THE FOUNDATION OF CAPABILITY MODELLING: A STUDY OF THE IMPACT AND UTILISATION OF HUMAN RESOURCES

A thesis submitted for the degree of Doctor of Philosophy

by

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ABSTRACT

This research aims at finding a foundation for assessment of capabilities and applying the concept in a human resource selection. The research identifies a common ground for assessing individuals' applied capability in a given job based on literature review of various disciplines in engineering, human sciences and economics. A set of criteria is found to be common and appropriate to be used as the basis of this assessment. Applied Capability is then described in this research as the impact of the person in fulfilling job requirements and also their level of usage from their resources with regards to the identified criteria. In other words how their available resources (abilities, skills, value sets, personal attributes and previous performance records) can be used in completing a job. Translation of the person's resources and task requirements using the proposed criteria is done through a novel algorithm and two prevalent statistical inference techniques (OLS regression and Fuzzy) are used to estimate quantitative levels of impact and utilisation. A survey on post graduate students is conducted to estimate their applied capabilities in a given job. Moreover, expert academics are surveyed on their views on key applied capability assessment criteria, and how different levels of match between job requirement and person's resources in those criteria might affect the impact levels. The results from both surveys were mathematically modelled and the predictive ability of the conceptual and mathematical developments were compared and further contrasted with the observed data. The models were tested for robustness using experimental data and the results for both estimation methods in both surveys are close to one another with the regression models being closer to observations. It is believed that this research has provided sound conceptual and mathematical platforms which can satisfactorily predict individuals' applied capability in a given job.

This research has contributed to the current knowledge and practice by a) providing a comparison of capability definitions and uses in different disciplines, b) defining criteria for applied capability assessment, c) developing an algorithm to capture applied capabilities, d) quantification of an existing parallel model and finally e) estimating impact and utilisation indices using mathematical methods.

DECLARATION

This dissertation gives an account of the research undertaken by Mona Shekarriz. I confirm that this work is own and all the references used are cited. The publications, conferences and seminars which were achieved as part of this research are as follow:

PUBLICATIONS, CONFERENCES AND SEMINARS

Shekarriz, M. and Mousavi A., (2011). Applied Capability Assessment; a robust tool for human resource selection, in progress, To be submitted *to International transactions in operational research.*

Shekarriz M. and Mousavi, A., (2010). Group assessment; a study on the impact of students' within group attitudes, *Issues on Education and Research, accepted.*

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Shekarriz M. and Mousavi, A., (2010). Group assessment; a study on the impact of students' within group attitudes, *The 12th Annual International Conference Education*, May 2010, Athens:Greece.

Shekarriz M. and Mousavi, A., (2009). A review on determining key capability factors and proposals on capability evaluation*, The 9th International Conference of Knowledge, Culture & Change in Organisations*, June 2009, Boston, USA.

Shekarriz M., (2009). Measurement of Individuals' Capability Impact; Methods and Applications, A presentation in 'Is your research REF FIT?, *British Academy of Management Seminar*, Brunel University, London November 2009.

Shekarriz M. and Mousavi, A., (2009). Individual Capability Evaluation; A Preliminary Model*,* A poster presented at Brunel University, Graduate School poster Conference and Brunel School of Engineering and Design 2nd Research Conference (RESCON 09), May- June 2009.

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Dedicated to my beloved ones;

Ali Shekarriz, Farideh Naseri

and Omid Mobasseri

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TABLE OF ACRONYMS

ACA	Applied Capability Assessment
AHP	Analytical Hierarchical Process
ANFIS	Adaptive Neuro Fuzzy Inference System
ANN	Artificial Neural Networks
CIP	Complexity of Information Processes
CIP	Competitive Industrial Performance Index
CIT	Critical Incident Technique
CM	Competency modelling
CMM	Capability Maturity Model
CODAP	Comprehensive Occupational Data Analysis Programs
EMP	Enablers, Moderators and Performance
FAHP	Fuzzy Analytical Hierarchical Process
HRM	Human Resource Management
ICI	Industrial Capability Index
KSAOs	Knowledge, Skills, Abilities and other characteristics
LDA	Linear Discriminant Analysis
MBTI	Myer-Briggs Type Indicator
MCDM	Multiple Criteria Decision Making
OLS	Ordinary Least Squared
PAQ	Position Analysis Questionnaire
P-E	Person-Environment
RBV	Resource Based View
S/K	Skilled Knowledge
SME	Small or Medium Enterprises
SME	Subject Matter Experts
SPSS	Statistical Package for the Social Sciences
T	Temperamental behaviour
TJA	Traditional Job Analysis
TOPSIS	Technique for Order Preference by Similarity to an Ideal Solution
UNIDO	United Nations Industrial Development Organization
V	Value

Chapter 1

Introduction

1.1 Aim and objectives

This research aims at finding a quantitative approach for human selection or appraisal practices by assessing people's application of their capabilities. In doing so, several objectives should be met as discussed below:

- To understand and analyse the current body of literature on the concept of capabilities in academic studies and to find a common ground to approach the problem

- To conduct a critical analysis of the current tools and techniques in human resource selection and appraisal

- To link the two above subjects by investigating the potential improvements which can be made in the selection procedure using the concept of capabilities and to build the conceptual development of an assessment approach

- To investigate the mathematical methods which are suitable for the proposed conceptual assessment approach in its quantification and estimation of the outputs.

- To design and conduct surveys to empirically examine the proposed conceptual design of the assessment method and the proposed mathematical estimation techniques.

- To test the validity and universality of the findings using further experimental and empirical data.

1.2 Rationale for the research

The process of selecting the most appropriate person for a project or appraising one's conformity to certain requirements has been one of the most widely discussed subjects in management literature and practice. This matter becomes even more important since organisations are experiencing rapid changes in their projects' definitions, technological development and organisational structure. Therefore fixed term contracts are becoming more common in all size organisations. However the length of the contracts does not change the fact that mistakes in selection of staff are expensive practices for companies. Although, the size of this effect differ based on the size of the business and the number of employees (Forth et al., 2006).

According to the Office of National Statistics (2009), 59.4 percent of the private sector employments (equivalent to estimated 23.1 million people) are held by Small or Medium Enterprises (SMEs). Research shows that SMEs are less likely to use professional help or career services in recruitment and therefore are more prone to mistakes and discrimination in the recruitment process. For instance, motivational factors are less important in selection process in SMEs than in larger firms, according to a study on manager's perspectives on this matter (Forth et al., 2006). In reality, they are more inclined to use informal practices such as "word of mouth" or referrals (Carroll et al. 1999). Their reliance on less systematic job analyses or selection methods can become costly at times because they have less room to move the employees within their enterprises and they may be forced to substitute their staff.

By and large, SMEs are more reliant on individual employees because of their size and scope of business (Forth et al., 2006). Hence, an incorrect selection process can cost them to either have ineffective employees or a high turnaround of employees (Carroll et al., 1999). Although as the size of businesses grows, the approach is turned to more formal practices of selection (Atkinson and Meager, 1994). Carroll et al. (1999) concluded that it is highly unlikely that SME employers adapt any methodical way of recruitment and selection. Understandably, one of the major reasons of infrequent use of employment practices and behavioural factors in SMEs can be the resource requirement of such procedures. Cognitive and personality tests, work samples or job simulation exercises and many more of these practices require a substantial amount of time, money and people to operate them. In the large firms on the other hand, systematic procedures such as job analyses, selection measures and tools are widely used. Most of these procedures are valid predictors of one's performance in the job.

However the first question is whether the benefits of using a collection of extensive tools repay the resources used for collecting and compiling all those information? The second question is on the purpose of the evaluation and selection procedure. An organisation does the selection procedure to predict the future success or failure of people in a specific job. The ideal situation is when people can have positive contribution and impact in the job while they feel that they have been placed rightly for the job and their capabilities are utilised properly. However, whether or not the organisations perform the selection practice to attain all such information is in doubt.

Therefore this research has been conducted in order to fulfil the following points. Firstly there is a need for a more accessible selection method which has a strong structure and algorithm in the assessment procedure rather than relying on extensive use of various tools and techniques. The structure and algorithm should include the criteria used for the assessment, the stages in the assessment and the use of the results. Secondly the proposed approach needs to be considerate of the assessors and the assessed people benefit in its definition and applications. Thirdly this assessment approach needs to be robust to be used in different contexts; therefore it should be based on a collection of knowledge which can satisfy the above requirements.

Concept of capabilities has been chosen to be used as the building block of this assessment approach because of its widespread reference across different subjects and its relevance to people's assessment. This research will provide a sound conceptual framework together with a robust mathematical structure which is proved to be essential for organisations regardless of their size and expertise. Although SMEs may benefit most from this approach as their current practices are not effective enough. This new look would allow the practitioners to use a simple yet structured framework in their decision makings on selections or appraisals.

1.3 Knowledge position of the research

In conducting any research numerous views and methods could be applied, however this contradicts feasibility and theoretical coherency. The way a methodology is chosen depends on researcher's background and preference, the research question, the desired outcomes, available time and resources, the nature of the population under study and many more issues (Wellington et al., 2005). Nevertheless, the chosen methods of conducting the research including collecting and interpreting data and the researcher's view on the knowledge needs to be clear and coherent to produce coherent and usable results.

The position in the current research is of a postpositivism kind which is associated with determination, reductionism, empirical observation and measurement and also theory verification (Creswell, 2003). Mainly there is a causal relationship which the research is interested to determine. Ideas or variables to be tested are preferably reduced to a discrete size as opposed to a more comprehensive set (Phillips and Burbules, 2000). This knowledge position has been maintained throughout the research in variable selection, measurements and quantitative data collections, survey design, mathematical modelling and analysis of the data.

In summary, this research is developing a conceptual model for assessing people's capabilities in a defined context and will then try to examine the validity of this conceptual model which is based on a collection of theories using empirical data. In other words, the theories and gaps in the knowledge and practice have led the creation of the "applied capability assessment" model which is the heart of this research. The created model is to be tested on its validity and robustness from two perspectives. One is from the participants' (potential employees) original numerical data which contributes to the statistical modelling. The other is from the experts' (potential employers) perspective which is also providing a mathematical model, the compliance of which is tested with the conceptual and the statistical models so far. The thesis structure as follows portrays the formation of the research and the outline of this thesis.

1.4 Thesis structure

A simple description of the thesis structure is shown in

Figure 1-1. This figure shows how the ten chapters in this research are placed in relation to each other and in the overall context of the research.

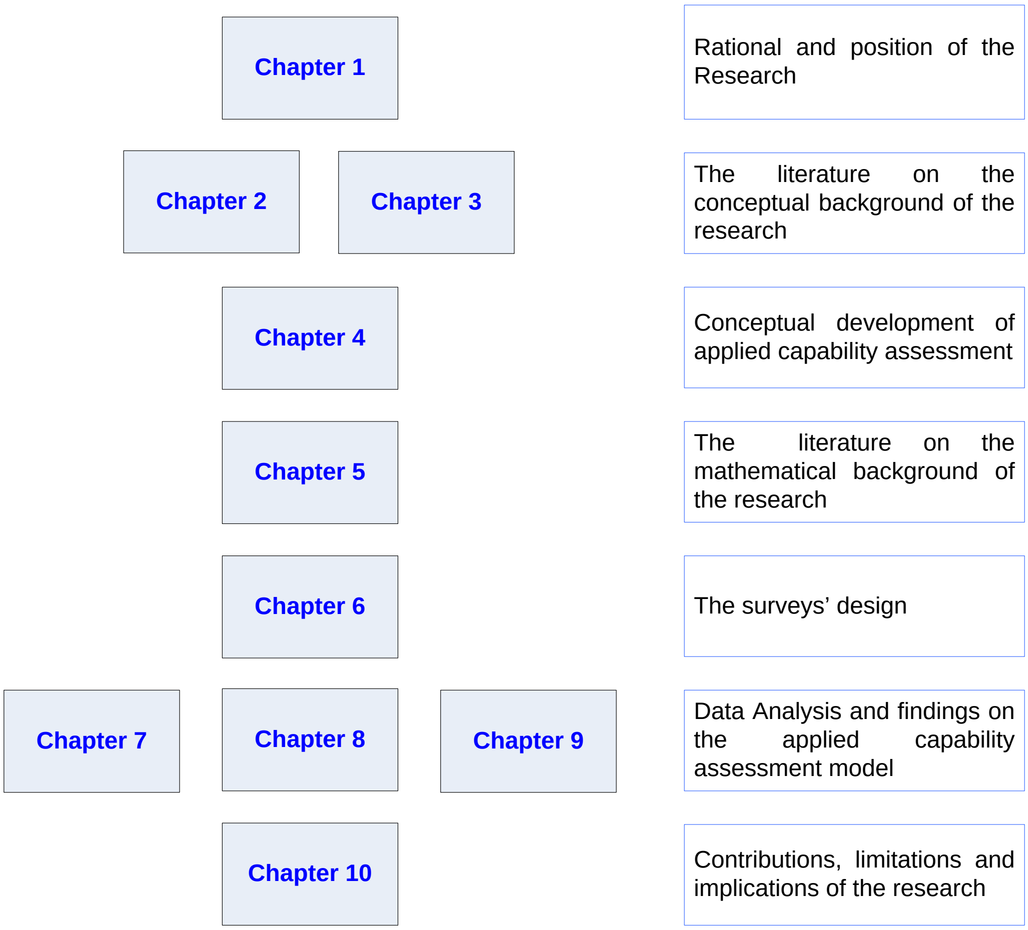


Figure 1-1 Thesis structure

The construction of the thesis and the flow of the information have also been showed in more details in the Figure 1-2. This figure describes the main question(s) which are answered within each chapter, the methods used in answering the question and the main findings within each chapter. Looking at both figures the content of each chapter and the flow of the material from chapter to chapter becomes clearer.

Chapter	Subject	Main Findings
1	Subject: What is this research about and what are the steps to be taken? How: Defining the rational of the research and its structure	• The main objectives are defined. • The structure of the research is depicted.
2	Subject: What are capabilities? Definitions, characteristics , Applications How: Literature survey on industrial, technological, economical, social and managerial subjects.	• Defining Applied Capability Assessment (ACA) based on universality in definitions and uses of capabilities in different subjects • Three criteria in ACA • Two viewpoints in ACA
3	Subject: How assessment of applied capability can be used for selection purposes and what are the current practices? How: Literature review on Job analysis, Candidate selection practices and the concept of "Fit"	• A combinatory job analysis practice has been given. • ACA shows people's suitability and conformance to requirement • Job Analysis, Candidate selection and fit literature should communicate with each other.
4	Subject: Based on the literature and the gaps, how the conceptual foundation of the ACA can be formed? How: Definition of the inputs, outputs and rules of the assessment	• The Impact and Utilisation indices are defined • An algorithm is proposed for obtaining and processing the information required for ACA based on two conceptual models (EMP, Jaque). • The proposed algorithm has encompassed the findings of the previous chapters.
5	Subject: What are the current quantitative methods in assessing capabilities and what are the possible estimation methods for the ACA? How: Literature survey on the current practices and studying the possible quantitative methods	• Based on the conceptual models, Multiple regression and Fuzzy inference can be used for data aggregation and estimation of indices.
6	Subject: How the conceptual and mathematical development on the ACA can be tested empirically? How: Study design, defining samples and settings, data collection and implications	• First survey is designed for examining the conceptual and mathematical developments. • Second survey is designed to check the conceptual and mathematical developments and the validity of the findings of the first survey.
7	Subject: Are the data obtained for the surveys valid and reliable for modelling? How: Sample characteristics defined, Questionnaire validity tests performed, Inter-rater reliability conducted	• Data obtained from both surveys are valid to be used for modelling purposes
8	Subject: Which conceptual and mathematical development of the concept are portraying the phenomenon under study more accurately? How: Statistical analyses on various components of the model using the empirical data from the first survey, Statistical analyses on the experimental data	• EMP is a more representative conceptual model for applied capability assessment. • Multiples regression showed the lowest error and highest robustness in estimation of the Impact index.
9	Subject: How the concept can be modelled based on expert knowledge and whether the expert knowledge model complies with the models obtained from the first survey? Are the produced indices valid? How: Statistical analyses on fitting an estimation method to the data from the second survey, Comparison of the results of the modelling on both survey, Experimental analyses on the produced indices	• An estimation method can be fitted to the data obtained from the second survey. • The results of the models obtained from the analyses on both survey are compatible. • The produced indices are logically sound and indicative of what they are designed to measure.
10	Subject: What can be concluded from this research and what is the way forward? How: Defining the contributions, findings, limitations, implications of the use and future works of this research	• Despite all the limitations, there are five main contributions to the existing body of knowledge. • The implication of the usability of this research are defined • The conceptual and mathematical developments of the research can be extended to other levels and contexts.

Figure 1-2 Contents of each chapter

Chapter 2
Research in Capability Evaluation; A review on the principles

The main aim of this chapter is to review the literature with regards to definitions, characteristics and application of the concept of capability in a number of subject areas. The studied disciplines include industry, technology, economy, social science and management research with a focus on published work in the past thirty years.

Research shows that in industry major business decisions are based on an assessment of organisations' capabilities (Barney, 1999). In economics, capabilities are used to represent people's quality of life and "what people are able to do or able to be" (Sen, 1985). In the works of psychoanalysts (Jaques and Cason, 1994), capabilities are evaluated to show the level of work an individual can carry out. In Human Resource Management (HRM), capabilities are indirectly evaluated in different ways to facilitate employee selection procedures (Curtis et al., 2002; Carroll, 1993). Cross-referencing the mentioned disciplines contributes to forming a clear comparison within the existing body of knowledge. Even though there are key differences in the definitions of capability in these subject areas, one can identify significant commonalities. We will discuss these commonalities to form the general philosophical basis to propose a novel approach in capability definition and evaluation.

2.1 Definitions of capability

2.1.1 Capabilities in industry

Defining capabilities in industry is critical as strategic decisions such as investments, mergers, and outsourcing and technology transfers require an in-depth knowledge of companies' capabilities (Argyres, 1996). This is an improvement compared to the previous approaches where most organisations based their business decisions on cost, time and quality measures (Holt et al., 1995). This point of view on capabilities is more reinforced when it was statistically shown that capabilities, strategic planning and performance were closely related (O' Regan and Ghobadian, 2004).

The existing literature explains a number of approaches in defining capabilities in industry and organisations. A closer look at these definitions in Table 2.1 reveals that they converge in principles.

Table 2-1 Definition of capabilities from different published works in Industry

Definitions	References
Capabilities represent the ability of the firm to combine efficiently a number of resources to engage in productive activity and attain a certain objective.	(Amit and Schoemaker, 1993)
Dynamic capabilities are manifested by sources and methods of creating wealth in a firm.	(Teece et al., 1997)
Capability is the way with which tools and methods are blended, coordinated and used in a company.	(Cantamessa, 1999)
"To be capable of something is to have a generally reliable capacity to bring that thing about as a result of intended action. The dynamic property of this capacity is its development and continuity."	(Dosi et al., 2000, p.2)
Capabilities come from exploration and exploitation of risks which moves the firm from current to critical positions. Capabilities are always associated with strategies to decide on options.	(Kogut and Kulatilaka , 2001)
An organisational level capability refers to the ability of an organisation to perform a coordinated set of tasks, utilising organisational resources, for the purpose of achieving a particular end result.	(Helfat and Peteraf, 2003)
"Capabilities are unique and idiosyncratic processes that emerge from unique and path dependent histories of individual firms."	(Pandza et al., 2003, p. 824)
"Organisational capability relates to the use of the resources in the attainment of the firm's strategic goals and objective."	(O'Regan and Ghobadian, 2004, p.307)
Capability is a concept which covers competence, strategy, ability and resources and is shown in technical and social issues of an organisation.	(Zehir et al., 2006)

Key conclusions about these definitions and the studied literature are as follow:

a) Resources: There is a distinction between capabilities and resources. A resource is an entity which is owned and controlled by a firm but a capability is the ability to deploy the resource toward an end result (Helfat and Lieberman, 2002; Capron and Hulland, 1999). In other words, use of resources in a specific direction or context can be interpreted as capabilities. Although instinctively, capabilities are associated with potentials in one’s mind, capabilities in industrial definitions are closely linked with applications and not potentials. Resources are believed to be building blocks of applied capabilities.

b) Performance: There is also a difference between capabilities and performance (level of attainment of objectives). It is concluded from the reviewed definitions that a capability can not be formed unless an objective is being attained as part of it (Amit and Schoemaker, 1993). This means that in evaluating a firm’s capabilities, performance records are one of the criteria to be considered. In other words, a good performance is not equal to having a specific capability however it is an essential part of forming a capability.

c) Strategies: Another terminology used in the definitions is strategies which hold the same importance as resources and performance in the definition of capabilities. This implies that the use of different strategies in different situations can contribute towards development of different capabilities in application (Zehir et al., 2006). One may decide to use these two terminologies (strategies and resources) interchangeably; however the strategies refer to more intangible issues compared to resources.

d) Context-based nature: The uniqueness of capabilities is a debatable characteristic which is mentioned by some researchers (Pfeffer, 1995; Schroeder et al., 2002) and it originates from the Resource Based View (RBV) by Wernerfelt (1984) which highlights firm-specific assets that provide unique services or products. This view focuses on different resource combinations and different productivity models (Conner, 1991; Mahoney and Panadian, 1992) which is also associated with different strategies. Resistance of scientists in providing defined capability sets and their persistence on keeping a grey box nature (Denrell et al. 2004) is a confirmation of the context-based nature of capability in this view. This perspective is challenged by researchers who see capabilities as routines used by organisations in different circumstances (Eisenhardt and Martin, 2000). It is believed that the same resources, strategies, and performance records can be applied differently based on the context. This is illustrated in Figure 2-1.

