noe (2010) express that besides intellectual human capital management or development approach to capability development, there is another crucial aspect that similarly bolsters capability. This is knowledge management initiatives. According to Wang and Noe (2010), the efficacy of knowledge management programs either directed at team capabilities or individual capabilities like in CAHRS (2012), Comim et al., (2008) depends on the level of knowledge and information sharing. Consequently, group cohesion and inexpugnability of network contributes significantly to the development of group and individual capabilities. In Wang and Noe (2010) work, qualitative and quantitative modelling of individual level sharing of knowledge is assessed. Additionally, they have developed a

framework of understanding how knowledge sharing in group dynamics can be enhanced to subsequently foster capabilities. Therefore, this literature is significant to the study in pointing out the methodologies of studying the concept of capability in group networks. Another contribution of Wang and Noe (2010) to the study of human resource management discipline is concerned and its link to the areas which emphases in knowledge management, motivational factors, organisation context, team and interpersonal and cultural attributes. Clearly, it can be seen that the deductions of Wang and Noe (2010) indicate that human network (teams and organisations) and capabilities are major aspects of focus in human resource management discipline.

Similar to the observations in United States Army (2010), Sleap, et al (2008) and Fukuda-Parr (2003) in the industry overview of the concept of capability, the human resource management discipline recommends intricate development programs. However, one aspect that is similar to social science deductions in regards to capabilities is the role of functioning in capability development. According to Deneulin and Shahani (2009), the significance of functioning in capability development is that it can be measured and consequently statistically determined. Their finding has had an important impact on the statistical modelling approach underlying in this research. However, Karami (2013) indicates that measuring the capability concept and developing models to measure is not as simple as Deneulin and Shahani (2009), Nussbaum (2000) and Nussbaum (2003) presume.

While some few researches have been done in regard to studies that aim at modelling and measuring capability both theoretically and empirically, no clear consensus has been achieved to intricately measure these concept. Author believes that, this field of study is yet to be exhausted and is rich in gaps that subsequent studies such as this can fill. Nonetheless, capability development requires freedom of choice as the key aspect that can satisfactorily

foster human resource management. Deneulin and Shahani (2009) and Anand et al., (2010) seem be to agree on this by indicating that if functions were not freely selected, then there is a significant defect.

According to Rothaermel and Hess (2007), the human resource management discipline has summarily identified diverse aspects that are met to enhance capability as described below.

"**Knowing which individual knows and in which network they are most suited for"**

In other words, human resource managers can use diverse procedures in order to measure, determine capability gaps and initiative appropriate capability development programs.

According to Becker et al (2008), the strength of human resource in any organisation is to know who knows what within a given network or group and how knowledge is shared between those who know and those who are not affluent. However, this process may not be easy to establish as organisational politics and inner fighting among network members impede knowledge sharing. These arguments are supported by CAHRS (2012) that power makes individuals consider themselves better than those who are not are capable in a given area and this will impede capability development. CAHRS (2012) adds that the approach of human resource managers will also determine whether diversity among work group members will promote network cohesion or wage or increase differences. Fukuda-Parr (2003) argues this deduction by indicating that the divergences or differences of networks could be related to group selection, level and ease of socialisation and management determine capability development.

2.1.3.1 External sources of knowledge and capability enhancement

According to Karami (2013), knowledge can flow from outside of the network and enhance capabilities. In reference to figure 2-2, the author demonstrates that diverse networks can

exist in the same environment. Consequently, there is a chance that interaction among these networks/systems will enhance knowledge sharing which can results in capability achievement.

Karami (2013) reports that access or sharing of information can emerge from outside the organisation in different ways such as training and development programs. Alkire (2002) supports this and adds that in human resource management, ideal capability development is a continuous process. Consequently, having a great team or network has an immediate impact on creativity and better capabilities.

According to Alkire (2002) there are diverse studies that have been commissioned in the area of human resource to assess the appropriateness of work groups and human network capabilities. Rothaermel and Hess (2007) observe that intellectual human resource management does not only involve imparting the right knowledge but also offering the human resource teams assigned to different areas the right tools. In their study of innovation and capability management, Rothaermel and Hess (2007) share the same views with Alkire (2002) in which they conceptualise that teams and networks will have star members and non-star members. To the organisation, the key resource is the capabilities that these individuals have. Rothaermel and Hess (2007) indicate that star team members are often legendary in capability and experience and the knowledge they have is a key competitive capability to the organisation specifically for innovation. Similar findings have been observed in Deneulin and McGregor (2010) who recognised the positive correlation between knowledge and capability for innovation.

Deneulin and McGregor (2010) add that there is need for continues improvement of knowledge by providing the work teams with the necessary resources to enhance their collective capabilities. They also indicate that when access to adequate knowledge is low, the

work groups or human networks have a limited access to tangible resources. This is because human resources that lack the appropriate resources do not seem to be very innovative. It seems that, Deneulin and McGregor (2010), Alkire (2002) and Rothaermel and Hess (2007) conclude that lack of accessibility to tangible resources is a significant detriment of capability to innovate specially when capabilities of work groups and their knowledge and experience is low. To understand these deductions better, it is good for one to look at the groups as a composition of diverse capabilities. Therefore, lack of diversity of knowledge will result in low knowledge and consequently results in lower collective capability for the whole team. Networks and organisational teams have to be offered the right knowledge (internally and/or externally) in order to leverage from the tangible resources and consequently make good of their capabilities. This is the core argument in the human resource management discipline as far as the concept of individual and team capabilities are concerned.

Another crucial link between human resource management principles and the concept of capability evaluation is that it promotes social capital and networks. Studies of Drèze and Sen (2002) have observed that there is significant diversity on how science and engineering work teams are managed. They share the same views by indicating that as the human networks and their capabilities become more intricate, diverse human resource managers initiate different policies which are aimed at enhancing the cohesion and coherence of the teams. Drèze and Sen (2002) argue that cohesion and coherence of teams and networks within an organisation is enhanced by the efforts of the human resource managers. The managers are responsible for ensuring that each individual's capabilities are matched effectively with the roles and responsibilities. Therefore, human resource management function in a firm serves diverse functions which collectively go to promotion of group capability and coherence. According

to Drèze and Sen (2002), there are many roles of HR in individual and team capability enhancement of coherence and team cohesion include:

i. Enhance the capability of human resource within the teams and human networks in order for them to effectively and sufficiently share knowledge. Drèze and Sen (2002) add that this is a function of determining who knows what in a given social network by fostering a high degree of trust between network members.

ii. HR also enhances the capability of work teams in accessing key knowledge from external network environment. This is similar to the arguments that have been presented by Rothaermel and Hess (2007) who emphasise that the diversity of work groups depends on their capabilities and continuously innovate and acquire knowledge. Therefore, when the individuals with significantly high knowledge in a given group (star employees/ team members) have adequately transfer equivalent knowledge to the other team members, it is the role of human resource management to ensure there is harmony across different groups. According to Braubach, et al., (2004) intergroup destructive politics are supposed to be suppressed by the human resource management function.

iii. Braubach, et al (2004) and Drèze and Sen (2002) argue that the human resource management should enhance accessibility to tangible resources (internally and externally) and consequently enhancing effective accessibility to capability boosters.

From the literature to date one can conclude that, in the human resource discipline, individuals and group capabilities are the core focus of any management initiative or program. Resourceful employees are those that are have adequate skills, knowledge and experience which in essence define the concept of capability (Braubach, et al, 2004; Drèze

and Sen, 2002; Deneulin and McGregor, 2010; Alkire, 2002; Rothaermel and Hess, 2007; Studies of Deneulin and Shahani, 2009).

2.1.4 Capabilities in Social Sciences

A major contribution to the study of capability in the realms of social sciences is presented by Robeyns (2011). In his article on capability approach, Robeyns (2011) states that sociology or social science is perceived as the basis or foundation of the concept of the capability. This is supported by Deneulin and McGregor (2010) who deduce that sociological studies on definition of capability can be traced back to the economist Amartya Sen who is one of the pioneer scholars to introduce the capability concept in 1980s. According to Deneulin and McGregor (2010), the reasoning of Amartya Sen was that the concept of capability could help as a way of thinking about human wellbeing. Robeyns (2011) and Pettit (2001) interpret Sen's definition of capability and express that the concept of capability is a framework that encompasses socio-economic and political realms. Robeyns (2011) defines the capability as wellbeing of a person. Narayanan and Shmatikov (2009) support these arguments and indicate that in Sociology, the concept of capability is a normative theory and not an explanatory theory. Surprisingly Deneulin and McGregor (2010) claim that there is no theory which relates capability to individuals or networks ability to fulfil a task. Consequently, the arguments of Deneulin and McGregor (2010) and Narayanan and Shmatikov (2009) contraindicate each other but Robeyns (2011) goes ahead to support the perspective of Narayanan and Shmatikov (2009). In other words, in social terms, capability approach is not a theory that explains issues such as inequality, poverty and wellbeing of individuals rather it is a theory that enhances conceptualisation of these aspects (inequality, poverty and wellbeing).

However, Goerne (2010) stages a grand clarification to the above confusion and contradictory arguments. From a social point of view, Goerne (2010) expounds by postulating that indeed there is lack of adequate clarity on the concept of capability. According to Goerne (2010), the blurriness is on the interpretation and operationalisation but not on it adequacy and usefulness in analysis of social policy.

Against the backdrop of Goerne's arguments, capability approach has been commonly applied to analyses social policies. Bayraksan (2009) supports the view of Goerne (2010). According to the arguments and discussion of the concept of capability, the approach does lie on policy evaluation rather on assessment of policy benefits (outcome). This occurs through the lens of diversity and individualisation. Consequently, the capability approach serves as normative foundation of social studies meant to address the dependent variable of social welfare. However, Hartog (2001) indicates that the aspect of capabilities simplifies the discussion of the concept of capability in social. Functioning and capability concept can be used to explain social phenomena such as poverty, quality of life, social change, inequality and social justice. It is these aspects of inequality, social justice and social change that bring out the concept of capability in social sciences.

According to Deneulin and McGregor (2010), social science vies the capability approach as a framework that consists of significant contribution to the social theory. However, Schokkaert (2007) argues that the significance of the potential of capability exhibits some diminishing aspect due to insufficiency on how it treats the social construction of life's meaning. According to Schokkaert (2007) social meanings helps people to make better judgments with regard to their capabilities (abilities in doing a given activity and their weaknesses). In comparison to the views of human resource discipline on capability concept, the perspective of social science is slightly divergent. For example, Deneulin and McGregor (2010) and

Schokkaert (2007) postulate that from a social science perspective, a person's wellbeing should be understood at a social and psychological level. In human resource discipline, the concept of capability can be understood on par value as the abilities measured from skills and experiences exhibited. Consequently, social science is assumed to take a deeper and extensive view on this aspect.

According to Sen, discussion and study of the capability concept in social science should be modified to living well collectively. At this point, human networks and groups or teams, depending on which stand point one is, come to light in the horizon of the capability approach or concept. On the same tone, Narayanan and Shmatikov (2009) indicate that social institutions and structures enhance people to be able to pursue the freedoms relative to others. The arguments of Narayanan and Shmatikov (2009) on this point mean that social institutions such as families but most important as far as this study concerned the human networks, consist of people who have different abilities which Sen described as capabilities and Pettit (2001) term as freedoms.

In order to bolster capability in social science perspective, Robeyns (2011) and Pogge (2002) indicate that paying significant consideration to the political and social decision making framework will help. In order to perform this, Pogge (2002) expresses that there are diverse aspects of capability which can boost wellbeing of individuals as described below.

2.1.4.1 Capability concept and functioning

Pogge (2002) posit that functioning is defined as *beings and doings.* In regard to beings, Pogge (2002) and Robeyns (2011) believe that it entails diverse states of people of human beings and activities that they are able to undertake. Robeyns (2011) explains the concept more by indicating that "beings" entail diverse aspects such well-nourished or under-

nourished, having good health, being literate or illiterate and being depressed. These are some of the beings that social science used to describe functioning. On the other hand, Braubach, et al., (2004) describes the second term, *doings*, as activities such as travelling, taking part in an experiment and preparing financial reports. These are just some of the critical and key "doings" which help in describing capability through functioning.

Therefore, the link between capabilities and functioning is explained by Robeyns (2011) where he concludes that capabilities form people's freedoms which help them to realise functioning. In other words, capabilities are precursors of functioning. While an aspect such as travelling is a functioning, the actual opportunity for a person to travel is the capability. Clearly, the perspective of social science on capability framework or approach is very extensive. No wonder, there are some confusions and contradictions in literatures concerning the concept of capability. Nonetheless, Robeyns's distinction between functioning and capability based on the contributions of Sen is what is realised/ achieved and what is possible to achieve. For example, it is possible to prepare a particular accounting report but without the right skills and experience, the right report cannot be realised. According to Woolley et al., (2007) the approach of capability, perceives capabilities and functioning as the best models or metrics for evaluations of social institutions and understanding of interpersonal relationships. Consequently, the two most important aspects in the *sociology* of capabilities are beings and doings as Woolley et al., (2007) observe. While functioning are meant to conceptualise interpersonal comparisons wellbeing (that is realised and achieved), capabilities are meant to conceptualise interpersonal comparison of the freedom to undertake wellbeing.

2.1.4.2 Diversities and human capabilities

As sociological perspective of capability concept is based on social structure and psychological dimensions, one of the unique aspects that social science emphasises is diversity as postulated by Robeyns (2011), Pogge (2002), Pettit (2001), Pierik and Robeyns (2007) and Narayanan and Shmatikov (2009). According to O'Murchu, et al (2010), diversity is a key aspect in capability studies and modelling. The psychological and social scientists believe that the makeup of each individual especially with what they can be able to do. When individuals come together and form social structures, the diversities of each individual complement each other. O'Murchu et al., (2010) support these observations and indicate that acknowledgement of diverse people is a strong theoretical driver of forces in capability approach studies. However, Backstrom, et al (2006) criticise the normative theory of capability is fuelled by the understanding that human diversity has not been fully understood in normative theories like distributive justice.

Backstrom et al., (2006) and O'Murchu et al., (2010) argue that the tendency of people to form networks or groups either at work or in social life is the basis for social science. The ways in which these groups take shape amid the diversities of that are exhibited by each individual group member. Whether studies have not sufficiently determined how significant diversity is to the whole group/network and each person by extension as postulated by Backstrom et al., (2006), based on the evidence in literature the author can conclude that, diversity is a great contributor of group cohesion and coherence.

According to Karami (2013), a number of studies of social groups' dynamics indicate that capability is a phenomenon that is best assessed through social science. Although group capability dynamics may be significant in other disciplines and fields of learning such as economic, social science should be considered as the common base. Diversity in capability

studies can be assessing from two perspectives. Firstly, Stewart (2004) explains that estimating group capabilities requires an emphasis on plurality of capability and functioning, analysis and evaluative space. Stewart (2004) explains that by incorporating an extensive range of parameters during the process of conceptualisation of the aspects of well-being and its respective outcomes, capability approach widens the information basis. Secondly, human diversity is one of the core aspects studies focused on capability approach because it helps decipher the socio- economic environment and personal attributes and conversion factors.

Summarily, social science perspective on capability concept emerges from social structure and social groupings and spirals to the individual perspective (Pettit; 2001; Pierik and Robeyns, 2007; Narayanan and Shmatikov, 2009; Pogge, 2002). From author's point of view, social science perspective of the capability approach on its own (like any other perspectives) is not exhaustive although Stewart (2004) and O'Murchu et al., (2010) argue that it is and it can deeply describe the capability. This is because from the review of this aspect in the antecedent subsections, social science does not indicate on how capabilities of individuals and groups can be fostered. For instance, studying and modelling capability aspect from the social science discipline point of view will not be reliable and may not fit in other disciplines such as human resource management or computer science. This argument has been supported by some of the key scholars and authors of capability concept such as Narayanan and Shmatikov (2009), Pogge (2002).

In the subsequent discussion, it will be observed that computer science domain perceives capability concept from a technical point of view. It is from a context of social structure rather content of the individuals in the social structures or groupings. Context in this case means that the surrounding and aspects extrinsic to the capability of social groups while

intrinsic or content of social grouping entail the diversity of capabilities (abilities, skills, knowledge of each individual).

2.1.5 Capabilities in Computer Sciences

According to O'Murchu, et al (2010), computer science lacks any significant interpretation of the concept of capability in social networks and grouping. However, they indicate that in human networks, facilitation of communication between individuals and sharing of information is important. O'Murchu et al., (2010) further adds that ability to communicate and share information through the internet or World Wide Web has transformed capabilities of individuals and even social networks as these technologies provide efficient access to information and services online and at the same time that ease the communications can "provide a central concentrated focal point and an information source that can be personalised". These arguments are shared by Russell and Van-der-Aalst (2011) who believe that workflow systems that are driven by technology have offered ubiquitous computing methodologies thereby changing the way people live and work. Reflecting on the arguments of Pogge (2002) and Robeyns (2011) under the social science discipline in the antecedent discussion, wellbeing or beings was one of the functioning which is a predecessor of capabilities. Of importance here is the aspect of beings. Back in the computer science discipline and the deductions of Russell and Van-der-Aalst (2011), information systems and workflow systems enhance *beings* (way people live) and how they work (*doings*). While Russell and Van-der-Aalst (2011) and O'Murchu et al., (2010) do not out rightly indicate that capabilities are enhanced by information technology concepts and methodologies, there is a clear allusion of the connection between computer/ information technology systems and capabilities. The information sharing that was discussed in previous sections within a

network or human grouping is using enhanced computer or information technology systems. Schienstock (2009) in his paper on the reflection on organisational capability concept indicates that information technology in human networks acts as web portals and content aggregators of information.

Stephenson (2000) posits that one of the most significant computer science developments that surround the capabilities of human grouping and networks is social networks with online platforms such as MySpace, Facebook, LinkedIn, Twitter and Instagram among many other useful tools that have enhanced information sharing. According to Russell and Van-der-Aalst (2011) and Peppard and Ward (2004) in recent years, advancement of the internet such as the world wide web has enhanced and bolstered communication among team of network members. The two literatures concord that ability or capability of people to send and mine information thus changing the way they work and live. In other words both literatures are trying to express the idea that having Internet and social networks as a part of day to day life give individuals the opportunity to empower their relationships with similar others which can help them to form and maintain more capable teams. Saith (2001) support these arguments and adds that internet communication in human networks has become ubiquitous. He further indicates that developments such as semantic internet technologies like web portals have undergone diverse developments. However, it should be noted that social network portals are recent developments. Peppard and Ward (2004) argue that social networking sites integrate and connect people in diverse locations. Therefore, the role of computer technologies is to further the efficacy of human networks. Hartog (2001) argues that social networking sites are used by human networks to connect the members and enhance cohesion despite the distance between each member. While human resource discipline recognised the significance of capability but emphasises the diverse ways through which capability can be enhanced,

computer science discipline does not emphasise of capability but on how efficacy of information sharing can be enhanced. Backstrom et al., (2006) study the formation of large social networks and the concept of capability. In order to effectively foster capability among the members of a large network, they indicate that information technology or systems will be a useful tool. These networks can either be professional such as LinkedIn or just personal like Twitter or Face book (Backstrom et al, 2006).

According to Backstrom et al., (2006) and Schienstock (2009), communities and networks can be made better through an effective information system on platforms such as online or internet. This in essence is giving capability to individuals the chance or ability to communicate correctly. In reference to deductions of Backstrom et al., (2006) who studied the dynamics of large networks, computer science is significant in capability concept development either in regard to doings or beings. Consequently, innovation in regard to human resource management and team coordination through tools like Team Viewer and Skype tend to improve sharing of knowledge even though the geographical demarcation can be significantly diverse. The motivation factors for development of virtual or social network help expand the members of the human networks. Boyd and Ellison (2007) postulate that social networks have been growing and attracted the attention of scholars and academic researchers due to their reach. Boyd and Ellison (2007) observe that the *Journal of Computer Mediated communication* has diverse articles which have exemplify the interest of computer science discipline on the concept of capability. However, one unique aspect that Boyd and Ellison (2007) observe that a plethora of articles featured in the *Journal of Computer Mediated communication* take a technical look at the concept of capability in human networks supported by technology platforms such as Facebook, MySpace and LinkedIn.

In essence, the perspective of computer science with regard to the concept of capability is more objective than the other disciplines such as human resource management and social science. In Backstrom et al., (2006), Hartog (2001) and Peppard and Ward (2004) researches among other contributors to the concept of capability, it has been observed that computer science discipline also focuses a lot on the technical side of capability in human networks. This is deduced by Mehta (2013) who presents an exclusive study on the innovation concept in the capability of networks. In summary, the computer science discipline looks at concept of capability from a more technical perspective and how capabilities of individual network members and ultimately the entire network can achieve efficacy especially in regard to information sharing. However, a key concern in this review is whether there are similarities and difference among the disciplines and how they view capability.

2.6 Conclusion

In a summary reviewing the relevant literature cleared that the concept of capability is a very important topic in diverse fields of study and disciplines. In this chapter the author, has presented the concept of "Capability" according to different perspectives in various disciplines such as philosophy, human resource management, computer science and industrial sector. One valuable finding from reviewing various literature was that Capability is perceived as a trait that is acquired and not inherited to human. The definition of capability in different disciplines has also been investigated. For example in philosophy the capability is defined as ability of people for being able to do or perform a given task effectively. In industrial sector however the concept of capability approach and framework had diverse definitions and levels of significance depending on the impact of capability on the objectives that are guiding each industry. As a result the capability concept reviewed in different

industrial sectors such as defence industry, automotive and furniture industry. The final results confirmed that even though there are some differences in defining the capability in different industrial sectors but there the high level of commonalities between all definitions as they all agree that in industrial sector having a high capable firm relates to efficacy, reliability and quality of process and output. In human resource management discipline the scientists relate the capability of the human networks to level of knowledge sharing of individuals and the strength of their relationships within the groups. In HRM the capability was mainly defined as: "Knowing which individual knows and in which network they are most suited for" Rothaermel and Hess (2007). Finally in computer science the main focus on concept of capability was from a more technical perspective and how capabilities of individual network members and ultimately the entire network can achieve efficacy especially in regard to information sharing. In conclusion in regard to concept of capability in diverse disciplines such as computer science, human resource management and social sciences, there is diversity in perspectives and point of views which have used to look at the concept however there are some major commonalities in all discipline which form the backbone of this research.

While current section was focused on the concept of capability in different industries and disciplines, the next chapter focuses on similarities on capability in different disciplines and the factors which influence the capability among human networks.

Chapter 3

Capability Concept Similarity in Different Disciplines

In this research the first review was on the concept of capability in the eyes of philosophy as a discipline. It was observed that in philosophy, the concept of capability is not a recent aspect. For instance, Robeyns (2011) and Rothaermel and Hess (2007) indicate that capability can be traced to studies of Aristotle, Karl Marx and Adam Smith who were all pioneer philosopher from eighteenth and nineteenth centuries. Other disciplines such as human resource management and computer science do not allude to the origin of the concept of capability. However, social science and philosophy disciplines have some commonality in regard to the true original study of the concept of capability. They agree that Amartya Sen was the pioneer of the concept of true capability approach. Sen in most of his studies has been perceived as critical contributor to the study of capability and how capability can be enhanced in a network and on an individual stance. There is one clear and convincing similarity among all the disciplines that soon will be reviewed in this section. All the disciplines define capability as the ability to undertake particular tasks (Backstrom, et al (2006); Carey (2010), Sleap, et al, (2008); Williamson, (2000); Constructing Excellence, (2012); Narayanan and Shmatikov, (2009)). Despite some slight deviation in depth of assessing the capability, the concept was basically perceived as the crucial concept in all disciplines that promotes competitive advantage. After reviewing a vast range of literatures from different disciplines, the author believes that the most important discipline that has explicitly and succinctly identified and studied the concept is social sciences. According to diverse studies in social sciences such as Robeyns (2011), Deneulin and McGregor (2010), Goerne (2010), Bayraksan (2009), Narayanan and Shmatikov (2009),Schokkaert (2007) and

Pettit (2001) social science is all about social structure and social underpinning. Human networks are social structures and that is why sociology has been perceived as very significant in the study of capability concept. An all-round review has enabled the researcher to understand the weakness of using only one perspective to study the concept of capability. Consequently, the significance of this review as far as assessment and measurement of the concept of capability is concerned, is that it is not one discipline that will be used in this study. According to Gombaz (2013), a slight comparison of capabilities among the disciplines such as human resource management, technical (computer science and institutional (lightly likened to social science/ study of society) indicate that capabilities are conjoined and similar. Although there are different capabilities for each discipline, Gombaz (2013) observes that at the basic level, the concept is the same and hence developed models (if any in future) in one discipline can easily fit into another. A general application of capability, related aspects across disciplines and industries is best illustrated by Bayraksan (2009) who indicates that the Capability Maturity Model Integration (CMMI) (discussed in a later subsection). The CMMI was developed in the military or defence industry of the United States but has been adopted across the board in many other fields and disciplines. The significance of Gombaz's observations and deductions in this research lighten the scope of the study. In other words, if modelling network capabilities in one area can easily be adjusted and applied in another area thereby enhancing reliability of the statistical models.

3.1 The Parameters Influencing Capability

Stewart (2013) and Kuklys (2005) argue that social institutions or groups/networks are critically significant in modelling people's capabilities or abilities (beings and doings). This is because social institutions directly affect individuals as their capabilities cannot exist

without social competences to share. Additionally, Stewart (2013) expresses that social structure and human networking influence people's choices within a given set of capabilities and their behaviour towards other network members. Another significance of the human networks is that capabilities from one human network/social structure influence the composition and capability of other teams or networks. Consequently, studying the dynamics of human networks is an important aspect of studying and modelling the human networks' collective capability. Stewart (2013) shares the same feelings and indicates that dimensions of capability are important aspects that cannot be left out in any study. He argues that a core building block of human capability and development is that people are autonomous (independent) and make their own strategies and policies geared on their preferences. Fukuda-Parr and Kumar (2009), Kuklys (2005) and Fukuda-Parr (2003) share Stewart (2013) deductions and indicate that while development of capabilities aims at expanding them, each individual is supposed to make an autonomous decision on which capability to use or develop. Basically, this is based on what each individual can do and wants to do. However, Stewart (2013) further observes that this only occurs if the individual is autonomous and independent. Additionally, there are two factors which inhibit the autonomy of individuals in choosing what to do. These include social norms and social structures/ institutions. In essence what Stewart (2013) is trying to imply here is that social structure or organisation otherwise herein called human networks impede the autonomy on what capability to use or develop.

In Table 3-1, diverse dimensions of human capability are presented as discussed in Stewart (2013).The dimensions have been presented based on the inhibitors of autonomy.

Table 3-1: dimensions of capability and how social institutions affect capability (adopted from Stewart, 2013)

Dimensions of Capabilities	**Social organisations**	**Social norms**
Bodily well-being	communities and families provide goods and services	Norms of health behaviour Attitudes to violence
Material well-being	Cooperatives NGOs Family (including remittances) Producer and workers' organizations	Attitudes to employment Discrimination
Mental development/well-being	Family and community effect	Social norms (positive or negative)
Work	Workers' associations	Norms towards female and child work
Security	Warring groups and criminal gangs (negative) Community associations (positive)	Societal norms
Social relations	Family and community	Clubs and associations
Spiritual well-being	Religious organisations	Societal norms
Empowerment and political freedom	Political parties Social movements Peoples' associations as basis of empowerment	Norms of hierarchy and discrimination
Respect for other species and for natural environment	Community action NGOs	Norms of behaviour

Table 3-1 makes special reference to dimensions such as bodily wellbeing, material wellbeing, mental wellbeing, security, work, social relations, spiritual wellbeing, political empowerment and respect of what is around you. The social and norm inhibitors above have a clear influence on the dimensions proving that individuals are not autonomous in accessing their capabilities rather bombarded by diverse aspects from the norm or social structure and network. The significance of this revelation to the study is that focus should be on three levels: how individuals develop capabilities on their own (skills developments), how individuals within a group interact (instrumental relationships), develop and apply capabilities and how different groups interact. Stewart (2013), Alkire (2010), Fukuda-Parr and Kumar (2009), Fukuda-Parr (2003), all agree that modelling human capabilities should

focus the concept on three levels and hence social norms and social structures/ organisations/ networks effects should not be overlooked. As a climax to the concept of human network capability, diverse researchers and scholars in different disciplines have formed a model that can enhance development of capabilities. This is the capability maturity model discussed by Felin et al., (2012) and Bayraksan (2009).

3.2 Capability Maturity Model (CMM)

According to Bayraksan (2009), the capability maturity model (CMM) is predecessor of Capability Model Integration (CMMI). This model was developed by US Department of defence by analysing data collected from software development projects. The main aim of creating this model was to aid in understanding the concept of capability in the defence industry by the United States Department of Defence. As it explained in previous chapter, the United States Army (2010) exhibited significant relationship among network components. Human networks are one of the critical components of the entire network. Therefore, development of a model that can help explain the concept of capability in these complex networks was necessary. It is from this literature on capability maturity model presented by Bayraksan (2009) that this study has been pegged. This study aimed at developing a statistical model that could help in measurement of human network capabilities; not in a specific field but in diverse fields similar to the CMM which was developed in the defence industry but has come to be an important tool in diverse fields and disciplines. In addition what makes CMM to be different from other improvement development models is that CMM is not based on theory but it's based on actual data.

Bayraksan (2009) defines this model as an organisation improvement approach which gives an organisation or social structure with critical elements that bolster and foster improved

performance. He adds that in Carnegie Mellon University, the Software Engineering Institute remodelled the defence industry capability model in order to be adopted in other fields of study. From this point on, the CMM was no longer a software engineering model in the defence industry but it was a general model (still not a statistical model) that can be used in any field and discipline. From this point any connotation of" software engineering" was removed from CCM meaning and to distinguish they added "integration" to CMM to have Capability Maturity Model Integration (CMMI).There are six constellations of the Capability Maturity Model Integration (CMMI) as Bayraksan (2009) explains: Product development (CMM development), service management and delivery (CMM services), product acquisition (CMM and acquisition), security (CMM and security), Risk (CMM and risk) and system design (CMM and organisational system design). The connection between people, networks and the CMM model is illustrated in table 3-2 below.

Table 3-2: capability Maturity Model (CMM) levels of development (Bayraksan, 2009, p. 5)

Level	Focus	Process Area
5-Optimising	Continuous process improvement	• Organisational innovation and development • Casual resolution and analyses
4-Quantitativly managed	Quantitative management	• Organisational process performance • Quantitative project management
3-Defined	Process standardisation	• Requirements development • Technical solution • Product integration • Verification • Validation • Organisational process definition • Organisational training • Risk management
2-Managed	• Basic project management	• Requirements management • Project planning and controlling • Process and quality assurance
1-Initial	Competent people	

According to Bayraksan (2009), the CMM constellations are divided into diverse levels which are subsequently divided into process areas which are then shared among the diverse constellation. This relational matrix implies that the initial level is related to competence of people. Going back to the start of this section, capability concept of people and human network has been defined as abilities, knowledge and technical skills of people attributes which basically define the degree of competence of people. This is the connection between the CMM constellation aspects in table 3-2 and the concept of capability.

3.2 The Key Gap in Existing Body of Knowledge with Regard to Measuring Capability

According to study of the existing body of knowledge in various disciplines (in this research) which confirmed "capability" as an important indicator of the state of a system, one cannot find a universally agreeable analytical model for measuring capability. The most related literature that seemed to come close to this objective was Bayraksan (2009) and is Capability Maturity Model (CMM). Even final achievement in CMM studies didn't provide a general statistical model to measure network level capability. Therefore, the research gap in this section is that there are no adequate studies that can succinctly model the concept of human networks and capability concept. This study intends to offer a potential method for objective measurement and prediction of capability within the context of human networks. In other words as it can be observed from reviewing the relevant literature around the concept of capability in various disciplines (in chapter 2 and 3 of this study) the vast majority of researches around the concept of the capability have been focused on defining and analysing the capability rather than attempting to mathematically model the capability. Introducing a mathematical model which can measure the collective capability of human networks can truly

contribute to current body of knowledge in this area. Before proposing a conceptual model for collective capability measurement in this study the concept of *Human Networks* must be reviewed and analysed in next chapter of this study.

3.4 Conclusion

In this chapter a comparison was conducted between different definitions and analyses of concept of capability, which had been reviewed in in chapter 2. The results of comparing definitions and analyses of capability in different discipline showed that despite some slight deviation in depth of assessing the capability, the concept was similar in various disciplines and basically the concept of capability perceived as the crucial concept in all disciplines that promotes competitive advantage. The fundamental of Capability Maturity Model (CMM) as the most related previous attempt in modelling capability across different disciplines was reviewed in this chapter.

In addition the influential parameters which can affect the people's capability have been reviewed in this chapter. Social institutes or human networks found to be a strong effective parameter on people's capability as it can limit and influence people's choices on the type and level of capability and also affect their interactions with other members of the network. As a result it has been felt by the author that studying the definition and fundamentals of human networks is a vital requirement prior to modelling the capability in this study.

While chapter two and three were focused on the concept of capability in different industries and disciplines, the next chapter (4) focuses exactly on the concept that is the baseline of this study: Human Networks. Human networks in this case can be lightly understood as work groups either formal or informal. This is conjoined with capability concept.

Chapter 4

The Review of Literature on Human Networks and Formation of Social Grouping

In this chapter the author aims to review literatures around an equivalent important concept (compare to "capability" in previous chapters), which is Human Networks concept. These two concepts together form the baseline of this study. In this case Human Networks are perceived as social structures or organisations in which the members of a network have diverse skills, abilities and in entirety capabilities. Therefore, there are some forms of link between capabilities and work groups/ work teams/ human networks. Some of the major elements of human networks are expounded and elaborated in the subsequent subsections. Unlike the concept of capability which has been mentioned in diverse disciplines such as social sciences, human resource management and computer science, the concept of human network is underpinned on the discipline of social science.

In this chapter the author's first attempt is to look at the background of *Human Networks* and presenting the background and basic formation of the *Human Networks*. The next effort in this chapter will be put on presenting the essentials of Human Networks and finally two of the main elements of Human Networks, *Homophily* and *Diversity* will be discussed and presented.

4.1. Background to the Human Networks

Kang and Lerman (2012) argue that in any work and social context or environment, people's decisions and actions are influenced by behaviours and actions of other people around them. Consequently, understanding the cohesion of networks and how communication and sharing of information in the network is achieved is important in deciphering or modelling the networks statistically.

Bisgin et al., (2010) support Kang and Lerman's arguments and add that communication and interaction within human networks is very important as it enhances: effective flow of information, solving of problems that are arising in within the groups, bolstering group consensus and formation of cohesive groups. The study of human network dynamics is not a recent development as Bisgin et al., (2010) explains. They argue that communication in today's human network is fostered by virtual means through information systems. On a similar tone, Kang and Lerman (2012) express that informal networks collaborate and interact with formal networks in an organisation. In chapter 2, figure 2-2 presented an overview of human networks in the defence industry. It was indicated that there are diverse networks within the human category thereby supporting and augmenting the deductions of Kang and Lerman (2012). Consequently, the study of human networks, either formal or informal in organisations has been undertaken for several years. For instance, Choudhury and Pentland (2005) indicate that teams and work groups are important facet in organisations.

Fowler and Christakis (2010) argue that the theoretical models of human networks can explain social networks influence on cooperation, cohesion and congruence of the groups. They further points out that there is no adequate experimental study to explicitly identify dynamics of human networks. One of the critical aspects which relates to dynamics of human networks and has been discussed in their literature is the possibility that members of the

networks may form groups which are opposing each other. In this form of network, there is little importance or constructive contribution to the whole organisation thereby there is challenges in regard to causal inference.