Furthermore, different categories of capabilities arise from a range of different perspectives on the nature and principles of the concept. Various scientists have categorised capabilities based on their type: physical, human or organisational (Barney, 1991), level: individual or organisational (Ethiraj et al., 2005) and originality: generic or unique (O'Regan and Ghobadian, 2004). These are based on different objectives and reveal how the same concept is viewed and used differently.

According to the definitions and the above discussions, one can assume that:

- A capability manifests itself when a number of resources, a blend of tools, methods and strategies are used. A capability can not be formed unless a certain level of attainment of objectives is met.

- The current literature addresses the problem of capability evaluation with a context based view. In fact the differences in researchers' view refer to whether they see the potential capabilities or the capabilities in application. Therefore, the term "applied capability" can be a better representation of this concept from industrial and organisational perspective as presented above.

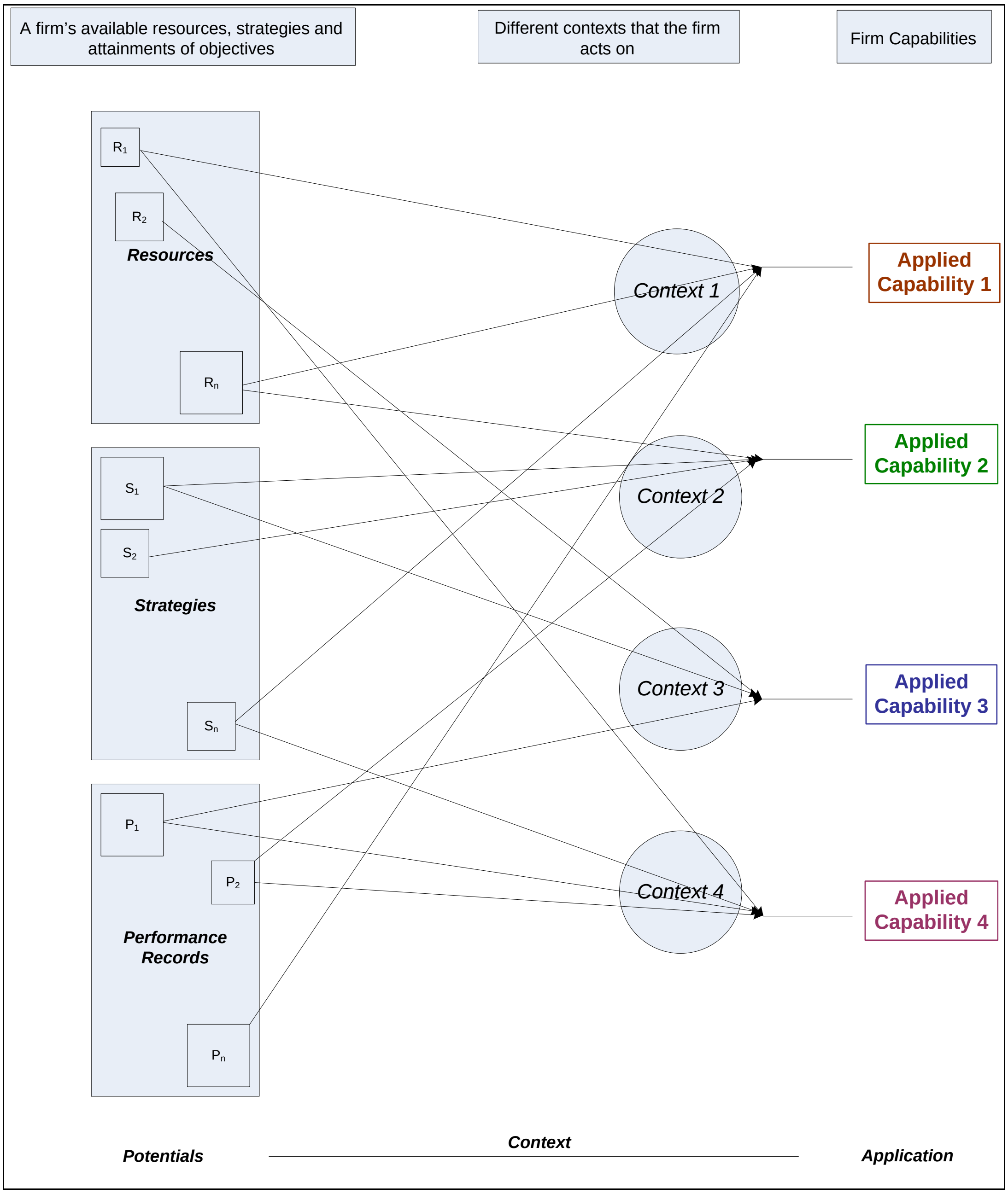


Figure 2-1 Illustration of how capabilities are being defined in Industry

2.1.2 Computer, Machine and Process Performance Evaluation

Traditional thinkers argue that a more capable system is the one with a better performance than others. In fact in more technical and less human centred systems, capable systems are only defined by their superior performance. This approach is based on how performance and capability are being defined. Therefore it has been decided to review some literature on performance evaluation to observe its relationships with capability evaluation. This section discusses performance evaluation for computers, machines and processes and attempts to find its structures and elements.

Svodobova (1976) argues that performance evaluation for computers can be done comparatively or analytically. In the former the performance of one system is compared with the performance of another (used in buying decisions, supplier selection, etc). In the latter, its performance is evaluated with respect to various system parameters and workloads. Workload is characterised by the distribution of demands on individual systems with a unit. A system performance is a function of the performance of individual elements and their interaction with other elements of the system.

Performance measures used by Svobodova (1976) are characterised by effectiveness (external) and efficiency (internal). Performance evaluation should be done with respect to the type and purpose of the evaluated system. System configuration, resource management, efficiency of the programmes, effectiveness of the instruction set processor and speed of the hardware are some examples of some measures of performance.

In reality users are important when evaluating the performance of a computer system. Users may not be competent to apply the best techniques, they may prefer general programmes than those tailored for that specific system, and they may not be conversant with the system characteristics on which optimum performance depends (Borovits and Neumann, 1979). This is where the performance of the system on its own is not the only predictor of its success. It means that performance measures should be combined with abilities and users' choices.

In Table 2-2 three sets of computer performance evaluation factors are presented. Performance evaluation domain and details of each are given for three sets. The first set has been divided into internal and external functions. The second set has taken into account the user interface with the computer system. The third set has added utilisation to the existing sets.

Computer systems are evaluated with the same measures of performance during their lifecycle. In other words their success is only attributed to their performance. The only exception is user interface related measures which are mostly affected by the user's abilities to work with the system. This implies that two similar computer systems are predicted to be equally successful unless a user decides to use them differently. So for the computer system itself, this is not in accordance with what is discussed in section 2.1.1 which is the different use of the available resources and strategies. Therefore this research and its attempt to find the elements and construct of capability, is more directed to human centred systems.

For machinery, the same inconsistency with this research can be seen. In design of a machine the same measures are used at every stage starting from designing the machine to evaluating the performance of the machine and even to predicting the success of the machines. A design engineer will give a specification set based on a design imperative from which a machine should be built and operated. Obviously manufacturing, assembly and processes are all designed on the same basis. The general criteria used by a designer are: Function, Safety, Reliability, Cost, Manufacturability, and Marketability. Table 2-3 shows the domains considered in machine design. A similar list can be used to evaluate the performance of a machine to check whether it conforms to the original designed specification.

Table 2-2 Computer performance domain

Domain	Details	Reference
Effectiveness	Throughput[1], Relative Throughput, Capacity[2], Turnaround Time, Response Time[3] ,and Availability	(Svobodova,1976)
Efficiency	External delay factor, Elapsed time Multiprogramming factor, Gain factor[4], CPU Productivity, Component Overlap, System Utility, Overhead, Internal Delay factor, Reaction time[5], Wait time for CPU ,and Page Fault Frequency	
System reliability	Probability of Failure on demand, Rate of Failure Occurrence, Mean time to Failure ,and Availability or Uptime	(Borovits et al.,1979)
Amount of work done	Throughput	
User Satisfaction	Response time and Ease of Use	
Economic Effectiveness	Overheads	

[1] "Throughput: amount of useful work completed per unit of time with given workload.

[2]Capacity: maximum amount of useful work that can be performed per unit of time with given work load.

[3] Response time: Turnaround time of requests and transactions in an interactive or real system.
[4] Gain Factor: Total system time needed to execute a set of jobs under multi programming / Total system time needed to execute the same sequence.
[5] Reaction time: Time between entering the last character on a terminal or receiving the input in the system and receiving first CPU quantum." (Svobodova, 1976, p 16-18)

Productivity	Throughput rate, Production rate, Capacity, Instruction Execution Rate, and Data-Processing rate	(Ferrari, 1978)
Responsiveness	Response time	
Utilisation	Hardware Module Utilisation, Operating System Module Utilisation, Database Utilisation ,and Public Software module Utilisation	

Table 2-3 Machine performance domain

Domain	Details	Reference
Function	Capacity, Rate, Quality, and Requirements	(Shigley and Mischke, 1986)
Operating constraints	Power supplies, Procedures, Maintenance, and Life	
Reliability	Probability of Failure on Demand, Rate of Failure Occurrence, Mean Time to Failure, Availability or Uptime	
Safety	Safety Integrity Level	
Cost		

In the process manufacturing, Process and Machine Capability Indices are widely used for the purpose of assessment based on conformance to specifications (Zhang, 2001). The evaluation is based on the number of defects a process or a machine generates over a period of time. Their main advantage is their quantitative form that plays a role in the decisions management or customer take. Their reliance on statistical and historical data is also another reason behind their extensive use. Processes are not separate from machines or computers in their inconsistency with the direction of our research.

This section has studied the performance evaluation in computers, machines and processes. It can be inferred from the review that there is no such definition as capabilities for computers, machines or processes as it was in the organisations. Machine or process capabilities are in fact a measure for performance prediction. They predict a future performance using the data on historical performance. The only similarity of the capability concept as described in the previous section is on the interface of human beings working with a process, machine or a computer. In this situation the individual's skills or strategies and previous performance can form different application of capabilities.

To get an alternative view of the concept, a review on some research in economics and psychology is presented below which is a step closer to human related capability.

2.1.3 "Capability Approach" in economics

"Capability Approach" in economics define capabilities as "what people are able to do or able to be" in contrast with "functioning" which is their actual deeds (Sen, 1987). In this perspective capabilities are the potentials and functionings are the applications. Capabilities and functioning are two distinct concepts which are related by the choices people make in their lives. The choices differentiate people in what they choose to be or to do (Beckly, 2002). Personal, social or environmental factors can be influential on the choices being made (Robeyns, 2005, a). There is another viewpoint in which Gasper (2002) categorise the capabilities themselves into O-capabilities (representing opportunities and options) and S-capabilities (representing skills and potentials). Capabilities have also been divided based on their origins (Lloyd-Sherlock, 2002). However, all these viewpoints are focused on the capabilities and not the bigger image of applying capabilities.

It can be inferred that for people, their potentials and options, their choices and their functioning represent the whole picture of how they apply their capabilities. Therefore, what people can do; what they choose to do and what they actually do, are the three building blocks of assessing their applied capabilities. Figure 2-2 can help in understanding the definitions of potential and applied capabilities in this section.

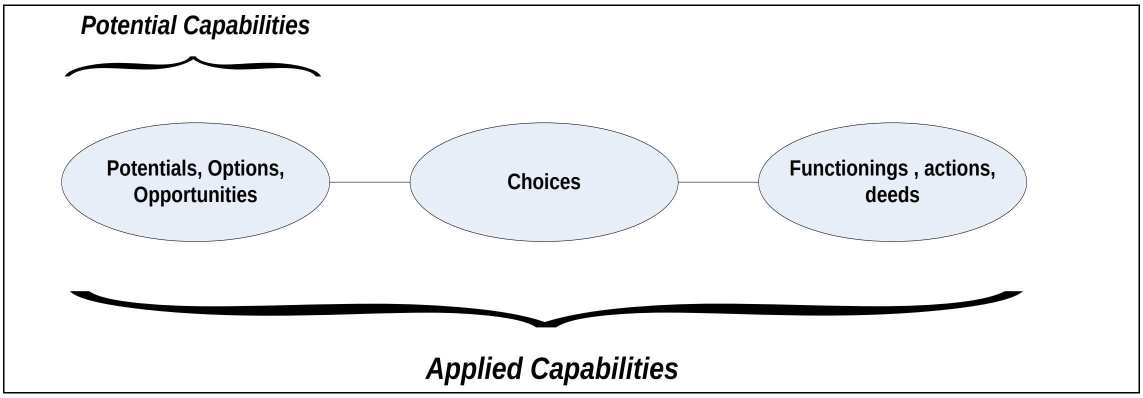


Figure 2-2 Potential and Applied capabilities

It is believed that capabilities are not originated from a rigid substance and they evolve and change over time and situation. In economics, like industry, different classifications have been made which reveal some controversies on the concept.

The same debate on whether or not a list of human capabilities in this view should be provided exists between the major theorists of the field. (Robeyns, 2005, a, b). Sen (1992) believes that instead of providing a list of capabilities and assessing people against it, we need to assess their wellbeing and compare it to their functioning. Nonetheless, listing on human capabilities has been provided by Martha Nussbaum (2000) and it has been modified to be used for variety of purposes (Stewart, 2005; Vogt, 2005). Table 2-4 presents a summary of the listings available in the literature.

Table 2-4 Measures of capabilities on “Capability Approach”

Measures of Capabilities	References
Life, Bodily Health, Bodily Integrity, Senses ,Imagination and thoughts, Emotions, Practical reasoning, Affiliation, Other Species, Play ,and Control	(Nussbaum, 2000)
Health, Household Income, House, Social Life, Amount of Leisure time, Use of Leisure time, Job ,and Partner	(Anand et al., 2005)
Health, Nutrition, Sanitation, Rest, Shelter, Security, Literacy, Intellectual and Physical Capacities, Self Respect, Aspiration, Positive freedom, Autonomy or Self-Determination, Negative Freedom or Liberty, Enjoyment, Understanding or Knowledge, Significant Relations with others, Participation in social life ,and Accomplishment (Achievements that gives life weight and point)	(Qizilbash, 1996)

What is learnt from the capability approach is that it emphasises on the distinction between potentials and actions. Each person has potential capabilities coming from his or her abilities, skills, backgrounds and even the experiences and opportunities in life. However people can be different in applying those in a specific context or environment. This is because any action may require a specific combination of the above factors. It is believed that application of potential capabilities would depend on the person’s potentials, the context and its requirements. Another important consideration in this subject is that all the above are normally being examined by the individual’s own perception. Inclusion of other’s views on one’s potentials and the context they are placed in could also be considered.

An alternative perspective on the concept of capability is “Capability Theory” which tries to examine one’s innate abilities (Jaques and Cason, 1994).

2.1.4 "Capability Theory" and Psychoanalysis

Jaques and Cason (1994) proposed to measure capability considering the level of work an individual can carry out (which he or she really likes) at any given time. The type of capability assessed by them is the capability in a work environment. Capability evaluation algorithm proposed by Jaques and Cason (1994) follows two pathways: Potential Capabilities (PC) and Applied Capabilities (AC). Potential capabilities can be evaluated by knowing one's complexity of information processes (CIP). However, individual's applied capability level in a certain task can be predicted by their complexity of information processes (CIP), value placed on that task (V), skilled knowledge owned for the task (S/K) and any dysfunctional or temperamental factor (-T). These can be presented as:

$$PC = f(CIP) \quad , \quad AC = f(CIP, V, S/K, (-T))$$

The above formulation has also been illustrated in Figure 2-3.

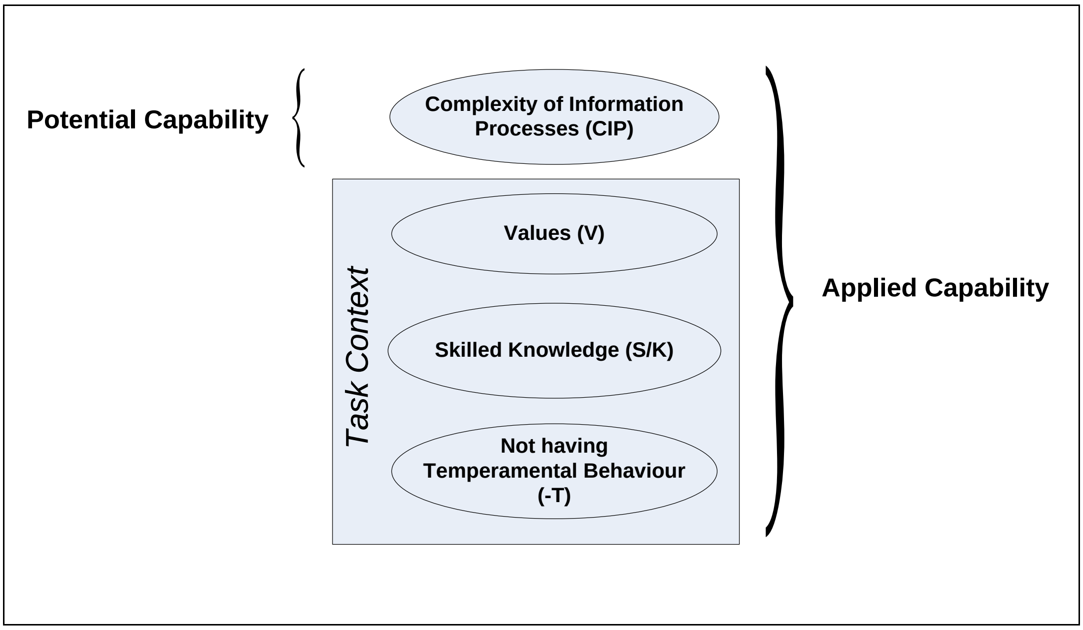


Figure 2-3 Potential and Applied capabilities in "Capability Theory" (Jaques and Cason, 1994)

The Judgements that are made about an individual's abilities are intrinsically based on the assumptions about one's mental processes and complexity of information. According to Jaques and Cason (1994) there are four types of mental processes (declarative, cumulative, serial and parallel) and four orders of information complexity (concrete verbal, symbolic verbal, abstract conceptual and universal). Although each of 4 processes can happen in each of the 4 orders of mental complexities, their work focuses on 4 mental processes in the two mid level forms of information complexity. Figure 2-4 describes the relationships of the information complexities and mental processes. CIP levels are in fact demonstration of where the individual stands in the information complexity and mental processes and this can be identified by interviewing the individual. The interview process is described in more details in Chapter 6. Jaques and Cason (1994) believe that social, educational and cultural situations are not part of one's potential capabilities since it is mainly defined by one's CIP. In other words, they believe that social and cultural issues will influence the application of the potential capabilities but not the CIP level. That is why factors such as value or dysfunctional behaviours are included in the applied capability evaluation and not in potentials.

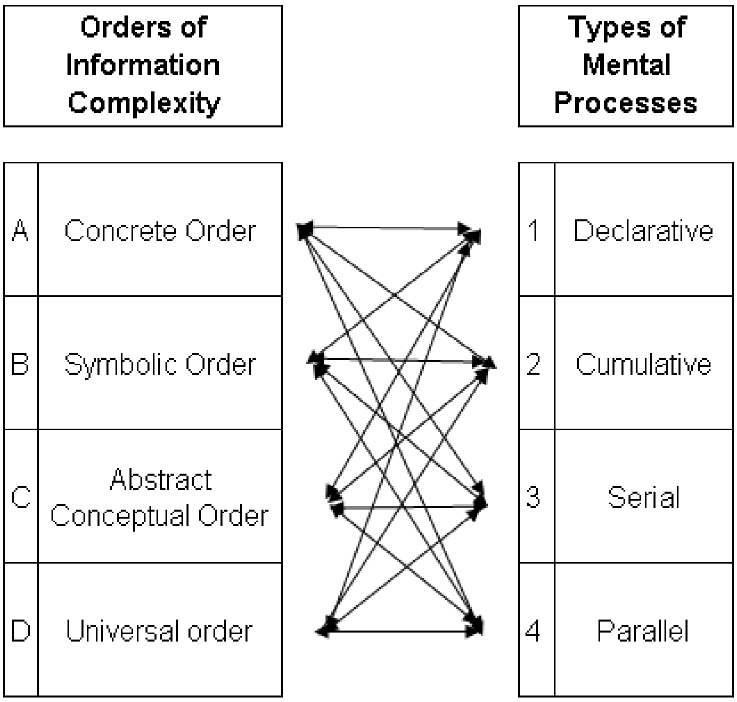


Figure 2-4 Information complexities and mental processes

The major validation on their work is done via mapping the CIP levels with the complexity level of the job roles. They have defined the complexity of a role as the longest completion time for the responsibilities within that role. With this definition and looking at organisational natural hierarchies, 8 different levels of role complexity have emerged. Based on this definition, the minimum and maximum role complexity is 1 day and 100 years. Jaques and Cason (1994) believe that these layers are correspondent to the levels of CIP and people with a specific level of CIP should work in a specific layer of the organisation. As the CIP matures in time the individual can grow to a higher layer of organisation. However this trend is different in each level as shown in Figure 2-5. In fact, the "Talent Pool Maturation Data Sheet" is a guide for application of their findings. Their findings have been validated through a longitudinal study.

It can be concluded that according to capability theory one's CIP which is a denominator of potential capabilities is not sensitive to internal and external factors. However it is stated that in application of their CIP in a specific task, people are affected by factors such as values, skilled knowledge and other behaviours. These factors are repeatedly used in the next section which deals with Human Resource Management's view on capabilities.

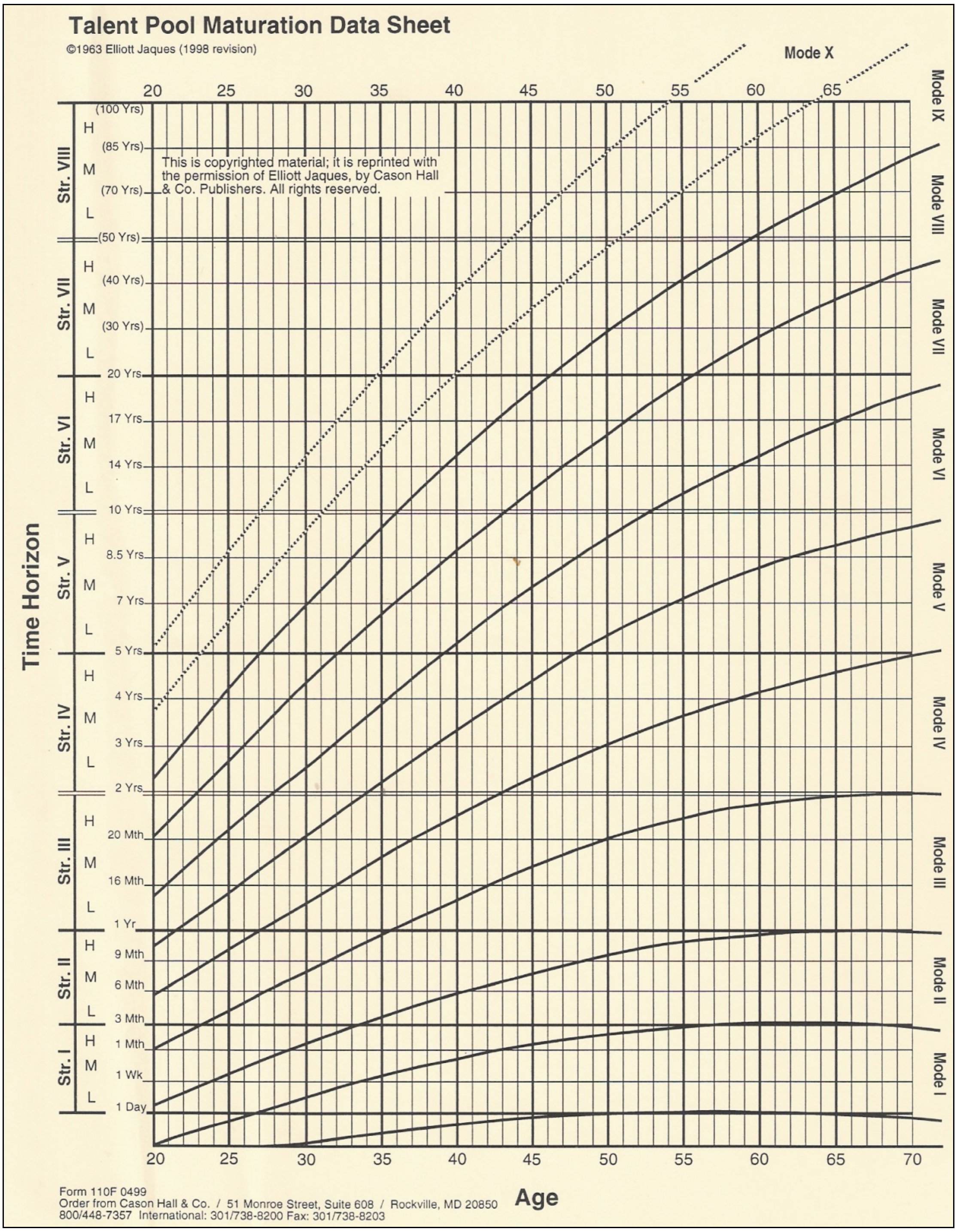


Figure 2-5 “Talent Pool Maturation Data Sheet” (Jaques and Cason, 1994)

2.1.5 Human Resource Management (HRM)

Human Resource Management (HRM) contributes to this review in two distinct ways; defining the key concepts such as capabilities, performance and their predictors and also the tools and techniques it owns to measures some of those. This section focuses on finding evidences on the conceptual development of capabilities and related concepts in HRM.

Literature in HRM do not directly use capabilities in their terminology, however in a work by Curtis et al. (2002, Pg 4), “Workforce capability is defined as the level of knowledge, skills and process abilities available for performing an organisation’s business activity”. Workforce is known by its constituent competencies, each competency shows an integration of knowledge, skills and process abilities gained through experience or education. Workforce capability mostly indicates an organisations’ readiness to perform critical business activities and their potential to achieve desired results (Curtis et al., 2002). This book is an extension of the capability maturity model (CMM) presented by Humphrey (1989). CMM was initially developed to structure and assess the capability maturity in software project contractors; however Curtis et al. (2002) have adopted the principles and used them as a guideline for workforce improvements. This model put organisations into 6 maturity levels in terms of their workforce capabilities and develops strategies for them to evolve into the next level. The maturation process can be in a continuous manner or in a staged way (Ahern et al., 2001). The main focus of the model is to provide frameworks and structure and to standardise workforce capability improvement practices. It is believed that this book have developed the infrastructure of organisations’ workforce capability in an extended and multi-layered format. However the fundamentals of assessing individual’s capability have not been discussed in the model. What is more, in their definition of workforce capabilities, the focus is on the available level in each of the criteria. This means that the application of these availabilities is not addressed directly. Also CMM is a process improvement method which deals with qualitative concepts and not involved with quantification of any kind.

A proper start to analysing HRM’s view on people’s assessment is to review the performance assessments which serve different purposes in this area of knowledge. In selection practices predicting future performance of people is prevalent. This is done using a set of criteria named “performance predictor domain”. In employee appraisals other set of elements are considered for assessment which are called “performance domain”.

In performance predictor domain individuals are assessed based on a set of criteria to predict their performance in completion of a future task. These criteria aim to assess one’s abilities, skills and preferences and are measured using a number of tests, interviews and data inventories (Hough et al., 2001). Abilities and skills have long been used as predictors of one’s future performance (Carroll, 1993; Schmitt and Chan, 1998) Researchers on personality and its effects on work related behaviours agree that situational and personal differences and preferences are both important in explaining one’s behaviour in a job environment (Kenrick and Funder, 1988; Snyder and Ickes, 1985). That is why people’s abilities, interests, personality and values are used in performance prediction domain (Schmitt and Chan, 1998).

Performance domain for people is evaluated using a different set of criteria. In section 2.1.2 a summary of performance definitions and measures have been presented in machines, processes and computers. In the human resource management Campbell et al. (1990) defined performance as “Actions that people take. Performance is not the consequence or result of action; it is the action itself”. Later the definition was modified to refer to measurable behaviours and action related to the task’s goal (Campbell et al., 1993, p. 40-41). In organisations and in the most recent performance evaluation literature, performance has been divided into Task and Contextual performance. Task performance represents conducts that contribute to the core of a business in providing products or services. Contextual performance consists of behaviours that facilitate task performance and contribute to the organisation’s culture (Hough et al., 2001). Campbell proposes the list of performance evaluation factors which he calls them competencies. Following Campbell’s work, Kurz and Bartram (2002) developed the great eight competencies model. One’s performance in conducting a task could be in the form of self-assessment, managers, peers or subordinates’ assessment.

There are certain key conclusions and shortages in the current knowledge and practice in HRM:

a) **Performance:** Although Campbell et al. (1993) has insisted on not separating abilities from performance, they are still perceived as cause and effect. Therefore in a task, individual’s track record of previous performance is as important as individuals’ abilities, skills and preferences. Moreover, previous task and contextual performance measures which are the most comprehensive performance measurement tools are not being used in predictors’ domain. This means that they are only being used as internal assessment tools in organisations and not as predictors for assessing potential candidates for a job. This research believes that they can be used as the criteria for measuring different aspects of one’s previous practice in similar tasks before joining an organisation.

b) **Values and Personality:** Personality traits and values for the job (interests) can be categorised as a construct which deals with patterns of individual behaviours (Schmitt and Chan, 1998). These patterns can sometime manifest themselves in people’s choices of how much and how long to exert effort in a task (Campbell et al., 1993). They can also be influential in one’ behaviours in specific circumstances in a job environment. This implies that motivational factors can intervene in the successful completion of a job.

c) **Context of the evaluation:** Different situations may change the way people use their knowledge, skills and habits (Mccrae and Costa, 1996). This is a key to one of the principles of this research which is capabilities in application. This means that people’s abilities, skills, motivational factors and previous performance records should be assessed in a defined framework. This indicates that assessment of individuals based on any criteria outside a strictly defined framework will not yield any practical or useable information.

This review of HRM literature shows that performance predictors, performance and preference can all contribute towards individual’s accomplishment in a task. This review has also shown that the selection procedure has never been viewed as a similar procedure to assessment of one’s applied capabilities. Further review on the HRM literature will be on the selection procedure which will follow this chapter. It shows different tools and measures used in HRM to assess jobs and individuals for fitting them together. But before that, it seems necessary to present the findings on the main criteria of the concept of applied capabilities as discussed in the past five sections.

2.2 Universal elements of capability assessment

In section 2.1 a review on the definitions, elements and uses of the concept of capabilities in different subjects has been done. As discussed in all the subjects, potential and applied capabilities are seen differently and different criteria are used to evaluate them. This section is designed to give a collective look at the similarities and the differences between the subjects in applied capability assessment.

Table 2-5 A summary of studied literature in section 2.1

<table>
<tr><th>Subject</th><th>What is actually being evaluated?</th><th>What are the criteria to evaluate it?</th><th>Key points in capability definitions</th><th>Resulted criteria to assess applied capabilities</th></tr>
<tr><td rowspan="3">Industry</td><td rowspan="3">Industrial Capabilities</td><td rowspan="3">Resources, Strategies and attainment of objectives</td><td rowspan="3">•Capabilities are context dependents.
•Capabilities can be defined in different levels of organisation.
•Capabilities are evolving.</td><td>Resources</td></tr>
<tr><td>Strategies</td></tr>
<tr><td>Attainment of objectives</td></tr>
<tr><td rowspan="3">Machines, Processes and Computers (M,P,C)</td><td>Future Performance</td><td>Effectiveness, Efficiency, Utilisation, reliability…</td><td rowspan="3">• Capabilities are measured by performance
• Users working with (M,P,C) can change their computed capability (performance)</td><td>(M,P,C) capability</td></tr>
<tr><td rowspan="2">Conformance to specifications</td><td rowspan="2">Number of defects, tolerance limits</td><td>User's skills and abilities</td></tr>
<tr><td>User's choice of use</td></tr>
<tr><td rowspan="3">Capability Approach</td><td rowspan="3">Well being</td><td rowspan="3">Life, bodily health, bodily integrity ….</td><td rowspan="3">•Capabilities are potentials.
•Capabilities are changeable.
•Applying capabilities results in functioning</td><td>Measures of wellbeing</td></tr>
<tr><td>Choices</td></tr>
<tr><td>Functioning</td></tr>
<tr><td rowspan="4">Capability Theory</td><td rowspan="4">Work and problem solving Capability</td><td rowspan="4">Complexity of Information Processes, Values, Skilled Knowledge and Temperamental behaviour</td><td rowspan="4">•Potential and Applied Capabilities are different.
•Applied capabilities are task based.
•Potential capabilities evolve over time.</td><td>Complexity of Information Processes</td></tr>
<tr><td>Values</td></tr>
<tr><td>Skilled Knowledge</td></tr>
<tr><td>Temperamental behaviour</td></tr>
<tr><td rowspan="4">HRM</td><td rowspan="4">Future and previous Performance</td><td rowspan="2">Abilities and skills, personality and motivations</td><td rowspan="4">• Workforce Capability is an indicator of organisational maturity.
•Environment and the context are important.
•Performance prediction is different from per</td><td>Abilities / Skills</td></tr>
<tr><td>Values</td></tr>
<tr><td rowspan="2">Task/Contextual performance</td><td>Personality</td></tr>
<tr><td>Performance</td></tr>
</table>

Table 2-6 Three main criteria for capability assessment and the contribution of each subject

		Applied Capability Assessment		
		1st Criteria	**2nd Criteria**	**3rd Criteria**
Subject Areas	**Industry**	Resources(Capron and Hulland's,1999) Generally reliable capacity (Dosi et al., 2000, pg2) Core Capabilities (Helfat and Lieberman, 2002) Zero Level capabilities (Winter,2003) Competence(Zehir et al. 2006)	Methods and strategies (Kogut and Kulatilaka , 2001)(Zehir et al. 2006) Complementary Capabilities (Helfat and Lieberman, 2002) Dynamic Capabilities (Winter,2003) Organisations' culture and structure(Kim and Lee, 2005)(Kimberly, 1979)	Move from Current to critical positions (Kogut and Kulatilaka , 2001) Attainment of objectives (Amit and Schoemaker, 1993)
	“Capability Approach”	S and O capabilities (Gasper,2002) Basic Capabilities (Lloyd-Sherlock, 2002)	Personal, Social and Environmental Conversion factors (Robeyns,2005,a)	Functioning (Sen, 1987)
	“Capability Theory”	Complexity of Information Processes (CIP) (Jaques and Cason,1994) Skilled Knowledge (Jaques and Cason,1994)	Value (Jaques and Cason,1994) Dysfunctional or Tempremental Behaviours (Jaques and Cason,1994)	Performance on a task (Jaques and Cason,1994)
	Human Resource Manageme nt	Performance predictor domain ; Cognitive and physical abilities (Caroll,1993)	Personality constructs (McCrae and Costa ,1996) Preferences (Mccrae and Costa,1996) Motivation (Campbell et al., 1993)	Performance (Campbell et al. ,1990) Great Eight Competencies (Kurz and Bartram, 2002)

Table 2-5 divides the subjects that were studied and within each, the problem of applied capability evaluation was appraised. For each of those problems the criteria for the assessment are listed. Then the issues regarding the assessment extracted from each subject area are presented. The last column of Table 2-5 is the guide to form the main categories of criteria which should be considered in applied capability assessment. Table 2-6 presents these three categories and the relevance of the studied literature to each category.

It is evident by now that this research is more concerned about the application of capabilities in real scenarios. Potential and applied capabilities are different in the fact that one is studied for a specified application with a defined framework and the other is not. This means that from the point where a task is defined for a person, the potentials can diverge from the applied. Table 2-6 is the reference point in forming the approach to measuring applied capability in this research. It is decided not to propose any new terminology for definitions or rules of applied capability assessment at this point. This has been done to allow the reader to follow the researchers' line of thought and rationale in structuring the concept. According to the reviewed literature and Table 2-5 and Table 2-6 certain points should be considered in structuring the applied capability assessment:

- **Criteria**

Table 2-6 shows how different terminologies and classifications in various subject areas can form the criteria to assess applied capabilities. In each subject area, there are numerous indications of each of the identified criteria. The table reveals that in industry, economics, psychology and human resource management the definitions of capability are associated with three main indicators. A more detailed explanation on these criteria will be presented in chapter 4. Whether individual or industrial capability is concerned, there is no significant difference in their view of the three mentioned indicators.

- **Interactions**

There may be a certain amount of interaction within the mentioned criteria. A number of studies have been carried out in each discipline to examine the possible relationships among different aspects mentioned in each row; e.g. relationship of personality traits and great eight competencies (Bartram, 2005; Kurz et al, 2004) or between performance and strategies (O' Regan and Ghobadian, 2004). However none of them show high positive or negative correlation between any of the elements. This provides an assurance that capability assessment using the mentioned criteria has construct validity and can be further developed.

- **View**

It is also noted that the purpose of most of the assessments presented in Table 2-5 is to help a decision maker to conclude on the conformance, performance, abilities or wellbeing of the subject(s) under study. The decision would then be made to maximise the benefits for the decision maker. A more inclusive assessment would incorporate the subject(s') benefit into consideration. This means that all the criteria presented in Table 2-6 should be assessed from both viewpoints i.e. managerial and personal benefit. In the applied capability assessment both assessment are fed into the decision making process.

- **Relevance of the criteria**

Wherever there is a need to assess one's applied capabilities the above criteria could be used. They should not change with the change in the purpose of the evaluation (fitting the best candidate to a task, forming the best team for a project) size of the evaluations (individual or group), benefiter of the evaluation (self, employer).

2.3 Chapter conclusion

The literature has been reviewed for several types of assessment such as assessing resources or strategies in industries, conformance to specification in machines, well being in economics, cognitive capability in psychoanalysis, performance prediction, values and personality in HRM. What is central in all of the above is the need to find potentials, seek suitability and conformance for the specific needs and predict the utilisation levels in undertaking the job duties. The current approaches in assessing capability do not produce a complete picture which can fulfil all the above. This happens despite the fact that the required information to draw this complete picture is not unattainable and a collective look at the assessment problem is required.

Applied capability assessment is an approach which is proposed in this research. It tries to assess people’s capabilities in applying them in a defined context. It is more comprehensive than just assessing abilities, strategies, motivations, or performance because it focuses on their application. It is inclusive in the criteria it uses and the viewpoints it considers to complete the assessment. This type of assessment can be used for assessing individuals or a network of people in an organisation. The assessment can be done to evaluate a previous applied capability of an individual, a group or an organisation. It can also be done to predict a future applied capability. For whatever reason the assessment is conducted, it certainly provides further-reaching information. It is believed that this novel look at the assessment problem strengthens the quality of the decisions made. The powers of the approach come from its:

- unrestricting nature in its applicability in different contexts
- Inclusiveness in the criteria it uses
- Breadth in the viewpoints it considers
- Applicability in individual and organisational levels
- Suitability of use for different purposes of assessment

To build up the foundations of the proposed approach it seems essential to study the implications in the individual level. This should entail answering the following questions:

1. What are the current methods in analysing a context (or a task)?
2. What are the possible tools and methods in measuring each of the criteria?
3. What theories are available to incorporate different viewpoints of people involved on an assessment procedure?
4. How this approach can be used for assessing people's application of capabilities in practice?

Chapter three aims to respond to the above questions.

Chapter 3
Applied Capability Assessment; Current tools

According to the studied literature in different subject areas, applied capability equals the application of capabilities in a specified context. A systematic approach in assessing applied capability for individuals is to be defined in this research. This chapter studies the fundamentals of developing the applied capability assessment for individual people.

Assessment of applied capability can yield useful information on one's suitability for a specific job in a defined environment. Therefore it is essential to have an extensive review of the current measures, tools and theories in human resource selection for jobs. This is done to identify the gaps of the current practices and possible contributions of a new assessment system.

A conventional procedure for selecting an individual for a job contains two key stages: Job Analysis and Candidate evaluation. When a job analysis is completed, candidate evaluation will then be performed to choose the best possible match. These two stages of selection procedure help clarifying two of the main questions in this research which concerns about definition of the context and the tools and methods of measuring different criteria in the assessment. These questions can be found in more details in final part of the previous chapter.

In fact, in applied capability assessment for individuals, job analysis is the equivalent of the context analysis. Because the definitions of a job best describe the context in which the individual is placed within an organisation. Candidate evaluation which is the next step in a conventional selection procedure can clarify the criteria and tools currently used in assessing candidates' suitability for a job. It has been seen that a variety of theories and tools have been developed in the human resource selection studies to perform each of the above stages. In this chapter a review of some of the important concepts and tools used in each stage of the process is presented. Measures, tools and information sources are to be studied and some of the most commonly used ones are explained in more details.

This chapter will consequently provide a review on the relevant literature and practices on fitting people to jobs or organisations. This review describes the practical implications that selection procedures have and all the dimensions which need to be considered. This will play a functional role in designing the algorithm and data processing in the development of the current research. In fact this subject will contribute to respond to another question we are seeking to answer which is analysis of the feasibility of inclusion of different viewpoints in the selection procedure.