Golub and Jackson (2012) argue that scholars in socioeconomic field who have studied the evolution of human interaction have turned their focus on the role of social networks. The deductions that these scholars have given is an indication that in large groups of people, interaction that is not structured significantly reduces the possibility of cooperation. While Fowler and Christakis (2010) tend to agree with the deductions of Golub and Jackson (2012), they indicate that cooperation and efficacy in fixed and small groups is better than in large groups.

Other studies such as Katz and Lazer (2007) show that diverse human networks could impede or promote effective selection. Additionally, network organisations, either small or large, can decipher the benefits/ outcome of the processes. Katz and Lazer (2007) say that interaction heterogeneity in the human groups can promote prospects for better cooperation. However, empirical and theoretical studies have not pointed out whether cooperative demeanour spreads in each tie between members. Additionally, both Katz and Lazer (2007) and Fowler and Christakis (2010) share the same sentiments by indicating that experimental studies that expound the concept of human network have emphasised more on coordination rather than cooperation. These deductions have significantly been reflected in the previous chapter where it was noted that capability can be enhanced through better information sharing. Additionally, the human resource management and computer science disciplines reviewed in the previous chapter seem to emphasise on how to improve capability.

According to Kossinets and Watts (2009), a significant number of studies indicate that many phenomena such as happiness, ideas or obesity can spread from one group member to another

in a given or particular human network. They further expound by indicating that social networks such as families, friend groups or even professional groups tend to exhibit similar attributes. Even dimensions such as age, profession, social economic status and race can influence social grouping and cohesion thereto (effect of homophily). Therefore, it is easy to assert that people are attracted to environments they have selected that seamlessly enhance meeting with other people of the same characteristics. Although this may be so, Kossinets and Watts (2009) is seemingly pessimistic and negative as far as the study and modelling of social networks is concerned. This is because Kossinets and Watts (2009) has observed that antecedent studies and scholarly research has not been able to identify causal impact of human network through observation research because similarities of observed features in networks can emergence from homophily, a concept that will be expounded further in subsequent subsections. It can be observed that the deductions of Katz and Lazer (2007) and Fowler and Christakis (2010) in regard to research gap that has not been filled.

Pentland (2007) argues a critical question in regard to the aspects that promote efficacy of intra-organisation networks. Upon a significant study of intra-organisation networks, Pentland (2007) indicates that a plethora of studies attempt to determine the factors that enhance human networks. However, Pentland (2006), like Katz and Lazer (2007) and Fowler and Christakis (2010), find that all these studies on the concept of human networks have ignored one important building block of networks: formal work groups/ teams/ human networks. This is also indicated by Choudhury and Pentland (2005) that neglecting formal teams/ work groups is considered a major lapse in the study of human network structure. This is because organisational formal groups/ teams have become critical in accomplishment of organisational mission and achievement of vision. Additionally, diverse literature covering

the concept of organisational work groups, either small or large provide rich findings that help in deciphering and dissecting the essence human networks.

Another perspective on previous studies touching on human networks is presented by Pentland (2007) who argues that a series of studies on coordination and cooperation in human networks have deciphered that between 35% and 80% of time spent in the work place is dominated by spoken conversation. On the other hand, between 14% and 93% of the time is dominated by opportunistic communication while 7% and 82% of the time is dedicated to meetings. Wimmer and Lewis (2010) bolster the arguments of Pentland (2007) and indicate that strategic management conform to this high end scales. One contributory literature to this conversation is Choudhury and Pentland (2005), who indicate that communication within groups or human network is very important. They indicate that recent studies on cooperation and coordination of members in small and large groups have been enhanced by development in information sharing capabilities.

According to Choudhury and Pentland (2005), the significance of developing models and methodologies to gauge the dynamics of human networks is very important in diverse disciplines such as social network analysis, organisational behaviour and theory and knowledge management in human resource. While Choudhury (2004) agrees to the above deductions and arguments, he adds that currently research on dynamics and measurability of social networks and organisation communication heavily rely on self- reports. Choudhury (2004) criticises this heavy reliance on self- reports in measuring dynamics and concepts related to human networks. However, he is not dismissing the self- report approach entirely but he believes self-reports are not exhaustive. This is because the practicability of this method diminishes as the group grows larger and the interaction among network members occurs in different locations.

In summary, researchers like Choudhury and Pentland (2005), Choudhury (2004), Kang and Lerman (2012) and Wimmer and Lewis (2010) among other social economists believe that by using a machine learning and statistical approach in measuring network dynamics and behaviour, it is now possible to illustrate how solid human network dynamic estimates. This in essence paints a succinct and explicit picture on how far research on human network dynamics has come and the future potential of even better studies. In the subsection that follows, the review switches from a background overview on the research on human networks to essentials of human networks.

4.2. Essentials of the Human Networks, Capability Factors for Modelling

Reagans et al., (2008) discuss diversity of work groups in an attempt to provide a road map for assembling effective work teams. Their approach combines the principle of social network and membership demographics. The approach suggests the method of evaluating the potency of work groups by focusing on demographic characteristics of members of the team and focus on interactions. These two characteristics of human networks: demographic homophily and members interactions have been nominated as two of the four capability factors for modelling the collective capability in this study. Moody and White (2003) have similar findings and concur with Reagans, et al (2008) that social networks need to be homophile with regard to demographic characteristics such as age, gender. In other words they believe in tendency of individuals to bond and associate with similar others. Reagans, et al (2008) also express the fact that the recommended approach in their research (combining demographic characteristics and social networks to evaluate the potency of work teams) is not always very simplistic. For example in their study of 1518 project teams in a contract

research and development firms, they found out many cases in which even when internal networks within organisations are extremely homophile with regard to demographic attributes, causal structure that underlies theories of demographic diversity carries ambiguous performance implications. This ambiguity is due to the fact that diversity of demographic characteristics among team members "has opposing effects on two social network variables-internal density and external range-each of which has a positive effect on a team".

To understand the dynamics of groups and human networks in an effort to statistically model their capabilities, more elements and types of groups needed to be discussed in next sub sections. Many scholars such as Moody and White (2003) and Reagans et al., (2008) have discussed and emphasised on the important role of the two elements of human networks: *Demographic homophily* of the network and *interactions between individuals (Instrumental relationships)* on the total network's outcome. Previous scholars' emphasise on the importance of demographic homophily and individuals' relationships within a network are in line with author's observations of successful project teams in real life. As a result it has been decided that *demographic homophily* level of the network and the *instrumental relationships' strength* (project related relationships' strength) among team members to be nominated as the first two suitable capability factors for the proposed conceptual collective capability model in this study.

In addition from the literature reviews on the concept of capability (in chapter two and three), *Skills diversity* of the members in a network and their *previous level of attainment*/*experience* have been disused as important factors which can affect the whole team's capability. These two factors have also been derived to be used in propose collective model in this study.

4.2.1. Types of groups/ networks

Macionis and Linda (2010) and Turner and Reynolds (2001) classify groups/networks into: primary and secondary. The primary groups are constructed on a small social group where the members of the group share some personal relationships. Turner and Reynolds (2001) add that people who are in a primary group spend a significant amount of time together sharing ideas and engaging in diverse activities. One good example of a primary group is a family. Another example is any group of friends that is tightly knit. The types of relationships among members in such groups are mainly informal. The relationships in primary groups are not necessarily form because of existence of a common goal or project among memebrs.

The secondary social group consists of a large collection of people in a formal and/or institutional relationship. Unlike the primary groups, Platow et al., (2011) argue that secondary groups have very weak links or emotional ties. Additionally, the members of the secondary group have little personal knowledge of their colleagues. Macionis and Linda (2010) add that in majority of secondary groups, relations start and end without any significant agenda. The period in which such groups stay in existence is short lived. Turner and Reynolds (2001) argue that some secondary do not even last a day. It is from within these secondary groups that primary groups might be generated. Additionally, there are situations where these two categories of groups co-exist. For instance, Platow et al., (2011) express that universities or schools exemplify how secondary and primary group or human networks co-exists. Similarly, some businesses may contain secondary and primary groups. Summarily, sociologists indicate that primary and secondary groups have one thing in common; they are held together by "*bonds"* often called "*reference groups"* Platow et al., (2001).

Looking at the concept from different angle, West and Leskovec (2012), Sen (2004) and Sen (2005) argue that groups can be studied through the social identity perspective that draws on

the insights of social identity theory. West and Leskovec (2012) express the fact that social groups can be defined as "collection of people who has been formed through psychological mind set based on conceptual and cognitive aspects". The necessary and sufficient condition for people to act as a group is guided by the true awareness of a given aspect in which they share common interest.

The results of some empirical studied by Platow et al., (2011) show that allowing people to form groups voluntarily and randomly, is enough for them to behave in an in-group favouring manner. Under the same belief, Macionis and Linda (2010) indicate that this has happened even when there is no common interest. However, Macionis and Linda (2010) have noticed that recent empirical study developments have indicated that meaningless grouping is precursor to perceptions and presumptions of interdependence among group members. In other words by defining shared goal and interest among people in a group the perceived interdependence will be formed.

Fowler and Christakis (2010) argue that while the above approach to the study of human grouping and networking is based on the concept of Social Identity Theory (SIT), other social studies have indicated that recent concerted exploration has turned to Self- Categorisation Theory (SCT). They further add that while the former theory of groups and networks (social identity theory) has focused on the dynamics of inter- group, the later self-categorisation theory was established explain how people perceive themselves as members of a particular social group and how self-grouping decipher any subsequent group behaviour.

In a Summary, table 4-1 shows different type of human networks (either formal or informal) and the main characteristics of each type of network. The various types of human networks in table 4-1 have been identified by different scholars such as Fowler and Christakis (2010), Platow et al., (2011) and Macionis and Linda (2010), Reagan's et al., (2008) and Moody and

White (2003). Table 4-1 only shows some of the most common types of social networks and is not conclusive and by no means exhaustive. There might be some other types of the social networks in other literatures but these are the most common types of human networks discussed by the pioneers in the fields.

Table 4-1 different types of social (human) networks

Type of Human Network	Characteristics of the Network	Identified by
Peer groups	• Group of people usually of the same age, interest and social status • members are relatively equal in regard to power and no one individual has overriding power	Macionis and Linda (2010)
Clique	• often found in school setting • Members of cliques have significantly common interest and define the coherence and cohesion.	Fowler and Christakis (2010)
Club	• a group which has a formal channel of entry • Sometimes clubs have exclusive memberships and no new members are allowed.	Macionis and Linda (2010)
Cabal	• a group where people have very tight cohesion with significant focus on particular ideologies, For instance, churches or communities	Moody and White (2003)
Gang	• a group which has common interest but are less formal • gangs have leaders • Getting into gangs is strict like in clubs but less formal	Reagans et al., (2008)
Mob	• a group that is usually not organised in any way and exists for a very short time • Usually mobs take the law into their own hands.	Macionis and Linda (2010)

Regardless of the type of social (human) networks (tables 4-1) social groups recruit new members through diverse channels. Macionis and Linda (2010) argue that in the earlier stages of group development, not every applicant is accepted rather a recommendation is usually made by the members based on the necessity of having more members. However, this approach is different from one group to another and may not be taken seriously in other groups such as social media groups but very stringently applied in clubs and gangs.

4.2.2. Transformation and dispersal of human networks

According to Platow, et al (2011), transformation of groups and human networks over time depends on the underlying code of operations. Moreover, Moody and White (2003) argue in their article on structural cohesion and embeddedness of social groups that members in group can develop more stable links and territorial relationship over time. As reviewed in the antecedent subsection, time will determine whether the group (s) will persist or exist in the future or not. According to Wimmer and Lewis (2010) even though stable groups are achievable but every group has a breaking point at a given time. Consequently, the establishment, development, maturity and "death" of a group can be likened to the organisational maturity curve. The proposed collective capability in this research is considering the time of maturity of work groups. This is presumed by Fowler and Christakis (2010) who indicate that there are numerous arguments developed by sociologists and socio-economists with regard to the malfunction and dispersion of social groups. Fowler and Christakis (2010) further expound that the dispersion of groups tends to be caused by lack of sufficient compliance to the elements of groups or human networks to be discussed later in this section.

According to Fowler and Christakis (2010), there are two major causes of malfunction in a group: entry of too many members and failure to adhere to one common purpose due to confusion of status and ideological differences. This is expounded by Platow et al., (2011) who indicate that in any society, there is a need to allow more people to their side of the camp. While this can be perceived as an achievement especially in groups such as political parties, it can also mark the reconnaissance or birth and the demise of specified social groups. The defence industry has often been used as a good example of groups where hierarchy of command and group leadership without any ideological differences can effectively lead to malfunction of and eventually dispersion of the whole group. Wimmer and Lewis (2010) supports this deduction by further arguing that in the military, there are diverse groups or human networks such as companies, regiments, divisions, platoons and even squads whose answerability converges to one leader. However, each group will have its own set of leaders depending on its configurations. This high- end and strict and formal type of hierarchy ensures that the groups do not disperse (Wimmer and Lewis, 2010).

Unlike the military, private organisations, clubs and agencies have established a comparable but less standardised framework to ensure longer live and perpetuity for the entire group (Wimmer and Lewis, 2010). This framework is designed to manage complexity of groups as they grow larger. Therefore, one can conclude that in the development of social groups, the management and complexity of formation of groups are two key factors.

Some other authors such as Macionis and Linda (2010), however argue that not all complexly large groups is under threat of dispersion of malfunction due to difficulties in enhancing group cohesion. They argue that, human networks and groups such as clubs and cabals (such as churches) rely heavily on the beliefs that members hold. For example, if church members

believe that committing suicide in the name of their God will buy them a ticket to heaven or eternity, extraordinary cohesion can be apparent.

An important question that arises from these discussions is what is an appropriate group size? According to the arguments and deductions of Macionis and Linda (2010), Wimmer and Lewis (2010) and Platow, et al (2011), a size of 5 to 10 is often considered as an ideal group that will have long standing cohesion. However, this number can be subjective and it all depends on the underlying circumstances and the principles under which the group operates.

The key concept here is that success (fulfilling the given project) of a human network is achieved through the fair coordination and cooperation (group cohesion) of each member (Stewart, 2001). Summarily, it can be observed from the arguments of Macionis and Linda (2010), Wimmer and Lewis (2010) and Platow, et al (2011) that weakening of a common direction and goal/ aim which also marks the start of failure for a given group can be brought about by: unresolved conflicts among members such as territorial disputes, emergence of dominance order where some members perceive themselves as superior than others and weak leadership. While Verdon (2008) perceives all this dimensions of failure as equally fatal, loss of leadership has been identified as the most fatal factor in dispersion and malfunction of groups. This is because loss of a leader tends to dissolve and disperse the dominance relationship and dedication to a common aim or differentiation of roles. Following the malfunction and dispersion of groups and human networks is the symptoms of a rocky inter-group relationship often characterised and summarised by inadequate efficiency, weakening participation and increased verbal or non- verbal aggression.

4.2.3. Key Terminologies in Human Based Networks

Social structure or human network structure is defined and approached differently by different scholars and sociologists (Paltow et al., 2011). This applies to the elements of a social structure which can summarily be described as follows.

Institutions: According to Platow, et al (2011), institutions are patterns developed and held together by human relationships such as families.

Social groups: Social groups are smaller but are driven by one agenda or purpose of existence.

Status: This is concerned with the relative position that one holds within a given social group. For instance, in a family, one can either be a child of someone or a parent of a given child.

Roles: The roles are the expectations and duties that are attached to each status. Platow et al., (2011) explain that that if it is a child, he/she is supposed to obey the parents and parents should provide food for their children. This has been likened to animal sociologists who have argued that those animals that live in groups such as ants have social status where one ant is the queen, others are workers and some are soldiers to defend the colony. Similarly, human networks have this kind of relationships with assumed/ implied or expressed status and roles.

Moody and White (2003) present a reliable and concrete methodology of studying group cohesion. In order to effectively model these group patterns, they indicate that a usual structural pattern for human networks is hierarchical nesting that is found at low levels of connectivity and lack of group overlapping at high end level of connectivity. To conceptualise these theoretical deductions, they use node diagrams with nested approach to identify group cohesion. They describe this statistical approach as cohesive blocking.

In cohesive blocking, Moody and White (2003) try to statistically model cohesiveness of groups. The process starts by identification of k-connectivity in an input graph and consequently cutting away the k- sets that holds the group as one. This procedure is repeated for subsequent sub graphs until there is no further cutting. Consequently, any k+1 set that is embedded in the human network or group can be identified. The further one goes in terms of cutting the k- sets the stronger of cohesive the group is considered to be (Platow, et al, 2011; Moody and White, 2003).

4.2.4. Dimensions and factors of human behaviour

In the previous sub section, it has been identified that group existence is diversely affected and influenced by extrinsic factors such as number of people in the network or group and lack of cohesive and reliable leadership. However, sociology studies such as Verdon (2008) allude that there are other innate human behaviours that define the success of a group or network. From the author's perspective these factors can be termed as "*elements*" of human behaviours because they frame the behaviours of the people forming the groups. West and Leskovec (2012) and Platow et al., (2011) indicate that some behaviours of people in networks (elements in this study) are presumed to the drivers of social media and any social grouping for that matter. According to West and Leskoves (2012), some of the most commonly discussed elements of human networks are: hedonism, homophily, memetic, tribalism, narcissism and altruism which will be briefly explained below:

i. **Hedonism:** This element has been defined by West and Leskovec (2012) as a perception where group members believe that pleasure it the only good thing. This is often observed with college students where peer groups often engage in pleasures at the detriment of better things such as learning. West and Leskovec

(2012) argue that hedonism can affect social groups from two perspectives: being involved or being part of a group is an enjoyable thing and the group allows them to access activities that enhance members' pleasure.

ii. **Altruism:** Group members devote themselves unselfishly to the service of other group members, West and Leskovec (2012), Linda (2010) and Fowler and Christakis (2010) .This is often explicitly expressed in cult like groups where secrecy is utmost principle and each member can sacrifice their own wellbeing for the wellbeing of the group. On a lighter note, Macionis and Linda (2010) bespeak that the normal groups such as social media groups exhibit altruism when they share information with no much thought on who gets it or not. Consequently, there is a form of unselfishness.

iii. **Homophily:** The tendency to join other people who have similar characteristics. This is likened to the proverbial saying that birds of feather often flock together. Consequently, homophily is the underlying factor (element) for majority of group formation, Macionis and Linda (2010). Therefore, for better understanding of the functionality and working of human networks, homophily shall be expounded further in the subsequent discussion.

iv. **Memetic:** According to West and Leskovec (2012) memetic is a concept where ideas and habits are replicated across a human or social network. For instance, reggae artists will often exhibit similar behaviours verbal and non- verbal implying a common believe or sense of purpose. Therefore, this factor is an underlying augment of the other elements of human behaviours such as homophily.

v. **Narcissism**: Excessive fascination in oneself is described as narcissism. Social science studies on virtual human network such as Face book and Twitter indicate that most people in this networks and subgroups often are narcissistic and extraverted, West and Leskovec (2012)

vi. **Tribalism:** this is loosely translated as fighting for your own group. In other words, the individuals in a group will tend to favour someone from their own group first before extending the same favour to other groups or individuals.

Among all above elements of human networks the homophily (specifically demographic homophily) has been discussed and highlighted by scholars in the field of social sciences as an important factor which play a vital role both the formation and success of human networks. As it mentioned earlier, this element (homophily) is one of the four capability factors which will be used for modelling the collective capability in this study. So it seemed useful to discuss demographic homophily with more details in following subsection.

4.3. Demographic Homophily of Human networks

According to Bisgin et al., (2010), homophily explains that individuals with similar characteristics are tending to associate with one another more often. Golub and Jackson (2012) support the deductions of Bisgin et al., (2010) and indicate that the links between two individuals form based on a probability which mainly depends on exogenously defined types such as demographic characteristics of both individuals involved.

Golub and Jackson (2012) in other similar studies found out that homophily relies on the large scale link among groups and human networks and to a large extent not on the idiosyncratic aspects of human network outcome. Consequently, the concept or element of spectral homophily is used to measure the degree to which the group members are biased

towards a given link among themselves. This is supported by Kang and Lerman (2012) who believe that the deductions of all the studies on the element of human behaviours called homophily converge to one point: *that group cohesion and sustainability is determined by homophily.*

This all gave the author the high level of confidence that "homophily" is an inevitable part of any human networks and if the purpose of this research is modelling the capability of Human Networks then "homophily" (specifically demographic homophily) can be one of the suitable capability factors in our proposed model.

It has been discovered in all socio-demographic studies that the strength or weakness of segregation links is determined or can be explained through homophily.

However, due to the absence of socio-demographic aspects, Bisgin et al., (2010) and Golub and Jackson (2012) notice that it has become more challenging to use homophily to model the cohesiveness and segregation of human networks. Nonetheless, a common understanding is that human behaviours and interest are robust factors for evaluating human network segregation and they apply to both virtual and physical human network platforms (Bisgin et al., (2010) and Golub and Jackson (2012)).This is echoed by Kossinets and Watts (2009) who define homophily as the principle of "*liking to associate with those who are like you"*. They support Bisgin et al., (2010) and Golub and Jackson (2012) by indicating that homophily is a very robust dimension to use when statistically or empirically modelling the concept of human networks.

The homophily offer opportunities to sociologists and socio-demographers in measuring the level of social mobility, inequality and segregation (Kossinets and Watts, 2009). However, the origins of homophily in a group need to be understood for better modelling of human network dynamics and capabilities. Kossinets and Watts (2009) indicate that theoretically,

homophily arise from two main areas: induced homophily and choice homophily. Golub and Jackson (2012) postulate that in correspondence to the theory of structuralism and individualistic, some of observed aspects of homophily can be attributed to either psychological or individual preferences. This is the choice homophily that has been alluded to by Kossinets and Watts (2009). Kossinets and Watts (2009) expound by indicating that the part of homophily can be attributed to the consequence of homogeneity of structural opportunities for interactions (as in work groups) can be labelled as induced homophily. Kossinets and Watts (2009) argue that although succinct and explicit in principle, differentiating the two concepts homophily is not that simple. This is complicated due to a third factor which in social life or science; the relevant social surroundings are not often deciphered by external factors. The term "homophily" used in this study covers both kind of homophily defined by Kossinest and Watts (2009). As it will be explained in further chapters the individuals who took part in this study had given the opportunity to form their work group voluntary which could give them ability to choose their group members based on their preferences. This can support the existence of choice homophily. Consequently when individuals formed their groups voluntarily we ended up having both homophile and heterogeneous groups in our study sample (based on demographic characteristic). This gave the author the opportunity to test the effect of induced homophily on work team's capability as well.

The significance of homophily cannot be overstated by Wimmer and Lewis (2010) as they indicate that the community or institutional structure of homophily imparts on social network may cause linked individuals to become even more inter-related or inter-linked. In other words, homophily, by choice or inducement, can foster and bolster better network relationship. Therefore, homophily is an aspect that cannot be left out during the process of

statistical human network modelling and determination of the strength of relationship (second capability factor in modelling this study) in a network. Although it was indicated by Moody and White (2003) that over time groups tend to lose their strength, cohesion and coherence, Kang and Lerman (2012) contra- indicate that with the presence of homophily, preferential linkages among structural aspects of human networks will make human networks and groups more sustainable and predictable. Consequently, understanding homophily of human behaviours can help researchers, both current and future; build better statistical and empirical models of explaining the concept of human networks in virtual and physical environments.

According to Kang and Lerhman (2012), people choose to be in groups precisely because they want to meet the kind of friends and other people who have similar likes. Hypothetically speaking, observed homophily can be the used to explain this selection and inclusion. There is one aspect that has overriding in all the studies involving homophily: homogeneity of opportunities that the people will get from joining certain groups or networks. Therefore, the impact of structural proximity in likes and dislikes as explained by Kang and Lerhman (2012) is essential in the measurement of latent variables in an attempt to measure the network concept in sociology of groups.

4.4. Diversity of skills among group members

Diversity in human networks has been identified as one of the most important aspects which determine the development of a human network or group, Knouse et al., (2008). The concept of diversity has been defined in terms of many variables especially demographic such as age, nationality, ethnicity, race and gender or skill, abilities and knowledge which were identified as capabilities in the antecedent literature review chapter. Von-Bergen et al., (2002) supports

this detailed description and indicates that the most important process in regard to the concept of diversity is diversity management. Von-Bergen, et al (2002) define diversity management as the capability of group or network members to optimise the benefits of network or group member diversity and parallel minimisation of group and individual problems.

Positive diversity

According to Von-Bergen, et al (2002) and Knouse et al., (2008), there are two forms of diversity: positive and negative. Positive diversity is concerned with aspects that enable group members or human network participants to adjust their behaviours in order to foster and bolster positive interaction among the group members. Von-Bergen et al., (2002) add that studies in socio-psychological field have indicated that group members are driven by the urge to behave positively. Additionally, these studies indicate that assessing and measuring human network diversity is not often accurate as diversity is not often static rather dynamic or ever changing.

Negative diversity

There is also a negative diversity dimension in human networks and groups. Negative diversity is caused by unrealistic expectations that occur when the positive recruiting aspects are contradicted by an adverse environment (Von-Bergen et al., 2002). The impact or consequence of unrealistic expectation which leads to negative diversities is low satisfaction and turnover among the group members (Von-Bergen et al, 2002; Knouse, et al, 2008; Hunter, 2007). However, Knouse et al., (2008) add that the exact influence of group and network skills diversity is not clear portraying that there is a research gap that can be filled in this study or can be part of research aims and objectives. They expound by indicating that sometimes the impact of diversity might seem positive but negative under different circumstances. In order to examine these contraindicating opinions, Knouse et al., (2008)

recommend that a group development model can be used to assess and ascertain the impact of diversity either positive or negative on group and networks.

On the other hand diversity is especially important if cognitive dissimilarity can influence group behaviours and elements to group behaviours such as homophily and altruism (Von-Bergen et al., 2002). If the outcome of cognitive dissimilarity is low degree of behavioural of group, then it will be very difficult to arrive at a consensus among the group members in case of destructive arguments. Von-Bergen et al., (2002) terms this as an indirect influence of cognitive dissimilarity. However, the same researchers argue that diversity and the consequent cognitive paradigm of dissimilarity can have *positive* influence on the efficiency and quality human networks. Ultimately, the impact of diversity on groups has been studied by Goluby and Jackson (2012) who deduce that there are two levels of impact: team level and individual level. At the individual level, Goluby and Jackson (2012) indicate that network members can improve performance, perception of utility and satisfaction in regard to personal performance, knowledge and skill which is enhanced through information sharing. On the other hand, the team can benefit from diversity of individuals and overly the whole group through membership stability and increased efficiency in performance.

It can be observed that there is a clear connection between collective capabilities of individuals who act as a team. This is the recap of the overall review and drawing of a connection or "marrying" this review to the antecedent literature review. This is why this study conjoined the concepts of capability and human networks or groups as they seemingly have a significant relationship.

4.5. Conclusion

In summary, having knowledge of the communication dynamics can be helpful in understanding the cohesion of networks. In addition understanding of how communication and sharing of information in the network is achieved is important in deciphering or modelling the networks statistically. In this chapter the author emphasised that the term "Human networks" used in this study are simply groups which can either be formal or informal. Reviewing the fair amount of literatures made it clear that success of a human network is achieved through the fair coordination and cooperation (group cohesion) of each member. Weakening of a common direction and goal/ aim which also marks the start of failure for a given group can be brought about by: unresolved conflicts among members such as territorial disputes, emergence of dominance order where some members perceive themselves as superior than others and weak leadership. There is a connection between capabilities of individuals and teams or human networks.

One other main outcome of this chapter was introducing four capability factors which the author has nominated for his conceptual collective capability model. The importance of four capability factors have been discussed while reviewing different related literatures in previous chapter. These capability factors were "Demographic Homophily level" of individuals within a network, "Instrumental relationships strength" among members "Skills diversity" of the individuals and also "Previous attainments/experiences" of individuals in a similar project.

In a quick summary both homophily and diversity in human groups have been recognised as two of the most important aspects which determine the development of a human network or group. The concept can be defined in terms of many variables especially demographic such as age, nationality, ethnicity, race and gender or skill, abilities and knowledge which were

identified as capabilities in the antecedent literature review chapter. This study is centred on this very objective of modelling, statistically, the concept of human networks and capability aspect. The extensive review in this chapter was purposely meant to bring out the picture on two main concepts: human networks and capability. This objective has been achieved and hence methodologies that were used in this study such as research strategy, paradigm and data collection are outlined for next chapters.

Chapter 5

Work Groups' Cognition and Collective Capability Measurement; existing Methods

The main purpose of this chapter in the first part is to give an overview on human work group's cognition and formation. In the second part the current existing methods for measurement of the capability of human work groups will be reviewed.

As it has been mentioned in the first chapter, a systematic approach in measuring and predicting collective capability of work groups (human networks) is the main aim of this research. By starting this chapter the main focus will be on the fundamentals of measurement of the collective capability of a group of individuals who perform as a group to fulfil a given project.

Being able to predict a group of individuals' collective capability can yield useful information for managers and decision makers to form their required work groups (from their potential resources) with the highest possible capability level. Therefore it is essential in this study to have an overview of the current measures, tools and theories about the formation of human work groups and consequently assessing the collective capability of those work groups in achieving a pre-defined outcome. This is done by highlighting the gap between the existing methods and the proposed method in this study.

Collective capability of work groups in this study refers to *group level outcomes which cannot explicitly described as the superposition of characteristics and behaviour of individuals in a group.* In other words the collective capability of work groups (human networks) can be expressed as linear or non-linear relationships between individuals and characteristics of the work groups. The characteristics of work groups (networks) have been

looked at in this study by using ***demographic homophily***, ***skills diversity of members***, ***instrumental relationships' strength and group members' previous level attainments/experiences in similar project***. These four elements are forming the capability factors for modelling collective capability of work groups in this research.

Over the past few years researchers have been putting little attempt to apply conceptual models for studying and predicting the collective outcome (level of achievement) of groups in wide variety of applications. These include the study of animal behaviour (Sumpter, 2010), disease dynamics (Levin and Durrett, 1996), and social networks (Watts and Strogatz 1998). In some research cases the researchers have gone a step further and have attempted to use modelling to explain the collective outcomes such as co-operation and altruism (Levin, 2003 and Nowak, 2006). However the vast majority of previous researches around the concept of collective outcome of groups have been more kind of analysing study rather than mathematical modelling. This is where the author can express the fact the modelling the collective capability of human network (work groups) in a way that is proposed in this study is the first serious attempt in mathematically model the concept.

Measuring collective capability of work teams (human networks) first requires having an explicit and accurate definition of work team. Sales et al. (1992) characterise human teams as *"a distinguishable set of two or more people who interact dynamically, interdependently, and adaptively towards a common and valued goal/objective/mission"*. In our study in line with this definition, we use the term "work team" as a set of two or more individuals who interact dynamically in a team to achieve the explicit outcome of a pre-defined project. It's important to clarify that in this study the focus will be on human-based work teams which can be defined as a result of human collaboration only. Besides human-based work teams, human-agent work teams have been introduced by some researchers (Chirstoffersen and Woods',

2002) which this kind of work teams are not within the focus area of this study. In human-agent work teams the role of software agents are as important as human collaboration whereas in our study we consider software agents as a set of skills or abilities which can be brought to the team by members of the team. In other words in our study the main actors of work teams are human individuals and any other factors such as software agents are inherited or acquired by main actors. This perspective about human work teams are however in line with Chirstoffersen and Woods (2002) perspective about work teams which desire to make agents an integral part of work teams.

Human-based teams' interactions have been studied by psychologist since early 1950s (Sycara and Sukthankar, 2006). In studying the concept of human networks, Paris et al., (2000) appraise different human-based theories by breaking them into eight main categories. Each category looks at the concept of human network from different perspective. Briefly reviewing this categorisation here can give us a wider vision about human networks' studies and also can help us to determine which categories (perspectives about human networks) can be covered through the modelling approach (using the four nominated capability mentioned earlier) in this study.

The main theories categorised by Paris et al., (2000) are:

1) **Social physiological approaches**: mainly relates to how individuals in a team relate and interact with each other
2) **Socio-technical approaches**: work-related implications of individuals relationships
3) **Ecological approaches**: how organisational or working team environments affect teamwork
4) **Human resource approaches**: how teams utilise individual member's capabilities and abilities,

5) **Technological approaches**: relating to technological progress of human networks
6) **Life cycle approach**: how team performance (outcome) changes over the life cycle of existence (dynamics of networks)
7) **Task oriented approach**: Focuses mainly on team roles, functions and tasking
8) **Integrative approach**: a fusion of multiple different approaches.

This categorisation can help one who aims to study about different aspects of human networks (work teams) to be more organised. In other words any researcher who aims to do research about a specific aspect of human work groups (For example: capability in our case) can focus on either one or some of above categories (perspectives) to give direction to his/her studies. For instance in our study we mainly focus on social psychological, ecological and human resources approach (1, 3 and 4) of Paris et al., (2000) categorisation for our modelling purposes. The reason is that the four nominated capability factors in our study which covers the effect of individuals' skills and abilities and their instrumental (task related) interactions on the whole team's capability level will look at the human work groups from the categories 1, 3 and 4's perspective.

Canon-Bowers et al., (1995) have looked at the whole concept from a different angle and have divided human networks into three dimensions: *cognitions, skills* and *attributes*. The first dimension (*cognitions*) mainly includes information about the task/project which team members need to fulfil such as objectives, norms and resources. Second dimension (*skills*) includes behaviours such as leadership, performance monitoring and finally third dimension (*attributes*) measures individual member's feeling about their team: team cohesion, mutual trust and importance of teamwork for each individual. Looking at our research from Canon-Bower et al., (1995) perspectives, the proposed model in this thesis covers all three dimensions introduced by Canon-Bowers et al (1995). This is because the capability factors

in this study not only take into account the effect of team members' skills/abilities and previous experiences on the whole team's outcome but also consider the effect of team member's instrumental relationships on the total collective capability of the network. In other words our approach in modelling collective capability (proposed in this study) covers *cognitions*, *skills* and *attributes* of human networks

5.1. Work Teams and Role of Shared Mental Models

The body of knowledge produced about human work teams' performance suggest that experienced teams develop a shared understanding or *shared mental model* which can assist group members to understand and predict each other's needs and can help them to adapt to their group project's demands (Fiore and Schooler, 2004). Further for such experienced teams both tacit and explicit coordination are vital strategies which can lead the whole team to success. According to *shared mental model (SMM),* explicit coordination occurs through external verbal and non-verbal communications whereas tacit coordination is thought to occur through the meta-cognitive activities of team members who have shared mental models of: what should be done, when and by whom (Entin and Serfaty, 1999; Fiore and et al, 2001 and Hoeft et al., 2006). Some researchers such as Cannon-Bowers et al., (1993) believe that for work teams to successfully perform their given tasks the team members need to possess commonly held knowledge structures which give them the opportunity to predict team behaviour based on shared performance expectations. The commonly held knowledge discussed by Cannon-Bowers et al., (1993) includes knowledge of the objectives of the project, each member's role and responsibilities along with timing of the given group project. To gain the discussed commonly knowledge the members in a network need to have positive and strong project related (instrumental) relationships with each other. This this another

reason which highlights the importance of looking at team members' instrumental relationships when modelling collective capability in this study.

Another important key factor for successfully achieving the outcome by a team is commonality of cognition which can be measured by rating team members' similarities (Rentsch and Hall, 1994). The similarity among team members at the macro level involves many characteristics and skills which can affect the collaborative processes. For the modelling purpose in this study we mainly focus on similarity of team members in skills to fulfil a given group project. This can help the author to test the effect of skills diversity among team members (as one of capability factors) on the whole team capability.