This chapter will be closed by an appraisal of the studied literature and the gaps which exist in the collection of the current literature and practices in the above subjects. These conclusions will be helpful in finalising the gaps, and proposing the way forward in enhancing the current practices using the applied capability assessment approach. The application of the proposed approach will also be clarified by this point which responds to the last question asked in the conclusion of the previous chapter.

3.1 Methods of job evaluation

Job evaluation is the first step to be taken in the selection procedures. Job evaluation methods are reviewed because they correspond to evaluating a context in which a person is to apply their capabilities. This is a fundamental part of this research.

Jaques (1996) believes that in order to understand a job, it is most reasonable to divide it into its constituent tasks. “Task is a quantity of things with a certain quality which should be done in a targeted time within a resource limit.” (Jaques, 1996, p9). Jaques gives four major attributes to a task: quantity, quality, time and resource; and he recognise them necessary to describe the task. In another perspective by Visser et al (1997) jobs are evaluated with three different views:

- Task oriented (work oriented)

  A job is described only based on its required results and performed tasks (e.g. comprehensive occupational data analysis programs (CODAP))

- Behaviour oriented (worker oriented)

  A job is defined in terms of general behaviours necessary to perform it in general. This means that the job characteristics are analysed and translated into human characteristics (e.g. position analysis questionnaire (PAQ)).

- Attribute oriented (trait oriented)

  A job is evaluated in terms of personal qualities, knowledge, skills, abilities and other characteristics (KSAOs) demanded to perform the job. This method is the most attractive one since it allows for between job comparisons in terms of the attributes.

However, there are two prevalent job evaluation methods which have an extensive use in practice. These are named Traditional Job Analysis and Competency Modelling. These two main methods of job evaluation are described and evaluated in the next two sections.

3.1.1 Traditional Job Analysis

The selection of a candidate for a job starts with understanding and analysing the job that needs a new incumbent. Job analysis in its conventional format entails knowing the job via the Subject Matter Experts (SMEs) such as the current job incumbent or supervisors and also knowing the organisation. In the traditional job analysis (TJA) this is done for the sole purpose of producing a list of Knowledge, Skills, Abilities and Other characteristics (KSAOs) required for the job. KSAOs are identified through knowing the detailed tasks within the job in a descriptive format. Knowledge is a body of information one owns in a specific subject. Skills are practical capacities to perform tasks and Abilities are mental capacities to do the tasks. Schmitt and Chan (1998) believe that there is no need to distinguish between the three of them since they are all from the same nature and are used for the same purpose. It is always worthwhile if the list of KSAOs is judged by a second group of experts (Schmitt and Chan, 1998).

Job analysis can also be done through Critical Incident Technique (CIT) which is done by documenting critical incidents that can happen in a job, the incumbent's actions and its consequences (Flanagan, 1954). While traditional job analysis is designed to capture the average or minimum requirements for a job, CIT is more focused to define the extreme situations and their requirements (Phillips and Gully, 2009). However it is still considered to be a traditional job analysis since it insists on giving KSAOs; even though they are for extreme conditions. There are certain other tools for job analysis such as using pre-defined inventories of tasks (Primoff, 1975). Phillips and Gully (2009) have presented a summary of the given methods and their advantages and disadvantages.

It appears that in the traditional job analyses, most of the techniques suffer from problems such as focusing on a number of key characteristics of a job and not all, their lengthiness, their requirement for resources or the difficulty in communicating them.

3.1.2 Competency Modelling

Another approach in job analysis is competency modelling (CM). In this approach workers are evaluated based on the competencies required for a maximal success. A definition proposed for competency is:

“A competency is an underlying characteristic of an employee (i.e., motive, trait, aspects of one’s self-image, social role, or a body of knowledge) which results in effective and/or superior performance in a job.” (Boyatzis, 1982, p.20)

A key in CM is the influence of organisational strategy, culture and context in defining the competencies. So a CM provides a set of required competencies with regards to the job and the organisational strategy and culture. Because of this unique feature, CM is often used as a complementary job analysis tool (Phillips and Gully, 2009). A CM should also be sourced from the subject matter experts (Boulter et al., 1998). According to Pearlman and Barney (2000) the downside of CM is that there is no proper definition or defined procedure to derive it. In the following section a comparison of TJA and CM is presented.

3.1.3 Comparison of TJA and CM

Amongst researchers there seems not to be a consensus regarding the differences between TJA and CM and some even consider them to be the same (Ruggeberg, 2007). However, It is logical to say that CM is more congruent with business goals whereas TJA is more accurate in developing job requirements and level of details (Schippmann et al., 2000). Sanchez and Levine (2009) have given a full comparison of the two approaches in six main criteria which are presented in the Figure 3-1.

	Traditional Job Analysis (TJA)	Competency Modelling (CM)
Main principle	• It is defined by a list of KSAOs which are required for the job • The list can hardly communicate with the audience.	• It gives a path between behaviours and organisations' strategy. • It communicate better because of being more behaviourally defined.
View of the Job	• Job is seen as a constant across job incumbents . • It defines a job for a non existent average job incumbent (Levin and Sanchez 2007)	• Job is seen as a "role" performed by an incumbent which do not have rigid characteristics. • It encourages the idea of enacting roles to pursue organisation's strategy (Sanchez et al, 1998).
Focus	• It focuses on the job and the official responsibilities. • It ignores the possibility that behaviours and actions in a job can be influenced by other factors.	• CM uses similar sets of competencies and behavioural indicators which cut across jobs in an organisation and • It gives a common language in an organisation.
Time Orientation	• It is descriptive, gives an account of the current average requirements. • The primary source of information is the current job incumbent (Bottom-Up).	• It is prescriptive (Sacket and Laczo 2003) and tries to prescribe the manner in which work should be carried to be aligned with strategies. • The primary source of information is organisation's strategy (Top-Down).
Future performance level requirement	• It addresses typical performance as can be done by an average incumbent. • It looks for people who have minimum requirements to undertake the job.	• It aims at maximal performance in all the behaviours which are all aligned with the strategies. • CM is more suited for incorporating contextual performance.
Measurement Approach	• It has construct valid latent traits which are related to certain KSAOs and standars.	• It encourages employees to following organisation's behavioural theme which may not be compatible with any psychometric standards.

Figure 3-1 Comparison of TJA and CM in six dimensions (Sanchez and Levine, 2009)

Sanchez and Levine (2009) have also proposed a guideline for cross fertilization of TJA and CM. According to this guideline, initially strategic and contextual competencies which are required for the people within the organisation should be set. Then a set of KSAOs and other contextual factors should be compiled which correspond to those competencies. Each organisation should develop their own competency language and subject matter experts should translate that language into KSAOs for each job. This strategy will solve the problem of complexity of CM and makes it more communicable.

3.1.4 The combined approach

The above review on the research and practice in job evaluation led us to build a guideline to do the job analysis with a new approach. This guideline tries to incorporate the TJA and CM while considering Jaques (1994) definitions of job and task. With the exception of Sanchez and Levine's work (2009), the existing job evaluation practices are focusing on either TJA or CM. This is happening while pros and cons of these two approaches are known and their combinations would be beneficial for job analysts. It therefore is useful to follow a method which is more structured in the initial steps of evaluation and combines company's strategy with KSAOs in a later stage. The proposed method can be broken down into several stages. These stages are listed in Figure 3-2 for an example job.

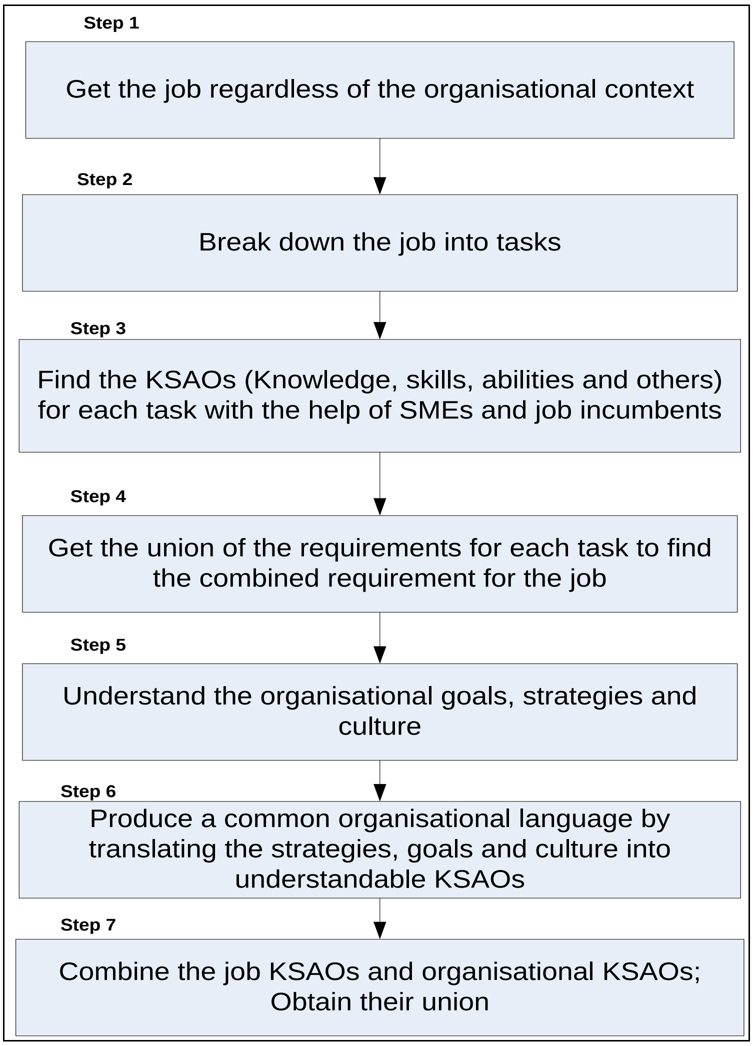


Figure 3-2 The stages of combined approach in Job analysis

In this approach, the list of KSAOs is once produced for the job and once for the organisational goals, strategies and culture. The requirements defined in steps 3 and 6 can be based on maximum (like CM), minimum (like TJA) or average requirements of the job. This should come from the organisational strategy on the selection procedure. It is also believed that by breaking down jobs into manageable tasks, this approach simplifies the current practices. Jobs should be broken down to tasks so that each task has as distinct requirements as possible to other tasks. Even though a complete separation seems to be impossible, this reductionist view can help to identify the requirements more accurately. A very simple example of how the method can be used for a secretarial job is presented in Table 3-1.

Table 3-1 An example of the use of combined approach in job analysis

<table>
<tr><th colspan="4"><u>Secretarial position in Company A</u></th></tr>
<tr><th>Step 1</th><th>Step 2</th><th>Step 3</th><th>Step 4</th></tr>
<tr><td rowspan="3">Secretary</td><td rowspan="3">1. Using a variety of software packages, such as Microsoft Word
2. Arranging meetings, taking minutes and keeping notes
3. Liaising with staff in other departments and with external contacts</td><td>1.1. General ability to use Microsoft Word, outlook</td><td rowspan="3">1. General ability to use Microsoft Word, outlook
2. Moderate Writing ability
3. Moderately skilful in organising
4.Likes working under time pressure
5.Extrovert
6.Average verbal and written communication</td></tr>
<tr><td>2.1. Writing abilities
2.2.Moderately skilful in organising
2.3.Likes working under time pressure</td></tr>
<tr><td>3.1.Extrovert
3.2.Average verbal and written communication</td></tr>
<tr><th>Step 5</th><th>Step 6</th><th colspan="2">Step 7</th></tr>
<tr><td>Company A's goals and strategies:
a) to enter the international market
b) to have a low staff turn round</td><td>For each employee of this organisation the requirements are:
1. Knowing a second European language
2. Being flexible with the changes in the job description
3. Having a higher than minimum capacities for the requirements of the job</td><td colspan="2">Final set of KSAOs required for the Secretarial position in Company A:
1. Good ability to use Microsoft Word, outlook
2. Good verbal and written communication
3. Likes working under time pressure
4. Extrovert
5. Skilful in organising
6. Knowing a second European language
7. Being flexible with the job description</td></tr>
</table>

In the typical example in Table 3-1 a secretarial job is defined to have three main tasks as stated in step 2. The interpretations of the requirement of each task in terms of the KSAOs are presented in step 3 and the union of all those are stated in the 4th step. Then the company's main goals and strategies are presented in the 5th step which are translated into KSAOs in the 6th step. Finally step 7 shows the union of job and organisation's requirements in terms of the items themselves and the level of requirements.

A similar method to the one proposed here has been used in the survey which has been done for this research. This approach can be used for defining any job, project or collaboration which has identifiable tasks, requirements and is conducted within a specific organisational context.

As stated in the beginning of the chapter, job analysis was the first stage in the candidate selection procedure. This process is followed by the candidate evaluation which is described in the following section.

3.2 Candidate evaluation; Research and Practice

Candidate selection literature and practice is a collection of different measures, methods, classifications and analytical research conducted in the past hundred years. As mentioned before, the selection procedure in HRM is a stepwise practice. The procedure starts with finding possible candidates for a job from a pool of applicants (screening stage) and will be continued with finding a potential employee among the candidates (evaluative stage) (Phillips and Gully, 2009). In each stage a set of tools and criteria are used which are shown in Figure 3-3. Some of the most prevalent of those presented in Figure 3-3 are described in the following sections.

Screening Stage
Applicants → Candidates

Biodata
CV and Resume
Applications

Evaluative Stage
Candidates → Employees

Cognitive and Physical Abilities
Values
Personality
Integrity
Job Knowledge
Work samples
Job Simulation
Interviews
Polygraphs
Reference Check

Figure 3-3 Tools and criteria in Human resource selection

3.2.1 Screening Stage; Biodata

Biographical data are the information which an individual provides based on their past experience, interests, educations or performance. Biodata is used as a screening tool for selecting possible candidates from a pool of applicants. Use of Biodata is based on the idea that one's previous conduct can be useful to predict his or her future success. Biodata is a valid tool which can pose very trivial adverse impact on the applicants (Mount et al., 2000; Karas and West, 1999). The scoring system in biodata inventories is very much dependent on the organisational and environmental background (Brown, 1981). Also the type of information asked in a biodata questionnaire can vary extensively in different job and environment contexts. Therefore, interpretation of Biodata can be sometimes problematic due to different measures and scaling used.

It is true that people may act differently towards their previous experience, they may learn from them or they may choose to seek a new way of approaching a problem. Either way, Owens and Schoenfeldt (1979) believe that biodata are good predictor of future success because they show the development of an individual in time. It's also been proved that biodata are satisfactorily reliable across gender and ethnic groups. Nonetheless, many of the items which are asked in biodata questionnaires can be collected via personality tests or other identified tests (Rothestein et al., 1990).

There are also other tools such as Curriculum Vitaes and application forms for the screening stage. These are more common tools and detailed explanations on them are avoided in this research. In the following sections some of the tools and methods used in the evaluative stage are described.

3.2.2 Evaluative Stage; Cognitive and Physical Abilities

Schmitt and Chan (1998) have conducted a review on the history of cognitive abilities and their definitions. They believe that one of the most descriptive definitions of cognitive abilities and their characterisation is given by Murphy (1996).Cognitive abilities become operational in undertaking a task which requires the person to use their individual features while dealing with information. Some examples of cognitive ability measures are verbal analogies, arithmetic reasoning or reading comprehension. Spearman (1927) believed that cognitive ability measures have two main components: a general and a specific component. The general component of a measure (g) is the part which is common among all the cognitive ability measures and the specific component is related to that measure itself. Researchers have tried to explore and challenge his theory; however they have reached somehow similar conclusions (Thurstone, 1938; Thurstone and Thurstone, 1941; Cattell, 1971). Another attempt in discovering cognitive abilities is by Guilford (1967) with his Structure of Intellect. Five operations (cognition, memory, convergent thinking, divergent thinking, and evaluation), five contents (auditory, visual, symbolic, semantic, and behavioural) and six products (units, classes, relations, systems, transformations, and implications) are the three dimensions of his structure. Each of the operations can happen in each of the contents to produce each of the products. Therefore there are 150 different combinations of measures of cognitive abilities in his work. The work has been disputed by other researchers over subjectivity of factor analysis, over extraction of the factors or not producing a better model fit than the previous models (Guilford, 1967; Bachelor, 1989). The trend in defining the cognitive abilities and their structure continued with Sternberg's (1997) and was furthered by Carroll (1993).

For cognitive abilities several tests have been used in selection procedures in industry such as Wonderlic personnel tests (1983), The Basic skills Tests (Ruch et al., 1985) and the General Aptitude Test Battery. Nonetheless, it is common to use more than one test for testing cognitive abilities (Schmitt and Chan, 1998).

As expected physical abilities have not been as extensively explored and characterised. Fleishman (1964) has completed the initial research on the subject and has identified nine physical ability dimensions. Later investigative studies on the categories have confirmed their reliability and their relationship with job success (Hogan, 1991).

A categorisation of cognitive and physical abilities, inspired by Hough et al. (2001) is presented in the Table 3-2.

Table 3-2 Categorisation of cognitive and physical abilities

Domain	Measures			References
Cognitive Abilities	**Crystallised Intelligence**	**Verbal Ability**	Anagrams, Speech Production, General Verbal ability, Analogies, Reading Comprehension, Vocabulary, Synonym Generation	(Hyde and Linn, 1988)
		Quantitative Ability	Computation (simple memorised mathematical facts), Concepts(analysis or comprehension of mathematical ideas) Problem solving (extension of mathematical knowledge or its application to new situations)	(Hyde et al., 1990)
		Science Achievement	Degrees, Awards	(Hough et al. , 2001)
	Fluid Intelligence	**Spatial ability**	Mental Rotation (mentally rotating a three dimensional object depicted in two dimensional space), Spatial Perception (determining horizontality or verticality) and Spatial Visualisation (visually locating a simple figure within a complex one)	(Linn and Peterson, 1985; Voyer et al.,1995)
		Memory	Primary and Secondary Memory, Memory Span tests	(Hough et al. , 2001)
		Mental Processing Speed	Cognitive Speed Test by Ideational Fluency, Figural Fluency, Association Fluency, Naming Facility. Decision Speed Test by Simple Reaction time, Choice Reaction time and Comparison time	(Carroll, 1993)
Physical Abilities	Muscular strength (Muscular tension, power and endurance), Cardiovascular endurance (Aerobic power), Movement quality(flexibility, balance, neuromuscular integration(Coordination))			(Hogan, 1991)

In practice, selection processes do not use the exact academic theories behind the cognitive abilities; Although Indications of the practical use of Carroll's (1993) and Thurstone's (1938) works exist. However this use is more of an implicit use rather than direct reference to the theories. What is more, the uses of the theories in a practical environment are normally tailored with respect to the job, the available resources or the environment and their strategies. Hunter and Hunter (1984) showed that the tests can have different validities according to the jobs that they are used for. As an example the general factor of cognitive abilities show a great correlation with performance in more complicated jobs compared to simpler jobs. In fact, different theories or tests could be differently applicable to different jobs in different environments. The choice should be made by the decision makers. Therefore, for the purpose of this research some of the measures discussed above have been used based on the context and the limitations of the study.

3.2.3 Evaluative Stage; Values and Personality

Personality is more related to the way people are behaving in an environment and values are more linked with one's preferences for tasks or environments. These two can also be combined in one construct which deals with patterns of individual behaviours (Schmitt and Chan, 1998). There are certain tools such as Holland's (1985) structure of interests or Strong Vocational Interest Bank which has been used in practice for several years to identify one's vocational interests and values. However as it appears from their names they are used to identify and explore one's general career interests as opposed to their values or interests in a specific job.

Personality has also been evaluated using several concepts or tools which are listed in Table 3-3. Personality taxonomy has also been followed by several researchers which resulted in different theories such as Hogan's six factor taxonomy (1991) or Big five (Costa and Mccrae, 1985) which was initially known as NEO personality inventory (Costa and Mccrae, 1976). Myer Briggs Type Indicator is another personality characterisation which pioneered the above taxonomies (Jung, 1971; Myers and Briggs, 1926).

Table 3-3 Personality Constructs

Domain	Measures	References
Personality Constructs	Extroversion (Introversion), Sensing(Intuition), Thinking (feeling), Judging (perceiving) **(MBTI)**	(Myers and Briggs, 1926)
	Agreeableness, conscientiousness (achievement, dependability), Extroversion (Affiliation and surgency), Neuroticism, Openness to experience **(Big Five)**	(Hough et al., 2001)
	Optimism, Service Orientation, Stress Tolerance, Emotional Stability, and Initiative or Proactivity	(SIOP,2006)

Personality is important to the extent that some studies have suggested defining preferred personality for a given job (Hogan and Rybicki 1998; Raymark et al., 1997; Rolland and Mogenet, 1994). Therefore it is logical to think that specific personality types are required for specific jobs.

Personality and values are considered to be important in assessing one's applied capability in this research. However, as mentioned before the tools used for assessing these dimensions are restricting because of the amount of resources they require. For the purpose of this work, evaluation of values and interests are task- based. This is because we were not looking for one's general vocational interests or work values. The main purpose is to evaluate the exact value requirements of the selected job. The preferred personality test is the Myers Briggs Type Indicator. Although most of the current tests have proven to be satisfactorily valid and usable, the choice made in this research is mainly due to the scoring system of the test and familiarity of the researchers with the dynamics of the test.