5.2. Some Technical Categorisation of Work Teams

According to Warner et al., (2004, 2005), there are two main factors that play an important role in defining and categorising of working teams. Understanding these factors can help the author in this thesis to be more focused and organised when choosing the working teams (Networks) as the sample of this study statistical data collection.

The first factor deals with the collaborative characteristics and it consists of two elements:

1. *Synchronous and asynchronous collaborations*: are when working team members' collaborative processes are conducted at the same time versus when the members collaborating at different times.
2. *The proximity of collaborators*: deals with the geographical proximity of group members. In this thesis the author focuses on the working teams that members are in the same geographical location. This again comes from nature of the work teams in our sample in this study.

The second factor discussed by Warner et al., (2004, 2005) can be drilled down into more detailed characteristics of work team and consists of three elements:

1. Command structure; evaluates the structure of the team and answers whether the structure is flat or hierarchical.
2. Homogeneity; the level of socio-economical, racial, age and other factors that distinct level of similarity or diversity of the members of the teams.
3. Team size; the number of individuals that are forming the team.

Any work teams by nature can adapt one or multiple of above explained factors.

As its mentioned before being cleared about the type of the work teams which are going to form the sample (for the empirical study) in this thesis, can help the author to conduct a more focused and successful modelling analyses about the work teams' capability level in following chapters.

Having a sample for the study which includes work teams with every combination of factors (explained above) could not be done within the time limit of this study. For that reason is good to know that the work teams which form the empirical sample in this study are from which category according to Warner et al (2004, 2005) categorisation. As it will be explained in more details in the next chapter (6), the work teams which are going to be used as the sample in this study for statistical data collection purposes are student work groups who are given a group project to complete during their MSc course at Brunel University. As a result considering the nature of student work groups the sample in this study are work groups which firstly are: synchronous and all team members are present and work together to fulfil the requirements of given group project. The reason for narrowing it down is that if the work teams are asynchronous and group members are working at different times then there are possibilities that other external factors can affect each individual's work related capability

and measuring all those external factors can be out of this research's boundaries. Secondly the proposed work teams are located proximally and all members are working under same condition and at the same geographical location. The proposed work teams are also following flat structures which in all members are equal and there is no hierarchical structure exists between members. The aim is to test homogeneity of the team works to a high level.

Over the past few years the discussion about the right size of work teams has been in focal point of research in many related literatures. In this study also it's important that the author to come to a decision about the size of the work teams which will form the sample for the study's empirical survey. It has been felt by the author that reviewing other researchers' findings about the right size of work groups (to get the highest outcome from the groups) can provide right information to set the group size for empirical survey in this study. According to a research by Laughlin et al., (2006) published in *Journal of Personality and Social Psychology*, groups of three to five people are able to solve difficult problems better than even best individuals working alone. While researchers had hypothesised that groups of two would outperform an equivalent number of individuals, the results of the study actually demonstrated that groups of two people performed at the same level as individuals working alone. Also, while groups of three, four and five people performed significantly better than an equivalent number of "best individual" and two-person groups, these three groups did not differ from each other in terms of performance. The final results of the study therefore suggest "three group members were necessary and sufficient for the groups to perform better than the best of an equivalent number of independent individuals" (Laughlin et al, 2006).

Some older studies by (Cooper, 1990; Johnson et al., 1991 and Smith, 1986) have also suggested that groups of four or five work best. In larger groups not all members get the opportunity to fully participate and the less skilful the members the smaller the group should

be. Interestingly and in line with previous literatures' suggestions on the best number of members in a work group the author's observations from real work environment at different organisations have also given the author the confidence that number of three to five people in a group can results in better outcome. As results it has been decided by the author that work teams which are formed of 3 to 4 people can be suitable size groups for our proposed work teams in this study.

5.3. Current Methods for Human Work Teams' Formation; the Two Main Stages

Existing conventional procedures for selecting and putting individuals in a team to do a pre-defined project can be very subjective and varies from one field to another and from one organisation to another. What is common in all cases is that in the most scientific way the whole procedure can contain two stages: *Project analysis* and *individuals selection*. When project has been defined and requirements of the project became clear the process of selecting suitable individuals to form the project group will be performed. The second stage can be excluded from the whole procedure if the individuals are given the opportunity to from their project groups voluntarily. Reviewing the common tools and techniques which currently exist for the purpose of individual selection (for different projects in organisations) can actually help the author to identify the current techniques that are used for assessment of the collective capability of work teams as well. This is because some organisations have recently started to think about collective outcome of their proposed project teams from the early stages of formation of the groups and have considered the collective outcome in the whole process of group formation. So the two concepts (individuals selection techniques and capability measurement techniques are currently two highly related concepts).

The main aim over the next sub-sections is to provide a review on the relevant literature on various methods and theories on work group's formation. Consequently we will discuss any existing method(s) which currently is used to measure the collective capability of a group of people.

This chapter will be closed by identifying the gaps which exist in forming work groups and in measuring collective capability of individuals in a group.

5.3.1. Project Analysis Methods

In current conventional methods for the formation of work teams, Project analysis is the first step to be taken in selecting the right individuals for a pre-defined project. Some researchers such as Jaques (1996) expresses the fact that best method to analysis and understanding a big project is to break it into constitute tasks. He then clearly explains that "*Task is a quantity of things with a certain quality which should be done in a targeted time within a resource limit*" (Jaques, 1996). What is important to understand from Jaques's definition of task is that he has given four major attributes to each task: quantity, quality, time and resource. In our study our main focus (by the nature of the study) is on the fourth attribute (resources) which is required to perform a group project. Project analysis produces a list of knowledge, skills, abilities and other characteristics (KSAOs) required for the project (Schmmit and Chan, 1998). Traditional project analysis includes knowing and defining the project through the Subject Matter Experts (SMEs) such as supervisors or managers in the field.

While traditional project analysis aims at capturing the requirements for the project there is another technique which focuses more on the extreme situations which may happen during the life time a project (Phillips and Gully, 2009). This method which looks through critical situations and its consequences is called Critical Incident Technique (CIT) and has been

introduced by Flanagan 1954. In CIT method also the aim is to breakdown a big project into smaller and more manageable tasks and process further to chooses the right individuals and gather them in a group to fulfil the project. In CIT method, Flanagan (1954) suggests that one should start with analysing objectives and critical information about specific activities (tasks) within the project. The general outline of CIT method consists of five main steps: establish the aim of the project, stablish plans and specification of the project, collect the data about possible critical situations (that might happen during a project), analyses the data and finally interpret the findings. Both traditional project analysis method and CIT method are useful in breaking down a big project into its main components which easier to be planned about.

5.3.2. Individuals Selection Methods

The second stage in conventional work team formation (after defining and analysis the project) is selecting the best suitable individuals (from the pool of available resources). The final results of this stage (in current conventional team forming methods) can be formation of work teams which can perform on a pre-defined project with best possible outcome. The selection procedure to form the human work teams (groups) is a step by step process. The whole group forming procedure in most cases starts with finding the interested possible candidates for the proposed pre-defined project (screening stage). This step can be skipped if external resourcing is not available for the project, the first step which in this case includes searching among the existing (internal) pool of resources.

The second step of the individuals selection (first stage was screening) introduced by (Phillips and Gully, 2009) is named as evaluating step and mainly will focus on individuals' skills and characteristics (Phillips and Gully, 2009). This step's aim is to investigate and putting the most suitable individuals in a group which can result in best outcome. In each

stage of group formation a set of tools and techniques might be used. A summary of these tools are presented figure 5-1.

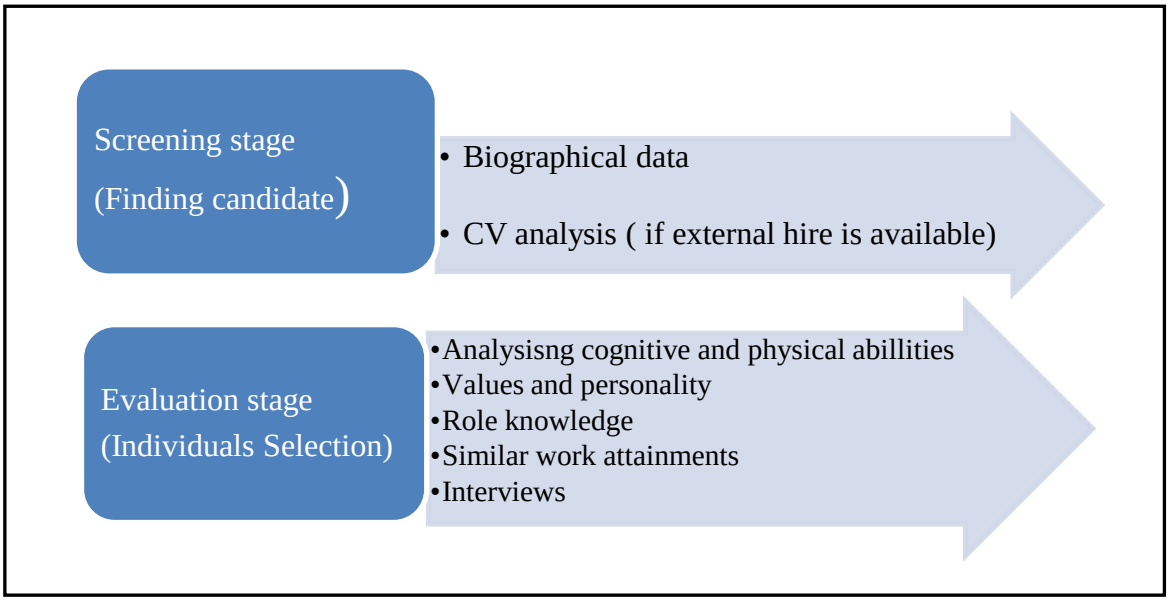


Figure 5-1 Tool and techniques in work teams forming (Phillips and Gully, 2009)

The two main stages of current conventional work team formation methods (Project analysis and Individuals selections) together have been used by managers and decision makers to form their required work groups with the hope that their formed work groups are those ones with best outcome. Even though following the two previously explained methods together could help the manger to reduce the risk of putting wrong individuals in groups but the main limitation which threats these methods is that there is no mathematical power (statistical models) behind these methods to predict and measure the collective capability of the formed groups. Hopefully findings of this study can fill this gap by providing a mathematical model which can help the managers to measure and predict the collective capability of work teams which they propose for their different projects.

One important aspect of the whole selection procedure using the screening and evaluating stages is the importance of biographical data which is attached to each individual's work history. The idea of using the biographical data for the purpose of individual selection has been widely used by many employers because they believe one's previous attainment and level of success can be a good predictor of his or her future success or loss (Mount et al., 2000). In the next section we will have a closer look at different individual selection methods which are currently used in conventional team forming method and the main aim of doing so is to investigate some of the factors which can affect the selection procedure in different circumstances.

5.3.3. Effective Factors on "Individuals Selection" Procedures

In the field of employee selection studies Robertson and Smith (2001) studied different methods for individual selection. Their study covered different selection methods such as interviews, personality test, bio data (using factual information about individuals' life and job experiences along with opinions, believes and values) and assessment centres (For more details about different methods look at *Personnel Selection* by Robertson and Smith, 2001). The results of this research in line with another major research by Browen et al., (2002) revealed that the selection criteria and processes varies nation to nation and culture and norms in each country can affect the selection procedures. For example Canadian organisations recruit people who their personal values are inline and match with the organisational culture and values. In Japan the highest score for selection criteria is given to individuals' trainability and their willingness to learn new skills (Robertson and Smith, 2001).

It's important for any organisation to pay attention to the economics side of selection processes. As for example Robertson and Smith (2001) in their research pointed out the

doubts in cost effectiveness of some techniques such as assessment centres for recruiting in small companies.

Phillips and Gully (2009) have also discussed the economics of selection methods based on their effectiveness possibility. They suggest five evaluation factors which enable organisations to compare and evaluate different selection methods. According to the five evaluation factors they used, they have been able to show that even though some techniques such as assessment centres and simulations can have good applicant reaction and have low advertise impact but their cost may make them a restricted tool which cannot be practical in many small to medium size organisations. In contrast they have found that some common tools such as personality tests review method are more practical and wieldy use in many organisations.

In summary choosing a cost effective selection criteria is an important exercise for team building. However the limitation of this study wouldn't allow the author to focus on the economic side of the team building analysis. But this at least will give a good direction which can open a good area of research for interested researchers.

Some of the most common tools and techniques for individual selection are listed in a table which can be found in appendix A. Each technique's pros and cons are explained in the same summary table.

In the next section the author appraises the existing models and techniques for measuring the collective level outcome of work teams. The appraisal will help us to highlight the gap in this area and suggest a suitable conceptual model for prediction of collective capability of work teams in this study.

5.4. Teamwork Models, Existing Models, Tools and Techniques

Any applicable model proposed for measuring the "collective capability" of a work team must be able to differentiate between individuals' capability and the collective capability of a team. In other words the proposed model (approach) must take into account the effect of individuals' interactions, co-ordinations and qualities into consideration. Smith et al., (2007) argue that a work team may fail in a project because the necessary information was not circulated effectively among the members which this can be as a result of a team level problem. However the same team may make the same mistakes because one of the members made a technical error or didn't have enough skills in a required field. This time the problem which has caused the team falter is an individual's level. The interpretation of the author to Smith et al., (2007) explanation is that, one should consider both individual level and team level capability factors (indicators) in modelling the collective capability of work teams.

Some previous researchers in the field of human system interaction and virtual reality (VR) such as Smith et al., (2007) believe that a useful method of measuring team level performance is by evaluating both outcomes and the quality of implementing the key processes in fulfilling a project. By outcomes they meant the end result of team performance (e.g. number of target hit) and by processes they meant the specific behaviours and performance strategies that explain how and why a particular outcome occurred. Some of the commonly used outcome measures include timeliness of group project, number of errors the group made during the project life cycle. In the case of measuring the quality of processes the efficiency and effectiveness of interactions, communications of leaders and members are considered. Final point to add to this is that even though the main aim of work team is to achieve to successful outcomes but measurement of processes and specifically members'

interactions is critical to diagnose performance related problems. For example it might be the case that a team has made a good decision despite poor interactions and communication among members. If the feedback to team is solely based on the levels of achievement of the outcome the shortcoming in the processes may not be corrected. As a result in this study the author has an attempt to cover both outcomes and interactions of work teams while modelling collective capability of work teams.

5.4.1. A number of effective Models for measuring team work outcome, Currently Exist

The US Army Research Institute for Behavioural and Social Sciences (ARI) is one of few research centres that have developed a PC-based unit collective Performance Assessment tools around the globe to support training feedback among army training teams. The tool which has been developed by them is called *Unit Performance Assessment System* (UPAS) and can help to eliminate some of the limitation with the previously built tools by them.

The UPAS tool is mainly designed to assess the collective performance of training teams in US army. The tool is simple and practical as it can be used by trainers and researchers to interpret the provided animated figures and tables. The UPAS tool's main menu has five divisions: Data collection, Data summary, Performance measurement, Archive database and Utilities. The data collection option is to collect data from recorded exercises and lode the data into database. The data summary option can summarise the data into graphs, charts and tables which can then be interpreted by the user. The data performance measurement and archive data base which are the two main options of the tool actually compare the achievements of the training teams against the set targets and standards. It has been designed in a way which can allow the user to change task, standards, targets and measure of performance. The more detail about how the tool has been designed was not available at the

time of this study because of the security reasons of US army. From the information which was available to public at the time of this study it understood that the final outcome of the tool provides feedback by performing all statistical data analyses in real or near real time. It collects data packaged and translates the collected data into relational databases. The data is further used to produce reporting tools such as maps and graphs displays of unit performance (Meliza and Tan, 1996). In a summary the UPAS tool compares the training teams' performance against a set of targets but it doesn't provide any statistical model for actual measurement and prediction of the capability of teams.

5.4.2. Shared Mental Model (SMM)

Pascual et al. (1998) believe for work teams to be effective and successful it is important for members to be able to predict what are requirements and expectations form team members.
This perspective is explained by hypothesising that team members exercise shared or common knowledge bases, i.e., shared mental models. Shared mental models are understood as "knowledge structures held by members of a team that enable them to form accurate explanations and expectations for the task, and in turn to coordinate their actions and adapt their behaviours to the demands of the task and other team members" (Pascual et al ,1998). In other words the greater the similarity and overlap in team members' model the greater the likelihood those members will predict and consequently adapt and co-ordinate with one another successfully. In other words this kind of model (Shared mental model) mainly works with the level of familiarity of members from each other can be also used as useful tool when members from one team needs to co-ordinate with members from another team. In these scenarios a measure is required to assess the degree of overlap between members from different teams.

Although it has been discussed that shared mental models can be used as to explain the work team collective outcome but there are few methods for investigating the shared mental models (Smith et al., 2007). Different researchers from different disciplines have used different methods to relate the shared mental models to team level outcome. For example in a recent study by Jo (2012), the shared mental model has been used to explain the performance of e-learning development teams. In his research it has been hypothesised that team members interactions' will result in development of shared mental models which can lead to similar interpretations of the given task and finally achieving better outcome for the team. To measure the SMMs the instrument developed by Levesque et al, (2001) has been used in his research (to read more about the SMM's measurement the work done by Levesque et al, 2001 is recommended).

5.4.3. Integration Organisation and Cohesion (IOC) Count Analysis Model

In a programme in 2003, UK Ministry of Defence (MOD) funded a research to develop a metrics to quantify the effectiveness of training for all levels and types of armed force teams. The research resulted in a novel approach to measure and represents the collective performance of teams. This approach is known namely as Integration Organisation and Cohesion (IOC) model and develops objective metrics and a methodology which will provide the MOD with a quantitative means of representing collective training among armed forces teams in a high level Operational Analysis(OA). The proposed IOC model considers the balance of investment and cost effectiveness models.

In this method a descriptive model provides the framework for measurement criteria. The proposed model is built based on this assumption that collective performance of a team of individuals is based on improvements in integration (I), organisation (O) and cohesion (C)

across the relevant people in a team. The model's outcome can provide a metric to assess how well a collective set of people are working together and thus used to quantify the extent to which collective training has had an impact (Smith et al 2007).

The IOC model breaks down the team's activities into two main types: *task work* and *teamwork*. The model assumption is that successful collective outcomes can be result of both good task work (sub-unit, e.g., formation performance) and good teamwork (processes).

The main idea in the IOC model is that there are three patterns of interaction within teams: actions based on response to orders, actions based on the need to co-ordinated with other individuals in the team and actions based on loyalty to the team.

The three patterns of interactions among individuals in a team are then translated into three constructs:

1) *Integration*: the extent to which realignment of team's goals arises as a result of interventions by the team leader. The integration can happen when orders and comments come from the team leader or as a result of information flow between team leader and team members in a group.

2) *Organisation*: the extent to which the functions of the members are distributed and aligned to achieve to the team common goal. This can happen through lateral communications which results in situational awareness or making suggestions among team members.

3) *Cohesion*: the extent to which the realignment of goals arises from group members themselves. Cohesion can arise as a result of reinforcing or supporting type communications.

The IOC model final hypothesis is that: state of a team in terms of *Integration*, *Organisation* and *Cohesion* would provide an indication of the effectiveness of the team as a whole. The proposed model assumes that the higher the scores for these attributes the more likely the behaviour which can support the overall goal of the team.

The main limitation of the IOC model is that it's more applicable to teams and work groups with hierarchical structure and where communication is central to success.

Over the past three decades very few tools and methods have been introduced by researchers to quantitatively measure the collective performance among teams. In an attempt by Dwyer et al, (1998) a technique was introduced which specifically aims to measure teamwork in a distributed training environment. These tools known as Event Based Training (EBT) links learning objectives, exercise events, performance measures and After Action Review (AAR).

Dwyer et al., (1998) have been first researchers who used the application of EBT approach systematically in a distributed training environment. They used the EBT to develop performance measures, namely as the TARGET checklist and the TOM instrument, which will be explained in the next sub sections.

5.4.4. The TARGET Checklist

The TARGET method which stands for Targeted Acceptable Responses to Generated Events or Tasks is an event-based method which involves the identification of events for training sessions. This method helps team members to exhibit examples of team behaviours.

In this method Dwyer et al., (1997) suggested to agree on an acceptable set of responses for each task in advance of the exercise. Anticipated behaviours for each training exercise can be captured based on training manuals, SME's inputs. In the next step the behaviours related to each training exercise will be arranged into a checklist in an approximate order they might occur during the exercise. As the exercise unfolds the person who acts as an observer in the exercise scores each event or task as acceptable, unacceptable or unobserved. Finally the collective performance of the whole team for each training exercise can measured in two different ways. One way is to calculate the proportion of behaviours correctly performed (to

acceptable level) to total set of behaviours. This simply can be the fraction or percentage of the tasks or behaviours which have met the pre-agreed target across the whole team (For example: number of tasks which have met the target divided by total number of the tasks in the project). The other way is to group the behaviours into functionality related clusters, which can be examined to see how well the whole team have performed during the training exercise. In this way the behaviours and tasks which are similar by nature (for example all computer related tasks or mathematical tasks) will be grouped together and then the process of evaluation of the grouped tasks against the target will be considered.

This method of measuring collective performance is mainly useful when one is trying to measure the collective performance among training teams which can actually limit the use of this method across other disciplines. The other limitation to this method is that it's only applicable in places where behaviours are observable and the observer (instructor) can determine if each behaviour has been hit or missed.

5.4.5. The Teamwork Observation Measure (TOM Method)

The Teamwork Observation Method (TOM) as the second performance measurement method introduced by Dwyer et al., (1997) was adapted from performance measurement techniques developed by US navy for tactical decision making under stress and critical situation (Muniz et al., 1998). The main aim of TOM method is to identify and highlight the strengths and weaknesses areas of performance of work teams which can lead to performance rating of work teams.

The TOM method's main focus is on four dimensions of working teams: communications, co-ordinations, situational awareness and team adaptability. Each of these four dimensions

then divided into its own key elements. The four main dimensions of TOM and the key elements can be found in figure 5-2:

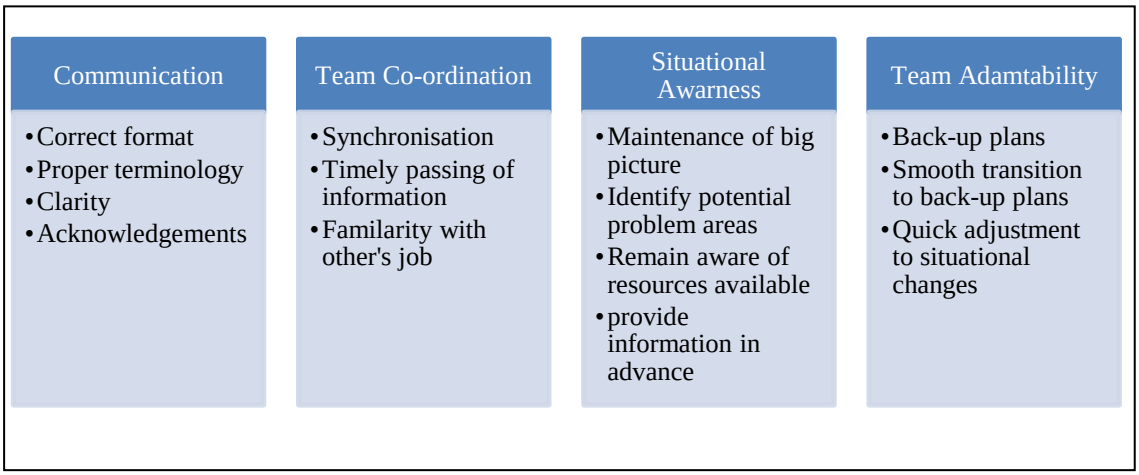


Figure 5-2 TOM dimensions and Key Elements (Smith et al, 2007)

In TOM method similar to TARGET method the assessors play a vital role in performance measurement as they need to provide specific comments on each dimension and the related key factors based on their observations made to be highlighted the critical points. In this method the assessors also provide rating of how well team members interact with each other on each of four main dimensions of TOM method.

A real life example which can explain the use of TOM model is the programme done by University of Washington (school of Medicine) in 2010 which aimed to provide support to local families to meet their children and youth complex and unique needs the TOM model used to assess the support teams' performance. The family driven, team based process for planning and supporting the local families in this programme is called *wraparound*. The wraparound team members identified the youth and children with unique and holistic needs and their families, their community members and their mental health professionals and meet them regularly to make sure about the supporting program's success. The observers in this programme used the TOM model to assess the quality and high standard of wraparound team

meeting sessions. The TOM model in this programme is organised according to 10 principles, with two items dedicated to each principle. Consequently each item has 1-5 indicators, which must be scored: Yes (if the item observed), No (if the time was not observed) and N/A (if the item was not applicable) during the wraparound meetings. The observers in this programme started the assessing process with recording some basic information about number of meetings, number of team members in attendance and demographic information. The indicators must be scored by observers as either "Yes" or "No" and of course for some indicators "N/A" would be an appropriate response. Needless to say " Yes" must be scored if the indicator was observed to have occurred during the meetings, "No" must be scored if the indicator was not observed to have occurred and "N/A" if for some reasons for an indicator the observer ca not provide either "Yes" or "No" score. In the next stage after scoring all indicators (Yes, No or N/A for all indicators within an item), the observer must assign a ranking score (0-4) to each item as a whole in a way that each item can get assigned a response scale from 0 to 4 whereby: 0: none of the indicators for this item were observed during the meeting sessions, 1: some but fewer than half of indicators for this items were observed, 2: about half of the indicators for this item were score "Yes" and 4: if all of indicators for this item were evident during the observations. Table 5-1 shows the results of calculating the response score (in different scenarios, based on number of "Yes" score for different item in TOM model:

Table 5-1 calculation of response score in TOM model (Bruns and Sather, 2010)

number of indicators that can be scored in the item	number of indicators score "Yes"	Item Score
5	5	4
	4	3
	3	2
	2	2
	1	1
	0	0
4	4	4
	3	3
	2	2
	1	1
	0	0
3	3	4
	2	3
	1	1
	0	0
2	2	4
	1	2
	0	0
1	1	4
	0	0

Finally using the response scores for each item in the model observers in this programme can decide how well the teams have done during the meeting sessions. This was just an example of using the TOM model in real life for assessing work team's outcome. This method can be adapted in any other similar team work environment which involves meetings and training sessions. In using the TOM model it's important that the observers should be well oriented with the scoring rules for each item and must be presented in each session.

Similar to TARGET method the TOM method also has some limitations which make it an unlikely tool which is neither a perfect or a general tool to measure collective performance. For example the author believes the role of instructors and assessors in both methods can increase the chances of human errors and untrustworthiness of these methods. As it also mentioned while explaining the methods, these methods are mainly useful in assessment of performance among training teams and adapting the methods in working teams with different natures from different disciplines is not a simple task. As a result it has been felt by the author that a more generic statistical model which can be used in varied disciplines to measure the collective capability of working teams can narrow the current gap in this area.

5.5. Conclusion

This chapter gave an insight on human work team formation and on how the work teams form in real life. Different stages of formation of work teams and the most common methods for work team selection disused in the first part of this chapter. The second part of this chapter focused on team work models and current tools and techniques which are in used for measuring the performance of the work teams. Specifically a collective performance tool which is built by US Army (UPAS) and two of the most common models for measurement of team level performance (shared mental model : **SMM** and Team Observation Model: **TOM** model) model was discussed and explained in details.

Its learned from this chapter that most of the current available tools and techniques for team level outcome (performance) measurement, are designed by specific organisations (e.g. US Army or UK MOD) and the limitations of the tools make them to be useful tools to measure the collective performance of teams only in those organisations or in the best scenario to be useful tools in a very similar environment. In addition some of the existing models (such as

TOM, and TERGET Checklist) require high level of human judgment (observers) in assessing the work teams' performance. The author believes the high level of judgment form observers in these two methods can increase the chance of human error and may result in not accurate measurement of working team outcome. Finally it has been understood that none of the existing tools/models takes into account simultaneously the effect of individuals level capability elements (such as individual's skills) and network level capability elements such as relationships among individuals or network homophily. Our proposed model in the next chapter aims to fill this gap by examining the effect of both individuals level and network level capability elements on the whole team collective capability level. The final results of this study will hopefully help managers and team builders in forming the most capable team out of their possible pool of resources.

Chapter 6

Conceptual Model Development and Empirical Survey Design

Based on the review of current body of knowledge and reviewing literature regarding human capability evaluation in previous chapters the author believes that there is an opportunity to propose the foundations of a conceptual model for measurement of collective capability of human work groups.

In this chapter a conceptual model for modelling collective capabilities of a network of human (work group) is put forward that satisfy the framework for measuring network capability.

This chapter will start with an introduction on the terminologies which are used in the modelling process with a specific focus on the four nominated capability factors as independent variables in the proposed conceptual model. A novelty of this modelling study is because of the fact the nominated capability factors in this study can cover characteristics (elements) related to both: individuals in the networks and their relationships. This is the first approach in modelling the human networks' collective capability which takes into account capability factors which are related to people's (individuals in the network) characteristics and their relationships in the network.

The second subsection of this chapter will define an algorithm which will explain the proposed model building procedure step by step.

This chapter also explains the design procedure of an empirical survey which has been used in this study with the aim of collecting required statistical data to test and validate the proposed model.

By the end of this chapter conceptual development of collective capability assessment model and the empirical survey to collect statistical data to test hypotheses (in further chapters) will be finalised.

6.1. The Terminologies Used in the Proposed Collective Capability Assessment Model

The main terminologies and concepts introduced for modelling purposes in this study are:

Node: a member of a network (work group) who owns a set of inherent and acquired skills that he/she uses them to contribute to a given pre-defined project. A node can interact with other nodes in network.

Skills: are set of inherent and acquired abilities of a node that collectively contribute to performing a pre-defined project.

Project: set of operations with a certain quality which should be completed in a given time within the limitation of available nodes. A project is a combination of smaller tasks each of them necessary to accomplish the whole project.

Task: a transformation from one state to another state for the network within a given time. A task can be done either by an individual or set of nodes in a network.

Work Group (Network): a network is a distinguishable set of two or more people who interact dynamically, interdependently, and adaptively towards a common and valued goal/objective/mission, borrowing from (Sales et al., 1992).

The four independent nominated capability factors and dependent variable (collective capability of the network) in the proposed model are:

Demographic Homophily (H): the degree of similarity of demographic characteristics such as gender, age and ethnic background among nodes in a network.

Diversity of Skills (D): the variations in type, nature and levels of required skills (to accomplish a project) among nodes in a network

Average Previous Attainment in similar projects (A): the average of previous experiences and attainments of individuals in a network relevant to the given project to the group.

Interaction Strength level (S): The frequency and level of instrumental (Task related) relationships among nodes within a network.

Collective Capability (CC): is an amalgamation and demonstrable by measuring the four nominated capability factors (demographic homophily, skills diversity, average previous individual attainment and nodes' relationships strength).

Based on finding in this research the collective capability of a network (work group) could be assessable using the four main capability factors. The model that the researcher is proposing in this research is named "HDAS" model which each letter represents one of the four nominated capability factors explained earlier. The four capability factors are the building block of the proposed model. Next subsections in this chapter will further explain the details of the four capability factors and the method which is used to measure each capability factor.

6.2. "HDAS" Model, The nominated Capability Factors

The proposed "HDAS" model expresses collective capability of a group of nodes in network as a function of the networks' demographic homophily (H), diversity of the required skills among the nodes (D), average level of previous attainment of nodes in a similar project (A) and finally strength of the instrumental relationship among the nodes within the network (S). In other words collective capability of a network (N) in performing a pre-defined project (P) is:

$$CC_{Np} = f(H, D, A, S) \qquad 6.1$$

For the sake of clarity the "HDAS" model is expressed in a visual diagram in figure 6-1 followed by detailed explanation about each capability factor.

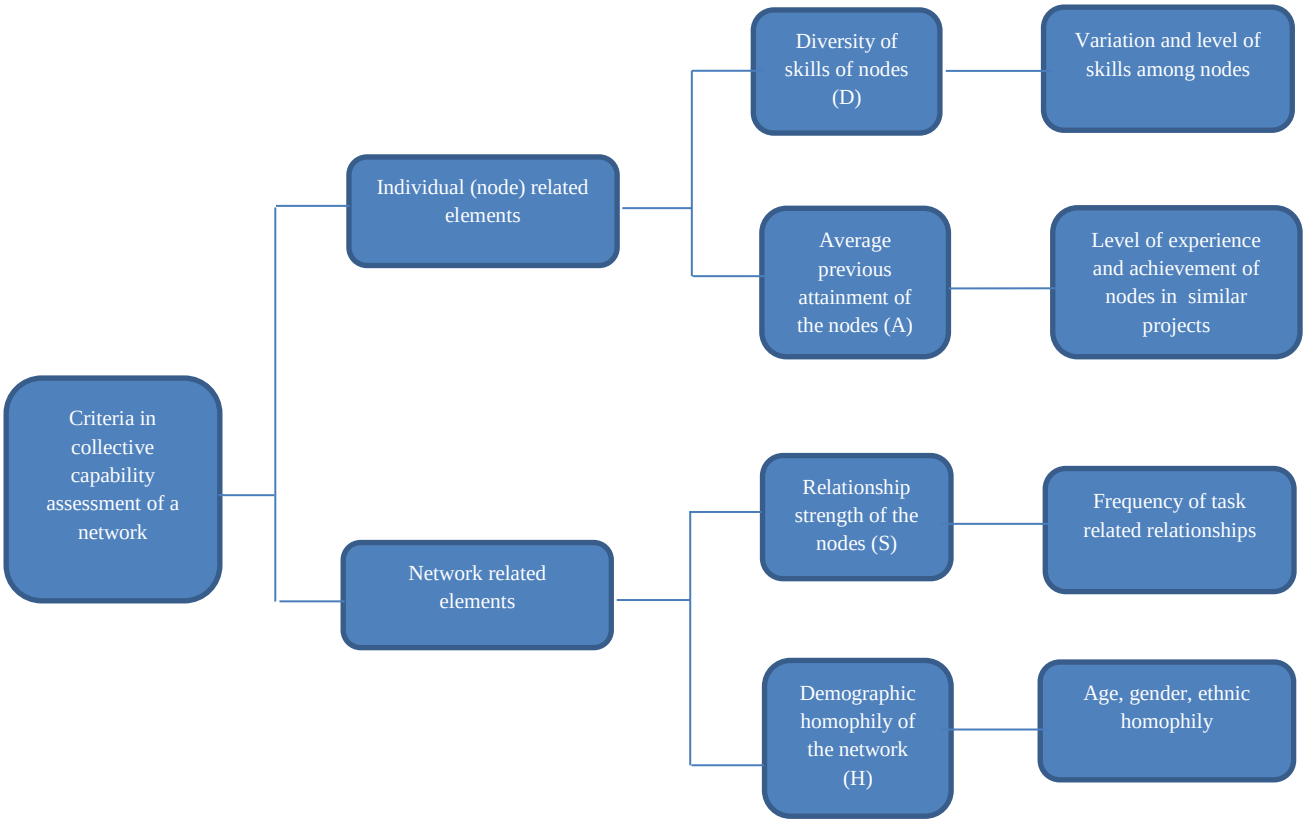


Figure 6-1 framework of network collective capability assessment in proposed "HDAS" model

The framework in figure 6-1 is an interpretation of "HDAS" model principles. It is stated in this framework that a model which will include both individual (node) related and network related criteria of capability can be a comprehensive model to predict the collective capability concept at network level. In other words if a capability model only focuses on one of the two criteria provided in above framework; only node related or only network related elements then the outcome of such model will ignore an important portion of characteristics and results in an unrealistic picture of a network's collective capability. The defined hypotheses in the next chapter will test the relationships between the four nominated capability factors and the collective capability of the human work groups.

6.3. Algorithm of "HDAS" Model; Overall View

This section lays out the steps which need to be followed as an algorithm to measure the four nominated capability factors in building "HDAS" model. Before moving to the explanation of the proposed algorithm a brief background about each nominated capability factor can keep the readers' mind more focused around the capability factors used in "HDAS" model. In a general view the algorithm of "HDAS" model building presented in this study is consist of four main parts which will be explained in subsections 6.3.1 to 6.3.3. The first part mainly focuses on the profiling and analysing the project (major work) to be done by the work groups. This part of algorithm mainly discovers the nature of the project, variety and level of skills required to perform that specific project. The theoretical background and idea of this part was taken from literatures which their main focuses have been around project management and work breakdown structure to plan projects. The reason that the author has decided to start the algorithm with breaking down the group project into smaller tasks is that according to (Heagney 2012), "a major problem for group project planning which might end

up to the project's failure is determining how long big projects take and how much it will cost". Sometimes it has been seen a significant part of the project has been forgotten or sometimes inaccurate estimation of time and cost have led the projects to failure. As a result the most useful solution to all these threats (provided by Heagney, 2012) is to use work breakdown structure (WBS) when planning the big group projects. The idea of using WBS is simple: you only need to breakdown the complicated and big given projects into smaller manageable tasks which are much easier to estimate about operations and timing. A simple example of breaking a big job into smaller tasks using WBS is presented in appendix B. Heagney, (2012) recent book on Fundamental of Project Planning is recommended for further reading about WBS.

In line with Heagney's solution for project breakdown before planning, the IPS (Integrated Project Systems) associates Inc. (2003) also expresses the fact a key to successful project scheduling and delivery regardless of the industry is to break down the projects into smaller tasks before even promising delivery dates, resource constraints or task dependencies. As a result the first part of proposed "HDAS "model algorithm in this study will cover project breakdown and identifying required skills for the project.

The second part of the algorithm explains the methods for measurement of the node related capability factors (skills diversity (D) and average previous attainments of the members (A)). This leads to the third Part of the algorithm which focuses on the measurement methods of the network related capability factors (demographic homophily level of a network (H) and instrumental relationships' strength among members (S)). In fact part 2 and 3 of the algorithm is inspired from framework 6-1 presented earlier in this chapter. The fourth and final part of the algorithm actually finalise the whole procedure and involves mathematical

models for the purpose of model building which will be discussed in details after conducting the empirical survey and analysing the data in the next chapter.

6.3.1. Part one of Algorithm, Project analyses and Breakdown

As its explained in section 6.1 the first part in "HDAS" model building algorithm is about breaking down the big group project into smaller tasks and consequently set the requirements of the each task respect to its required set of skills (i.e. computer skills, specific software knowledge, communication skills, etc.).

The nature of the proposed "HDAS" model in this study does not require applying top down or bottom up task lists. In other words it doesn't necessarily matter to list the tasks according to their importance to the project. What is vital to achieve from this part of the algorithm is a breakdown of a major project into smaller tasks and list all the required skills (for each task, according to expert in the field).

The part one of the algorithm includes the following steps:

Beginning of the "HDAS" model algorithm

Step 1: identify the tasks within the major work (group project), so we can say to fulfil the requirements of a project ***(P)***, a set of tasks $\boldsymbol{T = \{T_i\}}$, for $\boldsymbol{i=1, 2,\ldots I}$ needs to be performed. Where, ***I*** is the number of tasks within the project ***P***.

Step 2: define each task as a set of required skills

$\boldsymbol{T_i = \{S_{ij}\}}$, for $\boldsymbol{i=1, \ldots, I}$ where ***I*** is total number of Task within the project

$\boldsymbol{j=1, \ldots, J}$, where ***J*** is the total number of required skills for each task.

Step 3: Assign the minimum and maximum required level of each skill for performing each task and name this value as $X_{S_{ij}}$ and $Y_{S_{ij}}$ which represents minimum and maximum level of j_{th} skill for i_{th} task. The result of this step will help in further steps in algorithm, to measure individuals' skills level and consequently the diversity level of the skills among individuals in the network.

The whole procedure of part one of the "HDAS" algorithm (explained in 6.3.1) is shown schematically in figure 6-2 below. The final outcome of this part of the algorithm (Step 1, 2, and 3) as it can be seen in figure 6-2 is to breakdown a big group project into its smaller task and identify the require skills to perform on those task. :

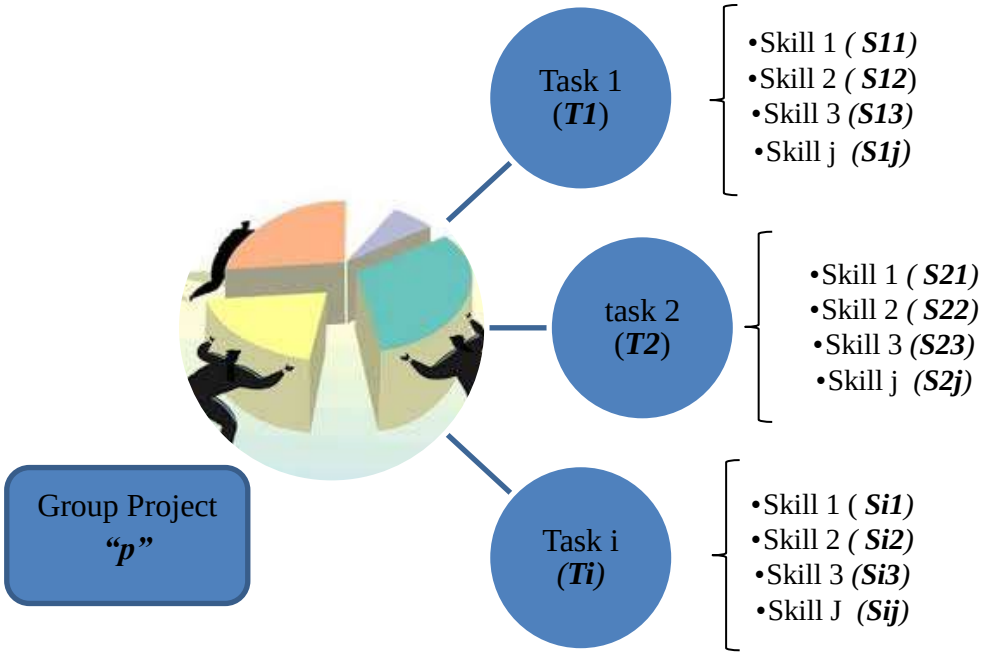


Figure 6-2 schematic representation of Part one of "HDAS" Algorithm

6.3.2. Part Two of Algorithm, Node Related Capability Factors Measurement

This part of algorithm covers the measurement of Skills diversity of individuals in the network **(D)** and average previous attainment of the individuals **(A).**

From results of step1 and 3 of algorithm a set of required skills $\boldsymbol{S_{ij}}$ for the project and also minumim and maximum required level of each skill $\boldsymbol{X_{S_{ij}}}$ and $\boldsymbol{Y_{S_{ij}}}$ have been identified. Now to meausre the capabillity factors the folowwing steps need to be followed:

Step 4: pending the nature of the project (***P***) given, classify the identified required skills ($\boldsymbol{S_{ij}}$) so that similar skills are grouped together. This classification is needed to be able to use the entropy based diversity index in further steps to measure the actual diversity of skills among individuals in a group. Grouping the similar skills together results in having ***K*** categories of skills, so we have:

($\boldsymbol{C_K}$), *where* ***K=1, ….K*** and ***K*** is the number of categories which skills grouped into. The number of skills in each category can be varied depends on the similarity of the required skills for the project. So every $\boldsymbol{C_K}$ can consist of **1** to ***m*** skill.

For example :Assume a project in a postgraduate level classroom is to submit a group assignment for Systems Modelling and Simulation module, which requires a set of skills that are classified into three categories (*Ck*), where *K = 1,… 3.* The required skills to fulfil the project' requirements fall into three main categories, *Written Report*, *Analytical Skills* and *Software Skill*. Each category itself can contain a number of skills. (E.g. written report category contains fluency in language, organisation of though and time management, each of this are counted as a required skill to perform the whole simulation project).

Step 5: identify each individual's (from the network **N**) level of expertise on every skill from $\{ \boldsymbol{S_{ij}} \}$ using a Likert scale between $\boldsymbol{X_{S_{ij}}}$ and $\boldsymbol{Y_{S_{ij}}}$. The results of this step will feed as input into **step 6** to measure a value (for each node) which represents total score of that individual in every category of skill defined in step 4.

Step 6: for each node in the network ***(N)*** assign a value $V_{(nm)_k}$ which is the summation of his/her scores on all skills which seat in each category of skills **($\boldsymbol{C_K}$),** defined in step 4.

Therefore for each individual n= ***[1, 2…, N]*** add all the values of his/her skills in each category and repeat this until the sum of all skills for individual ***n*** is calculated in each category of skills. Therefore;

For n =1 and k=1,…K $\quad V_{(1m)_k} = \sum_{m=1}^{M} v_{(1m)_k}$

For n=2 and k=1,...K $\quad V_{(2m)_k} = \sum_{m=1}^{M} v_{(2m)_k}$ **6.2**

For n=N and k=1,...K $\quad V_{(NM)_k} = \sum_{m=1}^{M} v_{(Nj)_k}$

Step 7: based on the results from step 6 assign each individual *(n)* name to the category of skills that he/she score the highest $v_{(nm)_k}$. In the case that one node scores same value in more than one skill category put his/her name under the category which best describe his expertise (according to his previous experiences and career history).

Doing this can assign every individual in the network to one of the categories defined in step 4.

For example: if the calculation in step 6 has shown that first individual in the network has scored the highest value on third category of the skills then this individual belongs to category 3.

Step 8: with respect to categorical variables and using the entropy based diversity index adopted from (Teacman, 1980) measure the whole network's skills diversity level.

$$D = -\sum_{k=1}^{K} P_k \, (lnP_k) \qquad \textbf{6.3}$$

Where,

$$P_k = \frac{number\ of\ individuals\ in\ the\ \boldsymbol{kth}\ \ category}{Total\ number\ of\ individuals\ in\ the\ network} \qquad \textbf{6.4}$$

The calculated index in this step **(D)** takes into account how individuals in each project group are distributed among the possible categories of required skills for the project.

Step 9: Calculate the Average previous attainments of nodes (***A***) in the network (***N***) using formula 6.5 below:

$$A = \frac{\sum_{i=1}^{N} P_i}{N} \qquad \textbf{6.5}$$

A: average previous attainment of the whole network with **N** nodes

$\boldsymbol{p}_i$: Previous attainment of individual i in a similar project (if the individual has any similar experince)

N: number of nodes in a network

The above formula suggested in this step to quantify previous attainment of the whole network in similar projects. It is taking into account the average of previous individual attainments (from each node in the network) attained on previous project with similar nature and requirements to the current project.

Creation of a scalar system in which the individuals themselves or their managers (supervisors) can specify their previous attainments in a similar project can be useful in conducting this step of the algorithm. In many cases in practice individuals' curriculum vitae or a reference from previous employer would allow the capability evaluator to define a level of previous attainment for the individuals. In some other cases "previous attainment" of an individual could be his/her attainment from a similar project (given to the group) which he/she has done in smaller scale (individually) in the past.

6.3.3 Part Three of Algorithm, Network Related Capability Factors Measurement

This part of the algorithm helps to measure the two capability factors which are derived from nodes' relationships and nature of human network. The two capability factors, average demographic homophily of the network (H) and instrumental relationships' strength (S) will be measured in following steps.

Step 10: In this step the homophily value related to each node in the network will be measured using the ***point correlation coefficient technique*** introduced by Grower and Legendre (1986). The individual homophily value (for each node in the network) will be calculated with respect to a set of predefined characteristics (i.e. gender, race, age…). This value is represented by $\boldsymbol{h_{id}}$ (i_{th} node's homophily value for d_{th} demographic characteristic) where

i=1, …, N represents number of nodes in the network

$$h_{id} = \sqrt{\left[\left(\frac{a}{a+c}\right) - \left(\frac{b}{b+d}\right)\right]\left[\left(\frac{a}{a+b}\right) - \left(\frac{c}{c+d}\right)\right]} \qquad \textbf{6.6}$$

a is the number of ties an individual sends to individuals with the same characteristic.

b is the number of ties an individual send to other individuals from opposite characteristic categories (i.e. opposite gender if measuring the gender homophily)

c is the number of people (nodes) with the same characteristic who the individual could have cited but chose not to.

d is the number of people (nodes) with opposite characteristic who an individual could have cited chose not to.

It's important to mention that to be able to measure the homophily values for each node in the network (with respects to each demographic characteristic) first we need to draw the network of instrumental relationships among nodes in the network and then represent each node using the demographic characteristic (e.g. gender: male/female) which the calculation will be regards to.

In the special conditions where either all the individuals in the network fall into same characteristic group (i.e. all male nodes) or in a situation where one node is the only node in a category (i.e. only one male and all others female), then the special case of formula (6 or 7) apply and formula 6.6 will respectively be replaced by either formula 6.7 or 6.8 depends on which of the two special conditions (explained above) is the case:

$$h_i = \sqrt{\frac{a}{a+d}} \qquad \text{if all nodes from same characteristic groups} \qquad \mathbf{6.7}$$

$$h_i = \sqrt{\frac{b}{b+d}} \qquad \text{if one node is the only one in a category} \qquad \mathbf{6.8}$$

Because in these special situations having ties with individuals from opposite characteristic (for example having ties with females, if everyone in the network is male) is impossible so the formula (5) for measuring the homophily has been amended and have been replaced by either formula 6 or 7 in this part of algorithm. The main point of calculating homophily values in this way is that, it takes into consideration the possibilities which a network offers to its' nodes for building ties with other nodes with specific characteristic. For example if there is no female in a network so there is no chance to build an instrumental relationship with a female node for any of the male members in the network. So this must be considered when calculating the homophily values using point correlation coefficient technique (formula

5). This has been done by amending and replacing formula 5 with either formula 6 or 7 if one of the two special conditions (explained earlier) is true about a specific network.

Step11: the homophily level of the whole network (regards to each demographic characteristic) is calculated as the average of individuals' homophily values on the characteristic calculated in step 10 using formula 6.9 below:

$$H_d = \frac{\sum_{i=1}^{N} h_{id}}{N} \qquad \textbf{6.9}$$

$\boldsymbol{H_d}$: Network's homophily level on d_{th} demographic characteristic

N: number of nodes in the network

D: number of demographic characteristics considered in the study, ***d= 1,…D***

Using the average of individuals' homophily values (as suggested above) to calculate the whole network's homophily level can help to reduce human biases and errors if any of the individuals in the network did not provide the correct information while measuring the individual values. The average also can be seen as an item which could replace and represent all other calculated individual values for the whole network in terms of homophily values.

To clarify the calculation of homophily level of a network using the method explained in this part of algorithm an example of calculating for a simple network is in appendix C.

Step 12: For every pair of nodes in the network (N) ask them to self-report the frequency of instrumental relationships between the pair during the project life. For each pair of node we initially record two values (one provided from each node) as the frequency of instrumental relationships between them. So for node ***i*** and node ***j***:

$\boldsymbol{f_{ij}}$**=** frequency of instrumental relations between the pair provided by node **i**

f_{ji}= frequency of instrumental relations between the pair provided by node **j**

Step 13: take the average of f_{ij} and f_{ji} for node i and j and record it as the average frequency of instrumental relationships between node i and j

$$\mathbf{F_{(i,\,j)}} = \frac{fij+fji}{2} \qquad \mathbf{6.10}$$

Calculating of the average of frequency of instrumental relationships between each pair of nodes in the network can assist to deal with the possible upward or downward biases in nodes' self-reported information; the two matrices will be symmetrised by taking the average of responses from any pair of nodes involved in the relationships (Borgatti, et al., 2002). For example if node A reported the frequency of his/her communicating (instrumental relationships) with node B four times during the project life, and node B reported instrumental relationships with node A, six times during the project life, the average frequency of instrumental relationships between nodes A and B will be recorded as five.

Step 14: normalise the value of **F(i, j)** for each pair of nodes in the network to a value between 0 to 1.

$$\mathbf{F(i,\,j)} = \frac{F(i,j)-F(Min)}{F(Max)-F(Min)} \qquad \mathbf{6.11}$$

Where, F(Min): smallest value of instrumental relationships' frequency recorded in the network

F(Max) : Largest value of instrumental relationships' frequency recorded in the network

Step 15: calculate the whole network's instrumental relationships' strength factor (S) using the average of relationships' strength between all possible pair of nodes in the network.

$$\mathbf{S} = \frac{\sum_{1 \le i \le N} \underset{1 \le j \le N}{F(i,j)}}{N}$$ where i≠j and N= number of nodes in the network **6.12**

End of the HDAS model building algorithm

The 15 steps algorithm provided in this chapter have formed the fundamental of collective capability model building in his research. In the following sub sections the application of this algorithm in a real case empirical study will be demonstrated.

To make it easier for the reader to follow the "HDAS" model algorithm a schematic representation of the 15 steps of the algorithm is provided in figure 6-3.

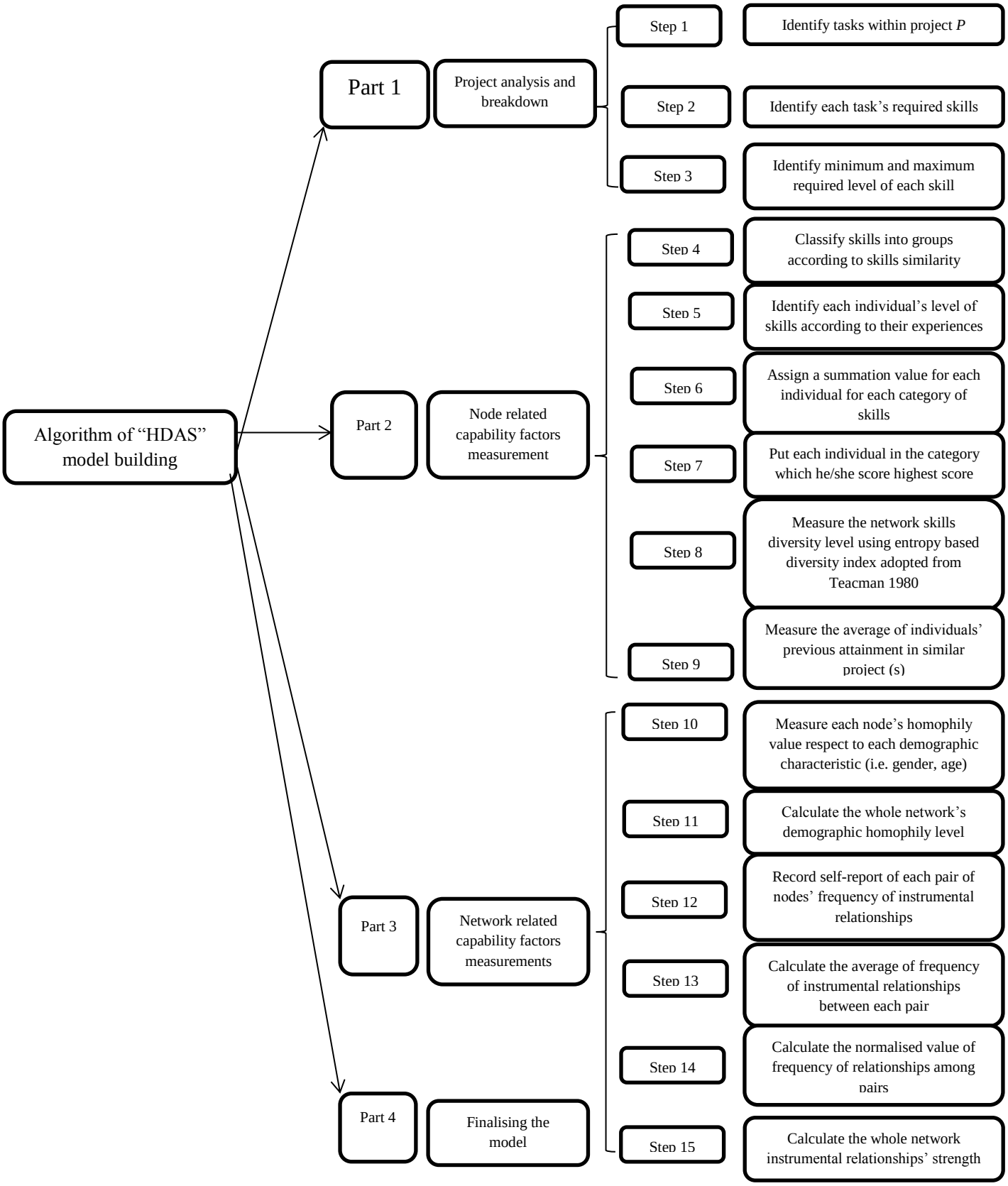


Figure 6-3 schematic representation of the 15 steps of the algorithm

6.4. The Key Characteristics of the "HDAS" Model Algorithm

The 15 steps algorithm of "HDAS" model was explained in this chapter. In a summary the following points are achieved after defining the algorithm:

In the first part it covers the breakdown of a major project into smaller and more manageable tasks and also defines the set of required skills for each task. The following bullet the main characteristics of the previously explained algorithm in all parts:

- Sets the minimum level of each skills for each task;
- The criteria which used in project breakdown are based on experts' opinion in the field. In other words expert(s) in the field decides on the requited skills of each task in this algorithm.
- The second and third part of the algorithm in a step by step procedure explains the measurement of the four capability factors for "HDAS" model.
- The final part of the algorithm is actually the mathematical modelling of the collective capability using "HDAS" model. The main modelling will be testing the correlation between independent variables (four capability factors) and dependant variable (collective capability of the network). The results will be used for forming a leaner model which expresses the relationships between the four capability factors and collective capability in "HDAS" model. This will be discussed in more details in chapter 7 of this study.

6.5. Empirical Study Design

In previous subsections of this chapter the conceptual design of the "HDAS" model was explained in detail. In the following subsections the focus will be on explaining the process of designing an empirical survey. The proposed empirical survey will help the author to collect required statistical data with aim of proving the previously proposed "HDAS" model using statistical techniques. The following sections of this chapter firstly provide an overview of how to conduct the empirical survey and the wireframe of the proposed survey. Secondly the type of the data collection methods and tools in designing the survey in this research will be explained. And finally the author explains the limitations and challenges of data collection from the target participants.

The outcome of this chapter is to demonstrate the mechanism for collecting and measuring collective capability in human based network (work groups). In other words this chapter in whole represents a practical example of collective capability assessment of human work groups based on the theoretical framework which has been provided in previous chapters.

6.5.1. Empirical Study Design, Idea and Background

A key to success in using observational and/or data collection experiments to test and validate a conceptual framework (in this study "HDAS" model) is having a clear definition of the study purpose (Creswell, 2003). As stated before in this research the author tries to model a group of individuals' collective capability using four nominated capability factors which can cover both individual (node) and network (group) related capability elements. The survey designed in this study firstly investigates if there are any significant relationships between four nominated capability factors (independent variables) and the collective capability of the

whole network (dependant variable). Secondly investigating the significant relationships between independent variables and collective capability of the whole network can help further to clarify an optimum and robust model for measurement of working groups collective capability level.

The ethical approval of the designed survey is obtained from "Brunel Research Ethics Committee" before conducting any data collection. A copy of the ethnic approval of the survey is in appendix D.

In a schematic view the process of survey design in this study is shown in figure 6-4:

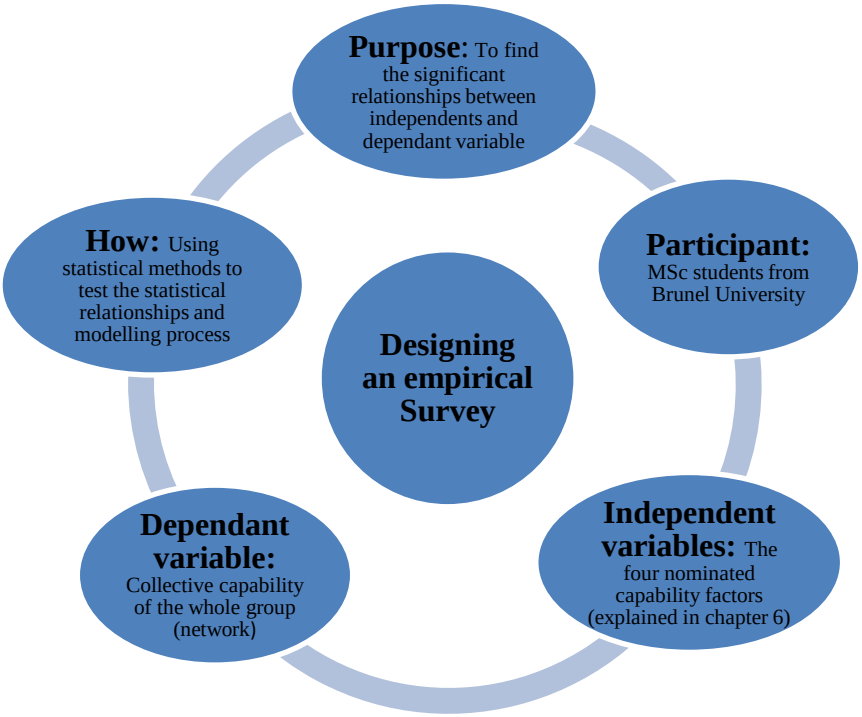


Figure 6-4 schematic presentation of study design

As it's shown in figure 6-4 the designed survey in this study has been done primarily to obtain the required quantitative data from MSc level student at Brunel University. The quantitative data is collected through questionnaires and interviews with participants with the

aim of translating the raw data into values which can represent the four independent variables for each group of students in this study. The row data from questionnaires have been translated into independent variables using the algorithm which explained in the previous subsections in this chapter. The proposed "HDAS" model will be tested through defining hypothesis and testing the proposed relationships. The idea of choosing the student project groups as the sample for this study will be explained in more details in next sub section.

6.5.2. The Group Formation and Sample Size in the Survey

The process of survey design and consequently data modelling in this study consists of project profiling, measurement of node related and network related capability factors, measurement of the collective capability of project groups and finally modelling and finding the relationships between independent and dependant variables.

At the very early stage of designing the survey for the purpose of this study, choosing the environment which the proposed survey will be conducted was an important decision to be made. The reason to say that is according to nature of this study the quantitative data must have been collected from network of human who are performing in groups to complete a given project and this made the process a bit more challenging considering the difficulties in accessing enough number of project groups who are all doing the same project.

Finally decision has been made to conduct the designed survey among post graduate students who enrolled for two MSc courses (Engineering management and advanced manufacturing systems) at Brunel University in London. This decision was made because student project groups are a good representative of human networks which we aimed to analyse in this study. The reason to say this firstly is because of that Brunel University is one the major academic institutes in London which attracts student from across the globe for post-graduate courses

and this opportunity can provide a good environment to take our sample with the hope of analysing work groups with diverse demographic characteristic, skills, previous experiences and knowledge. Secondly conducting the survey among postgraduate level students who are doing a group project can help the author to conduct analysis on project groups which a minimum level of instrumental (project related) relationships among individuals (nature of student project groups usually required them to form these relationships). This has been very important for us as *Instrumental relationship has* been one of the nominated capability factors in our conceptual model.

The potential participants for this survey (enrolled students at the two MSc courses, mentioned earlier) have taken part in the survey on a voluntary base. A consent form has been designed which assured the participants that the taking part in the survey will have no harm or risk to the participants. The process and result of the research is completely separated from the module and consequently will not affect the participants marking in the module in any manner. The willing participants to the study have the right to be withdrawn from the study at any stage during the research without any penalty. A copy of the consent form used in the surrey is in appendix E.

The students who decided to take part in the survey have been asked to form their project group voluntary. However the size of each group was limited to maximum four individuals in a group.

The first reason to limit the size of the project groups into maximum of four individuals in each group was that according to previous research on the impact of group size on developmental processes and groups' productivity (such as Wheelan, 2009), groups containing 3 to 6 members are significantly more productive and more developmentally

advanced than groups with larger number of individuals. secondly, because the level of difficultly and complexity of the designed group project, (according to experts in the field) did not require more than four MSc level students to fulfil the requirements of the project it has been decided to set the maximum size of the project groups in this study into 4 individuals in each group.

In two consecutive academic years (starting on Sep 2011) which the designed survey was conducted at Brunel University, 48 project groups (4 members in each group) did voluntarily take part in this study's empirical survey. These 48 groups were those ones which all four members of the group did take part in all stages of the survey so the collect data from these 48 project groups used in all statistical analysis in this study (will be discussed further in the next chapter).

6.5.3. Group Project Selecting for the Survey

To conduct the empirical survey among post-graduate level students a group project was needed to be designed and given to all project groups in the study. A vital factor which must have been considered while defining the proposed project was that the given project to all groups (networks) must have been from same level of complexity and size. This could increase the possibility of a fair comparison among different work groups when measuring their collective capability in performing the given group project.

A Discrete Event Simulation (DES) modelling project was designed for all project groups who wish to take part in the empirical survey. The simulation project was part of a module in the participants' MSc course. In order to complete this module the students were required to carry out two assignments: one individual assignment and one group project (used in the survey).

6.5.3.1. Proposed Group Project Requirements

Conducting few brainstorming sessions with the expert in the field of the systems modelling and simulation, it has been decided to define a group project for the survey which asked each group to choose a simple household device (for example: food mixer, or toaster) and dismantle the product. Doing this activity can help the members in each project group to identify the components which have been used in making the product. In the next stage the groups have been asked to design a simple production line for producing the product which they have dismantled. The next part of the project asked the students in each group to simulate the production line which they have previously designed (Using Arena simulation software, taught in the module) and try to improve the designed production line considering different key performance indicators (such as throughput time, production volume, efficiency of the resources, etc.). The group project will be completed by writing a comprehensive report which explains every stage of the project and by clarifying each member's role in every stage of the project.

The given project by the nature needed the students in each project group to have one or more brainstorming sessions to choose a product for their project. Having these sessions could help every member in a project group to know his/her group members better and this could result in forming stronger instrumental (project related) relationships during the life of the project.

Completing the requirements of the designed group project in this study could help the participants in the study to demonstrate the theoretical and practical concepts of systems modelling in a real world production line. In other words to do this group project each group's members needed to combine the theories which they have learned in the module with the applications of the systems modelling in real world problems. The participants in the

study also needed to use their innovative and analytical skills to hypothesise some "What-If" scenarios to improve their designed production lines. Finally the students must have used their writing skills to write a proper and professional comprehensive report on the project which they had completed. In a summary in designing the proposed group project in this empirical study it has been tried not to limit the required skills of the project to a specific skills category. In contrast it has been tried to design the proposed project in a way that can test the participants' various skills from different skills categories.

6.5.3.2. Group Project Breakdown and Required Skills

According to the proposed "HDAS" algorithm in this chapter the first three steps of algorithm is to breakdown the designed project into smaller manageable tasks and associate them with skill sets. Doing so could enable the author to identify the tasks which needed to be performed to complete the proposed group project.

Analysing and discussing the designed project with the experts in the field it has been concluded that the designed group project can be broken into nine comprising tasks. The nine comprising tasks are identifies as:

Task1. Conducting brainstorming session(s) to choose the right product to use for doing the group project

Task2. Arrangements to purchase the chosen product with the best possible price in the market

Task3. Dismantling the purchased product into its mail parts and components

Task4. Designing an appropriate production line which its final product can be the dismantled product in the project (using the methods which have been touch in their MSc course (applying theories into practice)

Task5. Analysing the cost, the market, and in general propose the business plan for producing the product (why producing the chosen product can be profitable?)

Task.6 Simulate the proposed production line (using Arena simulation software) to run the "As-Is" model of the designed production line

Task7. Measure the key performance indicators from the "As-Is" model and propose different "What-If" scenarios to improve the designed production line

Task8. Choose the most optimise production line among all discussed "What-If" scenarios

Task9. Write a comprehensive report which clearly explains every stage of the project including each group member's role in every stage of the project. The report should also explain and justify the proposed business plan and justify the suggested "What-If" scenarios in the project.

Completing the nine main tasks required the participants to use different skills, knowledge and abilities.

In a summary the main required skills and abilities for completing the nine tasks in the project were finalised as:

- Investigatory skill, Team working skill, Internet search skills, MS- office skills, and statistical skills, Self-confidence skill, Communication skill, Writing skill, Report

management skill, Arena simulation software, Adapting and coping skill, Creativity skill, Risk management skill, Learning skill, Problem solving skill, Show commitment to other individuals skills, Knowledge sharing willingness, Time management skill, Openness skill (to new ideas, listening to other group members), Presentation skill.

The listed required skills and abilities (20 skills named above), are clustered in the study, which will help the researcher to measure the *skills diversity* level of the members in each project group following steps 4 to 8 of the "HDAS" algorithm.

The Figure 6.5 shows the result of categorising the required skills (20 skills) for completing the designed group project in the empirical survey of this study.

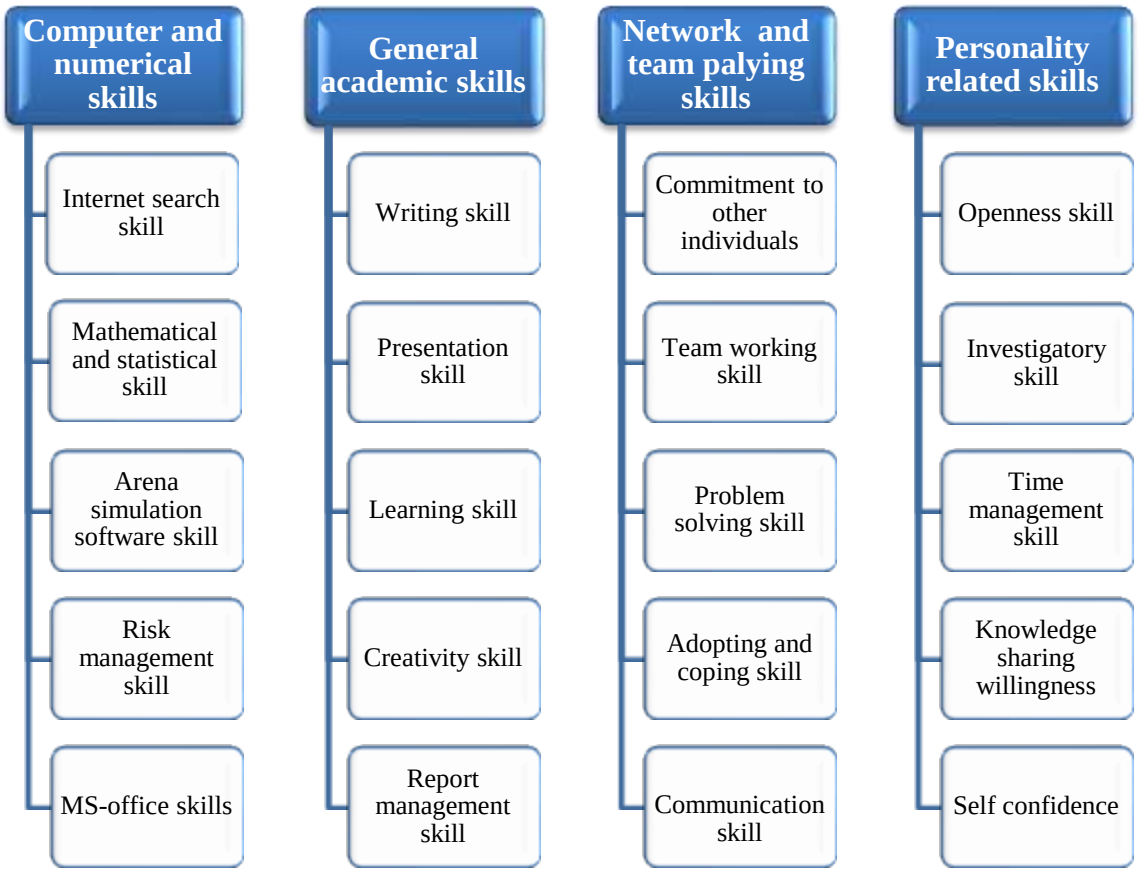


Figure 6-5 required skills categorisation

Defining and profiling the proposed group project for the empirical survey has led the researcher to the next stage of survey design which was mainly focused on data collection side of the study which will be explained with details in the next sub-section.