3.2.4 Evaluative Stage: Interviews, Work samples, Assessment centres

Interviews are one of the most commonly used methods of candidate selection, yet not proved to be among the most reliable or valid tools (Schmitt, 1976). Nevertheless factors such as proximity of the job and the interview questions, a structured interview session and number of independent interviewers can increase the reliability and validity (Mcdaniel et al., 1994). Interviews can be improved to the extent that they can even be substitutes of some cognitive tests (Campion et al., 1988). Interviews can be experience oriented (Behavioural interviews) or future oriented (Situational interviews) and their combined use has shown a high validity (Schmitt, 1976). In general, behavioural interviews showed higher validities than situational ones (Taylor and Small, 2002). Another line of research on interviews are focused on the decision making process after the interview. There are various personal and situational factors which can affect the interviewer's decisions (Schmitt and Chan, 1998). Demographic attributes are one of them but the relationship is too complicated to yield a specific conclusion (Schmitt, 1976).

Work sample is another type of evaluative methods. Candidates are asked to perform a set of tasks which can be related to the job in some way. The candidates' performance on those tasks is assessed. This is a widely practiced and valid method (Hunter and Hunter, 1984). However as any other method there are certain implicational issues associated with it. It focuses on a small manageable number of tasks in a job (Schmitt and Chan, 1998). What is more it is more reflective of one's maximum performance as opposed to a daily average performance which can be unrealistic (Schmidt et al., 1993)

Assessment centres are another way to evaluate the candidates. These are physical locations in which a series of exercises, tests and activities are given to potential candidates and their performance is being observed by examiners. These centres need a lot of resources to operate (Klimoski and Brickner, 1987). Like other methods, they have been proved to possess different validities in different practices.

In today's more technology oriented assessment systems, most of the above tests and measures have became computer-adaptive and intelligent. Questions are selected from a stock of tests and may be adjusted based on the respondent's answers.

Conventional forms of interviews, work samples and assessment centres are not used in this research. This is because the information required in this research are obtained from alternative methods which require fewer resources and yet are fit for purpose.

3.2.5 An appraisal of the current research and practices in the candidate selection methods

One of the most comprehensive appraisals of the employee selection procedures is done by Robertson and Smith (2001). They claim that up to sixty years ago, psychologists were always looking to find a single criterion which can gauge the reliability of their selection methods and the quality of the information they produce. This was later replaced by multiple criteria such as the real personnel data, production criteria and supervisory ratings (Schmidt and Hunter, 1998). Robertson and Smith (2001) has studied 17 methods of selection and used two criteria to assess their reliability. They used progress during training and job performance as the two criteria for checking the reliability of the initial selection methods used. Based on these two criteria, cognitive ability tests topped the validity chart in comparison to other methods in both criteria. After that, interviews, personality tests, biodata and assessment centres showed reasonable validity.

In a cross-national survey, Browen et al. (2002) have tried to find out the differences in human resource selection procedures around the world. They asked managers in ten different nations about the criteria they use or the ones that they should be using in future. The striking similarities among certain countries are attributed to their norms and cultures. In some countries (Canada and Australia) there is an increasing desire to recruit people whose personal value systems are compatible with the company's culture. In Japan a relatively low score is given to skills and cognitive abilities and they are mostly concerned about employees' trainability rather than their current skill profile. However Japanese managers ranked cognitive ability tests to be used in future which means that in the current job market technical expertise is becoming important to them. In Korea in some companies there are entrance exams for employment; employee referral is also a very common practice.

Robertson and Smith (2001) previously pointed out the doubts in cost effectiveness of some tools such as assessment centres. Phillips and Gully (2009) have collected some information on validity, applicant reaction, cost, usability and adverse impact of each tool. According to all the 5 criteria they have used, it is visible that although tools such as assessment centres, work samples and simulations have good applicant reaction and low adverse impact but their cost and usability are restricting their use. On the other hand, some tools such as weighted application forms, personality tests and biodata have shown an above average position in all the criteria which make them more appealing.

It can be concluded from the above that the choice of candidate selection tools may depend on factors such as reliability or availability of the tools and strategic or cultural considerations of the organisation. Assuming that the aim of a selection practice is to fit the best possible candidate into a job using limited resources, a possible selection strategy will emerge for any organisation. This means that a compromise should be made between the reliability of the selection procedure used and the amount of resources used in the process. Figure 3.4 lists some of the pros and cons of the current selection procedures and a possible schematic of how a selection procedure can be better formed. Based on the review on the current selection procedure it seems that a selection procedure can be more effective by incorporating issues such as using different information sources, tailoring tools for different jobs and focusing on required information solely.

Strengths of the current tools and measures

- Current tools are well defined in terms of their validity, adverse impact, cost, usability and applicant reaction.
- Most of the current methods (e.g. cognitive tests, assessment centres) are generic and their results can be used in other instances for the employee.
- The current methods are widely accepted.

Possible Shortages of a typical selection practice

- Organisations may stick to the same tools for a range of the jobs all of which may not be effective for those jobs.
- Application of those specific tools may require excessive resources.
- Organisations may seek to find a whole range of data, many of which may not be applicable to the job.
- They may only consider applicants' information in one time horizon (e.g. future, past).
- Information may be sought from just one source (e.g. applicant).

The proposed strategy for choosing candidate selection tools

- The selection tools should be tailored to the job and the organisation.
- The tools should only enquire the information needed for the selection purpose.
- A combination of the tools should be used which reflect the data from past, present and future of the candidate.
- The tools should be using different sources of information (e.g. applicant, peers, managers).
- Quantitative and qualitative tools are best to be combined.

Figure 3-4 The current selection procedures and the possible improvements

In this section the literature on the two main stages of the candidate selection has been studied. The studied material resulted into a combined approach for job analysis a strategy for choosing the candidate selection tools which have been discussed in details. The concept of "person-environment fit" which is to be discussed in the next section is a step further from the selection procedure. In other words, it elaborates on the practical implication of selection procedures.

3.3 The fitness of the person to the environment

Having studied different stages of candidate selection, the next stage would be to explore the outcomes of the selection procedure. Expectedly a good selection procedure should result in a good “fit” between the person and all the aspects of the environment he or she will be working on. Fit mostly refers to the congruence of person’s needs and/or supplies to the supplies and/or needs of the job, the group he or she will be working with and the whole organisation. For instance supplies of the person could be the person’s abilities or motivations and the needs could be the benefits he or she expects to get back from the job. Supplies of the job could be the benefits given to the person and the needs of the job could be the requirement of certain skills or abilities. This section explores different types of fit and different views and interpretations on the concept. The section will be finished with an appraisal of the reviewed literature on the fit concept.

3.3.1 Different types of fit

The concept of fit between the person and job, group or organisation was inspired by the idea of opportunity for skill use which was developed by Warr (1987). A definition for person-job fit is given by Edwards (1991) where he describes it as the match between person’s abilities and job demands on one hand and person’s desires and job rewards on the other hand. The concept then got extended to group, organisational or environmental fit. In fact the person-environment fit is a combination of person-job, person-group and person-organisation fit (French and Kahn, 1962; Cable and DeRue, 2002). This is depicted in Figure 3-5.

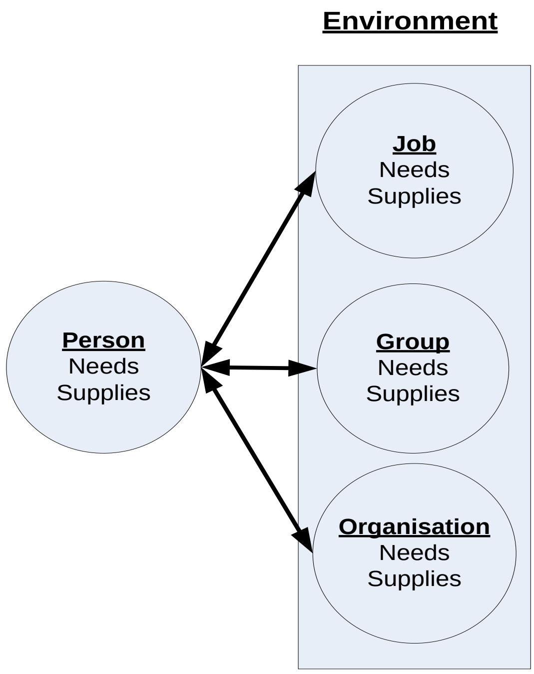


Figure 3-5 Different dimensions of fit

Person-environment (P-E) fit is getting more attention these days. The person-environment fit is mainly on the congruence of one's skills, beliefs, values and personality with culture, goals, norms and requirements of a job and an organisation (Kristof-Brown, 2000). This is to some extent different from the person-job fit which is focused on the congruence of skills and abilities. There is no fine line between the person-job fit and person-organisation fit and their constituent elements. However, they could not be substitutes of each other since they are measuring different things (O'Reilly, 1991). The question is how important the fit or misfit of the person and environment is. However, before proceeding to the benefits and risks of fit and misfit, there are two viewpoints on the subject, knowing of which can be important to us:

- **Complementary and Supplementary fit:** Muchinsky and Monahan (1987) believe that there are two ways in which people can fit to an environment: Complementary fit which is when they add new things to the environment and supplementary fit which is when they are similar to the needs of the environment. In a way, in both the fit is measured with the demands and supplies; however their definition of the demands and supplies are different from one another.

- **Objective and subjective fit:** the first one comes from the real characteristics of the person and environment and second one comes from the perception of the person from himself or herself and also the environment (Edwards et al., 1998; Harrison, 1978). It is nearly impossible to get an accurate objective person-environment fit; because the most valid tests and tools have a certain degree of subjectivity. That is probably why Harrison (1985) stated that seeking to find objective fit does not have much practical effect. This is because objective measures do not have a real representation and people mostly act on subjective information.

3.3.2 Person- environment fit and misfit

The benefits of the person-environment fit have been studied in literature. In the selection procedure, employers' perception of the applicant fit affects the selection decision (Cable and Judge, 1997; Kristof-Brown, 2000). Moreover employees' perception about his or her fit can affect their decision in keeping a job or leaving it which affects the staff turnaround (Cable and Judge, 1996).

The effects of P-E fit are not restricted to the selection and tenure issues. Spokane et al. (2000) have shown that when individuals work in an environment which is more congruent with their values, skills, knowledge, abilities and needs they will experience more positive work related outcomes. This means that congruence of skills, knowledge, values, beliefs or even needs with the job and organisation are required to produce a satisfied successful employee.

It has long been argued by psychologists that if people utilise and develop their skills in their workplace they become more satisfied in terms of "self-esteem and self-actualisation" (Maslow, 1970). HRM practitioners also believe that employees are more successful when they get to use their skills in the workplace (Boxall, 1992). Skill utilisation has been shown to have positive correlation with indicators of well being in work. However there is not enough evidence on which one is the predictor of which, this means whether skill utilisation makes people happier or happier people are more prone to respond positively to work related problems and use their skills better (Burke et al., 1993). In fact, It can be inferred that the KSAOs fit is more translated into success in the job and motivational fits are more translated into person's satisfaction.

P-E misfit can have psychological effects (anxiety, dissatisfaction, and restlessness), physiological effects (blood pressure, distorted immune system) and behavioural disorders (smoking, absenteeism) (Edwards and Cooper, 1988; Harrison, 1978, 1985) on the person. It results in different coping styles such as trying to either change self or the environment. It can also result in defence or denial of the situation (French et al., 1974). The most prevalent results however is the stress caused by misfit. Harrison (1985, 1978) believes that stress is provoked by two situations: when the environment does not fulfil a person's needs and when the person's abilities are not enough for the environment's demands. In fact the deficiency of organisational supplies to the person's needs could be a consequence of person's shortage in abilities and not fulfilling the environments' demands (Edwards et al., 1998). Warr (1987) has also mentioned that very high skill utilisation may harm people's well being at work and produce high strain levels. He stated that from a specific point onwards high utilisation does not support well being, although it may not necessarily impair it.

In the literature there are some guidelines on how the measures of the fit should be designed. In fact this is where the job analysis and candidate selection subjects get linked to the fit literature. In some cases researchers have asked people directly about their congruence; for instance asking them about their perception on skill utilisation (Meir et al.1990, Kornhauser, 1965; Caplan et al., 1975). However Edwards (1991) has advised that it is best to ask about one's skills and the job requirement separately rather than asking about the congruence itself. Therefore it seems that the best way is to do the job analysis to find out the job's needs and to use candidate selection tools to find out the candidate's supplies. Caldwell and O'Reilly (1990) believe that it is crucial to use the same set of criteria when analysing a job and analysing an individual. They also believe that collecting an expert set of characteristics for job and its requirement and assessing the individuals based on those is better than using generic measures (such as intelligence tests). This will also give a space for the organisation to include their specific normative expectations. This idea is compatible with the job analysis and the selection strategies we proposed in the previous sections. However, this is not the reality in the current practice (Edwards, 1991).

A question remains on how to relate the job needs and the person's supplies after measuring them separately. Assuming that these are measured in a quantitative format, differences of the values or dividing the values could give an indication of the fit. According to the literature, use of difference scores for the needs and supplies are prone to some problems and is not recommended (Johns, 1981; Edwards, 2001). Hence, it is more advisable to use relative scores between self rating and job requirements (Edwards & Van Harrison, 1993).

As a closing remark, it is important to note that fitting people to the organisations should not cost an organisation to be discriminating (Phillips and Gully, 2009). Therefore defining goals, values and cultures which are positively contributing to organisations' perfection and growth are of extreme importance.

3.3.3 Analysis on the fit literature; gaps and resolutions

As discussed before there are different types of fits, each of which can have certain effects on the person’s satisfaction, performance, strain or even job tenure. In analysing the existing literature on the concept we have identified several streams in which further progress could be made. For clarification, the simple message of the fit concept is extracted and showed in Table 3-4. According to Table 3-4 we will use person and environment fit in terms of their needs and supplies as the basis of the fit concept. This means that the focus will be on the requirements of the environment in all aspects and the person’s availabilities. Desires and rewards are not included in the discussions for the time being.

Table 3-4 what does fit mean?

Aspects of Fit	
Supplies	Needs
Abilities	Demands
Beliefs, Values, Personality	Goals, Norms, Culture
Desires	Rewards

Supplies (KSAOs, Personality, Values...)	**Needs** (The required KSAOs based on the job, the group and the organisation)

Certain gaps have been identified in the current literature on the fit concept. Firstly it seems that in the current literature there is no clear definition on who is conducting the fit practice and for whose benefit it is being conducted. In other words, it is not clear how the organisation’s benefit and the person’s benefit can be both satisfied. This question leads us to have a new look at the studied fitting practices. The idea is to check the degree to which the level of the supplies of a person can have an impact on the job or the environment. In other words, how much the person can contribute to the successful completion of the job in that environment? Meanwhile, there is also a need to monitor the level at which the same person would utilise him/herself in the job/environment. In the first instance the requirements of the job and organisation has the priority and in the second situation the availabilities of the person are important.

This vision is pictured in Figure 3-6 which shows how different levels of person's supplies and environment's needs can be fitted and perceived by the person and the environment. Suppose that the black circle represents the environment's needs and the dashed circles represented the person's supplies.

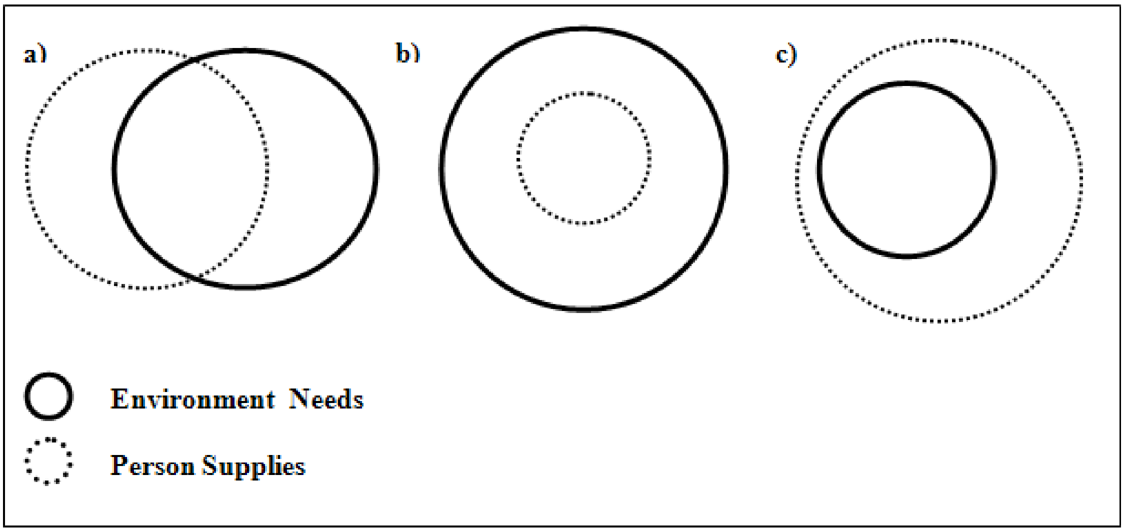


Figure 3-6 Different scenarios on person supplies and environment needs

a) Environments' needs and the supplies of the person have some similarities and some differences. This means that from the environment perspective the person's supplies partially fulfils the environment needs and from the person's perspective his/ her supplies would partially be used.

b) All the supplies of the person cover only a part of environment's needs. From the environment perspective person's supplies again partially fulfils the environment needs; however from the person's perspective utilisation of his/her supplies is to the full.

c) The supplies of the person are more than the environment's needs. So from the environment perspective the person's supplies fulfil all the environment needs but from the person's point of view the utilisation will only be partial.

In order to illustrate these scenarios in a simple quantitative format, assume that there is a specific environment need with a specific level of requirement (e.g. having a certain academic degree in writing). The supplies of a person can be higher, lower or equal to that requirement. A depiction of person's utilisation of self and fulfilment of environment's needs are shown in

Figure 3-7 for the above scenarios. Low levels of supply from the person's side results in low level of fulfilment on that environmental need. Then the supplies and needs equalise at a certain point (point E). From this point onwards where the person supplies are more than the environment's needs, the fulfilment level will remain at its highest level. Utilisation of the supplies for the person on the other hand has a reverse behaviour. It is in its highest value as long as the person's supplies are lower than the requirements and the person utilise all his/ her supplies. When the supplies exceed the needs the level of utilisation is lowered until the point that the person hardly utilise their supplies. This is one of the fundamental concepts in this research and it will be explained more in the future chapters. The logic here is inspired by the work of Edwards et al. (1998) in picturing the relationship of demand-abilities fit and strain levels.

The second identified gap is that the studies have not been done on the details of all the dimensions ranging from the abilities, to values, personality attributes and performance measure. They were either focused on relating fit of the person's abilities to job into the job performance or to test value congruence to job satisfaction or other similar studies (Hinkle and Choi 2009; Caldwell eand

O'Reilly, 1990). As mentioned above they have come up with different results while combining different independent variables. However, no single study has attempted to study the whole range of criteria (such as abilities, values, personality and performance) to assess one's perceived impact on the job within the context of the organisation.

Thirdly the fit literature has not been properly communicated with job analysis and selection methodology literature. This means that each of them has developed extensively while not effectively contributing to the enhancement of the others. For instance, different job analyses, uses of different candidate selection measures or different sources of information can result in different perceived fit from the person or environment's point of view. However such issues seem to be not studied in the existing literature.

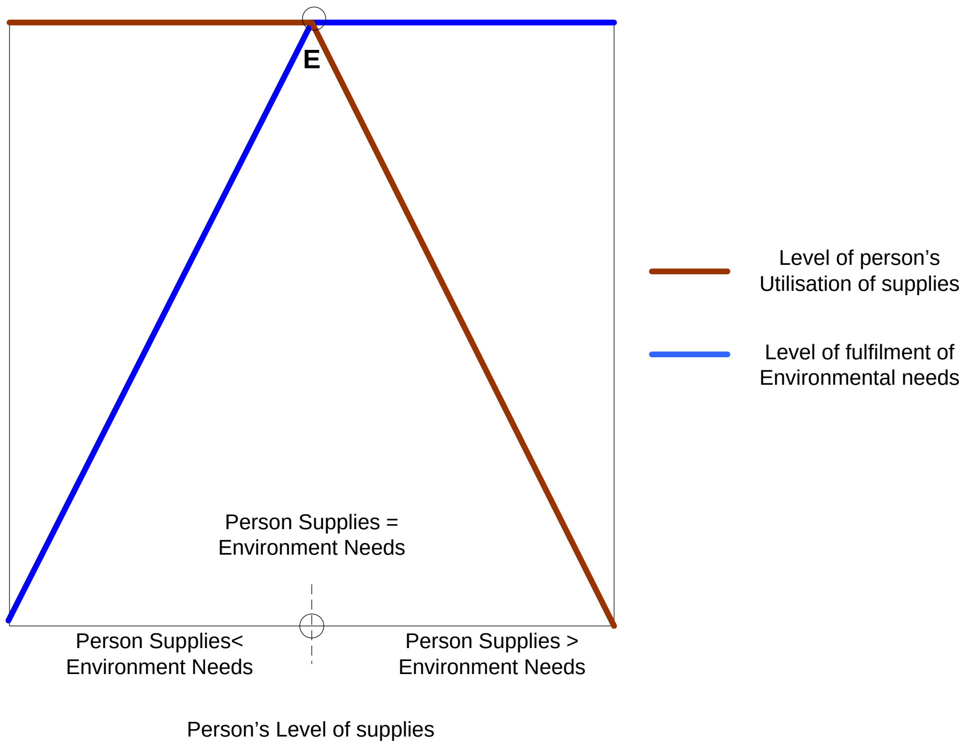


Figure 3-7 A simple representation of the two perspectives on fit of person and environment

As an attempt, this research is going to use a combination of TJA and CM in defining a job (as discussed in section 3.1.4), a set of measures and tools in evaluating a person's fit (section 3.2.5), a combination of sources of information and a mixture of different data collection methods and compute perceived fit within the job or the organisation from person's and environment's viewpoints as discussed in this section.