6.6. The Data Collection Process

The process of data collection for the survey was undertaken using two questionnaires and direct interview with all individuals. The reason to design two separate questionnaires in this study was firstly because, some of the required information in this survey must have been collected from the work groups after they have completed (or near to completion) of their group project. This required design and distribution of a separate questionnaire near to the

end of the academic term. Secondly having two separate questionnaires in the survey to collect the whole range of required data could assist the author to manage the length and complexity level of questionnaires. According to a research by Douglas, (1973) length of a questionnaire is an important factor to increase the response rate from the participants in questionnaire surveys.

The first questionnaire was designed mainly with the aim of collecting participants' demographic information and their previous relevant experiences in similar projects to the one which designed for the purpose of this survey. All the questions in the first questionnaire was put with the aim of collecting information about individuals' demographic characteristics such as age, gender, study background, ethnic group, and their previous level of experiences and attainments in similar simulation and modelling group project (which was the core topic of their given group project). Participants' responses to questions in the first questionnaire could assist the researcher in measurement of participant project groups' demographic homophily level and their average previous attainment in similar projects. The first questionnaire was distributed among participants prior to forming groups. A copy of first questionnaire which is designed in this study is in appendix F.

The second questionnaire was designed to inquire from the participants for the purpose of measuring two of the four proposed capability factors: groups' skills diversity level and strength of instrumental relationships. The questions which put in the second questionnaire collected data around two main concepts: individuals' level of skills and expertise on each required skill in the given project and data about existence and frequency of instrumental relationships among individuals in each working group. These data could further to be used in measuring the two capability factors which mentioned earlier.

The first part of the second questionnaire asks individuals from each group to self-assess themselves on each skill (for all required skills for the project) a Likert scale between 1 to 7. One on the Likert scale in the questionnaire represents minimum level of familiarity with the skill (basic level) and choosing 7 represents professionalism in the specific skill.

The reason for using Likert scale in the second questionnaire was that using Likert scale can give the respondents the opportunity to choose varying degrees of agreement with or endorsement of the statement (DeVellis, 2003). Because most of individuals had different and varied level of expertise and familiarities with regards to different skills based on their previous field of study and their interest to learn new skills having a Likert scale which could offer them a range (between one to seven) to rank themselves on each skill could be a good and reasonable measure. The questions in the second part of the questionnaire were mainly designed with the aim to measure the strength of instrumental relationships among members in each work group. The method which this data was going to be collected from the participants was a key data collection strategy which should have been considered carefully. This included decisions about how to get the participants interested in providing the right data with regard to the nature of the required data (network data). In fact interviewing every individual before responding to the second questionnaire was set to collect the necessary data for measuring the Instrumental relationships' strength among individuals in group. The term "*Instrumental relationships*" was explained to the participants. The interviews of all members in a group were conducted on the same day (time slots were previously agreed with all group members).The timeliness of data collection with regard to the nature of required data (network data) has been a challenge which must have been managed.

The data collection process was undertaken during the months which participants in the study were busy doing their MSc course's assignments and exams. This made the whole

process even more challenging to have participants who were happy to take part in all stages of the designed survey. The designed survey has been conducted in two consecutive academic years at Brunel University to collect data. Analysing the quality of the collected data and ignoring the data from project groups who one or more of the members had withdrawn their wish to take part in the survey before the final stage, at the end of the second year it revealed that 48 project groups have completed the survey and provided useful data for the purpose of modelling.

6.7. The Key Characteristics of the Survey

Considering the time and resource limitation in designing the proposed survey an appropriate data collection method should have been designed to obtain the most reliable statistical data for the purpose of modelling. The survey should respond to the following questions:

- What is the most appropriate group project to be designed for the survey?
- What should be the sources of the data collection considering the limitation and nature of required data (network data)?
- What are the best data collection tools considering the time limitation and requirements of the research?

The following subsections describe the designed group project's characteristics and measurement of the required data. This is followed by an explanation of data collection tools in more depth.

6.7.1. Designed Group Project's Characteristic

As it's mentioned briefly before in designing the group project in this survey it has been tried to design the proposed project in a way which fulfilling the requirements of the project

required varied skills and knowledge from the participants in the survey. This first characteristic of the designed project can give the opportunity to the researcher to investigate the effect of skills diversity among individuals in different project groups on the whole networks' collective capability.

The second important characteristic of the designed project is that completing the designed project requires the participants to form strong instrumental relationships (between group members), as the size of the designed project is over one individual's abilities. This characteristic also gives the opportunity to test the effect of instrumental relationships' strength on the whole networks' collective capability.

The third characteristic of the designed project is that the requirements of the main part of the project (simulation and modelling section) fall within the area of the expertise of the assessor of the project (senior lecturer in the field) which can assure the researcher of having a single professional and accurate measurement of all groups' collective capability. This is a very important factor when conducting an empirical survey because individuals' judgments and interpretations in surveys could be different and should be minimised (Wellington et al., 2005).

6.7.2. Measurement and Source of Collected Data

In general in qualitative or quantitative surveys four type of measurement might be used to collect data: Nominal, Ordinal, Interval or Ratio. Nominal and ordinal scales are usually used to collect data which belong to category or rankling order. Whereas interval and ratio scales can be used to give quantity for the factors they measure.

As it's mentioned briefly before while explaining the design of the survey, considering the nature of the data required in this study, different scales were used in both questionnaires.

In the first questionnaire which aimed to collect data on participants' demographic characteristics and their previous level of experiences and attainments on similar projects the scales for responses should be defined as nominal and ordinal scales.

The method was simply to choose the appropriate answer which best describe them in each question. The collect data from this questionnaire used in the study to measure the project groups' demographic homophily on various characteristics (e.g. age, gender, study background). The required data to measure the average previous attainments of the groups also has been obtained from respondents' answers to this questionnaire.

In the second questionnaire which mainly aimed to collect data on participants' level of familiarity with different skills and their instrumental relationships a mixture of nominal, ordinal and Likert scale have been used to collect data. The more information about different type of scales and measurement can be reviewed in the book by Clark-Carter, (2010).

The collected data from both questionnaires in this study only provided the researcher with the raw data which was required for measurement of the four independent variables (capability factors) and consequently statistical analysis and modelling purposes. In other words the respondents' answers to both questionnaires must have been translated to values which could measure the four capability factors for each project group. The process of measuring the four capability factors was explained previously in "HDAS" model building algorithm in this chapter.

As it can be derived from above explanations on the data measurement, there are multisource of data (self-assessment, manager assessment, peers) used to collect the required data in this survey. The idea of using multisource data collection is based on getting information from all people who are familiar with the proposed project, groups and individuals within the project groups. These people were individuals who took part in the survey, their senior lecturer who marked their group project and the researcher who conducted the one to one interviews with the participants in the study.

The self-assessment method for the collecting data which mainly used through questionnaires in this study proved to be a good and reliable method for data collection however over and under rating can always happen in this method (Yammarino and Atwater, 1993; Furnham and Stringfield, 1998). Supervisors or managers rating (Senior lecturer in this study) can also be a good method for data collection; however it's important to ensure that data provided from managers are fair and diligent (Phillips and Gully, 2009). In a previous research by Johnston and Miles, (2004), it has been shown that in academia for instance the marks given by lectures in a course, peers and students' self-assessment are very similar. In line with this finding Harvey (2002) also believes that if students realise that their self-assessment results are not threatening for them and their marks then these method would be a good reflection of the reality than other forms of assessment.

As a result it seemed essential to the researcher to use a mixture of sources and methods in order to collect the required data in this survey. In the current survey a combination of self-assessment, peer assessment and lecturer assessment are used. There are also other factors which have been considered which potentially enhanced the quality of the data obtained from all sources in this survey. Firstly, participation in the survey was on a completely voluntary base. Secondly the participants assured that their responses and self-assessments were not

impairing with their final mark in the course in any way. Thirdly the self, peer and lecturer assessment data were not shared or communicated with any of the assessors.

6.7.3. Data Collection Tools

This section explains that how requirements for measurement of each capability factor (four of them) is measured in the survey. These range from participants' demographic information, skills diversity, instrumental relationships, previous experiences and the whole team collective capabilities. Table 6-1 in a summary explains the raw data behind measurement of each capability factor, data collection method and the source of the data for each capability factor.

Table 6-1 raw data and data collection method behind capability factors measurement

Capability Factor	Raw Data	Collection Method	Source of the data
Homophily of Project Groups (H)	Demographic characteristic of individuals and their instrumental relationships	First and second questionnaire	Self-report and interviews
Skills Diversity of Project Groups (D)	Individuals levels of familiarity with different skills	Second questionnaire	Self-assessment
Average Previous Attainment of the groups (A)	Number of group projects individuals being involved in	First questionnaire	Self-report
Instrumental Relationships' Strength in Project Groups (S)	Existence and frequency of instrumental relationships among individuals	Second questionnaire	Self-report + One to one interviews
Collective Capability (CC)	The whole group outcome from group project	Marking the group project	Lecturer assessment

6.7.4. The Data Collection Process; Timeliness and Limitations

The collected information from participants in this survey was collected in the following order:

1. Information about the designed group project, its constitute tasks, skills requirements, before the start of the questionnaire design.
2. Part of the information required as the raw data to measure demographic homophily values of the project groups and also data required to measure previous attainment of the groups are obtained from the first questionnaire in the fourth week of their course commencement
3. The participants asked to form their project groups (voluntarily) in the fifth week of the course
4. The group project was given to participants in the fifth week and they had given twelve weeks to complete and submit the group project
5. The second questionnaire was distributed 2 weeks before the deadline for group project and at the same time a time table has designed and agreed between the researcher and participants to attend one to one interviews and fill in the second questionnaire in the researcher's office
6. The groups' collective capability in fulfilling the designed group project was based on detailed module feedback by the senior lecturer and are collected after the course completed (17^{th} week from start)
7. Overall data collection for project definition and raw data collection for capability factors measurement in each academic year have respectively required 17 weeks to be completed.

There are a number of factors which must have been considered (limitations) during the data collection process in this survey:

1. All members took part from start to the end of the survey.
2. The data collection was conducted in multiple stages and cannot be done in one step (some data must have collected near to completion of the group project)
3. The survey was on a voluntarily basis
4. The data collection method used in the study were limited to less costly ones

The above consideration has helped the researcher to obtain data form the participants sample using tools which explained earlier in this chapter. The key assumption in data collection was that collated data will be sufficient for the modelling purposes in this study.

6.8. Conclusion

This chapter in the first place explained the building of the proposed "HDAS" capability assessment model. The main focus of the chapter in the first part was to explain the steps which must be followed to measure each capability factor to build the capability model suggested in this study. Following the 15 steps algorithm can provide the researcher with the value for all four capability factors ready in hand to find the correlations between dependants variable (capability factors) and dependant variable (collective capability) in this study. Finally some key characteristic of such algorithm and its unique features were described in this chapter.

Therefore in this chapter we discussed the exact procedures which need to be taken to measure the principles of "HDAS" model. This was mainly done with the theoretical

background about the four capability factors combined with some of statistical and social network theories.

The results of this part of the chapter lead the author to get to the next stage of this research which is designing an empirical survey to collect data and empirically test the proposed "HDAS" capability model. The following subsections of this chapter (after designing the "HDAS" model algorithm) were mainly designed to respond to this requirement.

The design of the proposed empirical survey, its scope and limitation has been described in this chapter. In more details; the foundations of data collection and preparation for measurement of capability factors for "HDAS" model have been developed. The tools and methods used for data collection process have also been discussed.

This section provides the basic information for data acquisition and justification for the method and type of data collected.

The chapter has provided a real case for modelling the collective capability of human project groups in performing a given group project and clearly explained the steps to be taken in order to get to the modelling stage. There is no reason to not believe that the introduced methodology cannot be universally used in other cases.

The data collected from conducting this survey should now be tested using appropriate statistical methods to approve the proposed "HDAS" model collective capability of work groups. Therefore the next chapter (7) will provide the relevant statistical analyses on the collected data from the empirical survey.

Chapter 7

Data Analysis and Results

The aim of this chapter is to stablish the relationship between the dependant (collective capability) and independent variables (demographic homophily (H), skills diversity (D), Average previous attainments (A) and instrumental relationships' strength(S)) using analytical techniques.

In the first step the data collected via the empirical survey are validated and verified using reliability and validity tests. The collected data from the participants in the survey (project groups) will be tested to determine the reliability of the data collection tools (questionnaires) used in the survey and to verify that the collected data are measuring the variables which they meant to measure (four independent variables).

For the purpose of reliability test the Cronbach's Alpha measure which was first introduced by Cronbach (1951) is used. The test helps to determine the internal consistency of the four capability factors (H, D, A, S). There are different methods which can be used to measure the internal consistency of data such as "Slip half" or "Cronbach's Alpha" (Field, 2009). In this research however the author has decided to use Cronbach's Alpha method as its one of the most widely used method to measure internal consistency of the data (Nunnally and Bernstein, 1994).

After testing the reliability and validity of the data, the main purpose of quantitative analysis (aim of this chapter) in this study was answering the following research questions:

1. Are there any significant relationships between the nominated capability factors in the study and the collective capability of the project teams? (one to one relationship)

2. Is it possible to devise a model that can be used for predicting the collective capability of project team? (Linear model using Regression analysis)

3. Is there a direct or indirect interrelationship between the four capability factors and collective capability?

Two of the main statistical analysis method which were used in this chapter to investigate the relationships between independent variables (four capability factors) and the collective capability of the project groups (dependant variable) includes Pearson's correlation analysis and multiple linear regression modelling. The concluding part of this chapter tests the direct and indirect effect of independent variables on the collective capability of the work teams. The Structural Equation Modelling (SEM) technique is used for this purpose. The SEM path analysis is adopted to examine the pattern of inter-correlations among independent variables and also to test both direct and indirect effect of four independent variables on the dependant variable in the study. Using the SEM path analyses will actually provide an opportunity to test the researcher's theory of which, some independent variables are causing other independent variables. For a modelling study according to Bryne, (2010) the specification of the model is actually a declaration of the researcher's beliefs regarding the causal links among the variables of interest. Sources of information that could influence these beliefs include literature review, formal/informal theories, personal observations, expert opinions, and common sense and logic (Tate, 1992). As to be best of the author's knowledge there was little research conducted in the area of capability modelling, the path in SEM analysis in this study was based mainly on Pearson's correlation coefficients obtained from the correlation analyses prior to SEM analysis section. The logic and procedures behind the SEM modelling technique will be explained with details in the related section further in this chapter.

By the end of this chapter, a model which can best connect the independents and dependant variable will be nominated.

7.1. Sample Basic Descriptive Data

The participants in this study were post-graduate students over two consecutive year period. The total number of students doing the courses (in two consecutive academic years) was 248. From that number 192 students voluntarily participated in this study. The students formed voluntary their project groups of 3 to 4 students in each group. A total number of 48 project groups participated in the study over the two years. Table 7-1 shows demographic information of the sample in the study.

Table 7-1 demographic information on the sample of the empirical survey

	Gender			*Age*		*Ethnic Background*					
						Asian, Far east	*Asian, Middle east*	*Asian, Indian*	*European*	*African*	*South American*
	Female	Male	Not Known	Mean	Range	*Count*	*Count*	*Count*	*Count*	*Count*	*Count*
First year	32	72	0	24.0	16	46	24	8	8	12	6
Second year	26	62	0	25.6	16	34	25	11	7	8	3
Total	58	134	0	24.8	16	80	49	19	15	20	9

Looking at total number of students who participated in the study, it's clear that 77% of the students who were enrolled for the post graduate courses in two consecutive years took part

in all stages of the survey. The participation rate was higher than expected considering the voluntarily nature of the survey and length of data collection process which needed participants to engage in all stages of the survey simultaneously doing their MSc degree's course works and exams. The table 7-2 shows the participation rate of potential sample in the study.

Table 7-2 participation rate from potential sample (all students in the course)

Total number of enrolled students (Two consecutive years)	248
Not attended in the survey at all	44 (18 % of total)
Attended until some stages	12 (5% of total)
Attended in all stages	192(77% of total)

Completing the descriptive information of the sample in the study, we will start with some analysis which will test the validity of the collected data and tools used in the empirical survey before moving to the actual statistical analysis part in this chapter.

7.2. Reliability and Validity Tests, Methods Used in the Study

The two designed questionnaires in this study were used as main tools to collect data set for modelling purposes. The four capability factors (independent variables, H, D, A, S) are calculated from the participants' answers to number of questions in the two designed questionnaires. The raw data from the two questionnaires have been transferred into values which represent the four capability factors for project groups (using the "HDAS" model algorithm explained in chapter 6). Therefore it seems important to show the reliability and validity of the data is acceptable before we use the data for modelling purposes in the study.

To start this section it's important to understand well the difference between reliability and validity tests. The general reliability tests aim to test the consistency or repeatability of the measures whereas construct validity defines how well a test or experiment measures up to its claims. It refers to whether the operational definition of a variable actually reflects the true theoretical meaning of a concept (Presser et al., 2004). Going into more details, in reliability test the main concern is to investigate the extent to which an experiment or any measuring procedures yield the same results on repeated trials (Carmines and Zeller, 1979). The reliability tests become useful as there is always a certain amount of chance errors in any measurement procedures and error free measurements has never attained in any of scientific research (Stanley, 1971). Instead the Stanley has observed that "The amount of chance error may be large or small, but it is universally present to some extent. Two sets of measurements of the same features of the same individuals will never exactly duplicate each other" (Stanley, 1971). As a result the tendency towards the consistency of repeated measures of a same phenomenon is called *Reliability* and can be measured using different consistency measurement methods The higher the consistency of results from repeated measurements the more reliable the measurement method (Carmines and Zeller, 1979).

On the other hand the validity of a construct is mainly to look the degree to which a measurement tool does what it intended to do. In other words the validity test is investigating how well a tool is measuring what it promised it was going to measure. For example, "an intelligence test may be valid for assessing the native intellectual potential of students, but it would not necessarily be valid for other purposes, such as forecasting their level of income during adulthood "(Nunnally, 1978). Validity is also like reliability is a matter of a degree (Carmines and Zeller, 1979).

When it comes to the measurement of reliability of data in statistical analyses there are number of methods which could provide the measurement. Two of the mostly common used measures are "split half" and "Cronbach's Alpha" (Field, 2009). In this research however it has been decided to use Cronbach's α (first introduced by Cronbach, 1951) firstly because it's one of the most reliable method to measure internal consistency of the four capability factors to gauge its reliability (Field, 2009). Secondly according to McLeod (2013) the "Slip Half" method which compares the results from one half of test to the results from other half the test (to find the extent to which all parts of the test contribute equally to what is being measured), is mostly useful in tests which collect data using large questionnaires. In our study however the two designed questionnaires are not very large questionnaires which can be easily sliced into two parts to be used in "Split half" method. As a result it has been decided the "slip half" method it not the most suitable method for reliability tests in this study. In contrast it has been felt that the Cronbach Alpha method which is the most widely used method for internal consistency measurement when the research is concerned with several Likert scale questions (Field, 2009) is the best suitable method for the purposes of internal consistency measurement (reliability tests) in this study.

Equation 7.1 measures Cronbach's α value (borrowed from Cronbach 1951):

$$\alpha = \frac{N^2 \bar{c}}{v + (N-1)\bar{c}} \qquad \textbf{7.1}$$

Where **N**: is the number of items (questions in this case) that measures a specific variable

$\bar{c}$: is the average of the covariance between the items in that variable and

v: is the average of variance within the items (questions).

Cronbach's alpha is believed to indirectly indicate the degree to which set of items consistently measure a single latent construct, i.e. collective capability in this case. The consistency ranges from $\alpha \geq 0.90$ are excellent, $0.70 \leq \alpha < 0.90$ are good, $0.60 \leq \alpha < 0.70$ are acceptable, $0.50 \leq \alpha < 0.60$ are poor, and $\alpha < 0.50$ are unacceptable (George and Mallery 2003).

In addition to Cronbach Alpha measures, the Principal Component Analysis (PCA) was used in this study to explore the underlying dimensions of the four independent variables (capability factors: H, D, A, and S). Principal components analysis (PCA) is a variable-reduction technique that shares many similarities to exploratory factor analysis. Its aim is to reduce a set of variables into a smaller set of artificial variables, called *'principal components'*. In other words the PCA is a mathematical algorithm that reduces the dimensionality of the data while retaining most of the variation in the data set (Jolliffe, 2002). The PCA accomplishes the reduction by identifying directions, called "*principal components*", along which the variation in the data is maximal. Specifically in large scale studies the PCA can help the researchers to represent their data sample by relatively few variables rather than thousands and thousands of variables.

In our case by using PCA we are aiming to test if all four capability factors (H, D, A, S) are necessary to measure the dependant variable (collective capability). The results of doing PCA can suggest if one or more of the four independent variables can be eliminated from the future modelling analyses.

There are a number of common uses for PCA in studies which involve statistical analyses. Some of the mostly common uses of PCA are when:

(a): in studies where many independent variables have been measured (to be used for modelling purposes) and the researcher believes that some of variables are measuring same underlying construct. In other words if the independent variables are highly correlated the researcher only wants to include the ones which he/she feels mostly represent the construct.

(b): The PCA also is useful where the researcher is interested to see if a current measurement scale (questionnaire) in his/her study can be shortened to include fewer items

(C): to test how well a test or experiment measures up to its claims

The above three points are the most common uses of PCA. It is also important to mention that whilst the PCA is conceptually different to factor analysis in practice it is often used interchangeably with factor analysis, and is included within the 'Factor procedure' in SPSS software.

The validity of independent variables in this study can be obtained and be explained under point (a) and (b) of common use of PCA analysis which explained earlier. So as a result in order to ascertain the validity of the choices of independent variables: level of demographic Homophily (H), skills diversity (D), average previous attainments (A) and instrumental relationships strength (S) as true representative of collective capability (CC), PCA seems to be the a trustable analytical method. Using PCA can help us to recognise if all four capability factors are truly needed for further regression analysis in this chapter. Pett et al., (2003) suggested that the general rules of the factor loadings, (the final stage of PCA) in excess of: 0.71 are considered excellent, 0.63 are considered very good, 0.55 are considered good, 0.45 are considered fair, and 0.32 are considered poor. The factor loading as the final stage of PCA can suggest if any of the factors (four capability factors in our case) are not a true

predictor or measure of a specific construct in a study. The higher the loading of a factor the stronger that factor would be as predictor of the construct in the study (Pett et al., 2003).

To start the PCA analysis, it's essential to determine how many components should be extracted for analysis. The way that PCA works is that it combines a set of variables (capability factors in our case) into smaller set of artificial variables called "principal components". The PCA determines several orthogonal lines of best fit on the data. The orthogonal lines are perpendicular to each other in *n* dimensional space. There are as many dimensions as there are variables in the study (4 in our case). The greatest variance of the data set is captured by the first axis (called the first principal component). Final stage of PCA is about loading the variables on each factor. An observed variable "loads" on a factor if it is highly correlated with the factor (has a large eigenvalue). The loading factor values can indicate which of the variables in the study are good and true predictor of the construct in the study.

In our study, the final goal of conducting PCA analysis is to investigate the underlying dimension of our independent variables (H, D, A, S). In other words the researcher is trying to find out if all four independent variables (H, D, A, S) measure a single latent variable (collective capability), as proposed in the study? Or do (H, D, A, S) measure two/three different latent variables? Or do (H, D, A, S) indeed each measure a different latent variable? Note that *latent variables* are variables that are not directly observed but are rather inferred (through a mathematical model) from other variables that are observed (Pett et al., 2003).

The two criteria which used in this part of analysis for determining the number of components that should be extracted in PCA according to Johnson and Wichern, (1992); Tabachnick and Fidell, (2013) were:

- **Kaiser's criterion**

Which compute the eigenvalues for the correlation matrix and determine how many of the eigenvalues are ≥ 1. The number of eigenvalues ≥ 1 is the number of factors to include in the model.

- **Cattell's scree plot**

In a scree plot, eigenvalues are plotted successively, and attention should be made toward a spot in the plot where the plot abruptly levels out.

Note that to help determine whether the component model was appropriate, the Kaiser's Measure of Sampling Adequacy (MSA) and Bartlett's test of sphericity were reported in this part of analysis (Pett, et al, 2003; Kaiser and Rice, 1974). MSA is a summary of how small the partial correlations are relative to the ordinary correlations. Small values of MSA indicate that the correlations between variable X and the other variables are unique, that is, not related to the remaining variables outside each simple correlation. Kaiser has described MSAs above .9 as marvellous, above .8 as meritorious, above .7 as middling, above .6 as mediocre, above .5 as miserable, and below .5 as unacceptable (Kaiser, H. and Rice, J. 1974). Thus, in this study, the researcher declared that MSA above 0.6 was acceptable.

Bartlett's test of sphericity can be used to test the null hypothesis that the sample was randomly drawn from a population in which the correlation matrix of the survey items was an identity matrix (a matrix full of zeros, except for ones on the main diagonal). Larger values of Bartlett's test (smaller p-value) indicate greater likelihood that the correlation matrix is not an identity matrix and that the null hypothesis should be rejected.

Thus MSA (testing whether the partial correlations among variables are small) and Bartlett's test of sphericity (testing whether the correlation matrix is an identical matrix) are both indications of whether the factor model is appropriate.

All the methods which were used for testing the reliability and validity of data sample have been explained in this sub-section. The results of doing the reliability and validity tests in the study are presented in the next subsection (7.2.1)

7.2.1 Reliability Test Results

The results of initial analysis on the mean and standard deviation (*SD*) values of the four capability factors in this study shows that one of the factor: skills diversity (D) has a larger variability *(SD= 0.46)* compared to other three factors (H, A, S) in the study (Mean and standard deviation values are in table 7-3).

Table 7-3 descriptive statistics of H, D, A, S, CC, and D1.

Variable	Mean	Standard deviation	Minimum	Maximum
Homophily level (H)	0.64	0.15	0.25	0.91
Skills Diversify (D)	0.67	0.46	0.00	1.38
Average Previous attainment (A)	0.61	0.14	0.30	0.96
Instrumental Relationships' Strength (S)	0.58	0.17	0.20	0.90
Collective Capability (CC)	0.62	0.10	0.31	0.84
Normalised skills Diversity (D1)	0.66	0.25	0.26	0.99

As a result before moving to any further analysis and to stabilise the variance of skills diversity factor (D) to be in line with other three factors' variances a simple formula has been used which helps to stabilise the variation of skills diversity factor (D). The following formula was used:

$$D1 = Ln\ (D + 1.3) \qquad \textbf{7.2}$$

D1 is the newly named factor which is the stabilised version of skills diversity factor (D) and will represent the skills diversity level of the work teams in further analysis. Note that with back transformation, factor (D) could be obtained as

$$D = exp(D1) - 1.3 \qquad \textbf{7.3}$$

The constant "1.3" was chosen so that the mean, standard deviation, minimum, and maximum were compatible to the other three variables, H, A, and S.

The above formula (7.2) has been obtained through trial and error by the researcher to stabilise the mean of skills diversity (D) to be consistent with other three factors (H, A, S). Replacing the values of D with D1 doesn't affect the future analysis' outcome as the formula (7-2) has mapped the D value for all work groups into newly named D1 using the same pattern. In other words the value of D has been shifted with the same rate for all project groups in the study using formula 7.2 and aim was just to get the variance of factor D inline to other 3 factors in the study.

Table 7.3 shows the descriptive statistics of the four measured capability factors (**H, D, A, S**), the newly named **D1** factor and the collective capability values **(CC)**.

By importing the values of the capability factors and the values of collective capability (feedback of the senior lecturer on the groups outcome of the project) into SPSS software and

deploying the Cronbach alpha method the results of consistency analysis before and after transforming D into D1 is summarised respectively in table 7.4 and 7.5

Table 7-4 Cronbach's alpha analysis for factors: homophily (H), skills diversity (D), average previous attainment (A) and instrumental relationships' strength (S)

Capability Factor	Item-total correlation	Cronbach's alpha if item deleted
H	0.42	0.36
D	0.31	0.64
A	0.33	0.41
S	0.40	0.35

***Note: Overall Cronbach's alpha = 0.47**

From the results of Cronbach alpha analysis in tables 7-4 the "item-total correlation" is the correlation of the item designated with the summated score for all other items. A low corrected item-total correlation implies that the particular item is a somewhat different construct than the other items. "Cronbach's alpha if item deleted" represents the scale's Cronbach's alpha reliability coefficient for internal consistency if the individual item is removed from the scale. This value can be compared to the overall alpha coefficient value (represent under each table 7-4) to make a decision if one wants to delete the item.

As it can be seen from table 7-4 the overall Cronbach's alpha for (H, D, A, S) was 0.47. The results of Table 7-4 indicated that D was a somewhat different measure from the other 3 items, H, A, and S, as D has a slightly lower item-total correlation (0.31) than the rest of the items. The "Cronbach's alpha if item deleted" = 0.64 for D also suggests that if D was deleted, the overall Cronbach's alpha would significantly increase from 0.47 to 0.64. This results would suggest deleting the factor D from further analysis but because as we have

transformed the factor D to D1 (to stabilise its variances) we need to check the reliability test on the four factors this time replacing the D with D1 which might suggest the reliability of D1 as well. Table 7-5 shows that results of Cronbach' alpha analysis after transforming (normalising) skills diversity factor (D) into newly named D1.

Table 7-5 Cronbach's alpha analysis for factors: homophily (H), normalised skills diversity (D1), average previous attainment (A) and instrumental relationships' strength(S)

Capability Factor	Item-total correlation	Cronbach's alpha if item deleted
H	0.48	0.47
D1	0.31	0.64
A	0.35	0.56
S	0.48	0.46

***Note: Overall Cronbach's alpha = 0.62**

From table 7-5 results, after stabilising the mean of D (using formula 7-2), the overall Cronbach's alpha for (H, D1, A, S) became 0.62, larger than the overall Cronbach's alpha for (H, D, A, S). The results of Table 7-5 indicates that D1 is a somewhat a different measure from the other 3 items, H, A, and S, as D1 has a slightly lower item-total correlation (0.31) than the rest of the items. The "Cronbach's alpha if item deleted" = 0.64 for D1 suggests that if D1 was deleted, the overall Cronbach's alpha would have a **minor** increase from 0.62 to 0.64. This indicates that after transforming skills diversity factor (D) to (D1) removing the factor D1 can only **slightly** (only 0.02) improve the overall Cronbach alpha's value. As it mentioned earlier George, and Mallery, (2003) suggested the general guidelines for alpha values as: $\alpha \geq 0.90$ are excellent, $0.70 \leq \alpha < 0.90$ are good, $0.60 \leq \alpha < 0.70$ are acceptable, $0.50 \leq \alpha < 0.60$ are poor, and $\alpha < 0.50$ are unacceptable. Thus, with (H, D1, A, S),

the overall Cronbach's alpha = 0.62 indicated that the reliability of all four factors was acceptable and hence that we can declared that the four capability factors (after D was transformed to D1) reliably measured an underlying construct.

7.2.2 Construct Validity Test Results

In this section the validity of data will be tested using the Principal Component Analyses (PCA). As it's explained in section 7.2, there are some prerequisite to be done to determine the number of components to be extracted in PCA analyses and also to ensure that if PCA model is appropriate. The Kaiser's criterion test has been used to determine the number of components (number of components are equal to number of independent variables: capability factors in our case) to be extracted in PCA. The results of the calculated eigenvalues are shown in table 7-6

Table 7-6 preliminary eigenvalues

Component (equal to number of the capability factors)	**Initial Eigenvalues**		
	Total	**% of Variance**	**Cumulative %**
1	1.941	48.513	48.513
2	0.828	20.703	69.216
3	0.803	20.065	89.282
4	0.429	10.718	100.00

The eigenvalues presented in (table 7-6) are the variance of the each component. As this is before the factor rotation, the first factor will account for the most variance (proportion = 0.4851). The column of *"% of variance"* is the proportion of the total variance that each factor accounts for. For example, the first factor accounts for 48.513% of the total variance

of the measures. Cumulative % is the sum of the column of "% of variance". Thus the first 3 factors account for 89% of the total variance.

The represented "Eigenvalues values" are also shown on scree plot in figure 7-1.

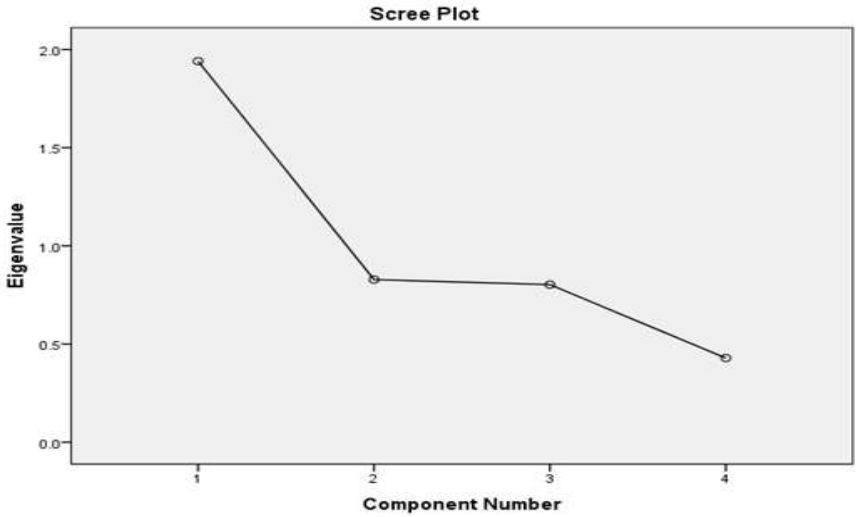


Figure 7-1 scree plot- Eigenvalues for each capability factor

Components with eigenvalues ≥ 1 will be extracted in PCA analyses. As a result according to eigenvalues in table 7-6 and scree plot shown in figure 7-1, one factor with eigenvalue of 1.941 will be retained for PCA analyse. The table 7-7 shows the factor loadings of the 4 capability factors for the single factor. The greater the factor loading, the more the variable (capability factor) is a pure measure of the factor.

Table 7-7 factor loadings values for each capability factor

Item	Factor loading
H	0.770
D1	0.565
A	0.619
S	0.804

To interpret the result of factor loading (table 7-7), according to Pett et al.,(2003) the general rules for loadings are as follows:

- 0.71 are considered excellent,
- 0.63 are considered very good,
- 0.55 are considered good,
- 0.45 are considered fair, and
- 0.32 are considered poor.

Considering the factor loading values (table 7-7) and comparing them with the general rules (above) , in can be conclude that all four capability factors (H, D1, A, S) have measured an underlying proposed construct (capability in this case) with high validity and none of the capability factors should be eliminated from the analysis.

The calculated Kaiser's MSA was equal to 0.622 and Bartlett's test of sphericity was significant ($p = 0.000$), indicating this common factor model is appropriate (these tests' details explained in 7.2). Thus, based on the results of Cronbach's alpha and PCA, we conclude that the four nominated factors are the true indicators/predictors of collective capability.

The obtained results from conducting the reliability and validity tests which represented up to this point in this chapter can give the researcher the confidence that the collected data from the sample in the empirical survey are highly valid and reliable data to be used for the purpose of statistical modelling in this study. In the following sections firstly the statistical methods which used for modelling purposes are explained. In each section this will be followed by the representation of the results from statistical tests.