3.4 Identification of problems and gaps; the new method

This section aims at giving a summarised picture of the current body of knowledge in the last two chapters. This is done for two main purposes; firstly to show how the varieties of reviewed subjects have connected to each other and secondly to identify the gaps in the studied literature. These two will help in better understanding the relevance of the proposed changes and the projected new concepts and views in assessment of applied capabilities. Figure 3-8 provides a complete picture of the main streams, gaps, proposed improvements and the sequence of the development of the new concepts. The section in which each part is discussed in this thesis is mentioned in the parentheses. In the last column, the proposed changes and improvements are also listed and the ones which are related are connected using blue lines. The questions about the new approach which are needed to be answered in this thesis are also presented in this figure. Figure 3-8 clarifies the findings and contributions of the research to this point which are stated in the bottom left of the figure. These are mainly the purpose of the new approach, the criteria it uses, the importance of defining the context in the new approach, the language used in the evaluation and the viewpoints it considers.

The main problem in the current practices is the focus on tools and measures which can be more applicable to one situation and not valid in another organisation. Therefore there is a need for a selection strategy which is less reliant on a specific method or tool and more concrete in its approach and algorithm. The strategy and its foundation should be compatible to most selection practices.

The main finding up to this point is the criteria to be used in assessing one's applied capability in a specific context which equals their suitability for a job in an environment. The vast body of literature on different subject have led this research to relook the practices and investigate the underlying elements. As mentioned in the previous chapter three major criteria have been identified which build the structure of assessing applied capabilities. The first two criteria have been widely used as performance predictors in research and practice. These two are more focused on abilities, values and personality. However it is believed that a third criterion is ignored which is one's previous performance. This is another indicator of how suitable the person can be for the job. This shouldn't be confused with the notion of previous experience in its conventional format which is measured using years of previous experience rather than being assessed with the measures used for assessing performance. The current exercises lack this view on the concept. The exact same problem exists in job analysis exercises and use of similar criteria is essential to analyse a job in the same way as measuring the person's availabilities. It is stated by Robertson and Smith (2001) that theories of job and contextual performance which were developed by Borman and Motowildo (1993) and Campbell (1994) are not incorporated into job analyses. Therefore, this indicates that more contextual aspects of a job characteristic are normally neglected (Viswesvaran and Ones, 2000). This will be discussed in more details in the future chapters.

There are numerous other gaps and findings which are listed in Figure 3-8, details of which can be found in the previous sections. It has been learnt in the previous two chapters that applied capability assessment can be a useful evaluation tool. Although there maybe a variety of different purposes, levels, aspects and criteria associated with this evaluation, in this research we intend to focus on the fundamentals of the concept.

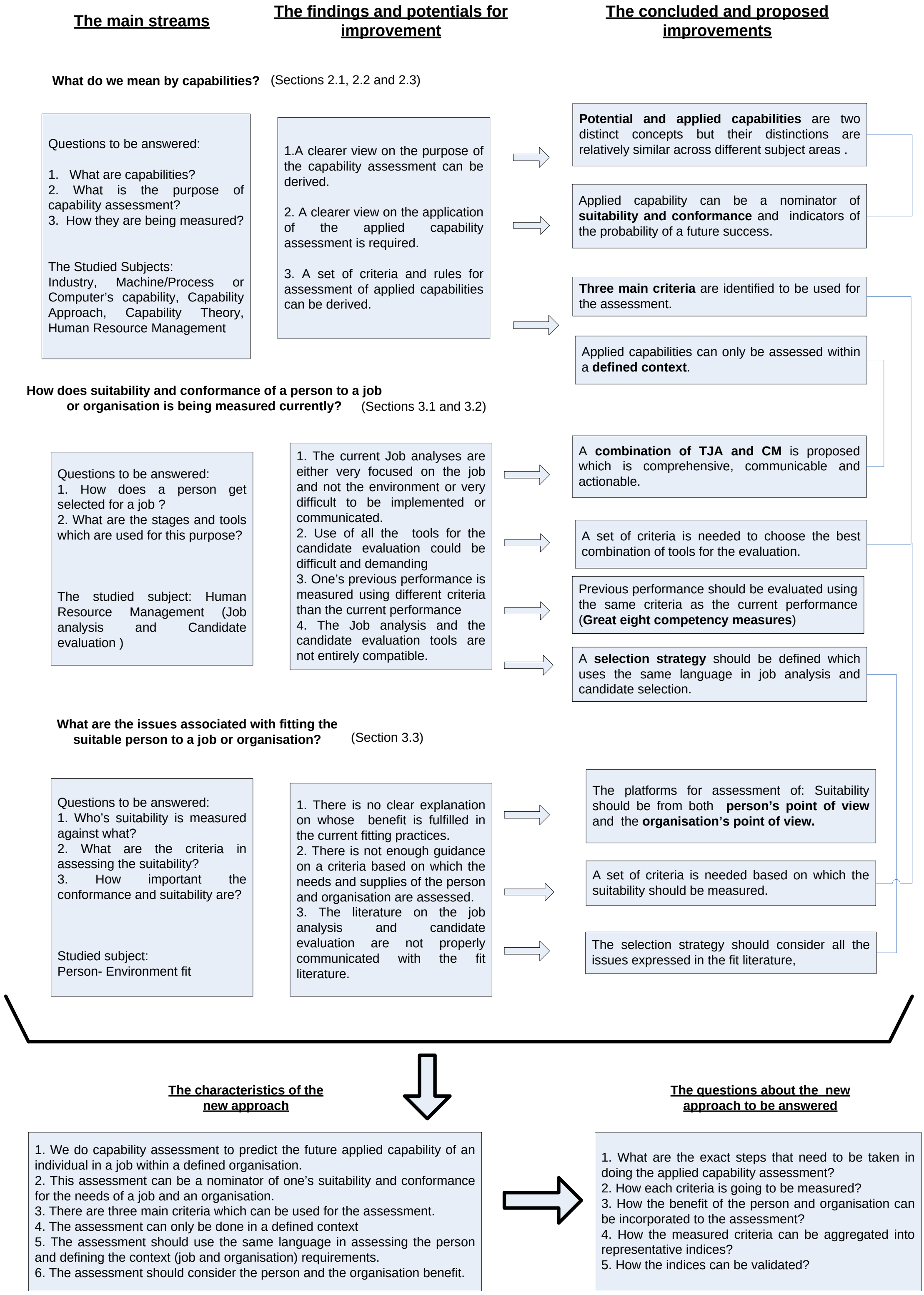


Figure 3-8 The findings of the research based on the studied literature

Therefore it is concluded that this research is focusing on the individual applied capability assessment using three main criteria in order to solve the selection problem while considering the benefit of the person and the organisation. This idea can be seen in Figure 3-9.

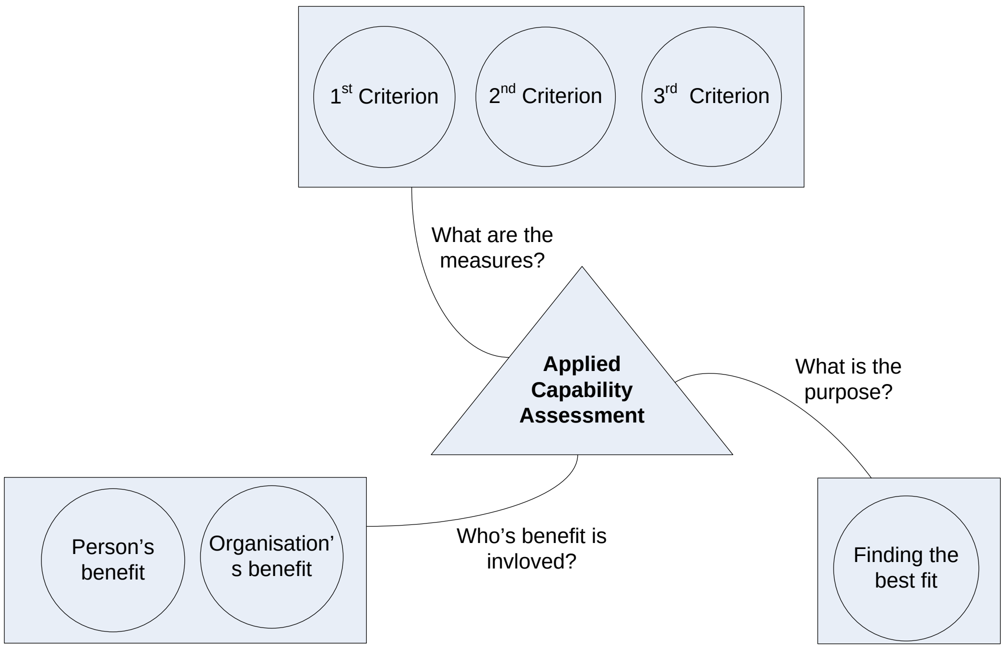


Figure 3-9 The simple picture of the applied capability assessment approach

3.5 Chapter conclusion

In this chapter the literature on the selection tools and methods and fitting procedures are reviewed. The studied literature and the analysis on these subjects clarified a number of key issues in the research. These included studying the current methods in defining a context in which an individual can be placed for a job, the possible tools and methods in measuring people's availabilities in certain criteria such as abilities, values, personalities and performance. Moreover, discussions on the concept of fit in this chapter helped in realising the importance of including different viewpoints in assessing ones' suitability for a job. The findings of the past two chapters were all summarised and linked in this chapter which can give the reader a clearer view on the way forward in the research. The main characteristics for the new approach are described and a number of questions to be answered in the following chapters are proposed. It is concluded that the main purpose of this research is to use the theories of capability assessment in fitting people to jobs with a special attention to the assessment and with consideration of person and organisation's benefit.

The next chapter will focus on the fundamentals of the model building based on the findings from the current literature.

Chapter 4
Model Development

In the previous chapters the foundations of a new approach in assessing applied capability was proposed. As stated before, applied capability can be assessed in order to find people’s suitability for a defined context (a job within a defined environment); this is done through assessing the person and the context with certain criteria while considering the benefits of both in the fitting practice. This chapter aims at defining the foundations of this new approach and its conceptual development.

The outcomes of this approach should satisfy all the characteristics which have been identified so far. This conceptual development results in identifying two indices as the outcomes of the assessment. Their expected characteristics are introduced in the first section of this chapter.

The chapter will then introduce certain key definitions of the proposed new approach. An introduction to the platform that the research uses to test the new approach using an existing similar method in applied capability assessment is presented. The proposed new approach comes from the gaps and findings from the literature and the other approach is based on Jaques “Capability Theory” (1994) previously presented.

The chapter will be finalised by presenting the data processing logic and algorithm. This logic is a fundamental part of this research since it accommodates the main required characteristics of the assessment. Some further explanations and features of the algorithm will also be presented at the end of the chapter.

By the end of this chapter the conceptual development of building the capability assessment platform will be finalised and the exact steps to conduct the assessment are clarified. This will lead to the following chapter which will focus on the possible mathematical methods which can be used for modelling the applied capability assessment.

4.1 The outcomes of the applied capability assessment

In summary the main characteristics of the proposed approach should be:

1. The assessment is done to predict the applied capability of an individual.
2. The results of the assessment indicate one's suitability and conformance for the needs of a job and an organisation.
3. There are three main criteria which can be used for the assessment.
4. The assessment can only be done in a defined context
5. The assessment should use the same criteria in assessing the person and defining the context.
6. The assessment should consider the person and the organisation benefit.

In fact the above characteristics are clarifying the purpose (1^{st} and 2^{nd}), inputs and the rules of the assessment (3^{rd}, 4^{th} and 5^{th}). However, the exact outcome(s) of the assessment need to be more distinctly clarified and explained. This is done based on the 6^{th} characteristic of the approach.

The logic behind this characteristic is to consider both the organisation's and the person's benefit when the suitability and conformance are assessed. What is meant by benefit is the conformance of candidate's supplies with the organisation's and job's needs so that none of them exceeds the other noticeably. In order to clarify how the two views can be captured a small focus group has been formed to elaborate their perception on the subject. The participants were 4 researchers in their early career. They have been given two questions and expected to explain their understanding of the questions and the logic they use when they want to respond to them. The questions they were given are:

Consider the job you are doing now and the environment of the job.

1. How much your capabilities contribute to the fulfilment of the requirements of **this job in this environment**?
2. **How much are you** using your capabilities in **this job in this environment?**

The answers should be in the range of 0-100 percent. Please elaborate your thoughts on how you come up with the answers.

According to the respondents, when answering the first question they initially think about the job requirements and the organisational cultures and norms. They then think about different aspects of their capabilities while trying to interpret their capabilities with respect to those requirements and evaluate their excesses, deficiencies and matches. If the overall requirements of the job and organisation are well above their standards and availabilities they will give a value well below 100%. Because they think that they would hardly be able to have an impact on the organisation or the job. On the other hand, if they easily fulfil the requirements of the job and accept the norms of the environment or even are over qualified for the job they will give themselves a 100%. This means that they believe they can have a 100% contribution or impact on the job and organisation based on the given requirements.

In the second question, they start thinking about their capabilities, and then try to picture the job requirements within those capabilities and qualities. If their availabilities are well below the requirements and they are constantly working up to their limits for this job they will then give a 100%. If they are exactly fit for the purpose they will again give a 100%. If they are above the requirements they will give a figure below 100%. This is because they believe that they are not using their capabilities in doing this job within this organisation.

The above exercise is hindsight on how the person and organisation's viewpoints can be captured and analysed further. The above responses align well with the fit literature and the representations given in figures 3.6 and 3.7 on different scenarios for person supplies and environment's needs. They all ascertain the existence of differences in viewpoints of person and organisation when it comes to assessing their suitability for each other.

Therefore practically, in finding the suitability of a person to an environment the main foci should be on:

- A criteria for assessment
- The supplies of the person
- The needs of the environment
- The benefits of the person and the environment

In this approach using a set of criteria the supplies of the person and the needs of the environment (job and organisation) are assessed which would result in some suitability indices. These suitability indices should demonstrate how the person can contribute to the job and organisation and how his/her capabilities are utilised. These two indices complement each other in portraying the whole picture of the dynamics between a given job in an environment and a person. It has been decided to name the first index as the person's "Impact" and the second one as the person's "Utilisation". These two indices can portrait one's applied capabilities in a certain environment.

Some key definitions regarding the new approach are presented in the next section. These terminologies and definitions are going to be used henceforth.

4.2 The conceptual development of the new approach

The main terminologies and concepts that are used in this research are:

Agent: A person who owns a set of resources that they use to undertake a task. Agents can also interact with other agents.

Resources: are inherent and acquired qualities of an agent that collectively contribute to completing a specified job. Resources have an impact and can be fully or partially utilised in the job.

Job: is defined to achieve certain objectives. A job is a combination of its constituent tasks each of which is necessary to accomplish the objectives.

Task: a predefined transition from one state to another state to be achieved within a given time. A task is interpreted into a set of required resources and their levels of requirement leading to agent selection process (agent-task matching). The requirements of the environment are also translated and reflected into the task requirements. A job is a combination of tasks.

Applied Capability: is demonstrable by measuring the impact and utilisation of the resources that an agent owns to complete a job.

Resource Impact: The degree to which an agent'(s) resources contribute to the fulfilment of the job/organisation requirements. This is called impact in this research

Resource Utilisation: The extent to which the agent(s) use their resources in a job/organisation. This is called Utilisation in this research.

Based on the findings in this research, the applied capability could be assessed using three main criteria. In the individual applied capability assessment these three criteria are used to define the agents in terms of their available resources and the tasks in terms of its required resources. The model that we are proposing in this section is named “EMP” model. The three criteria are the building blocks of this model. These criteria are going to be compared against the criteria used by Jaques and Cason (1994). What is going to measure the aptness of the “EMP” model as a conceptually valid model in future chapters, is its extrapolative ability in predicting the impact and utilisation indices. The study design in chapter 5 will further explain the details of the mathematical development for these evaluations. The “EMP” and Jaques criteria for evaluation are presented in this section.

4.2.1 EMP Model

Impact and Utilisation of an agent (A) in a specific job (K) is a function of enablers (E), moderators (M) and performance (P) in completing that job.

$$\textit{Impact and Utilisation Indices } (I, U)_{AK} = f\,(E, M, P)_{AK}$$

E, M and P are all different resources which are owned by the agent or required by the task. Their definitions are as follows:

1. **Enablers (E):** are the substantive cognitive and physical skills and abilities that agents deploy during the job life cycle. They can pre-exist and/or be developed in time.

2. **Moderators (M):** are the personal qualities that allow agents to cope with different situations (e.g. personality, motivation …).

3. **Performance (P):** is the historical knowledge of agents’ performance in similar situations (e.g. task and contextual performance).

To be more specific about the three major criteria in applied capability assessment, a more detailed framework is provided in Figure 4-1.

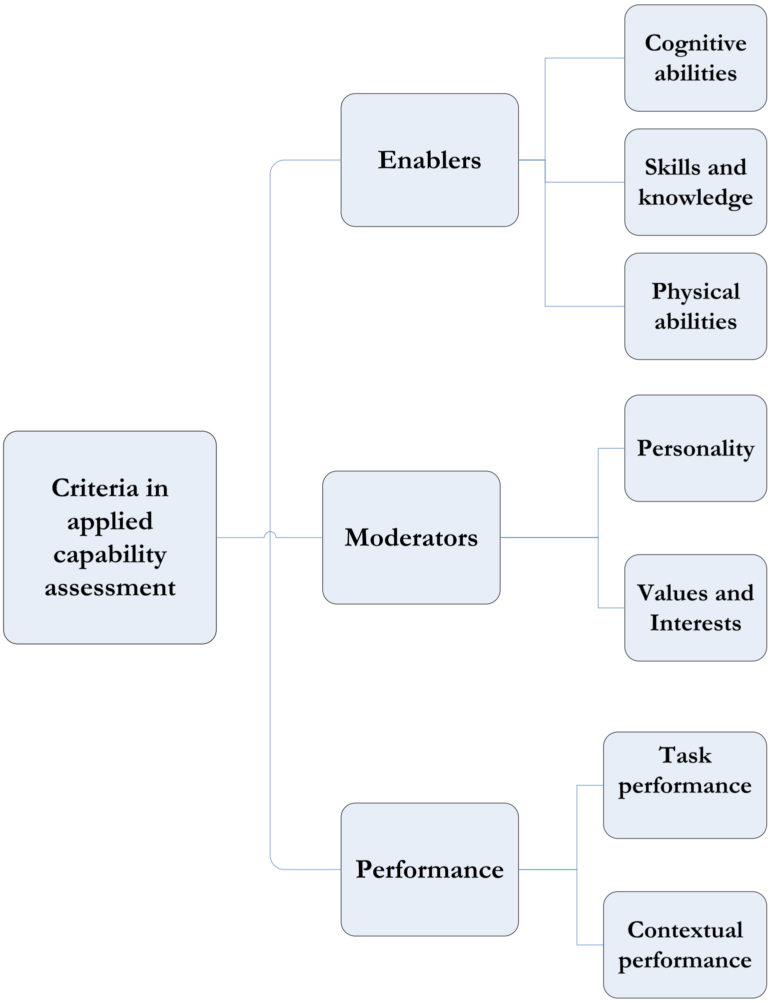


Figure 4-1 Depiction of criteria in applied capability evaluation in “EMP” model

The framework in Figure 4-1 is an interpretation of HRM principles and illustrates the practical tools that can be used in assessing applied capability. It is stated that what inherently enables human beings to complete any given task is their cognitive abilities, skills and knowledge and physical abilities (Caroll, 1993; Jaques and Cason, 1994). The second element important in applied capability is the moderators (M) which come from aspects of a human mentality which can affect their style of behaviour within the job and its environment. People with different personalities are likely to act differently. Biodata and personality tests are proved to be valid and logical tools to obtain these information (Robertson and Smith,2001).The last element is previous performance records (P) in similar task(s) which for human agent is proved to be best evaluated by task and contextual performance (Great Eight Competencies) measures (Kurz and Bartram, 2002).

The proposed definition of impact and utilisation manifests themselves in undertaking a job. It indicates that in fitting an individual to a job, considering only enablers or moderators or performance will result in an unrealistic picture of one's applied capability. In this definition a perfect fit means a good level of match between an agent and a given job in terms of their available and required resources in the three criteria (enablers, moderators and performance).

The next section describes a benchmark for our assessment approach which is used to test the validity of the "EMP" model in future.

4.2.2 Jaques Model

Impact and Utilisation of an agent (A) in a specific job (K) is a function of Complexity of Information Processes (CIP), Skilled Knowledge (S/K) values (V) and not having any dysfunctional behaviour (-T) in completing that job.

$$\textit{Impact and Utilisation Indices } (I, U)_{AK} = f\,(CIP, S/K, V, -T)_{AK}$$

The four main criteria in defining the resources are:

1. **Complexity of Information Processes (CIP)**: The level of complexity that an individual uses in order to process a specific set of information.

2. **Skilled Knowledge (S/K)**: Specific skilled knowledge for the given job (experience and skilled knowledge). It comprises information related to the work

that people accumulate during education, training and experience. Skills are the abilities to use knowledge.

3. **Value (V)**: The amount of value and interest the person has for the job (committed to type of work).

4. **Not having Temperamental Characteristics (-T)**: Extreme personality characteristics which result in dysfunctional qualities in doing jobs. These qualities affect applied capability directly and indirectly.

In this approach Jaques capability theory has been used in defining the important criteria for assessing the resources required by a job (or its task) or available by the agent. According to Jaques (1994, p76) “no one is Omni competent, Omniscient, or equally interested and committed to everything” so the way to quantify one’s applied capability can only be within the frame of a specific task. What have been added to Jaques capability theory to make it comparable to the “EMP” model are the two indices as the outputs. As a known conceptual model for assessing applied capability, Jaques model is used to be compared to the “EMP model”. For this purpose, data processing, modelling techniques and outputs of both models would follow the same logic.

This section established the two main conceptual models which are going to be compared later in this research. The next section explains the logic which is used to prepare a model for the assessment.

4.3 Algorithm of model building

This section lays out the steps which should be taken to do the assessment. The algorithm is only presented for the “EMP” model, but the exact same logic should be used for the Jaques model.

The algorithm has four main parts. The first part mainly deals with job profiling and has five steps. The steps describe how a job can be broken down. The theoretical background of the first part comes from the job analysis literature. The second part of the algorithm is about the agent profiling based on the task requirements. In fact the logic behind the first two parts is inspired from the selection strategy presented in Figure 3-4. The third part is the core of the algorithm since it transforms the inputs such that they produce two different indices. This is based on the fit literature (Section 3.3.3) and the discussion presented in Section 4.1. The fourth part finalises the algorithm and suggest the use of mathematical models for building a model.

Beginning of the Algorithm

This algorithm shows how the capability assessment practice have been done and modelled in this research. Assume that we are looking for a model to predict agent's applied capability in doing a job which involves *n* number of tasks. This algorithm divides the main steps into job definition, agent profiling, normalising the values in the profiles and finally to prepare for the mathematical modelling.

4.3.1 Job Definition

Set the requirements of the job with respect to its required resources (i.e. enablers, moderators and performance). This part of the algorithm corresponds to the combined approach presented in Section 3.1.4 and the flow chart presented in Figure 3-2. The requirements are listed here in terms of the resources presented in Sections 4.2.1 (E, M and Ps).

Step 1. Identify the tasks within the job. A job may consist of 1… n number of tasks.

Step 2. List the required resources for each task, *T =1, 2…n,* as the C_{ijt}s. C_{ijt} is the j^{th} required factor within the resource *i* for task *t*.

$$i = \begin{Bmatrix} 1 & an\ Enabler \\ 2 & a\ Moderator \\ 3 & aPerformance \end{Bmatrix} \quad and \quad \begin{array}{l} j = 1,2,3..e\ for\ i = 1 \\ j = 1,2,3..m\ for\ i = 2 \\ j = 1,2,3...p\ for\ i = 3 \end{array}$$

e is the number of factors in Enablers, *m* are the number of factors in Moderators and *p* are the number of factors in Performance. Tasks in this model should be defined in terms of their required enablers, moderators and performance.

Step 3. Assign the required level for each C_{ijt} and call it X_{ijt}

$$\mathrm{X}_{\mathrm{ijt}} \in (0 \to 1)$$

So C_{ijt} is the resource required and X_{ijt} is a value assigned to the requirements (E.g. writing ability (0.8)). C_{ijt} and X_{ijt} are defined using expert knowledge.

Step 4: Get the final definition of the job (maximum requirements in case of similar C_{ijt}*s)* : start with the first requirement C_{ijt}, for *i=1 j=1 t=1*, check whether there is any similar C_{1jt}, The resulting C'_{ij} and X'_{ij} are based on the following logic:

$$X'_{ij} = \begin{Bmatrix} \max(X_{ijt}) & for\ similar\ C_{ij}s \\ X_{ijt} & for\ dissimilar\ C_{ij}s \end{Bmatrix} \quad t = 1,2,...n$$

Then compile all the C'_{ij} and X'_{ij}, with this respect; by going through all the *j*s within each *i* for all tasks.

The final profile will include a set of C'_{ij} with the corresponding values of X'_{ij}.

Step 5: Allocate weights for each of the factors within each resource *i* so that

$$\sum_{j=1}^{e} \mathrm{W_{ij}} = 1 \; For\, i = 1$$

$$\sum_{j=1}^{m} \mathrm{W_{ij}} = 1 \; For\, i = 2$$

$$\sum_{j=1}^{p} \mathrm{W_{ij}} = 1 \; For\, i = 3$$

4.3.2 Agent profiling

Step 6. For each agent *k* (*k* =1, 2, 3…r), where *k* is the agent number and r is the total number of agents, find the availability of agents for the required C'_{ij} s and name the values A_{kij} s. A_{kij} is the level of agent *k*'s availability of for the j^{th} factor from the i^{th} resource. The availabilities of the agent are to be tested using the exact same tools which were used in assessing the requirements of the job. Details of the data collection methods and tools which can be used in this step are described in Chapter 6.

4.3.3 Normalisation process on the inputs

Step 7. For each agent normalise A_{kij} s for X'_{ij} s for all the C'_{ij} s and denote them as A'_{kij} *and* A''_{kij} *where*

$$A'_{kij} = \frac{\min(A_{kij}, X'_{ij})}{X'_{ij}} \quad and \quad A''_{kij} = \frac{\min(A_{kij}, X'_{ij})}{A_{kij}} \quad for \forall\, k, i \; and \; j$$

Step 8. Calculate A'_{ki} and A''_{ki} as:

$$A'_{k1} = \sum_{j=1}^{e} W_{1j} A'_{k1j} \;\; and \;\; A''_{ki} = \sum_{j=1}^{e} W_{1j} A''_{k1j} \qquad For \forall k$$

$$A'_{k2} = \sum_{j=1}^{m} W_{2j} A'_{k2j} \;\; and \;\; A''_{k2} = \sum_{j=1}^{e} W_{2j} A''_{k2j} \qquad For \forall k$$

$$A'_{k3} = \sum_{j=1}^{p} W_{1j} A'_{k3j} \;\; and \;\; A''_{ki} = \sum_{j=1}^{p} W_{3j} A''_{k3j} \qquad For \forall k$$

4.3.4 Modelling to predict the Impact (I) and Utilisation (U) indices

Step 9. Ask the agents to estimate their level of impact in the job I_k.

$$I_k \in [0 \rightarrow 1]$$

The same question can be asked from the managers about the agents.

Step 10. Use statistical methods on A'_{ki} and I_k for $i \in \{1,2,3\}$ and $k=1,2,\ldots r$ to build the underlying model:

$$I_k = f(A'_{ki}) \quad for \; i \in \{1,2,3\}$$

The statistical analyses will uncover the closest possible function *(f)* to approximate this index.

Step 11. Use the derived statistical method *(f)* from step 9 and apply it to A''_{ki} to predict U_k.

$$U_k = f(A''_{ki}) \; for \; i \in \{1,2,3\}$$

End of the Algorithm

The algorithm presented in this section would be the foundation of the model building in this research. In chapter 6 the application of this algorithm in a real case scenario will be demonstrated. Using this algorithm as a foundation, we will be able to build up a number of mathematical and statistical models for predicting individual’s applied capability.

4.4 The key characteristics of the proposed algorithm

4.4.1 The characteristics of the job and agent profiling

The first two parts of the algorithm deal with defining the job and the agents. These two parts have certain characteristics:

- Job profiling should include all the elements related to the tasks, the organisation and the whole environment.
- The criteria used for assessment of resources in task and agent profiling are either based on the “EMP” or Jaques model. The algorithm is based on the “EMP model” but it can easily be used for Jaques model.
- Finding a final job profile based on all the tasks rather than having a number of task profiles helps in simplifying the process.
- One language should be used for job and agent profiling. This has been extensively discussed in section 3.2.5. This means that the requirements of the tasks should use the same terminology and logic as the person’s evaluations. Requirement and availability levels are to be tested using a variety of tools and methods which were discussed before.
- Requirements and availabilities and weights are all quantitative values.
- Experts decide on the requirements of the tasks and their weights.

4.4.2 The characteristics of the normalisation and modelling

The third part of the algorithm is developed based on the findings from the fit literature (section 3.3.3). As stated previously the best form of profile matching is to assess the availabilities and requirements separately rather than asking the agent directly about their match to requirements (Edwards, 1991). In finding the relative match of the required and available levels for each of the factors, a minimum function has been used. This is done on the 7^{th} step which is the mathematical representation of the logic presented in the analysis of fit literature.

The final part of the algorithm prepares for mathematical modelling of the inputs in order to predict the outputs. Since the predictive ability of the inputs needs to be tested, we need to find a model(s) which estimate the perception of the agent's or the assessors on the impact and utilisation of each agent. This will be done using the observed values of these perceptions which are obtained in step 4. The rational for using perception values is based on Harrison (1985) which can be found in chapter 3. The impact and utilisation indices will then be mathematically estimated. The main modelling will be performed on predicting the impact index. The resulted model will be used for predicting the utilisation index in this research. This is done because both models are expected to have the same mathematical dynamics. This will be discussed in more details in chapter 9 of the research. Henceforth the key points for last two parts of the algorithm are:

- Relative match (step7) is the core of the algorithm which is based on the studied literature on fit and corresponds to formation of the indices.
- The given weights to each factor should be incorporated into the relative figures (step 8).
- There is no restriction on the type of mathematical model which can be tested as long as it provides continuous scale results on impact and utilisation indices.

- The modelling is done for predicting the impact index.
- The utilisation index will be modelled based on the impact estimation models.

4.5 Chapter conclusion

This chapter described the principles that the proposed capability models are based on. The chapter defined the possible outcomes of the assessment. The basic definitions and criteria using which the assessment can be done were presented. A second set of criteria (Jaques model) with which the predictive ability of the proposed model would be tested was also provided. The main difference of the two models is in the way they categorise the resources available to an agent or required by a job. Then an algorithm was presented which highlights the steps to be taken in assessing one's applied capability. Finally some characteristics of the proposed algorithm and its unique features were described.

Therefore we have discussed the exact steps which need to be taken in the applied capability assessment. This was done with a focus on the theoretical background of the model and not the exact tools to be used in the assessment. The chapter has also integrated the person's and the organisation's viewpoint in developing the outcomes of the assessment.

The results of this chapter lead the research to get to the next stage of the model development which is the mathematical development of the model. This requires a comprehensive study on the variety of mathematical methods which can be used for this purpose. Chapter 5 is designed to respond to this requirement.

Chapter 5
A review of relevant mathematical literature

In the previous chapters the conceptual developments of individual's applied capability assessment were discussed. In this chapter the author will explore the potential existing mathematical modelling techniques relevant to this research.

The first section of the chapter studies the statistical or mathematical methods used in assessing capabilities in literature. The subjects which were discussed in chapter 2 are relooked in terms of their attempts in quantification of an index, aggregation of factors or other modelling technique. Process capability evaluation, Industrial and organisational capability evaluation, Capability approach and economical indexing and also quantitative methods in Human Resource selection procedures are the main studied subjects. The mathematical models and statistical inferences are studied regardless of whether they are used to find potentials, seek suitability and conformance for a specific need or to predict the probability of a future success.

The chapter will then focus on the most appropriate mathematical and statistical methods for the purpose of modelling in the current research. Multiple regression and fuzzy inference systems are chosen to be used as the main modelling techniques in this research. Modelling the possible interactions between the variables will also be discussed.

Overall the chapter will clarify the possible mathematical and statistical modelling and aggregation techniques which can be used in the new approach. This will be a major step in building up applied capability assessment approach.

5.1 Existing mathematical models for capability evaluation

5.1.1 Process capability evaluation

In manufacturing and production, process and machine capability indices are by far the most used measures to evaluate the conformity of a process or a machine to specifications. Process capability index (*C_p*) was introduced by Taguchi (1986) and is being applied and expanded by researchers and practitioners since. This index can compute potential or actual capability of a process. The capability measures developed are based on analytical methods. The measures normally follow statistical techniques using sampling from the production line. In the process capability index there is a predefined accepted tolerance limit, which represents the required specification of the product in that certain criteria. Then the population of the produced parts dictates the variations in the process performance. Process capability is calculated using the formula 5.1 (Krishnamoorthi, 2006). Although the formulation is based on the assumption of central tendency of the process, off-centred processes can also be tested. A process can further be tested on a specific target specification.

$$C_p = \frac{Variability\ allowed\ in\ spec}{Variability\ present\ in\ process} = \frac{USL - LSL}{6\sigma} \qquad 5.1$$

C_p = Process capability

USL=Upper specification limit

LSL=Lower specification limit

σ = Standard deviation of the process

According to DelMar and Sheldon (1988), process capability evaluation can be used for other management decisions as well. For example employee selection or training decisions in some jobs can be treated be assessed using this logic.

Match or lack of skills related to the job shows the fitness or further training requirement for that person. However they believe that the formulation can best be used when a physical attribute (e.g. employee's coordination of eyes and hands) is tested.

Now the question is how the process capability assessment as described above can be used for developing a mathematical model for the capability assessment proposed in chapter 4. Process capability is calculated based on a specified tolerance limits and comparing that with the actual outcome of the process. The tolerance limits defined in process capability assessment is very similar to the task (or context) requirements as discussed before. However the big difference is that in process capability evaluation, **one process** is assessed using a population of parts with the same requirements whereas in the applied capability assessment using the "EMP" model **one person** is assessed based on different requirements for a job using a number of criteria. Therefore one can conclude that calculating C_p is in line with the proposed approach in defining the limits or specifications of the requirements. It is also in accord with the algorithm presented in chapter 4 in terms of the comparison of the required specifications with the available (real produced) specifications. However it is not much helpful because:

- It does not use a number of criteria in finding C_p, (The only criterion used is the part size) therefore it is not helpful in finding aggregation methods to combine different criteria.
- It uses statistics in a way which is not applicable in finding suitability or conformance of one person for one job

5.1.2 Industry: capability evaluation and contractor selection

In this section some studies on quantitative assessment of capabilities in industrial level are discussed. Contractor selection which is a case of predicting conformity to specification or success will also be discussed in this section.

Most of the studies in the area of firm level capabilities are conceptual or theoretical, many of which were presented in chapter 2. Quantitative analyses on the subject were mainly centred on finding correlations between certain factors. For instance, the relationship of capability measures and firm level performance is one of the most attractive topic (Coombs and Bierly, 2006; Deng et al., 1999). In other words they have taken a specific aspect of firm level capabilities such as citation counts (DeCarolis and Deeds, 1999) or technologies (McCutchen and Swamidass, 1996) and test it against a performance measure. Studies in which an index is formed based on the capability assessment criteria are not very common.

United Nations Industrial Development Organization (UNIDO) has developed the competitive industrial performance index (CIP) which can be used as an indicator of industrial capability of a country (Industrial development report, 2002). The index is an arithmetic average of four dimensions of industrial development. Each of the dimensions are normalised to be in (0, 1) using the formula below.

$$I_i = \frac{X_i - Min(X_i)}{Max(X_i) - Min(X_i)} \qquad 5.2$$

Where X_i is the value of factor *i* for country *X* and min and max are the minimum and maximum values of factor *i* among all countries. The normalised inputs are then averaged to form the CIP:

$$CIP = \frac{1}{4}\sum_{i=1}^{4} I_i \qquad 5.3$$

Although the comprising factors of the index are different now from the initial development (Industrial development report, 2009) the formulations and the used logic are the same. Finding the industrial capability index (ICI) has also been investigated by Crespo-Cuaresma et al. (2001) where they have added an estimate weight of each factor. This work has developed the current index because it replaces weighted sum to an arithmetic mean for *n* factors:

$$ICI_i = \sum_{i=1}^{n} w_i \,.\, x_i \qquad 5.4$$

Another study by Zhao and Guo (2009) developed China's innovation capability index, with a simple arithmetic mean of 50 factors. So in computing large-scale international or industrial capability levels, rather simplistic methods of aggregation have been used.

However there are numerous instances of using more complicated mathematical methods in computing firm level capabilities. Multiple criteria decision making (MCDM) is a techniques used when there are a combination of different criteria to be measured and a set of different decisions should be made. Analytical Hierarchical Process (AHP) is one of the MCDM tools used in this context. Mousavi et al. (2007) have proposed a technique for capability evaluation using analytical hierarchy process (AHP). AHP has been developed by Thomas L. Saaty in 1970s. The process has been widely used in variety of disciplines; more relevantly in industrial capability assessment and personnel selection (Mousavi et al., 2007; Gungor et al., 2009; Taylor et al. 1998). The main elements of the AHP method are hierarchies, priorities and logical consistency (Saaty, 1995). AHP method relies on pair wise comparisons of the decision making criteria and the decision options. The model presented by

Mousavi et al. (2007) is a generic model in which capability assessment criteria and their relative weight in the index are sourced from expert knowledge and a ranking is given to different companies in terms of their overall level across the criteria. They have used a normalisation process similar to formulae 5.2 and then applied the AHP into the normalised values.

As stated before, quantitative methods used in contractor selection in industry can be quite relevant to quantification of capabilities in any industrial setting. Holt (1998) has done a review on the methods used for contractor selection in construction industry. He concluded that cluster analysis, multiple regression and fuzzy set theory are set out to have good predictive ability for this problem. Simple Additive Weighting is a common decision making tool used in contractor selection in which decision makers are giving weights to the criteria and perform an ordinary weighted average (Hwang and Yoon,1981). Darvish et al. (2009) have considered interdependence of the contractor selection criteria and showed that incorporating this idea will improve the decision made. El-Sawalhi et al. (2007) have done a comprehensive comparison of the current methods used in contractor pre-qualification models. Their comparison led them to use a combination of genetic algorithm and neural networks to the problem. In their proposed model subjective judgements of the experts are minimised.

It can be concluded from the above that for assessing capabilities in industrial level or selecting the best contactor different mathematical methods have been used. These range from simple averaging methods, to more complicated methods such as genetic algorithm or neural networks. There were also cases of using MCDM tools. These methods are to be compared in Section 5.2 and the ones most relevant to the definition of capability assessment in this research are selected.

5.1.3 Economics: Capability approach; Production function

In economics there are studies in quantifying and indexing different phenomena and therefore examples of mathematical modelling are more available. In this section quantification in two fields are discussed; Capability approach and production function. Current mathematical modelling in Capability approach is discussed in order to extract their possible uses in forming capability assessment in our research. Production functions are representing the output of an organisation or a country based on several criteria. This function has taken different forms and discussed for nearly a century. Therefore in this section these two subjects are briefly explained.

Capability approach has a mostly qualitative look into human well-being and quality of life and there are hesitations to even produce a set of capability factors affecting well being yet alone an aggregation of the factors (Robeyns 2005,a,b). This can show the existing criticism on attempts to quantification of capabilities and human well being. Despite those, there have been different studies on quantification of capability approach in economics. Comim (2001) has given some guidelines on how to operationalise the capability approach. Operationalising can involve measurement and quantification of all or parts of the theory. The capability approach has been operationalised using multivariate analyses in some cases. One example of the multivariate analysis on the subject is the work of Martinetti (2006), in which a well-being level has been calculated using fuzzy set theory in defining the capability assessment criteria. In this work, each criterion comprises several factors and all of them are defined in fuzzy sets. Fuzzy sets define characteristics using a membership function. If in a crisp set theory a person either has a characteristic or not, in a fuzzy set a person can have a degree of attainment in that characteristic. An interested user is referred to the work of Zadeh (1965) in fuzzy set theory. After defining the inputs, the use of a form of generalised mean has been suggested as an aggregation method to find the final output in Martinetti (2006). Martinetti (2006) has also used fuzzy inference in predicting one’s well being using the factors in capability approach. The use of fuzzy set theory and factor analysis in extraction of the factors has been compared by Lelli (2001). This study showed that both methods are equally valid and can be used in the subject. In fact Lelli (2001) encourages economists to make use of other approaches which are used in other fields and further the operationalisation of Sen's capability approach. Another example of use of fuzzy sets in this topic is the work of Qizilbash and Clarck (2005). So this section so far discussed the use of different methods in quantification of capability approach.