7.3. The Systematic Approach to Structural Data Analysis and Modelling

To be able to answer the three research questions which explained in introduction part of this chapter, data analysis started by examining the one to one relationship between each of four nominated capability factors (independent variables: **H, D1, A, S**) and the collective capability of working teams (dependant variable: **CC).** The examination could lead to answering the first research question. Proving the existence of significant relationship between each independent variable and collective capability of the work teams (CC) may lead to proving a best fit linear model that predicts the collective capability (CC). Each of the four independent variables has been measured from the provided information (by the sample teams) and using the "HDAS" model algorithm (explained in chapter 6). To answer the first research question four separate hypothesis is suggested (one for testing relationship between each independent variable and dependant variable) and tested further in this section.

This will be followed by developing the general model which is the best estimation of the dependant variable using the multiple linear regressions modelling technique. Conducting the multiple linear regression modelling can answer the second research question with the final outcome of linear model to predict collective capability using all four capability factors in a general model. The third research question (explained at the beginning of this chapter) will be answered by investigating the ***direct and indirect*** relationship between the four capability factors, H, D1, A, and S, and the whole team's capability level, CC. Structural Equation Modelling (**SEM**) was proposed to model the direct and indirect relationship between the four capability factors, H, D1, A, and S, and the whole team's capability level, CC. By using

the results of current study we hope we could provide the necessary knowledge for managers and team builders to identify capable project teams.

At the end of this chapter, the reader will be presented with a model that connects the independent variables (capability factors) and dependant variable (collective capability level). The resulted model could be considered as the best estimation of collective capability (CC).

The systematic plan and sequences of data analysis and modelling is presented in figure 7-2

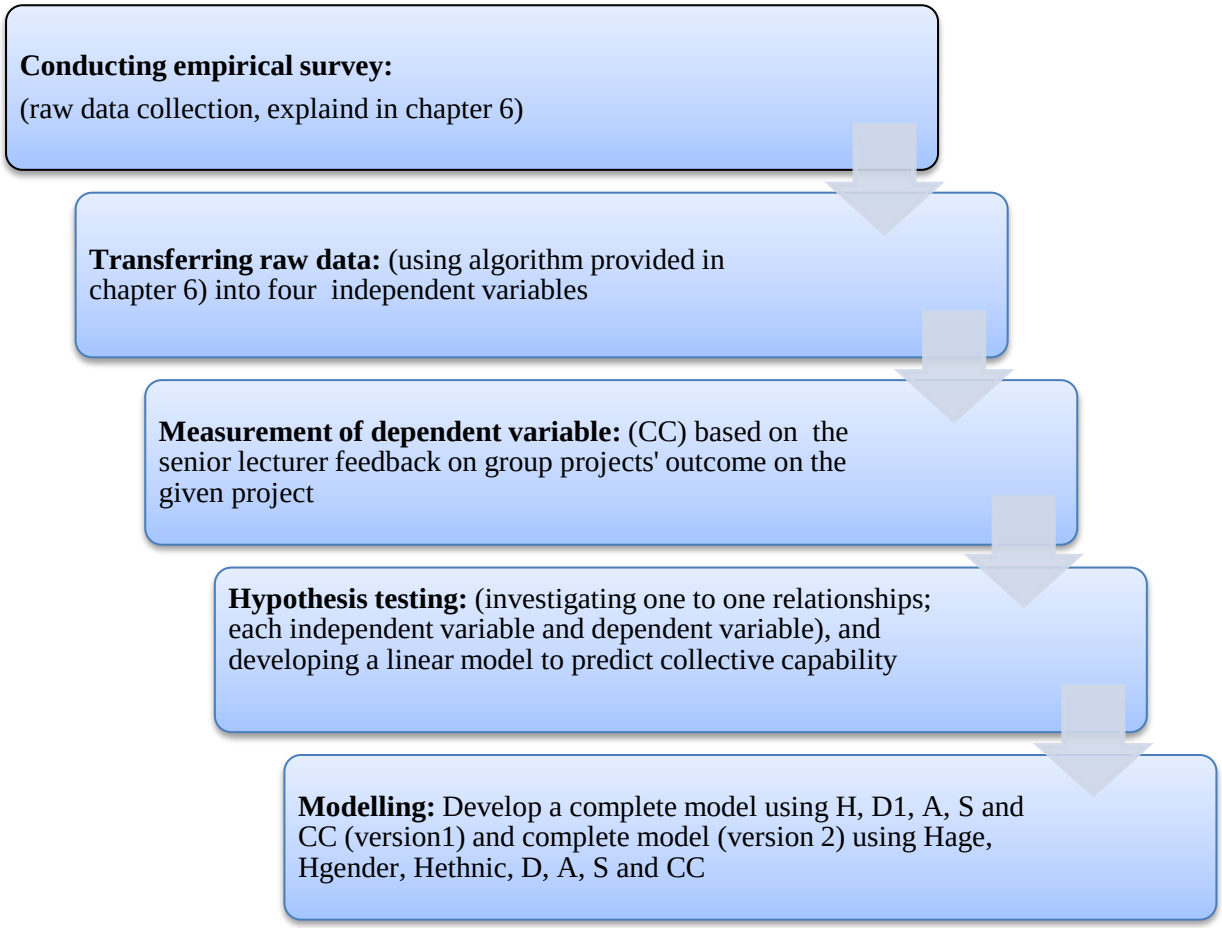


Figure 7-2 plan and sequences for modelling and data analysis

7.4. The Hypotheses Testing of One to One Relationships of Capability Factors and Collective Capability of Work Teams

In this section the one to one relationship between each capability factor (independent variables) and the collective capability level of the project teams (dependant variable) will be tested. The method used to test the one to one relationships was *Pearson's Correlation Coefficient* which is a suitable and widely used technique for investigating the linear relationships between two quantitative continues variables. The *Pearson's correlation coefficient* test is the most suitable method to test the correlation between two sets of variables when data are following a normal distribution. If the data in the study are not normally distributed the Spearman Rank Correlation method can be used to test the correlations. In our case the Shapiro-Wilk test has done on the four capability factors (variables) and measured values of collective capability to test the normality of variables. The results of normality tests as presented in table 7-8 showed that we cannot reject the null hypothesis in Shapiro-Wilk test which claims the normality of variables in the test. This is because from table 7-8 and using the sig. value which are all greater than 0.05 (for all variables) the null hypothesis in Shapiro-Wilk test cannot be rejected (for both independent variables and dependant variable) and we can conclude that all variables following a normal distribution. As a result the Pearson's Correlations Coefficient method is an appropriate method to test the correlations between each independent variable and the dependant variable in the study.

Table 7-8 results of Shapiro-Wilk normality test on four capability factors

Variable	Shapiro-Wilk		
	Statistic	df	Sig.
Homophily (H)	.920	48	.062
Skills Diversity (D1)	.955	48	.154
Instrumental Relationships Strength (S)	.982	48	.673
Average Previous Attainment (A)	.967	48	.185
Collective Capability (CC)	.965	48	.167

The obtained coefficient of correlation from the Pearson's Correlation Analysis describes the nature (negative or positive) and strength (weak or strong) of correlation between the two variables. The *P*-value (shown as "Sig." in Pearson's' correlation tables) serves as criterion to check the significance of the correlation coefficient. This *P*-value must be less than 0.05 for 95% confidence interval. Correlation coefficient represents the degree to which the trends of two variables are related to each other. The coefficient takes values between -1 and 1, the more it is closer to -1 or 1; stronger is the correlation between the variables.

Calculation of the correlation coefficient between the pairs of the variables will be done via SPSS software package and a correlation matrix consisting variables of each model equation will be obtained.

When faced with more than two variables, economists or researchers arrange the correlation between each pair into a matrix. There is caution over interpreting correlation coefficients (Caner and Kilian, 2001). Correlation does not mean causation. Another limitation associated with correlation coefficients is in the way data is collected. Narrow and restricted data always give a deflated correlation. It is good to look for an explanation of correction as many

instances correlation are explained by a third variable (Caner and Kilian, 2001). In this study however the correlation test is applied in order to find out how strongly pairs of variables are related and if they are related or not.

As we have four independent variables (H, D1, A, S) defined in this study, so we have four hypothesis (one for each independent variable and dependant variable) to test the correlations. The final results of four hypotheses test can answer the first research question defined in the introduction section of this chapter.

The first hypothesis is outlined in order to find out how strongly the total demographic homophily level of project groups (H) is related to the collective capability (CC) level of the project groups. So the first hypothesis is defined as:

H10: There is not exist significant relationship among networks' (teams') collective capability (CC) and total level of homophily of the network (H).

H1a: There exists significant relationship among networks' collective capability (CC) and total level of homophily of the network (H).

Importing the data (from survey) into the SPSS software packaged and conducting the Pearson's correlation analysis, the result of testing the first hypothesis is presented in table 7-9.

Table 7-9 results of Pearson's correlation analysis to test first hypothesis

Correlations

		Networks Capability (dependent variable)	Total level of Homophily (independent variable)
Networks Capability (dependent variable)	Pearson Correlation	1	.647**
	Sig. (2-tailed)		.000
	N	48	48
Total level of Homophily (independent variable)	Pearson Correlation	.647**	1
	Sig. (2-tailed)	.000	
	N	48	48

**. Correlation is significant at the 0.01 level (2-tailed).

The table7-9 presents the findings of Pearson's correlation analysis which is carried out among network collective capability (CC) and total level of homophily (H). It can be observed that the value of person correlation is 0.647 ($r = 0.647$, $p = .000 < .05$), showing strong and positive relationship between demographic homophily level of the networks and the collective capability of the networks. As value of significance is less 0.05 thus the null hypothesis will be strongly rejected and the rejection of the null hypothesis supports the assertion that there is a significant relationship among network collective capability and total level of total homophily (H). This results indicate that having group groups which members are similar in terms of demographic characterises can possibly affect their network level capability in fulfilling a given group project.

The next hypothesis in the study was outlined to test the possible relationship between skills diversity (D1) of the project groups and collective capability (CC) of the project teams. So the second hypothesis was defined as:

H20: There is not exist significant relationship among networks collective capability (CC) level and skills diversity of members (D1)

H2a: There exists significant relationship among networks collective capability (CC) level and skills diversity of members (D1)

The results of the analysis are presented in table 7-10:

Table 7-10 results of Pearson's correlation analysis to test second hypothesis

Correlations

		Networks Capability (dependent variable)	Skills Diversity Level(independent variable)
Networks Capability (dependent variable)	Pearson Correlation	1	.521**
	Sig. (2-tailed)		.000
	N	48	48
Skills Diversity Level(independent variable)	Pearson Correlation	.521**	1
	Sig. (2-tailed)	.000	
	N	48	48

**. Correlation is significant at the 0.01 level (2-tailed).

The table 7-10 presents the findings of Pearson correlation analysis which is carried out among network collective capability level (CC) and skills diversity level (D1) of the sample. The value of person correlation is 0.521 ($r = 0.521$, $p = .000 < .05$). It means that the null hypothesis can be rejected at 99% confidence level. The test confirms that there is a strong and positive relationship exists among collective capability of the networks and the level of skills diversity of the networks (teams). In other words the result from testing the second hypothesis is indicating that forming project groups while using individuals with diverse

skills (required for the project) and not just focusing on individuals who are all professional in one category of skill (required for the project) can significantly improve the collective capability of the network.

The third hypothesis in this section tests the existence of a significant relationship between Average Previous Attainments (A) of the work team' members and the collective capability (CC) level of the teams. The third hypothesis is defined as below and the results of the Pearson correlation analysis can be found in table 7-11.

H30: There is not exist significant relationship among networks capability (CC) and average previous attainments of team members (A).

H3a: There exists significant relationship among networks capability (CC) and average previous attainments of team members (A).

Table 7-11 results of Pearson's correlation analysis to test third hypothesis

Correlations

		Networks Capability (dependent variable)	Average Previous Attainment(independent variable)
Network Capability (dependent variable)	Pearson Correlation	1	.434**
	Sig. (2-tailed)		.002
	N	48	48
Average Previous Attainment(independent variable)	Pearson Correlation	.434**	1
	Sig. (2-tailed)	.002	
	N	48	48

**. Correlation is significant at the 0.01 level (2-tailed).

The results from Pearson's correlation analysis (presented in table 7-11) shows that the value of person correlation is 0.434 ($r = 0.434$, $p = .002 < .05$) and the P value is significant. The

results of test (similarly to the first two hypotheses) reject the null hypothesis. The test reveals that there is a significant positive relationship between the average previous attainment of members in work teams and the collective capability level of the teams. This finding interestingly can give more value to some conventional ways of project team formation in organisations which highly rely on individuals' previous work history and experiences (such as CVs and referencing from previous jobs).

The fourth and final hypothesis to be tested in this section was suggested to test the one to one relationship between the strength of team members' instrumental relationships (S) and collective capability (CC) level of the work teams. The fourth hypothesis was outlined as:

H40: There is not exist significant relationship between networks collective capability (CC) and strength of instrumental relationship among team members (S).

H4a: There exists significant relationship between networks collective capability (CC) and strength of instrumental relationship strength among team members (S). The same technique was used to test the hypothesis and obtained results are in table 7-12.

Table 7-12 results of Pearson's correlation analysis to test fourth hypothesis

Correlations

		Networks Capability (dependent variable)	Relationship Strength (independent variable)
Networks Capability (dependent variable)	Pearson Correlation	1	.686**
	Sig. (2-tailed)		.000
	N	48	48
Relationship Strength (independent variable)	Pearson Correlation	.686**	1
	Sig. (2-tailed)	.000	
	N	48	48

**. Correlation is significant at the 0.01 level (2-tailed).

The result of the fourth Pearson's correlation analysis in this section rejects the null hypothesis. From table 7-12 it can be observed that the value of person correlation is 0.686 ($r = 0.686$, $p = .000 < .05$). It can be concluded that there is a strong and positive relationship among the strength of instrumental relationships of the team members and their collective capability level. As value of significance is less 0.05 thus it can be said that there is a significant relationship between network collective capability (CC) and the strength of instrumental relationship among members of a project team. The finding from testing the fourth hypothesis in this section was highly in line with previous researchers' concern (discussed in literature review chapters) who all tried to relate the outcome of human groups to existence of strong relationships and knowledge sharing between team members.

In summary the results of the hypothesis testing on one to one relationship confirms that all four nominated capability factors (H, D1, A, S) are the suitable factors in prediction of the collective capability (CC) of the project teams. This is said because all four Pearson's correlation tests rejected the assumed null hypothesis (which there is no significant relationship) and proved the existence of a significant and positive relationship between each capability factor (independent variable) in the study and the collective capability of work teams. This is a good obtainment which can lead the data analysis to the next stage and finding the best fit model to predict the collective capability (CC) using four discussed capability factors. The finding of next section can answer the second research questions of the study.

7.5. Collective Capability Statistical Modelling, Regression Analysis

In this section the data which obtained from empirical survey in the study and processed into capability factors (independent variables) will be used for modelling purposes with aim of introducing a linear model which can best predict the collective capability level using the discussed capability factors.

It's important to begin this section with providing a description of a statistical model.

What is a statistical model?

A statistical model is "a simple description of a state or process" (Levins, 1966). It's important to differentiate between a statistical model and a hypothesis. "A model is neither a hypothesis nor a theory" (Levins, 1966). In other words, "unlike the scientific hypothesis, a model is not verifiable directly by an experiment. For all statistical "True" or "False" model, the validation of the model is not that its "true" but it actually generates good and testable hypothesis relevant to a problem". (Levins, 1966).

In modelling procedure, Yan and Su (2009) explain that Linear regression analysis can be used as method to find the relationships between one or more response variable (dependent variables, *Y*) and predictors (independent variables,X_1, X_2,.. X_P).

Three types of regression modelling technique can be used for modelling purposes. The first type of regression modelling is used when one wants to find the linear relationship between one response variable (*Y*) and one predictor (independent variable X). According to Yan and Su (2009), the simple regression model is usually written as:

$$Y = \beta_0 + \beta_1 X + \varepsilon \qquad \textbf{7.4}$$

Where:

Y: is response (dependant) variable,
X: predictor (independent) variable
β_0 : is Y intercept
β_1 : is gradient or slop of regression line and
ε: is the random error

The second type of the regression modelling is used when more than one independent variable predict the dependant variable. This type of regression modelling is named *multiple linear regressions* and it has several predictors (independent variables). In other words in multiple linear regression one response variable is a linear function of model parameters and there are more than one predictors in the model.

It is expressed in the form of:

$$Y = \beta_0+\beta_1 X_1+\ldots \quad +\beta_P X_P +\varepsilon \qquad \textbf{7.5}$$

Where:

Y: is response (dependant) variable
$\beta_0, \beta_1, \ldots \ \beta_P$ are regression coefficient
X_1,.. X_P are predictors(independent variables)
ε: is the random error

In classical multiple regression modelling ε follows a normal distribution with $E_\varepsilon = 0$ and a constant variance *Var* (ε) =σ^2

In statistics, the coefficient of determination, R^2 pronounced "*R squared"* is a statistic used in the context of a statistical model whose primary purpose is to predict future results or test a hypothesis. The coefficient determines the quality of the model to replicate the results, and the proportion of variation in results that can be explained by the model (Lee and Baskerville,

2003). In other words the "*R squared"* value in regression analysis is used to determine how close the data is to the fitted model. It's also known as coefficient of determination.

There are several different definitions for R^2 that are sometimes equivalent and commonly refer to linear regression. In this case, the R^2 is simply the square of the Pearson correlation coefficient, which is only true for simple linear regression. If multiple results for a single variable, namely X exists for Y, Z... determination coefficient is the square of the coefficient of multiple determinations. In both cases, R^2 takes values between 0 and 1. Value of 0 for R squared indicates that the model explains none of the variability of the response data around its mean whereas in contrast value of 1 for "R squared" indicates that the model explains all the variability of the response data around its mean. As a result the higher (closer to 1) the value of the "R squared" the better the model fits to the data (The Minitab Blog, 2013).

For the regression R^2 is sufficient to the square of the Pearson correlation coefficient (Lee and Baskerville, 2003, 23).

$$R^2 = \frac{\delta^2{}_{XY}}{\delta^2{}_X \delta^2{}_Y} \qquad \textbf{7.6}$$

Where:

- $\delta_{XY}$is the covariance of X,Y
- $\delta_X$is the standard deviation of the variable X
- $\delta_Y$is the standard deviation of the variable Y

The third and final type of regression assumes that the relationships between response (dependant variable) and the model predictors (independent variables) are nonlinear relationships. This type of regression is more complicated, compare to the first two types in the terms of model parameters, model selection, and model diagnosis. It's written in the form of:

$$Y = \frac{\alpha}{1+e^{\beta t}} + \varepsilon \qquad \textbf{7.7}$$

Where:

Y: is growth of an organism as a function of time *t*
α and β are model parameters
ε is the random error

General theory of non-linear regression is out of scope of this research because from one hand the statistical modelling for the concept of collective capability is still at its early stages (to be best of researcher's knowledge) and its seems logical to start the modelling process with the linear modelling technique to predict the concept rather than using non-linear technique which involves and requires different careful examinations of predictors at different stages (Archontoulis and Miguez, 2013). Choosing the best modelling technique (for example: linear or non-linear) for a specific concept is not always an easy task. Especially if the modelling study is at its early stage in a specific area (capability in our case) it's better to start with linear models which are more flexible and less complicated to interpret (Archontoulis and Miguez, 2013). On the other hand there have been some prerequisites checks (to be tested on the data in the study) which can confirm the suitability of the linear regression modelling technique for modelling purpose. The four main required prerequisites: independence of observations, linearity, normality and homoscedasticity of the variables

which can confirm the suitability of linear regression techniques have been tested on the collected data in this study and all four checks confirm the suitability of the technique. The four prerequisites and the tests' results are explained in further sections.

In summary as results of above explanations, in this study we start the modelling procedures on the concept of collective capability with testing the linear relationships between the collective capability and the nominated predictors (capability factors). However in future testing the non-linear relationships between the discussed variables in this study can be an interesting area of research which will be discussed in future work section.

In statistical modelling *descriptive statistics* is a big part of the whole modelling process that is dedicated to collect, analysis and represent a set of data in order to properly describe the features of this. This analysis is very basic. Although there is a tendency to generalise to the entire population, the first conclusions after a descriptive analysis is a study by calculating a series of measures of central tendency, to see to what extent the data is grouped or scattered around a central value (Welch et al., 2002).

The descriptive statistics of the variables used in this study (H, D1, A, S and CC) have been provided and discussed earlier in data validity and reliability section. Just a quick recall that between all independent variables (measured from empirical data), the skills diversity of project groups (D) had a higher deviation (compared to other variables) in the study. As a result the researcher has decided to use a formula (formula 7-2) to stabilise the variance of D which can help to be more consistent with other predictors in the study and have more accurate analysis (the descriptive information of variables of the study can be found in table 7-3). The variable obtained from transformation of D (using formula 7-2) is named D1 in the study.

As its shown in table 7-3 earlier in this chapter, the networks capability (CC), total level of homophily (H), skills diversity level (D1), average previous attainment (A) and relationship strength (S) deviates with a value of 0.10, 0.15, 0.25, 0.14 and 0.17 to mean value of 0.62, 0.64, 0.66, 0.61 and 0.58, respectively. This indicates that the results do not deviate with a high proportion. This behavior was expected from the data collected from empirical survey sample in this study as the majority of participants in the study had similar demographic and professional profiles.

To conduct the multiple linear regressions on the dependent and independent variables in this study the following prerequisites needed to be tested on the collected data and the author needed to be satisfied that data are suitable data to be used for linear modelling purpose. The four prerequisites which have been tested on the data are as:

1. **Independence of observations** - residuals are independent.
2. **Linearity**: the relationship between the dependent and independent variables is linear.
3. **Normality**: the distribution of the residuals is normal.
4. **Homoscedasticity**: the residuals have constant variance (equal variance).

It's important to make sure that these prerequisites on the data are satisfied for linear regression analysis. The reason is that satisfying the four prerequisites can result in obtaining a good fit model from doing the linear regression analysis on the variables. Each of these prerequisite can test the suitability of the linear regression modelling as a potential technique to find the relationships between dependent and independent variables in this study. For example the satisfaction of the first assumption (independence of observations) can assure the author the independence of occurrence of observations within any particular group in the sample. This means that the occurrence of one observation does not change the probability of occurrence of other observations within the same group.

The second prerequisite: linearity (as it says its name) specifically can assure the researcher the suitability of the linear regression technique for modelling purposes. The satisfaction of this prerequisite can actually confirm the linearity of relationships between variables in this study.

The normality test on the data however can test and assure that the variables used in modelling have normal distribution as non-normal variables (highly skewed or kurtotic variables or variables with substantial outliers) can distort relationships and significant test (Osborne and Waters, 2002). So it's very important to test and check if the calculated values for independent variables in the survey are following a normal distribution before doing regression analysis.

Finally Homoscedasticity can assure that the variances of errors are homogenous. In other words testing the homoscedasticity can assure that the noise or random disturbance in the relationship between the independent variables and the dependent variable is the same across all values of the independent variables.

To test the above prerequisites on the data different statistical measures have been used while doing the linear regression modelling in this study. The used statistical measured are explained further in this section.

The normality of the data was examined through:

- **Skewness:**

  The sample skewness measures the tendency of the deviations to check if it is larger in one direction than in the other. Skewness is a measure of symmetry. Observations that are normally distributed should have skewness near zero, as normal distribution is

symmetric (Boyer et al., 2015). A negative skew indicates that the tail on the left side of the probability density function is longer than the right side and the bulk of the values lie to the right of the mean (skewed to the left). A positive skew indicates that the tail on the right side is longer than the left side and the bulk of the values lie to the left of the mean (skewed to the right).

- **Kurtosis:**

  The sample kurtosis measures the peakedness of the distribution and the heaviness of its tail (relative to a normal distribution). Observations that are normally distributed should have a kurtosis near zero. A high kurtosis distribution has a sharper peak and fatter tails, while a low kurtosis distribution has a more rounded peak and thinner tails (Jones et al., 2011)

- **The Shapiro-Wilk test of normality:**

  The Shapiro-Wilk test procedure is a goodness-of-fit test for the null hypothesis that the values of the analysis variable are a random sample from the normal distribution. P-value less than 0.05 of the Shapiro-Wilk test leads to the rejection of the null hypothesis of normality (Salkind and Rasmussen, 2007).

- **The quantile-quantile (Q-Q) plot:**

  The Q-Q plots compare ordered variable values with quantiles of a specified theoretical distribution (in our case, normal distribution). If the data distribution matches the theoretical distribution, the points on the plot form a linear pattern - following the 45 degree straight line (Dhar et al., 2014).

  Residual plot (residuals versus fitted values) was used to investigate if the variance is constant/equal and if the relationship between the dependent and independent variables was linear. Plotting residuals versus the value of a fitted response should

produce a distribution of points scattered randomly about 0, regardless of the size of the fitted value. The residuals should be

- **Unbiased:** the average value of residuals in any vertical strip should be zero.
- **Homoscedastic (homogeneity of variance):** the spread of the residuals should be the same in any vertical strip.

In addition, *variance inflation factor* (VIF) was used to detect whether collinearity exists among the independent variables in the regression model. With collinearity, it is hard to investigate the distinct effects of the independent variables on the dependent variable and collinearity also makes the parameter estimates unstable. The value of VIF greater than 10 indicates the presence of collinearity (Balsley et al., 1980).

Importing the data from survey into SPSS software and conducting the required tests (to check the prerequisites explained earlier) and finally conducting the multiple linear regression analysis on the data the obtained results are presented in table 7-13.

Table 7-13: results of the linear regression

	Unstandardised Coefficients		Standardised Coefficients	t statistic	p-value	Collinearity Statistics	
	B	SE	Beta			Tolerance	VIF
Intercept	.207	.047		4.437	.000		
H	.204	.065	.314	3.119	.003*	.686	1.459
S	.233	.061	.396	3.840	.000*	.652	1.535
A	.109	.064	.155	1.708	.095**	.845	1.183
D1	.123	.035	.307	3.477	.001*	.889	1.125

Note: * significance at the 0.05 level. ** Significance at the 0.1 level. SE = standard error.

Using the results from multiple linear regressions (table 7-13), the Unstandardised Coefficients used to generate the fitted model which can describe the relationships between independent variables (H, D1, A, S) and the dependant variable (CC) and as a result the linear predictor of collective capability when people work in a group can be expressed as:

The Linear Predictor model of the collective capability suggested by this study:

$$\mathbf{CC = 0.207 + 0.204*H + 0.233*S + 0.109*A + 0.123*D1} \qquad \mathbf{7.8}$$

The calculated *R squared* value in the regression was R^2= 0.837, indicates that 84% of the variation in the dependent variable (Collective Capability) can be accounted for by the model. The results of the *t-test* for testing if there was a significant relationship between the dependent variable and the independent variables in a linear fitted model indicated that:

- There was a statistically significant relationship between Collective Capability (CC) and Homophily level (H) at the 0.05 level of significance (t(43) = 3.119, p = 0.003). The number in the bracket (43) indicates the degrees of freedom in the regression. The degree of freedom is the number of values in a calculation which we can vary and is calculated as:

$$\text{Degrees of freedom: DF = n-p-1} \qquad \mathbf{7.9}$$

Where:

n: sample size (48 groups in our case)

P: number of predictors (independent variables)

According to the (unstandardised) regression coefficients, for every unit increase of H, CC would increase by 0.204. Thus, there was a positive relationship between CC and H, i.e., the

greater the demographic homophily level of the network (H), the greater collective capability of the whole network (CC).

- There is a statistically significant relationship between Collective Capability (CC) and level of Strength of instrumental relationships among group members (S) at the 0.05 level of significance ($t(43) = 3.840$, $p = 0.000$). According to the (unstandardised) regression coefficients, for every unit increase of S, CC would increase by 0.233. Thus, there was a positive relationship between CC and S, i.e., the greater the instrumental (task related) relationships' strength among the individuals in a network (S), the greater collective capability of the whole network (CC).

- There is no statistically significant relationship between CC and A (Average previous attainment of members) at the 0.05 level of significance ($t(43) = 1.780$, $p = 0.095$). However this relationship was significant at 0.1 level.

- There is a statistically significant relationship between CC and D1 (skills diversity level) at the 0.05 level of significance ($t(43) = 3.477$, $p = 0.001$). According to the (unstandardised) regression coefficients, for every unit increase of D1, CC would increase by 0.123. Thus, there was a positive relationship between D1 and S.

The standardised regression coefficients, Beta, are shown in Table 7-13 as well. Beta represents the change in response for a change of one standard deviation in a predictor, and can be used to compare the effects of the predictors on the dependent variable. The larger the standardised regression coefficient (absolute value, if consider the +/- sign), the larger the effect of x (independent variable (or predictor)) on y (dependent variable). Based on the results of Table 7-13, S has the largest effect on CC (Beta = 0.396), followed by H, D1, and A. These results suggest that work groups who their members can get on well and form

strong instrumental relationships can achieve high level of collective capability. Homophily as the second effective factor also had a significant positive effect on the collective capability of the work teams. This suggests that having homophile work groups can result in getting higher capability level from the work teams.

Interestingly according to *t-test* the previous attainment of the members (A) in a group has the least (but still significant at (0.1 level) effect on the work team's collective capability level. According to this finding the author can suggest the team builders and manager to put more effort on gather individuals who are willing to form strong task related relationships with other group members (because of strong effect of this factor, shown in table 7-13) rather than focusing on individuals with high previous profile who are not willing to share information and building strong ties with other group member. This is because the result of the analysis in this study showed that the effect of strong instrumental relationships (among team members) is much higher (0.233 for S compare to 0.109 for A) than effect of previous attainments (experiences) of the individuals on the total capability of the team.

As its shown in table 7-13 the measured value for *variance inflation factor* (VIF) was smaller than 10 for all four independent variables indicating that there was no collinearity among the independent variables in the regression model. Note that the other collinearity statistic, "tolerance", was equal to 1/VIF.

The prerequisites checks (discussed earlier) which can confirm the suitability of linear regression modelling were also checked and the obtained results expressed that the obtained linear model (shown in 7-8 formula) is a suitable representative model for variables in the study. The measured values to satisfy the suitability of linear modelling are presented in the next page:

- The skewness and kurtosis of the residuals from the fitted model were -0.367 and -0.364, respectively. The Shapiro-Wilk test did not reject the null hypothesis that the residuals were from a normal distribution (p = 0.465). The QQ plot (Figure 7-3) suggests that the residuals seem to follow a normal distribution.

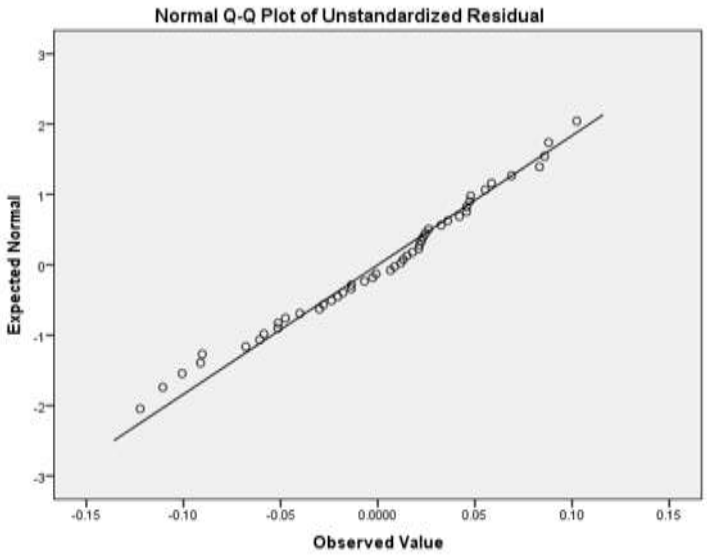


Figure 7-3 Q-Q plot for unstandardised residual

- The plot of unstandardised residuals and fitted values (Figure7-4) suggests the variance was homogeneous and the relationship between the dependent and the independent variables was linear because as it can be observed on the plot the predicted unstandardised values are following a random pattern centered on zero line. From the plot in figure 7-4 we can see no relationship between the residuals and the predicted values which is consistent which assumption of linearity.

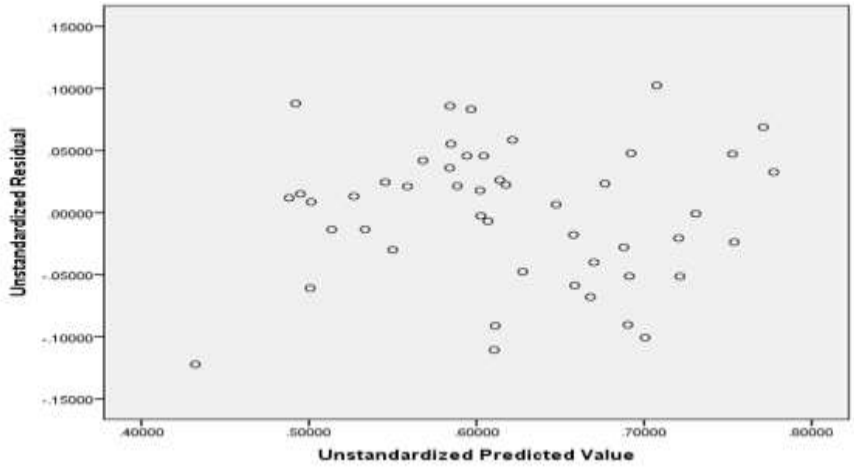


Figure7-4 residual plot

Thus we conclude that different measured values to test the suitability of a linear model can confirm the fitted model was a good fit. The finding of this part of analysis has answered the second research question which was introducing a linear model as a predictor of collective capability of the work teams (introduced in formula 7-8. In the following section the Structural Equation Modelling technique (SEM modeling) will be concocted on the data to investigate the direct and indirect effect of the capability factors on the collective capability of the work teams.

7.6. Structural Equation Modelling (Path Analysis)

The Structural equation modelling, SEM (Path analysis) used for modelling the direct and indirect relationships between four independent variables and the work teams' collective capability level (dependant variable). The SEM analysis should be differentiated from Collinearity test conducted earlier in this chapter and solely investigated the possibility of collinearity between four independent variables.

The SEM modelling in statistical analysis is a useful method to test hypothesised existence of directional and non-directional relationships among a set of measured (independent) and

latent (dependant) variables (MacCallum and Austin, 2000). The main objectives of SEM modelling are firstly to investigate the patterns of correlation among the variables in the study and secondly to explain as much of their variance as possible with the model specified (Kline, 1998).

There are some similarities and differences between SEM and multiple regression analysis. In terms of similarities both SEM and regression modelling are based on linear statistical models. In addition both method are valid if the a set of assumptions (prerequisites discussed earlier) are met. In more details the regression analysis assumes the existence of a normal distribution among variables and SEM assumes the existence of multivariate normality.

However the differences between the two methods are in some ways. Firstly the SEM analysis is much more flexible and comprehensive method compare to regression as it can be used in variety of concepts such as investigating the achievements, economic trend and self-efficacy (MacCallum and Austin, 2000).

Secondly the regression method starts with a default model (like our presented conceptual model in this study in chapter 6) whereas the SEM requires formal specification of a model to be estimated before any analysis is conducted. In other words the SEM starts with no default model and as result places few limitations on the type of relationships which will be tested. This can give the research more freedom in investigating the potential relationships between variables. Defining a specified model for SEM to start the analysis requires the researcher to support the proposed hypotheses with the theories related to his/her research.

Thirdly the SEM analysis is able to solve more than one related equation simultaneously to determine parameters. More importantly each variable in SEM modelling could be

independent **and** dependant whereas in regression variables are **either** independent or dependant.

Fourth, in SEM a graphical language (Paths diagram) can provide the researcher a powerful tool to present the possible complex relationships between variables in the study. This is very useful when there are multiple variables in the study which are required to be included in the modelling process. Finally traditional statistical methods, such as regression analysis usually use only one statistical test to determine the significance of relationships among variables (such as R Squared in regression analysis). In SEM however several statistical tests will be conducted to determine the adequacy of the model fitted to the data. For example for the path analysis in our study we used following goodness-of fit indices to determine the model fit. The goodness-of fit indices used in this study are as below and are adopted from Bryne, 2010; Hooper et al., 2008; Hu and Bentler, 1999 and Baumgartner and Homburg, 1996 studies:

- **Ratio of Chi-square to Degrees of Freedom (χ^2/df):**

The chi-square tests the hypothesis that the model is consistent with the pattern of covariation among the observed variables, smaller rather than large values indicate a good fit. General rule for an acceptable fit: Ratio of $\chi^2$to degrees of freedom ≤ 2 or 3

- **Root Mean Square Error of Approximation (RMSEA)**

The RMSEA tells us how well the model, with unknown but optimally chosen parameter estimates would fit the populations covariance matrix. The RMSEA ranges from 0 to 1, with smaller values indicating better model fit. A value close to 0.08 or less is indicative of an acceptable model fit.

- **Normed Fit Index (NFI) and Incremental Index of Fit (IFI)**

NFI assesses the discrepancy between the chi-squared value of the hypothesised model and the chi-squared value of the baseline model (where all covariances among manifest variables are assumed to be zeros, i.e., all measured variables are uncorrelated). IFI was developed and can address the issue of parsimony and sample sizes which were known to be associated with the NFI. A cutoff value of 0.9 for NFI and IFI is an indication of an acceptable model fit.

- **Comparative Fit Index (CFI)**

CFI takes into account the sample size and is a revised version of NFI. A cutoff value of 0.9 for CFI is an indication of an acceptable model fit.

In this section we use SEM modelling method to investigate the direct and indirect relationships between five variables (H, D1, A, S, CC) in the study. Presenting the obtained results from SEM modelling requires a brief explanation of the SEM modelling technique's terminologies and different type of SEM modelling technique in this section.

According to Suhr, (2008) the implementation of SEM requires taking the following nine steps:

1) Review the relevant theories and literature to support a model to be analysed
2) Specify the model (in case of using SEM : drawing the diagram)
3) Select measures for variables represented in the model (in our case we have used "HDAS" model algorithm in chapter 6 to measure capability factors)
4) Collect data (empirical survey)
5) Conduct preliminary descriptive analysis (scaling, missing data)
6) Use SEM modelling technique (using software package) to estimate parameters

7) Asses the fitted model
8) Re-specify the model if meaningful
9) Interpret the results and discus the finding of the study

It's very important for the reader to be familiar with terminologies and graphical aspects of the SEM modelling before we move on and representing the findings from this technique. This is because SEM is a modelling technique which its main power comes from its graphical representation. The usual way to represent the findings from SEM modelling is mainly involve discussion on the existence and strength of relationships between variables in the study rather than just providing a single linear formula.

In the case of capability modelling the required data to conduct the SEM modelling have been collected from empirical survey in the study and the collected data has been transformed into the values for four capability factors using the provide "HDAS" algorithm in chapter 6. The next step of doing the SEM modelling requires us to draw a diagram to specify the proposed model and conduct the path analysis (will be explained 7.6.2). The software packed which is used to conduct the SEM analysis is AMOS supported by SPSS.

7.6.1. SEM Analysis Terminologies

In SEM modelling a **Measured** variable *(MV)* is a variable that is directly measured whereas a **Latent** variable *(VL)* is a construct that is not directly measured (Suhr, 2008). Different types of relationships which can be assumed between variables are:

- Association: for example correlation, covariance
- Direct relationship: a directional relation between two variables: e.g., direct effect of an independent variable on dependant variable

- Indirect relationship: is the effect of an independent variable on a dependant variable through one or more intervening (mediating) variable

In SEM modelling the term "Model" like any other statistical modelling technique is a "statistical statement about the relations among variables" (Suhr, 2008) and a path diagram is graphical representation of the proposed model. Parameters are specified as fixed or free. The free parameters are estimated from the data whereas fixed parameters are not estimated from the data and typically are fixed to zero or one.

The diagram symbols which are used in SPSS AMOS software (used in this study) to draw the path diagram for SEM analysis are presented in figure 7-5 as:

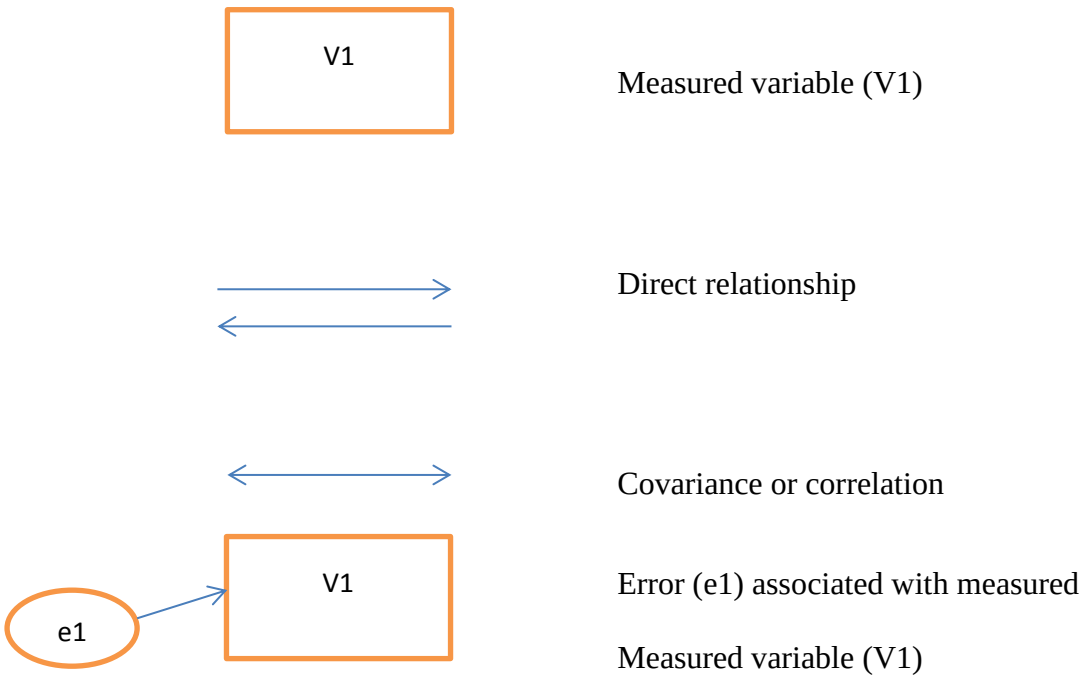


Figure 7-5 symbols used in path diagram for SEM analysis

As Bryne, (2010) discuses in his book, there are three types of structural models: just-identified, over-identified, and under-identified. In a just-identified model, there is a direct path from each variable to each other variable. In other words, the number of data variances

and covariances equals the number of parameters to be estimated. However, as there are no degrees of freedom for the just-identified model, the just-identified model cannot be used for parameter estimation. An under-identified model is one in which the number of parameters to be estimated exceeds the number of variances and covariances. Therefore, an under-identified model contains insufficient information for determining a determinate solution of parameter estimation. An over-identified model is one in which the number of parameters to be estimated is less than the number of variances and covariances, i.e., an over-identified model is one in which at least one pair of variables are not connected to each other by direct paths. Only over-identified models could be of use in causal inference as in such models there are more knowns than of unknowns. Because of this explanation, we will use an over-identified model in this study to investigate the direct and indirect relationships between variables in this study.

Note that in SEM modeling the number of covariances according Byrne, (2010) is calculated from formula below:

$$\text{Number of covariances} = K\,(K+1)/2 \qquad \textbf{7.10}$$

Where:

K: is the number of known variables.

In our case for a model with 5 variables (H, D1, A, S, CC), the number of data variances and covariances equals 5*(5+1)/2 = 15.

7.6.2. SEM modelling Results

To draw the paths diagram for SEM analysis in this study, observations (from measuring Pearson's correlation coefficients earlier) and common sense and logic were used to determine the paths of the proposed model. Table 7-14 shows the measured Pearson's correlation coefficients for H, D1, A, S and CC.

Table 7-14 Pearson's correlation coefficients for H, D1, A, S and CC

	D1	A	S	CC
H	0.293(0.043)*	0.214 (0.144)	0.530 (0.000)*	0.647 (0.000)*
D1		0.216 (0.140)	0.215 (0.143)	0.521 (0.000)*
A			0.367 (0.010)*	0.434 (0.002)*
S				0.686 (0.000)*

Numbers in parenthesis are the p-values. * indicates significance at the 0.05 level.

From table 7-14, it appears that there was a strong correlation between CC and all of H, D1, A and S. It was also noted that there was a moderate to strong correlation (based on the *P*-values in brackets) for S vs. H, S vs. A, and D1 vs. H. Thus, it was decided that the structural model would result in direct paths between H vs. CC, D1 vs. CC, A vs. CC, S vs. CC, H vs. S, A vs. S, and H vs. D1. Note that for each pair, the direction of the path was from the first variable to the second variable. In other words, the path determines the effect of the first variable on the second variable.

With respect to identifying the appropriate model with 5 variables (H, D1, A, S, CC), the number of data variances and covariances equals 5*(5+1)/2 = 15. The number of parameters to be estimated equals 12 (5 (variances of H, D1, A, S and CC) + 7 (paths between H vs. CC,

D1 vs. CC, A vs. CC, S vs. CC, H vs. S, A vs. S, and H vs. D1)). This leads to a (15-12) = 3 degrees of freedom for estimating a unique set of parameters consistent with the data.

Using the Pearson's correlation coefficients (presented in table 7-14) for assessing the suitable paths in the proposed model the path diagram for SEM analysis is drawn and presented in figure 7-6. The SEM analysis has been conducted using the drawn path diagram and result will be presented further in this section.

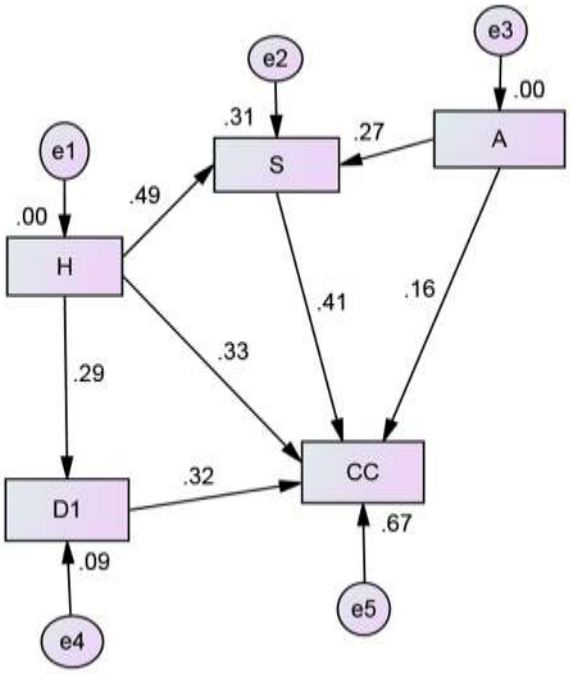


Figure7-6 path diagram used in SEM modeling

The results of conducting the path analysis is presented on the diagram presented in figure 7-6. For each path, the number shown on the arrow connecting two variables is the standardised parameter estimate. For each error term (e1,.. e5), the number shown is the squared multiple correlation. Squared multiple correlation estimates the percentage of the error variance of the variable explained by its predictors. For example, for collective

capability (CC), the squared multiple correlation equal to 0.67, indicating the predictors of CC (H, A, D1, S) explained 67% of its error variance.

To interpret the results of SEM modelling table 7-15 represents the unstandardised and standardised regression weights obtained from conducting path analysis. The standardised and unstandardised regression weights are shown for each pair of variable in the study.

Table 7-15 regression weights from Path Analysis

	Unstandardised regression weights	SE	Critical ratio	P-value	Standardised regression weights
H → S	0.523	0.130	4.015	<0.001*	0.486
A → S	0.318	0.141	2.257	0.024*	0.273
H → D1	0.476	0.227	2.102	0.036*	0.293
S→ CC	0.233	0.058	4.016	<0.001*	0.405
A → CC	0.109	0.059	1.845	0.065**	0.163
H → CC	0.204	0.062	3.285	0.001*	0.330
D1 → CC	0.123	0.033	3.686	<0.001*	0.323

Note: * significance at the 0.05 level. ** significance at the 0.1 level. Critical ratio = Unstandardised regression weights/SE. P-value was based on z-statistic for testing if the unstandardised regression weight was statistically significantly different from zero.

The results suggest that:

- There was a statistically significant relationship between S and H at the 0.05 level ($p < 0.0001$). The unstandardised regression weight = 0.523, indicating when H went up by 1, S went up by 0.523. The standardised regression weight = 0.486, indicating when H went up by 1 standard deviation, S went up by 0.486 standard deviations.

- There was a statistically significant relationship between S and A at the 0.05 level ($p = 0.024$). The unstandardised regression weight = 0.318, indicating when A went up by 1, S went up by 0.318. The standardised regression weight = 0.273, indicating when A went up by 1 standard deviation, S went up by 0.273 standard deviations.

- There was a statistically significant relationship between D1 and H at the 0.05 level ($p = 0.036$). The unstandardised regression weight = 0.476, indicating when H went up by 1, D1 went up by 0.476. The standardised regression weight = 0.293, indicating when H went up by 1 standard deviation, D1 went up by 0.293 standard deviations.

- There was a statistically significant relationship between CC and S at the 0.05 level ($p < 0.001$). The unstandardised regression weight = 0.233, indicating when S went up by 1, CC went up by 0.233. The standardised regression weight = 0.405, indicating when S went up by 1 standard deviation, CC went up by 0.405 standard deviations.

- There was no statistically significant relationship between CC and A at the 0.05 level ($p = 0.065$).

- There was a statistically significant relationship between CC and H at the 0.05 level ($p = 0.001$). The unstandardised regression weight = 0.204, indicating when H went up by 1, CC went up by 0.204. The standardised regression weight = 0.330, indicating when H went up by 1 standard deviation, CC went up by 0.330 standard deviations.

- There was a statistically significant relationship between CC and D1 at the 0.05 level ($p < 0.001$). The unstandardised regression weight = 0.123, indicating when D1 went up by 1, CC went up by 0.123. The standardised regression weight = 0.323, indicating when D1 went up by 1 standard deviation, CC went up by 0.323 standard deviations.

Next we have used the the unstandardised and standardised weights to calculate the direct, indirect, and total effect for each pair of variable. For example the direct, indirect and total effect of Homophily (H) on collective capability (CC) of the work teams are calculated as:

- The unstandardised direct effect of H on CC was 0.204, indicating that, due to the direct effect of H on CC, when H went up by 1, CC went up by 0.204. The standardised direct effect of H on CC was 0.330, indicating when H went up by 1 standard deviation, CC went up by 0.330 standardised deviations.

- The unstandardised **indirect** effect of H on CC was 0.181. The unstandardised indirect effect was calculated from sum of the product of related path coefficients: 0.523*0.233 + 0.476*0.123 = (H → S)* (S→ CC)+ (H → D1)* (D1→ CC). The unstandardised indirect effect of H on CC indicated that, due to the indirect effect of H on CC, when H went up by 1, CC went up by 0.181. This is in addition to any direct effect that H may have on CC. The standardised indirect effect of H on CC was 0.2914. The standardised indirect effect was calculated from sum of the product of related path coefficients: 0.486*0.405 + 0.293*0.323 = (H → S)* (S→ CC)+ (H → D1)* (D1→ CC).

The standardised indirect effect of H on CC indicated when H went up by 1 standard deviation; CC went up by .2914 standardised deviations.

- The unstandardised total effect (sum of direct and indirect effects) of H on CC was 0.385. That is, due to both direct and indirect effects of H on CC, when H went up by 1, CC went up by 0.385. The standardised total effect (sum of direct and indirect effects) of H on CC was 0.622. That is, due to both direct and indirect effects of H on CC, when H went up by 1, CC went up by 0.622.

The remaining of direct, indirect and total effects between variables in the study are calculated in a same manner and it's represented in Table 7-16. Blank call in the table means effect was not estimated in the model.

Table 7-16: unstandardised and standardised direct, indirect, and total effect among variables

	Unstandardised direct effect				Standardised direct effect			
	H	A	D1	S	H	A	D1	S
D1	0.476				0.293			
S	0.523	0.318			0.486	0.273		
CC	0.204	0.109	0.123	0.233	0.330	0.163	0.323	0.405
	Unstandardised indirect effect				Unstandardised indirect effect			
	H	A	D1	S	H	A	D1	S
D1								
S								
CC	0.181	0.074			0.292	0.111		
	Unstandardised total effect				Unstandardised total effect			
	H	A	D1	S	H	A	D1	S
D1	0.476				0.293			
S	0.523	0.318			0.486	0.273		
CC	0.385	0.183	0.123	0.233	0.622	0.274	0.323	0.405

From table 7-16 and using *unstandardised total effects' weighs* it's understood that the highest total effect from capability factors on the collective capability of work teams is from Homophily level of the work teams (0.385). It's followed by total effect of Instrumental relationships among members (0.233), individuals' previous attainment (0.183) and finally total effect of skills diversity (0.123) on the collective capability. These results (considering total effects: direct and indirect) which gives the first place (as the highest effective factor) on collective capability to homophily is slightly different from results of Regression analysis (in previous section) which suggested the Instrumental relationships (S) as the most effective factor on the collective capability. This difference in obtained results from the two methods can emphasise on the need which was felt by the author in this study to contact the SEM analysis. As it explained earlier the SEM modelling technique made the author to able to discover both direct and indirect and consequently the total effect of capability factors on the

collective capability of the teams. In other words the SEM modelling in this study can be counted as an expansion to the regression analysis which used earlier in this chapter.

By interpreting the SEM results, the Standardised total effects' weight also suggest the first and second place for *homophily* and *Structural relationships' strength* as the most effective factors on the collective capability of team. However the Standardised weights give the third effective factor's place to *Skills diversity* of individuals followed by *Individuals' previous attainments* as the fourth effective factors on the total collective capability.

In terms of the effect of the four capability factors in the study (H, D1, A, S) on each other, some interesting findings has obtained as a result of SEM modelling in this study. From table 7-16 and using the unstandardised weights it can be suggested that there is a strong effect from homophily level of the work teams on the strength of instrumental relationships between group members (even stronger than the effect of homophily or instrumental relationships themselves on the capability of work teams). This is a result which suggests having homophile work groups can result in having stronger instrumental bonds between individuals in working groups. The other interesting observation suggested that there is a strong effect of previous attainments of the members on their future instrumental relationships in the group (unstandardised weight: 0.318). This finding can be interpreted in this way that because individuals with high previous profile (lots of experiences) are usually mature individuals with years of experiences who can feel the value of good relationships with other group members so they will value other group members' idea and behaviours and form stronger instrumental relationships during the life cycle of the project.

While conducting the SEM analysis in this study the results of the fit statistics have been also used (From results of the path analysis) to make sure that the fitted model (presented in table 7-16) is an acceptable model. The summary of the fit statistics are as:

- $\frac{\chi^2}{df} = \frac{3.516}{3} = 1.172$, The ratio of Chi-square $\chi^2$to degrees of freedom ≤ 2, indicating an acceptable model fit.
- Mean Square Error of Approximation: RMSEA = 0.060, indication of an acceptable model fit.
- NFI = 0.958 and IFI = 0.994, both greater than 0.9, and hence indicated an acceptable model fit.
- Comparative Fit Index: CFI = 0.993, indicated an acceptable model fit.

The fit statistics have suggested the model fit (from SEM) was acceptable.

Table 7-17 (in the next page) shows the skewness and kurtosis of each variable. The multivariate kurtosis and the critical ratio of kurtosis were also displayed. All kurtosis was less than 7, indicating the data were not departure from normal distributions (Bryne, 2010). Furthermore, the critical ratio of the multivariate kurtosis (-1.191) indeed represents Mardia's normalised estimate of multivariate kurtosis. The value was less than 5, indicating the data were normally distributed (Bryne, 2010).

Table 7-17: assessment of normality, Path Analysis

Variable	Skewness	Kurtosis	Critical ratio of kurtosis
H	-0.130	-0.721	-1.019
A	-0.220	-0.214	-0.303
D1	-0.503	-0.926	-1.039
S	-0.112	-0.302	-0.427
CC	-0.221	1.032	1.459
Multivariate		-2.878	-1.191

7.7. Conclusion

This chapter used the data from the empirical survey in the study for statistical modelling purposes. To do so different statistical methods used to statistically test the relationships between collective capability (CC) of work teams and the four nominated capability factors (H, D1, A, S).

The chapter firstly tested the validity and reliability of the collected data to make sure that the data collected from questionnaires in the study are consistent and can well measure the experiment up to its claims. Conducting the validity and reliability tests on the data proved that the data are consistent and reliable data and can be used for purposes of statistical analysis in the study. The Cronbach alpha method and principal components analysis (PCA) used in this section to test the validity and reliability of the data.

The main part of the analysis started with providing descriptive information on the sample in the study. To test the relationships between dependant and independent variables the Pearson's correlation method is used and the one to one relationship between each capability

factor (independent variable) and the collective capability of work teams (dependant variable) tested in a separate hypothesis. The results of all hypotheses in this section showed the existence of a significant positive relationship between each of four capability factors and the collective capability of work teams.

In the next step the multiple linear regressions modelling is used to investigate a general model which can fit all four independent variables and the dependant variable in one general model. This model was obtained from conducting the linear regression modelling technique using SPSS software package and the obtained model was presented as one of the main findings in section 7-5 of this chapter.

The final part of this chapter has expanded the modelling and using the Structural Equation Modelling (SEM) technique investigated the direct, indirect relationships between all variables in the study were investigated. The aim of using SEM modelling technique was mainly to investigate any indirect relationships which capability factors might have on the collective capability of the teams which cannot be discovered using regression method.

Chapter 8 which is the final chapter of this thesis will provide a conclusion and implication about the findings of this research. It also expresses the limitations, and future area of research.

Chapter 8

Research Conclusion and Implications

This chapter aims to recap the main findings of this research and link the main findings to the proposed objectives of the research. For this purpose the research will be summarised and its main findings, practical use of the findings and limitations of the research will be presented in this chapter. The possibilities for furthering this research to extend its contribution to the knowledge will also be discussed in this chapter.

8.1. A summary of the Research

This thesis main aim was to introduce a statistical model which can be used for assessing and predicting the collected capability of work groups (human networks) in performing a given project. To achieve to this aim several objectives must have been met. Firstly, the concept of capability and human network (the two main concepts which form the backbone of this research), specifically their definition and practical use must have been reviewed at in variety of disciplines. Doing so could give the author the confident that he has in-depth knowledge about the two main concepts before entering the research to further stages.

In the next step the existing methods and models for measuring the capability must have been explored by the author. The finding of this part of the research could help the researcher to come up with a conceptual model which would be unique and has the power to eliminate the limitations of existing models. After reviewing the existing models and techniques for capability measurement and consequently exploring the limitation of the existing models the researcher was in a good position to further this research into the main value added part

which involved proposing a unique conceptual model for measuring and predicting the collective capability of human teams in future. To able to statistically prove the proposed conceptual model in this research, a survey has been designed and data from the survey (collected over two years) has been used to conduct appropriate statistical tests which statistically proved the validity of the proposed model in measuring the collective capability of human teams.

Figure 8-1 in a schematic view explains how this research aims to assess the collective capability.

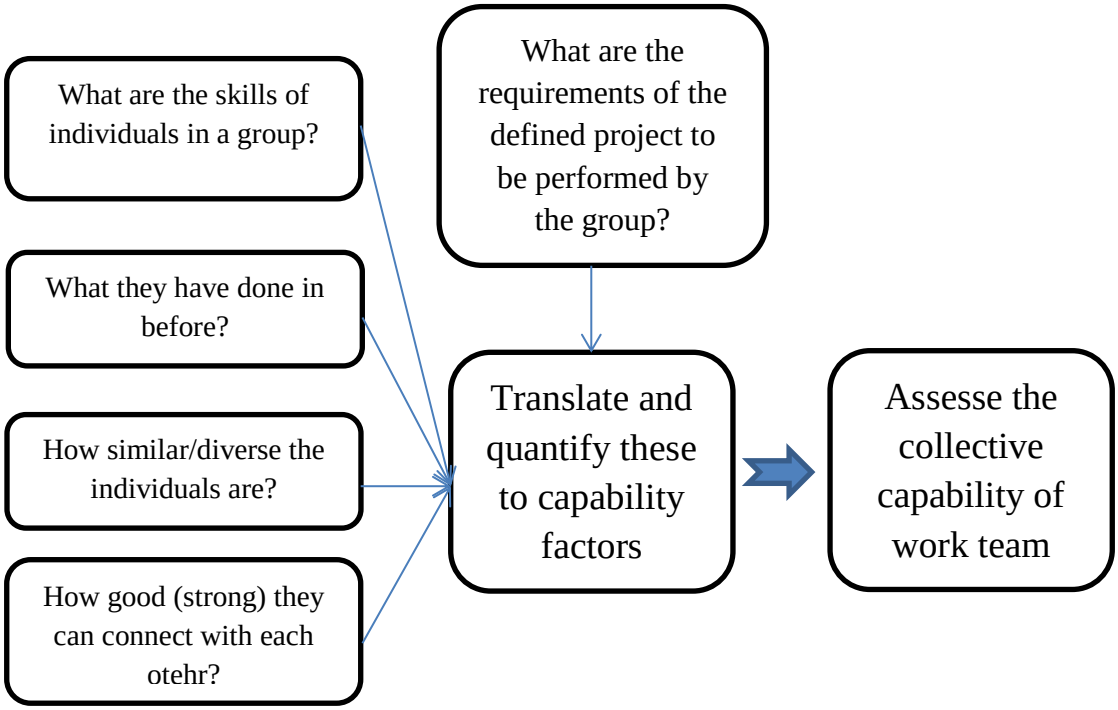


Figure 8-1 schematic view of the conceptual background of the research process

In more details, this conceptual framework has led the author to nominate four capability factors: demographic homophily of individuals in a network (H), their level of skills diversity (D), the average of individuals' previous attainment/experiences in similar project (A) and

their instrumental relationships' strength (S) to quantify the collective capability (CC) of a group (network) in fulfilling a given project's requirements. A linear conceptual model has been suggested to measure the collective capability of human networks using the four nominated capability factors. Further a unique algorithm ("HDAS" algorithm) was introduced to quantify the four capability factors. The input for "HDAS" algorithm included a combination of the project's requirements and some information about individuals' demographic characteristics, their professional (project related) history and their dynamic instrumental relationships. Using the "HDAS" algorithm one can measure the quantitative value of all four capability factors for a proposed group. Two main modelling techniques: Linear multiple regression modelling and Structural Equation Modelling used in this study and the results of mathematical modelling in both techniques showed a strong positive relationships between the independent variables (capability factors) and collective capability of work teams in the sample of this study. As a unique and final finding of this research a linear model was introduced which can be used in future to measure and predict the collective capability of a group of individuals in performing a given project. Mangers and decision makers can use the obtained model from this research to test the result of their interventions when building their project teams from their available pool of individuals.

8.2. The Modelling Approach Uniqueness

This research looked at the concept of capability from a unique perspective which combines both individual related and network related capability factors in defining and modelling the collective capability of human networks. In other words the finding of this research has proposed a quantitative measurement tool for predicting the collective capability of work groups which considers both: effect of individual member's contributions (i.e. skills and

experiences) and dynamic interactions in a network on the total capability of the network. This is a unique attempt in modelling the capability, as all previous research looked at the capability concept while only focusing on one of the two previously mentioned categories of effective factors.

The power of the model which is introduced in this research, is also comes from its generalizable applicability among different types of work teams in different organisations regardless of their industry field. This is because, none of the capability factors (used in the proposed model in this research) was related to specific characteristics of work groups which in that case they could only be meaningful if the work group is from specific industry. As a result the proposed model can be in used in different industries to measure the collective capability of project teams.

In addition to best of author's knowledge the results of this research is the first serious attempt in modelling the network level capability using statistical methods. All previous research in this area have theoretically analysed the capability concept rather than mathematically measuring the concept.

8.3. Revising the Research Questions and the Findings Explored in the research

This research aimed to answer to six main research questions. Answering to these research questions has helped the author to meet the proposed objectives of this research. The main research questions are as below:

1) What are the different perspectives and definitions around the concept of capability and is there any similarity between different definitions of capability?

2) What are the fundamentals of human networks which can affect the formation and success of this type of networks?
3) What are the existing methods and models (previously introduced) for measuring capability? And limitation of existing methods?
4) Is it possible to propose a conceptual model (for collective capability measurement) which can eliminate the limitation of the existing models?

   And after proposing such a model in the research, the following research question must have been answered:
5) Are the four capabilities factors (used in the proposed model) true and effective factors on collective capability of human networks?
6) What are the direct and indirect relationships between independent and dependant variable in this research?

The above research questions have been answered through completing different stage of the research, which together have formed the current body of the thesis. In more details, the research has started by reviewing the concept of capability in different disciplines. The results of reviewing the concept of capability in variety of disciplines have revealed the fact that they are of course different perspectives which look at capability from their own unique point of view. However a more in depth review of the concept across different industries gave the author the confidence to express the fact that even though there is some dissimilarity in terms of definition of capability in different disciplines but the fundamentals of the capability concept are highly similar across all disciplines. The findings from reviewing the concept of capability in different industries and across variety of disciplines revealed the important fact that: in all disciplines capability has been defined and explained as a factor which can be gained by individuals. In none of disciplines (regardless of the field) capability has been

defined as something that can be inherited by human. This important finding together with reviewing the fundamental of human networks (in chapter 4) has answered to the first and second research questions of this research. The result of the first four chapters equally helped the author to meet the first and second objective of the thesis (summarising different views about capability concept and fundamental of human network foundation).

By completing the next chapter (chapter 5) which mainly involved reviewing and analysing the existing methods for capability measurement, the third research question of this research was also answered. In addition completing chapter 5 helped the author to explore the limitation of the exiting capability measurement models. Using this finding together with findings from the first four chapters enabled the author to propose a framework for assessing the collective capability of human networks (HDAS model in chapter 6) in this research. This was a successful answer to the forth research question in the thesis. By end of chapter 6 the third and fourth objective of thesis (analysing the current existing model and proposing a conceptual model for measuring collective capability) was also met.

To be able to answer to the research question 5 and 6 and finally meeting the final objective of the thesis (statistically proving the conceptual model) an empirical survey has been designed and data from conducting the survey used to conduct the appropriate statistical tests in chapter 7. To answer to the research question 5, four hypotheses which each one aimed to test the existence of a positive and significant relationship between each of the nominated capability factors and the collective capability of the project teams in the survey have been designed and tested in first part of chapter 7. The results of all four hypotheses test together confirm the existence of significant positive relationships between independent variables (capability factors) and the collective capability in this study. The final research question (6) of this research was answered through conducting linear multiple regression modelling and

SEM analysis in chapter 7. The result of linear regression modelling provided the research with a linear model which can measure the collective capability (independent variable) using the four capability factors. The introduced model suggested the strength of instrumental relationships among individuals in a network has the highest effective on the whole network's capability level. The model also showed the other three capability factors are suitable capability factors as the effect of all four capability factors (independent variables) on the collective capability of work teams were statistically significant.

The modelling process in the research was expanded using SEM modelling technique which investigated both direct and indirect effect of capability factors on the collective capability of the work teams. Using this modelling technique also helped to discover the effect of independent variables on each other. Even though the final outcome from conducting SEM modelling suggested slightly different results and suggested homophily as the most effective capability factor on the collective capability of work teams but the results still proved the significant effect of all four capability factors on the collective capability. The results of SEM modelling also showed strong inter-relationships between two pairs of independent variables: average previous attainment of the members in a group (A) and their instrumental relationships' strength (S) and also strong relationships between homophily level of the network (H) and the instrumental relationships' strength (S). In a summary both modelling techniques used in this study, statistically approved the suggested conceptual linear model for measurement of the collective capability in this study.as a result and by end of chapter 7 the final objective of the research (statically proving the proposed model) was also met.

8.4. The Contributions of the Research and Practical Use of Findings

This research contributes to the current body of knowledge through following points:

1. Firstly this research provided a comprehensive comparison of the concept of capability in different disciplines and explored similarities in fundamentals' of the concept in different subjects. Specifically chapter two and three of this thesis are dedicated to investigation of definitions and similarities of capability concept in different disciplines. Reviewing these chapters of the current thesis can be a good guideline and starting point for future researchers who are interested to conduct research around capability concept.
2. Secondly this research has investigated the important factors related to human networks (work groups) which can be translated to quantitative capability factors for modelling the collective capability. The demographic homophily level of the network and instrumental relationships' strength are the two factors which have been dug out from reviewing the fundamentals' of human networks. This analysis on the capability concept is furthered by reviewing the current capability measurement methods in chapter five.
3. Thirdly this research has introduced four capability factors which all four capability factors can be measure quantitatively. The four capability factors together, can cover both: the effects of individuals' contributions (skills and abilities) and the effect of dynamic relationships in the network on the collective capability of the whole network. This has been the first attempt to look at the concept of capability covering both types of effective factors.

4. A unique algorithm ("HDAS" algorithm) has been defined to measure the four nominated capability factors.
5. A linear conceptual model has proposed to measure and predict the collective capability in this research.
6. The proposed model has been statistically tested and proved to be the true and suitable model to measure the collective capability of work teams. The proposed capability measurement model in this study is the first quantitative model for measurement of the capability of human networks.

8.5. The Limitations of the Research

This research produced reliable conceptual and mathematical model for measurement of the collective capability of human networks however like any other research a number of limitations existed in conducting the research. The main limitations which the author faced with while conducting this research are as follow:

- The main limitation was sample size and collecting enough data from designed empirical survey in this study. The nature of required data in this study (network data from work groups and not individual data) made the whole data collection process more challenging. Even collecting data from available work groups (sample in the study) required a huge amount of time and effort. Moreover the participants in the study required to have a minimum knowledge about the study and some scientific terms (such as Instrumental relationships) to be able to answer to some of the questions in the designed questionnaires. This required the researcher to spend more time to explain the terms to them.

- Source of the collected data in many instances in this study were self-assessment (i.e. individuals' skills level) which in some cases can result in having participants who over or underestimate themselves. However because participation in this study was on voluntary basis so hopefully there wasn't much intention for participants to consciously over or underestimate themselves. Its recommend by the author that in the case of using the introduced capability measurement model in this study in practice use different methods (such as self-assessment, supervisor assessment) for evaluations and measurement of capability factors.
- The model which introduced in this thesis is a case study in an academic environment. Although its generalisability has been tested in various occasions, it is advisable that its use in other settings and sample should be done with considerations.

8.6. Future Work

The result of current research is a fundamental and valuable finding which showed how the capability of a network of individuals can be measured quantitatively. As it has been mentioned in earlier chapters, the mathematical modelling of the capability concept (specifically at network level) is still in its early stages and using the findings of this research as the basis for modelling approach can provide potentials for furthering the research in this area. Some of the potential options for furthering this research are recommended by the author as:

- Inclusion of other capability factors: even though it has been tried in this research to include capability factors which can truly predict and measure the collective capability but there might be other capability factors which could affect the capability of a group of individuals when working as a group and are disregarded in this study.

For example the effect of external factors (from outside the network) can studied and tested as effective capability factors

- As it has been explained in chapter 7, the statistical modelling of the collective capability was a blue sky area of research at the time of this study and as result it has been decided to start with linear modelling of the collective capability in this study. Findings of this research can be furthered by testing the nonlinear model technique using proposed capability factors in this study or maybe using other newly capability factors.
- Testing the findings of this research (linear capability measurement model) with larger sample size and possibly in indifferent environments and industries is also recommended by the author.
- As a final suggestion the author would like to suggest an opportunity for furthering this study by looking at the economical side of building capable teams when using findings of this research.

Appendix A

Most common tools and techniques for individual selection

Method of individual selection	Pros	Cons
Assessment centres	Have been demonstrated to produce valid inferences for a number of organisational outcomes (e.g., promotion rates). Can reduce business costs by identifying individuals for hiring, promoting or training those who possess the needed skills and abilities. May be viewed positively by test takers who see the close relationship between the test and the job. Can provide useful feedback to test takers regarding needed training and development. Focus more heavily on behaviour demonstration than simply assessing characteristics.	Can be costly to create and administer. Require more labour (e.g., assessors, role-players, etc.) to administer than most other methods. Require more time to administer than most other methods. Can be difficult to keep calibrated or standardized across time and locations.
Biographical data	Can be administered via paper and pencil or computerized methods easily to large numbers. Can be cost effective to administer. Have been demonstrated to produce valid inferences for a number of organizational outcomes (e.g., turnover, performance). Are typically less likely to differ in results by gender and race than other types of tests. Does not require skilled administrators. Can reduce business costs by identifying individuals for hiring, promotion or training who possess the needed skills and abilities.	May lead to individuals responding in a way to create a positive decision outcome rather than how they really are (i.e., they may try to positively manage their impression or even fake their response). Do not always provide sufficient information for developmental feedback (i.e., individuals cannot change their past). Can be time-consuming to develop if not purchased off-the-shelf.
Cognitive ability tests	Have been demonstrated to produce valid inferences for a number of organizational outcomes (e.g., performance, success in training). Have been demonstrated to predict job performance particularly for more complex jobs. Can be administered via paper and pencil or computerized methods easily to large numbers. Can be cost effective to administer. Does not typically require skilled administrators..	Are typically more likely to differ in results by gender and race than other types of tests. Can be time-consuming to develop if not purchased off-the-shelf.

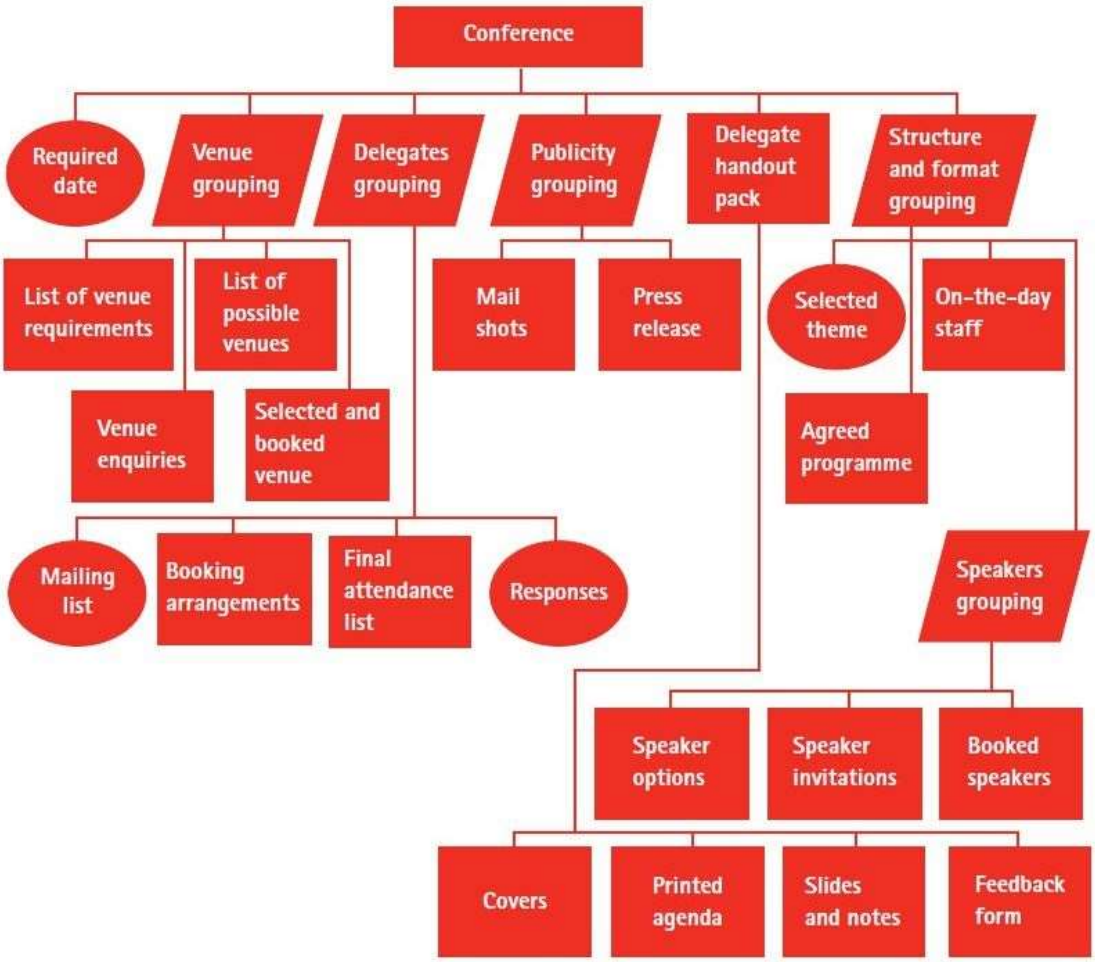
Interviews	Are expected and accepted by many job applicants. Provide an opportunity for a two-way exchange of information. Provide a measure of skills such as oral communication skills not measured via paper and pencil or computerized tools. Have been demonstrated to produce valid inferences for a number of organizational outcomes, if properly developed and administered Can reduce business costs by identifying individuals for hiring, promoting or training those who possess the needed skills and abilities. Are typically less likely to differ in results by gender and race than other types of tests.	May be affected by different kinds of rating errors and biases by interviewers. Are often more time-consuming to administer than paper and pencil or computerized tools. May be practically less useful when a large number of individuals must be evaluated because of administration time. Can be costly to train interviewers. May be difficult to keep interviewers calibrated and the interview process standardized. May lead to individuals responding in a way to create a positive decision outcome rather than how they really are (i.e., they may try to positively manage their impression or even fake their response).
Job knowledge tests	Have been demonstrated to produce valid inferences for a number of organizational outcomes, such as job performance. Can reduce business costs by identifying individuals for hiring, promoting or training those who possess the needed skills and abilities. Are typically less likely to differ in results by gender and race than other types of tests. May be viewed positively by test takers who see the close relationship between the test and the job. Will not be influenced by test taker attempts to impression manage or fake	May require frequent updates to ensure test is current with the job. May be inappropriate for jobs where knowledge may be obtained via a short training period. Can be costly and time-consuming to develop, unless purchased off-the-shelf.
Personality tests	Have been demonstrated to produce valid inferences for a number of organizational outcomes. Can reduce business costs by identifying individuals for hiring, promotion or training who possess the needed skills and abilities. Are typically less likely to differ in results by gender and race than other types of tests. Can be administered via paper and pencil or computerized methods easily to large numbers. Can be cost effective to administer. Does not require skilled administrators.	May contain questions that do not appear job related or seem intrusive if not well developed. May lead to individuals responding in a way to create a positive decision outcome rather than how they really are (i.e., they may try to positively manage their impression or even fake their response). May be problematic for use in employee selection if the test is one used to diagnose medical conditions (i.e., mental disorders) rather than simply to assess work-related personality traits
Physical ability tests	Have been demonstrated to produce valid inferences regarding performance of physically demanding tasks. Can identify applicants who are physically unable to perform essential job functions.	Are typically more likely to differ in results by gender than other types of tests. May be problematic for use in employee selection if the test is one used to diagnose medical conditions (i.e., a physical disability)

	Can reduce business costs by identifying individuals for hiring, promotion or training who possess the needed skills and abilities, by minimizing the risk of physical injury to employees and others on the job, and by decreasing disability/medical, insurance, and workers compensation costs. Will not be influenced by test taker attempts to impression manage or fake responses.	rather than simply to assess ability to perform a particular job-related task. Can be expensive to purchase equipment and administer. May be time consuming to administer. May be inappropriate or difficult to administer in typical employment offices.
Work sample simulations	Can reduce business costs by identifying individuals for hiring, promotion or training who possess the needed skills and abilities Less likely to be influenced by test taker attempts to impression manage or fake responses	Does not assess aptitude to perform more complex tasks that may be encountered on the job. May not assess the ability to learn new tasks quickly. Often not conducive to group administration. May require some level of job knowledge and therefore may be inappropriate for jobs where knowledge may be obtained via a short training period.

2014 Society for Industrial and Organizational Psychology website- accessible on : http://www.siop.org/workplace/employment%20testing/testtypes.aspx

Appendix B

Example of work breakdown using WBS

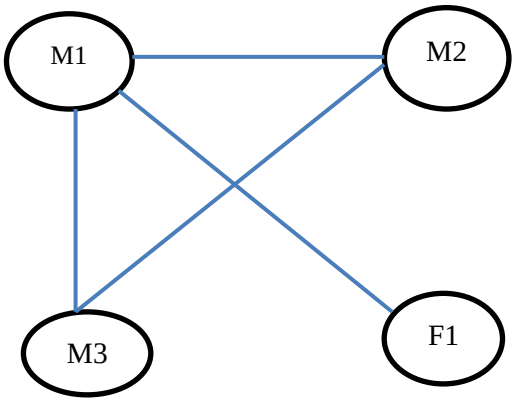


Borrowed from: http://www.stakeholdermap.com/plan-project/WBS-prince2-conference-full-size.jpg

Appendix C

Example of measuring Homophily Value for individuals in a network, using ***point correlation coefficient technique***

Assume we have a network consistent of four nodes: 3 male and 1 female who are performing on a given group project. According to a self-report questionnaire the network which represents their instrumental relationships is drawn as below:



*Existing of a line between two nodes represents the existence of instrumental (project related) relationships between those pair. If there is no line between two nodes (for example between M2 and F1) its means no instrumental relationships has been reported between the pair. To calculate the homophily level of the above network (of gender) using the explained method in section 6.3.3 of the thesis we have:

For node:

M1:	$a = 2$	$b = 1$	c= 0	d= 0
M2:	$a = 2$	$b = 0$	c= 0	d= 1
M3:	$a = 2$	$b = 0$	c= 0	d= 1
F1:	$a = 0$	$b = 1$	c= 0	d= 2

The definition of a, b, c and d can be reviewed in section 6.3.3 of the thesis.

As a result using the formula (5) provided in section 6.3.3 the calculated value of gender homophily for each node in the network will be:

For node:

M1 $h_{gender} = \sqrt{\left[\left(\frac{a}{a+c}\right) - \left(\frac{b}{b+d}\right)\right]\left[\left(\frac{a}{a+b}\right) - \left(\frac{c}{c+d}\right)\right]}$ = 0

M2 $h_{gender} = \sqrt{\left[\left(\frac{a}{a+c}\right) - \left(\frac{b}{b+d}\right)\right]\left[\left(\frac{a}{a+b}\right) - \left(\frac{c}{c+d}\right)\right]}$ = 1

M3 $h_{gender} = \sqrt{\left[\left(\frac{a}{a+c}\right) - \left(\frac{b}{b+d}\right)\right]\left[\left(\frac{a}{a+b}\right) - \left(\frac{c}{c+d}\right)\right]}$ = 1

F1 $h_{gender} = \sqrt{\frac{b}{b+d}}$ = 0.57

Considering the calculated values of gender homophily for all nodes in the network and using formula (8) explained in section 6.3.3 the total gender homophily level for the network in this example will be calculated as:

$$H_d = \frac{\sum_{i=1}^{N} h_{id}}{N} = \frac{0+1+1+0.57}{4} = 0.64$$

Just a note that: the calculated homophily level of a network in this was can be a value between 0 to 1 which a value closer to one, represents a higher homophily for the network respect to the specific characteristic which used to draw the instrumental network (gender in this example).

Appendix D

Copy of Ethnic approval of the Empirical Survey in the research

UNIVERSITY RESEARCH ETHICS COMMITTEE

APPLICATION FORM
FOR
RESEARCH ETHICS APPROVAL

SECTION A: GENERAL

1. Title of the Study:	**Mathematical Modelling of Human Networks' Capability**		
Project Start Date:	**01.09.2009**	Project End Date:	**30.09.2013**

2. Full name of applicant: **EHSAN HOSSEINI**					
Position Held:	PhD Research Student				
School:	**Engineering and Design**	Course Title (if student):	**Systems Engineering Research**		
Email:	**Ehsan.hosseini@brunel.ac.uk**	Telephone:	**07882143477**	Fax:	**N/A**
Please provide details of any and all other researcher(s) who will work on the research project:					
Name(s):	**N/A**				
Position Held:					
Location:					
Contact details (e-mail/ telephone/fax):					
Name(s):					
Position Held:					
Location:					
Contact details (e-mail/ telephone/fax):					
Name(s):					
Position Held:					
Location:					
Contact details (e-mail/ telephone/fax):					

3. Is this a student proposal?	Yes	*	No	
If yes, please complete the remainder of this section.				
Supervisor Name:	**Dr. Alireza Mousavi**	Position held:	**Lecturer at School of Engineering and Design**	
Location:	Howell Building, Brunel University			
Contact details (email/telephone/fax):	**Ali.mousavi@brunel.ac.uk** **01895-265788**			

4. **Declaration to be signed by the Applicant or the supervisor in the case of a student:**

I confirm that the research will be undertaken in accordance with the Brunel University Ethical Framework, Good Research Practice Policy, and Code of Research Ethics.

I will undertake to report formally to the relevant University Research Ethics Committee for continuing review approval.

I shall ensure that any changes in approved research protocols are reported promptly for approval by the relevant University Ethics committee.

I shall ensure that the research study complies with the law and Brunel University policies on the use of human material (if applicable) and health and safety.

I am satisfied that the research study is compliant with the Data Protection Act 1998, and that necessary arrangements have been, or will be, made with regard to the storage and processing of participants' personal information and generally, to ensure confidentiality of such data supplied and generated in the course of the research.

(Note: Where relevant, further advice is available from the Information Access Officer, e-mail data-protection@brunel.ac.uk).

I will ensure that all adverse or unforeseen problems arising from the research project are reported in a timely fashion to the Chair of the relevant University Research Ethics Committee.

I will undertake to provide notification when the study is complete and if it fails to start or is abandoned.

I have met and advised the student on the ethical aspects of the study design and am satisfied that it complies with the current professional (*where relevant),* School and University guidelines.

Signature of Applicant: ……Ehsan Hosseini……..
Date:……10/01/2010…….

Signature of Supervisor:……A. Mousavi…….....
Date……10/01/2010……

SECTION B: FUNDING

5. If the research is externally funded, what is the source of the funding?				
The research is self-funded.				
5.1. Are there any conditions attached to the funding?				
YES		**NO**	*	
If yes, please specify.				

SECTION C: THE RESEARCH

6. In **lay terms**, please provide an outline of the proposed research, including: background objectives research methodology contribution of research justification of benefit (*max 1000 words)*.
Please see the attachment 1.
Attach any questionnaires, psychological tests, etc. **Please see the attachment.**
7. Who originated the study?
The researcher and Academic supervisor.
8. Location of study
8.1 Where will the study take place?
Brunel University.
8.2 If the study is to be carried out overseas, what steps have been taken to secure research and ethical permission in the country of study? (Please attach evidence of approval if available.) N/A

9. Multi-centre and off-campus studies					
If this is a multi-centre or off-campus study, please answer the appropriate questions below; otherwise, go to Question 10.					
9.1 Does this project involve a consortium (other research partner organisations)?					
YES		**NO**			
If yes, please complete the details below in Question 9.2.					
9.2 Who has overall responsibility for the study?					
Please provide details of the contractual agreement between Brunel University and the other organisation(s).					
9.3 Is this an off-campus study?					
YES		**NO**			
If yes, please provide signed, written permission from an appropriate level of management within the relevant organisation(s).					
10. Has approval been sought from other Ethics Committees and LRECs?					
YES		**NO**	*		
Please enclose copies of approval letters, where applicable.					
11. If appropriate, has the protocol been reviewed by a statistician?					
YES	*	**NO**			
If yes, give the name of the statistician:	**Dr. Alireza Mousavi,**				
Position held:	**The academic supervisor**				
11.1 Define *(where necessary)* the statistical power of the study.					
The study will examine different mathematical methods (using the collected data) to investigate the most accurate method for modelling the human networks' capability.					
12. Who will have overall control of the data generated?					
The researcher and supervisor.					
13. How do you propose to disseminate the results of your research?					
The results of the research will hopefully be presented in several related conference and will be published in related national or international Journals. The final results will be also available at Brunel University's library on a PhD thesis format.					

14. PROCEDURES			
Please state whether the project includes procedures which: (*please tick the appropriate box)*			
	YES		**NO**
a. are physically invasive;			*

b.	involve the use of human tissue or taking of bodily samples;			*
c.	involve the use of biological, radiological, chemical or hazardous substances;			*
d.	are psychologically/socially intrusive.			*

If you have answered YES to any of the questions in 14 above, please complete questions 15; otherwise proceed to question 16. You must also consult the Head of Risk and Radiation to ensure compliance with Health and Safety regulations. ***If you are using human tissue in your project, you must complete section H.***

15. Specific procedures involved:

Include details, as applicable, of:
-the dosage and route of administration of the drug(s) used in and under research, other substances and/or appliances to be administered/used, and the method of administration or use,
-measurements and samples to be taken;
-tests to be performed;
-the use of visual aids or the administration of psychological tests.

N/A

15.1 Might the procedure(s) cause pain, distress, disruption or intrusion to a participant?

YES		**NO**		

If yes, please explain.

15.2. Are there any particular requirements or abstentions which will be imposed upon the participant (e.g., multiple visits, abstention from alcohol, tobacco, etc.)?

YES		**NO**		

If yes, please explain.

16. Products and devices

16.1 Does the research involve the testing of a product or device?					
YES			**NO**	*	
If yes, please describe it.					
16.2 If this research involves a drug, is it being used in accordance with its licensed uses?					
YES			**NO**		
If no, please explain why:					
N/A					

SECTION D: THE PARTICIPANTS

For the purposes of this section, "participants" include human subjects, their data, their organs and/or tissues. For participants to be recruited to the research, please state:					
17. the number of participants:	**Volunteer students from Engineering Management and Advanced Manufacturing MSc course at Brunel University.**				
18. if data are to be collected on different sites, please state the number of participants at each site: **N/A**					
Site 1:		Number of participants:			
Site 2:		Number of participants:			
(insert additional sites if necessary)					
19. How have you arrived at this number? Please state proposed inclusion/exclusion criteria.					
The more the number of participants in our research the more accurate results we will come up with. **(The nature of quantitative researches). As a result we target the total number of registered MSc student at the two previously named courses who are volunteer to be involved in our research.**					
20. Age group or range *(e.g., under 60s)***:**	**There will be no age restrictions for participants who wish to take part in our research.**				
21. Sex:	Male	*		Female	*
22. Do participants belong to any of the following vulnerable groups?					
Children:	**YES**		**NO**	*	
Participants unable to give informed consent in their own right *(e.g., people with learning difficulty)*:					

	YES		**NO**	*	
Other vulnerable groups *(e.g., mental illness, dementia, students, refugees, unemployed, prisoners)*:					
	YES		**NO**	*	

The above list is indicative, not definitive. Care will need to be taken to formulate inclusion/exclusion criteria that clearly justify why certain individuals are to be excluded, to avoid giving the impression of unnecessary discrimination. On the other hand, the need to conduct research in "special" or "vulnerable" groups should be justified and it needs generally to be shown that the data required could not be obtained from any other class of participant.

If the answer to any of the above is yes, please complete Questions 22 to 27; otherwise proceed to Question 28.

23. Please explain why it is necessary to conduct the research in such vulnerable participants and whether required data could be obtained by any other means.

N/A

24. Please state what special or additional arrangements have been made to deal with issues of consent and the procedures to safeguard the interests of such participants.

N/A

25. Please describe the procedures used to ensure children (i.e., persons under 18 years) are able to provide consent/assent to participation.

N/A

26. If appropriate, please state whether and how parental consent, or the consent of the legal guardian and/or order/declaration of the court, will be sought in relation to the participation of children in the research.

N/A

27. If the participant is unable to consent in their own right, will you seek the prior approval of an informed independent adult and any other person or body to the inclusion of the participant in the research?

	YES		**NO**		

State precisely what arrangements will be put in place.

N/A

Recruitment and Selection					
The Research Ethics Committee will need to be satisfied with the effectiveness and propriety of recruitment and selection procedures given the participant involved, e.g., that the participant will not feel in any way obliged to take part, that advertisements do not appear to offer inducements. The Committee will be particularly interested in cases where a participant's relationship with the investigator could raise issues about the voluntary status or motive of the participant's involvement in the research (e.g., students).					
28. How will the participants in the study be selected, approached and recruited (please indicate the inclusion and exclusion criteria)?					
There will be no exclusion (in terms of age, sex, etc) for any volunteer participants who wish to get involved in our research. In addition as the researcher in this research I can confirm that there is no relationship which can affect the participants' voluntary for either take part or not take part in this research. There will be no written advertise in the research but a short (5 minutes) verbal speech will be conducted in their lecture (through co-ordinating with their lecturer) to explain them the about the nature of the research and their voluntary right to get involved in this research. There will also a written consent from for participants who wish to take part in this research which is attached to this application form.					
If you are proposing to advertise, please attach a copy of the advert to be used.					
29. Where are you recruiting the participants?					
Within the extra time which has been given to proposed students (as their trouble shooting for the simulation module) (have been discussed and accepted with their lecturer).					
30. Relationship of participant to investigator:					
31. Will the participants take part on a fully voluntary basis?					
	YES	*	**NO**		
32. Will Brunel University students be involved as participants in the research project?					
	YES	*	**NO**		
If yes, please provide full details.					
The volunteer MSC students at Engineering Management and Advanced Manufacturing Systems course.					
33. Will payments or other inducements be made to participants?					
	YES		**NO**	*	
If yes, give amounts, type and purpose.					
Information to Participants and Consent					
34. Will participants be informed of the purpose of the research?					
	YES	*	**NO**		
If no, please explain why.					

35. Will the participants be given a written information sheet?					
	YES	*	**NO**		
If yes, attach a copy. **A copy of Information and consent form is in attachment 2.**					
If no, please explain why.					
36. Will written consent be obtained?					
	YES	*	**NO**		
If yes, attach a copy of consent form. **A copy is attached.**					
If no, please explain why.					
37. Where potential participants will/may suffer from any difficulties of communication, state the methods to be employed both to present information to the participants and achieve consent. If written, please attach a copy.					
As far as the researcher investigation proves (Through information from their lecturer) there is no potential participants who might have any difficulties in his/her communication skills which might affect his/her abilities in taking part in this research if he/she wish to do so.					
38. Please state how you will bring to the attention of the participants their right to withdraw from the study without penalty.					
There is noted in the consent form that any participant can withdraw from the research without any penalty.					
Where relevant:					
38.1 Will information be given to the participants' GP (if deemed necessary)? **N/A**					
	YES		**NO**		
38.2 Have the participants consented to having their GP informed? **N/A**					
	YES		**NO**		
39. Please state what measures will be taken to protect the confidentiality of the participant's data (i.e., arising out of the research and contained in personal data).					

Firstly the collected data from participants will be stored on a private computer system at Brunel University which is just accessible by researcher of the study. Secondly there will be no data sharing with any third party while doing or after finishing of the research. Finally all the collected data which might result in identifying the participants in the research will be destroyed after the research is been done. In addition in case of publishing the results of the research, all participants' anonymity will be reserved.
40. How long will the data be retained following completion of the study?
Until required analysis on the collected data have been done and viva session for awarding the PhD degree for the searcher has been conducted.
41. How will participants be informed of the results of the study if they so wish?
The results of the study can be emailed to the participants who might wish to know the results. In addition the results of the research will be accessible in a thesis format at Brunel University's library.

SECTION E: RISKS AND HAZARDS

42. Risk to research participants					
42.1 Do you think there are any ethical problems or special considerations with the proposed study?					
	YES		**NO**	*	
If yes, please give details:					
42.2 Are there any potential hazards or risks to participants?					
	YES		**NO**	*	
If yes, please specify them and state what precautions have been taken to minimise and deal with them:					
43. Risk to researchers					
43.1 Are there any potential hazards or risks for the researchers and others associated with participation in the research (as distinct from the research participants)?					
	YES		**NO**	*	

If yes, specify them and state what precautions have been taken to minimise and deal with them.					
44. Has a Health & Safety risk assessment been carried out? **N/A**					
YES			**NO**		

SECTION F: COMPENSATION FOR DEATH OR PERSONAL INJURY

45. Is Brunel University providing indemnity for compensation in the event of personal injury or death arising out of participation in the research? **N/A. As there is no physical or chemical activities will be involved in the study.**					
	YES		**NO**		
46. If the insurance cover is **not** being provided by Brunel University, please provide written confirmation that you have insurance cover for negligent **and** non-negligent harm.					
47. Has a manufacturer provided commercial equipment and/or mechanical devices?					
	YES		**NO**		
If yes, please state what arrangements have been made to compensate or provide indemnity in the event of personal injury or death arising from the use of the equipment or mechanical devices.					
N/A					

SECTION G: CONFLICT OF INTEREST AND INTELLECTUAL PROPERTY

48. Are there any potential conflicts of interest arising from the project, deriving from relationships with collaborators/sponsors/participants/interest groups?					
	YES		**NO**	*	
Please disclose all relevant personal and commercial interests.					
49. Does the project require access to intellectual property rights (IPR) belonging to third					

parties?					
	YES		**NO**	*	
49.1 If yes, has use of such IPR been cleared with the relevant owners?					
	YES		**NO**		
50 Are arrangements in place to ensure the proper attribution and acknowledgement of inventive contributions to the project by all participants/collaborators?					
	YES	*	**NO**		
If yes, please provide evidence of this. **While publishing the results as the PhD thesis there will be an acknowledgment part for the contribution of the participants in the study. The participants will also be acknowledged at the end of the questionnaire which they will fill out.**					

SECTION H: USE OF HUMAN TISSUE

51. What types of human tissue or other biological material will be used?							
N/A							
52. Will the material be obtained from participants in this study? **N/A**							
	YES		**NO**				
If yes, please go to question 59.							
53. Will you know the identity of the donor? **N/A**							
	YES		**NO**				
If yes, please explain.							
54. Has consent been obtained previously to use the samples for research? **N/A**							
Yes, for all samples		**Only for some samples**		**No consent has been given**			
55. Do you plan to seek further consent to use the samples in **this** project? **N/A**							
	YES		**NO**				
If no, please explain.							
56. Will any of the samples be imported from outside the UK? **N/A**							
	YES		**NO**				
If yes, please justify the use of imported samples.							
56.1 Please indicate if there is evidence that consent was obtained from the donors.							
56.2 If you are obtaining the samples from a tissue bank **within** the UK, please provide evidence of consent from the donor(s) and the HTA licence number for the tissue bank.							
57. What types of tests or analysis will be carried out on the samples? **N/A**							

58. Will the research involve the analysis or use of human DNA in the samples? **N/A**					
	YES		**NO**	*	
Please go to question 68. *The following questions apply to human tissue or other biological material which is to be obtained from participants in **this** project.*					
59. Please state the nature, amount and frequency of the samples to be taken.					
N/A					
60. Who will collect the samples? **N/A**					
61. From whom will the samples be removed? **N/A**					
	Living donors		**Deceased donors**		
62. Will you obtain consent from living donors for the use of the samples in **this** project? **N/A**					
	YES		**NO**		
If no, please explain.					
63. Will you obtain consent from living donors for the use of the samples in future projects? **N/A**					
	YES		**NO**		
If no, please explain.					
64. Please state the arrangements for obtaining consent to remove and use samples from the **deceased** for this project.					
N/A					
65. Will you or others on the research team be able to identify the donors after the samples have been obtained? **N/A**					
	YES		**NO**		
If yes, please justify.					
66. What types of tests or analysis will be carried out on the samples?					
N/A					
67. Will the research involve the analysis or use of human DNA? **N/A**					
	YES		**NO**	*	
68. Please give details of where the samples will be stored, who will have access, and the custodial arrangements.					
N/A					
69. What will happen to the samples at the end of the research? **N/A**					
Disposal in accordance with HTA Code of Practice/University Standard Operating Procedures					
Storage by research team pending ethical approval for use in another project					
Storage by research team of acellular material					
Other					
Not yet known					

Please provide further details for the proposed arrangements.					
70. Have you received training on obtaining consent for the use of human tissue? **N/A**					
	YES		**NO**		
If no, when do you expect to attend the training session?					
71. What experience do you have in handling human tissue? **N/A**					
72. Please provide evidence from the Biological and Genetic Modification Safety Committee that they are satisfied with the safety protocols for this project. **N/A**					

Appendix E

Consent form used in the Empirical survey of the research

Consent Form

Researchers
Ehsan Hosseini, PhD Student, Ehsan.hosseini@brunel.ac.uk
Dr. Alireza Mousavi, Academic Supervisor, Ali.mousavi@brunel.ac.uk
Prof. Kai Cheng, Second Academic Supervisor, Kai.cheng@brunel.ac.uk

Research Tile: Human Network Capability Evaluation

The study's main aim is come up with a mathematical model which can measure human network's capability level in fulfilling a specific task. The proposed model will measure a human network's capability based on homophily of members within the network, the networks' structural balance and internal and external relationships of the proposed network's members. This study will consider past, present and future data of the participants for building up the proposed capability model.

Information for the participants:

This study requires the volunteer participants to fill out a questionnaire. The study will have no harm or risk to the participants. The process and result of this research is completely separated from the module and consequently will **not** affect the participants marking in the module in any manner. The willing participants to the study have the right to be withdrawn from the study at any stage during the research without any penalty. **The collected data from participants will be stored strictly confidential and participants' identities will be secured**. **Data with participant's identity will be only accessed by researcher of the study for the purpose of relating questionnaire and further analysis**. Nameless data will also be analysed by academic supervisor. There will be no other use or access to the participants' data other than this study. **Participants are ensured that their personal information will be destroyed upon the completion of this study**. In the case of publication of the study's result anonymity of the participants will be reserved. This study has been approved by Brunel University's Research Ethics Committee.

	Yes	No
I have read the research Participant Information sheet.	☐	☐
I understand the content of the study	☐	☐
I have the opportunity to ask questions about the study	☐	☐
I understand that I will remain anonymous in any publication of the result	☐	☐
I know that this study will not affect my assessment in the course	☐	☐
I agree willingly to past in the study.	☐	☐

Signature of the participant
Name Date:

Appendix F

First questionnaire designed and used in empirical survey **(Participants demographics and background profile)**

Student's Full Name:

Gender:

1. What is your gender?

Male ☐ Female ☐

Age:

2. Please indicate your age: ……..

Marital status:

3. What is your marital status?

Married ☐

Single ☐

Divorced ☐

Separated ☐

4. Please choose the field which best describe your field of study in your previous degree

Engineering and Design ☐

Social sciences ☐

Information technology, computing and mathematics ☐

Business ☐

Management ☐

Health sciences and social care ☐

Law ☐

Art ☐

Sports science ☐

Please indicate your **previous degrees' subject**……..

Employment Status:

5. Are you currently…?

Full time employed	☐	Full time student	☐
Part time employed	☐	Unable to work	☐
Self employed	☐		

6. Please indicate your nationality? ……

Past experience (performance in similar task)

7. Have you ever been a member of a group (either academic or professional) to perform a group project?

Yes ☐ Go to question 8 No ☐ Go to question 10

8. How many group projects (either academic or professional) have you been involved in?

1-3 ☐ 4-6 ☐ 7-10 ☐ more than 10 ☐

9. To what extend do you believe you were successful in fulfilling your previous group project? (Any of them that you can remember better)

+ →

0	10	20	30	40	50	60	70	80	90	100

10. To what extend do you believe you are interested in subject areas such as the one you doing in this module? (Please choose your level of interest on the 0 to 100 percent scale provided below)

+ →

0	10	20	30	40	50	60	70	80	90	100

11. Have you got any previous experience/expertise in doing Systems modelling and Simulation projects?

Yes ☐ Go to question 13 No ☐ Go to question 14

12. What are the length and/or number of projects which you have done in the area of E-Business?

Months of learning or working in Systems modelling and simulation: ……
Number of projects which have been done: …….

Appendix G

Second questionnaire designed and used in empirical survey

Part 1: Individuals' skills Diversity self- assessment:

On a scale between 1 to 7, how do you rate yourself on each of the statement in question 1 to 20:

1. Effective Internet Searching +

1	2	3	4	5	6	7

2. Mathematical and statistical skill

1	2	3	4	5	6	7

3. Arena simulation software skill

1	2	3	4	5	6	7

4. Risk management skill

1	2	3	4	5	6	7

5. Effective use of MS- Office

1	2	3	4	5	6	7

6. Writing skill

1	2	3	4	5	6	7

7. Presentation skill

1	2	3	4	5	6	7

8. Learning skill

1	2	3	4	5	6	7

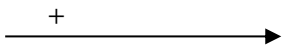
9. Creativity skill

1	2	3	4	5	6	7

10. Report management skill

1	2	3	4	5	6	7

11. Communication skill



1	2	3	4	5	6	7

12. Team working skill

1	2	3	4	5	6	7

13. Problem solving skill

1	2	3	4	5	6	7

14. Adopting and coping skill

1	2	3	4	5	6	7

15. Commitment to other individuals

1	2	3	4	5	6	7

16. Openness skill

1	2	3	4	5	6	7

17. Investigatory skill

1	2	3	4	5	6	7

18. Time management skill

1	2	3	4	5	6	7

19. Knowledge sharing willingness

1	2	3	4	5	6	7

20. Self confidence

1	2	3	4	5	6	7

Instrumental and expressive relationships

In this part of the questionnaire, the two kind of relationships that can exist between two members in any group (such as your groups) will be briefly explained to you and then you need to indicate whether if you have or have not developed relationships such as these kind with each member in your group. In each case if you have had relationships with any specific member please indicate the number of your meeting with that specific member during the project.

To make the task easier for you, your group mates name are printed below.

First: **Instrumental relationships** or simply **task related** relationships are those relationships which are based on information, advices and resources exchanges that needed to accomplish (do) a task. In your case it can be your relationships with your group mates specifically (only) regarding your group project.

Second relationships: **Expressive relationships** or simply **friendship**: are effective ties carrying either positive or negative emotions that are not necessarily task related. For this second kind of relationship in your case please rate the chances (in terms of percentage) that you might continue your friendship with any other member of your group after finishing your simulation project.

21. I have had a Task related (instrumental) relationship with

Team member 1 (name) Yes ☐ No ☐

If yes number of meeting with him/her

2 meeting or less	2 to 4 meeting	4 to 6 meeting	6 to 8 meeting	8 or more meeting

Team member 2 (name) Yes ☐ No ☐

2 meeting or less	2 to 4 meeting	4 to 6 meeting	6 to 8 meeting	8 or more meeting

Team member 3 (name) Yes ☐ No ☐

2 meeting or less	2 to 4 meeting	4 to 6 meeting	6 to 8 meeting	8 or more meeting

22. I see myself in position that I can say that I have a non-task relationship (Friendship) with

Team memebr 1 (name) ☐ Yes ☐ No

Team member 2 (name) ☐ Yes ☐ No

Team member 3 (name) ☐ Yes ☐ No

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