The concept of production functions is briefly introduced here, because of their use in capability evaluation itself, and also their potential effect in combining the use of impact and utilisation indices. Production functions have been introduced in various mathematical forms (Lovell, 1976). However, Cobb-Dauglass function is one of the most known functions. Charles Cobb and Paul Dauglass (1928) has statistically tested a function which relates labour and capital to the production output of a country.

$$P(L,K) = bL^{\alpha} K^{\beta} \qquad 5.5$$

where, P is the production, L is the labour, K is the capital, b is a coefficient and α and β are output elasticity of labour and capital. The multiplication of the two inputs shows that production would only exist in the presence of both inputs. This function has been the subject of numerous studies and investigations since it was presented. In fact it has many applications from micro to macro economics (Lovell, 1976) and even to subjects such as education (Hanushek, 1979). In a recent work by Abell et al. (2008) production function has been used to compute production output of individuals using information on their motivated skills. Their work was the inspiration of brining production function into our research in two levels:

1. Production function has been used to produce one's production output provided that motivated skills are used as the input. In this research we have furthered the inputs into three criteria and named the output as impact/utilisation. It has also been learnt from the Cobb-Dauglass function that interacting effect between the variables could be important and should be tested. Although the format of the function used in this research may be different from the Cobb-Dauglass function the concept is quite similar.
2. Providing that we can find a collective impact and utilisation index for each person and eventually for groups of people working in an organisation, there is a possibility that this collective look can be used in a production function as a representation of people's applied capability which can affect the outputs of an organisation. This will be discussed in the future work of this research.

Overall in this section some attempts on quantification of capability approach has been studied. Use of fuzzy set in defining the inputs, averaging methods or fuzzy inference in aggregating the inputs have been studied in this subject. Production function has also been studied here and its possible contribution to this research has been pointed out. Section 5.2 will present the set of chosen methods that may be used in this research based on the studied literature.

5.1.4 Quantitative Human Resource selection procedures

Many of the analytical studies on human resource selection decisions are correlation or regression analyses on some aspects of candidates' traits and their success in the job in later times (Raju et al., 1991; Mount et al., 1999; Borman, 2004; DeFruyt and Mervielde, 1996; Roth and Bobko, 2000). There is also another stream of research which focuses on mathematical model for the selection process in order to find the best candidate for a given position.

There are a number of prevalent mathematical methods in selection procedure in HRM. Multiple criteria decision making methods such as Analytical Hierarchy Process or Technique for Order Preference by Similarity to an Ideal Solution (TOPSIS) are some examples. Fuzzy logic in defining selection criteria and assessment is another common method. There are also cases of using neural networks in personnel selection studies. Moreover some studies are combining some of the methods to reach a new optimised solution for the selection. Yet, most of the used methods and the proposed solutions are demanding a high amount of complicated mathematical calculations which impair their practical use. In this section a review on a number of these empirical studies are presented and their potential gaps and contributions to selection of other methods are discussed.

Parallel to capability evaluation in industry, many of HRM practices are also using the MCDM methods. One of the first uses of AHP in personnel selection has been done by Taylor III et al. (1998). They have used the traditional logic of AHP and establish decision criteria, the relative importance of each criterion, comparison of the candidates on each criterion and finally aggregation of the relative importance of the criteria and relative priority of each candidate in each. AHP is normally a comparison method and its expected result is ranking of the options or the candidates. To better the selection process, Gungor et al. (2009) have used the Fuzzy AHP (FAHP) method in which they use fuzzy inputs rather than crisp inputs. However a comparison between their results and a much simpler method, weighted goals method by Yager (1978) which is quite similar to the AHP method, shows that they produce the same rankings. This means that the use of fuzzy inputs does not necessarily enhance the results therefore the use of a less computationally intensive method can be more logical. Overall whether fuzzy sets are used or not, AHP hugely relies on pair wise comparison which can be difficult when the number of factors are not small.

TOPSIS is another MCDM method which was used in human resource selection practices. The original method was presented by Hwang and Yoon

(1981). The approach defines an example positive and negative (best and worst) solution for its selection purpose and finds the distance of each candidate from those solutions. The candidate who is closer to the positive solution and further from the negative solution is the best fit. The criteria in defining the ideal solutions and their weights are based on the expert knowledge and have crisp values. Kelemenis and Askounis (2010) have used a fuzzy TOPSIS method in human resource selection. This means that the weight of each criterion and the level of candidate in each are presented using linguistic variables. These assessments which were done by decision makers will then be interpreted into fuzzy numbers. What Kelemenis and Askounis (2010) added to the fuzzy TOPSIS method is a veto option. For each criterion they have set a value, below which the candidate will be rejected regardless of the results in other criteria. Dursun and Karsak (2010) has also used fuzzy TOPSIS method in a selection problem, however they have used a different method in solving the problem. They have built an algorithm which considers the different weights and ratings given by different decision makers. Their ranking results are very different from a similar study by Liang and Wang (1994) because of associating fuzzy inputs. In fact use of fuzzy numbers has been identified to produce contradictory results in ranking problems in some cases (Bortolan and Degani, 1985). As any other MCDM method, TOPSIS is used to solve ranking problems. Therefore it is mainly used to position candidates within the population and chose the best one. Their use of expert knowledge in defining the positive and negative solutions is not any different from the other methods discussed so far.

Fuzzy logic has been mentioned in this section quite frequently. Not only being used as part of other methods, fuzzy sets have also been used solely to predict the ranking of candidates. Work of Alliger et al. (1993) is a perfect example of this type of application of fuzzy logic. Petrovic-Lazarevic (2001) has developed a more detailed process for selection using fuzzy logic. In this research fuzzy logic has been used in shortlisting the candidates (evaluative stage). The shortlisted candidates will then go through a formulation which was developed previously (Prascevic and Petrovic-Lazarevic, 1992) and the final selection is been made. Cannavacciuolo et al. (1993) used a simplified version of fuzzy logic for the problem. Yaakob and Kawata (1999) also used the same model as Cannavacciuolo et al. (1993) in an industrial setting and improved it with adding workers' relationships in assigning them to group works. Drigas et al. (2004) have also used fuzzy set in matching a database of unemployed to an advertised job. They have set seven criteria for the selection. They have used previous records of employment with regards to the level of each criterion and set up the rules for their fuzzy model. Golec and Kahya (2007) have also used fuzzy logic in determination of the criteria, their weight and candidates' level of attainment in each criterion and defined a rule based to come up with a ranking for candidates. Among the mentioned studies, Drigas et al. (2004) are the only one who assessed the candidates using a given index for their fitness to the position. Other than that, selection studies are more centred on ranking problems.

Neural networks have been widely used within the past twenty years in different modelling scenarios. Wilkins and Sands (1994) have compared the usefulness of artificial neural networks (ANN) and ordinary least squared linear regression (OLS) in a simple selection problem. The problem is based on one predictive variable and one performance related variable. They have found that OLS regression analysis outperforms ANN in cases where the two variables were linearly related. In case of curvilinear relationship of the two, ANN are proved to be a better predictor of the dependent variable. In another study by Sommer et al. (2004) predictive ability of ANN is compared with logistic regression and linear discriminant analysis (LDA). They have used categorical variables such as passing or failing an assessment as the output of their study. The results show that ANN is a superior method. It is noteworthy that ANN outperforms LDA especially in cases where the initial assumptions of LDA are breached. In fact one of the powers of ANN is its few assumptions with regards to the data characteristics and the variables' relationships (Sommer et al., 2004). In a more recent attempt Doctor et al. (2009) have built an automated CV ranking approach using expert knowledge and ANN method.

So in this section some major methods used in quantitative candidate selection have been discussed. It appears that MCDM methods such as AHP and TOPSIS and fuzzy logic are used widely in decisions made in the selection procedures. Artificial neural networks are another method which has been widely used in aggregating the values of the candidates in different criteria. The method is a robust method in cases where the relationship between the criteria is curvilinear.

In Section 5.2 a comparison of the methods presented in this section is done and a set of possible aggregation and estimation methods are chosen to be tested.

5.2 The modelling techniques to be tested

This section intends to settle on the statistical or mathematical modelling techniques that can be used in the capability assessment approach that have been proposed in Chapter 4. This means that at the end of this section we should be equipped with a number of methods to be used in modelling the proposed approach. We mostly focus on the types of data that we can use and the data aggregation models.

Any model which is built based on a set of data (case study) can be expressed as (Judd and McClelland, 1989):

$$Data = Model + Error$$

This means that the better a model represent the variation in the data the lower the error term will be. Now the question is how to decide on the modelling technique which can represent low error terms. Therefore, it seems essential to review the concept that we intend to model and the type of data used in the model.

We are trying to assess an agent's applied capability in a specific job (in a defined environment). This is done through assessment of agent's available resources and environment's required resources. A number of criteria is used to assess the resources. The values obtained based on each criterion for each agent are to be normalised based on the algorithm provided in Chapter 4. As the result of this exercise we are trying to find the agent's impact on the job and utilisation of his or her capabilities in conducting the job. Now what is sought for in this section is to find modelling techniques using which we can best aggregate the independent variables (resources in three criteria) and come up with the dependent variables (the two indices). In choosing the techniques it is important to note that:

- The independent variables are defined to be continuous variables.
- The dependent variables are continuous variables and not rankings.
- The independent variables have gone through a normalisation procedure in which the job requirements and the person availabilities have been compared.
- The exact type of relationship between the independent variables and the dependent variables (linear, curvilinear) is not known.
- The independent variables may have interactions with each other.
- The independent and dependent variables are to be assessed using variety of measures and tools (self assessment, expert knowledge…)

Now based on the reviewed literature in Section 5.1 there is a need to decide on the preferred aggregation method which is most appropriate for the modelling. Figure 5-1 pictures the studied methods used in the studied subjects.

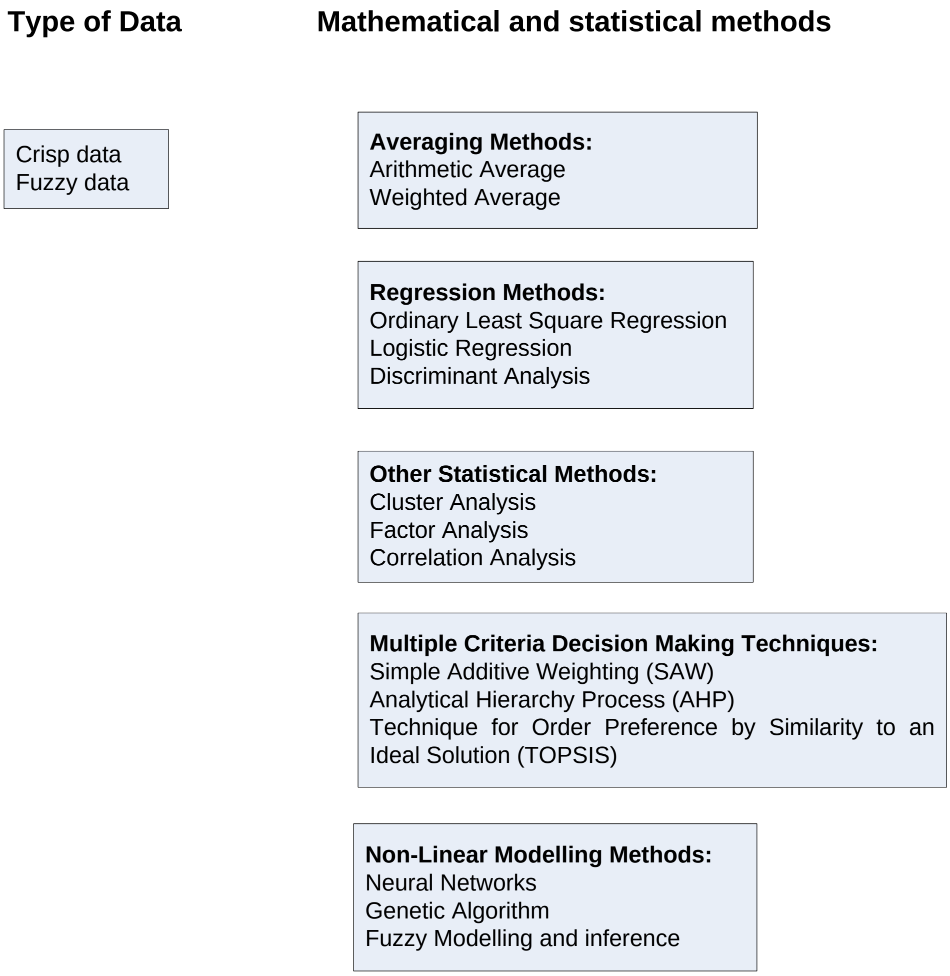


Figure 5-1 The used mathematical methods in the studied subjects

The data used in the studied researches have been either crisp or fuzzy values. If in assessing an agent on a criterion, the agent either have or not have the requirements of the criteria this means that the data is crisp. Whereas this can be fuzzified; this means that the agent could have the requirement of that criterion to a certain extent. According to the algorithm proposed in Chapter 4 the type of data which is prepared for our modelling is fuzzy in some sense and crisp in another. The fuzziness is due to the availability levels of an agent and their comparison to the requirement level which produces relative figures. However the crispness is because there is no direct fuzzification of the inputs (defining membership functions which are described in more details later). Therefore it can be concluded that the data which is used in this research is a crisp data which has a relative nature.

Knowing the type of data being used for the model, most suitable modelling techniques could be selected.

Certain statistical methods used in the previous studies are not applicable in this study. The reason is that this research aims at modelling a set of independent variables on some dependent variables. It does not intend to cluster agents into groups or to extract factors form a set of sub factors or to find a specific correlation. Although in the course of data analysis certain statistical methods such as correlation analyses may be used, but these analyses wouldn’t be able to offer an estimation technique.

Multiple regression analysis is one of the most widely used modelling techniques which cater for a variety of different types of independent and dependent variables (Categorical, continuous, quadratic variables, and interaction of variables…). Therefore multiple regression can be used as a possible modelling technique in this research. Section 5.1.1 describes the use of regression analysis in this research in more details.

MCDM is another family of methods which has been discussed widely however the output of such methods is not compatible with the requirement of the assessment approach that is defined in this research. This is mainly because these methods are giving a ranking for the agents. Although the rankings are based on the person’s availability on a set of criteria with different importance levels; they actually wouldn’t have the essential characteristics that are proposed in Figure 3-8. Therefore use of these methods is not compatible with the characteristic of the applied capability assessment approach.

Non-linear modelling techniques have also been discussed in the previous section in several instances. In fact fuzzy inference techniques and artificial neural network techniques can be good choices for modelling applied capability. This is because they are capable of detecting different types of relationships among the independent variables and between the dependent and independent variables. These methods are not restricted in terms of the type of inputs and outputs they can accommodate.

The following parts of this section give some more details on the selected modelling techniques for the research.

5.2.1 Multiple Regression

Multiple regression is a widely used modelling technique which relates a number of independent variables to a dependent variable.

$$Y = a_0 + a_1X_1 + a_2X_2 + a_3X_3 + \ldots + a_nX_n \qquad 5.6$$

Y= Dependent variable

X_i= Independent variables

a_i= Coefficients

n= Number of independent variables

A multiple regression can be used to produce explanatory or predictive models. Explanatory models are mostly concerned with finding the justification for a phenomenon whereas predictive models are focused to produce an application for the current understandings (Venter and Maxwell, 2000). Multiple regression analysis can have a linear or nonlinear form.

Multiple regression is chosen to be used as one of the modelling tools in this research. Ordinary Least Square regression is the chosen regression analysis to be devised. Other forms such as quadratic variables could also be tested to check for a possibility of a linear relationship between other forms of the input variables to the output. This is a common practice in multiple regression analysis since the actual relationship of the independent and dependent variables are unknown. Examples of such practice can be seen in Cable and Cable (2004) and Edwards and Parry (1993). What is more, possible interaction of the independent variables could be tested. In order to be clearer about the types of interaction which can be tested, moderation and mediation effects are described in more details in the following section.

5.2.1.1. Interaction between independent variables

The relationship of independent and dependent variables can also be demonstrated using path analysis developed by Wright (1921).

Figure 5-2 shows the possible causal relationship between three endogenous (independent) variables and an exogenous (dependent) variable. Apparently, any causal relationships that may affect the exogenous variables and not described by endogenous variables are not demonstrated here (Pedhazur, 1982).

However, there are cases in which a variable can have a moderating or mediating effect on the causality of another independent variable on the dependent variable (Baron & Kenny, 1986). Moderator is a variable, whose level can influence the effect of an independent variable on a dependent variable. Mediators on the other hand are there to explain the relationship of the independent and the dependent variables. This means that the mediator is the reason behind the relationship of independent and dependent variable (Baron and Kenny 1986; Edwards and Lambert, 2007; Alwin & Hauser, 1975).

Figure 5-2 a shows a direct relationship between the independent (X_1, X_2, X_3) and the dependent variable (Y), and

Figure 5-2.b shows a moderation effect of one of the independent variables (X_2) on the other 2 independent variables (X_1, X_3) in their relationship with the dependent variable (*Y*). X_2, itself may or may not have a direct effect on the dependent variable.

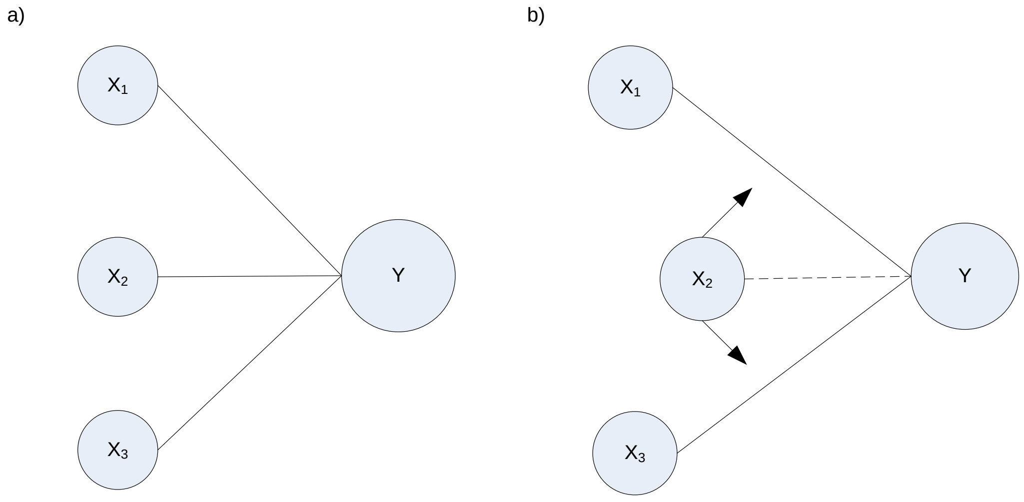


Figure 5-2 Direct relationship or moderating effect

Now consider a simple example in which there are 2 independent variables (X_1, X_2) one of which (X_2) may have a moderating effect on the relationship of the other one (X_1) with the dependent variable (*Y*). In practice, to test this effect in a regression analysis, the following regression can be run:

$$Y = d + a_1X_1 + a_2X_1^2 + bX_2 + c_1X_1X_2 + e \qquad 5.7$$

If c_1 is non zero and significant then the X_2 variable is linearly moderating the effect of variables X_1 on *Y*. Otherwise the variables would be considered as being 2 independent variables which are determining the dependent variable without any moderating effect on each other.

As expected, in the current research the type of relationships between the independent and dependent variables are unknown. It may be the case that some moderation effects may exist. That is why the above theoretical background of testing moderation effects is provided.

Fuzzy logic is another modelling technique which can be used as part of the modelling and is described in the next part.

5.2.2 Fuzzy logic

Fuzzy logic deals with complex problems for which getting a precise solution is difficult. This characteristic allows us to consider fuzzy logic as one of the methods to model the current research. Fuzzy logic was initially developed by Zadeh (1965). Two of the major contributions to advancement of fuzzy logic applications has been done by Mamadani (1977) and Sugeno (1985). Zadeh (1975) have stated that fuzzy logic could best be used in “Approximate Reasoning”. Mamdani’s work (1977) is considered as one of the first attempts for reaching this aim. Sugeno (1985) on the other hand, has developed the use of fuzzy logic in more industrial settings which is more compatible with mathematical analyses.

Fuzzy logic is a powerful tool in defining input categories and assigning membership values to each input. This means that the uncertain nature of the input categories can be well modelled using the fuzzy sets, memberships and rules. In modelling real problems fuzzy logic can be used in two different ways. The first way is that the membership functions of the inputs and outputs and the rules connecting the input and output space can be defined based on expert knowledge or a set of data. Then by using a modeller (software package), inputs and outputs, their rules and membership functions result in a fuzzy model. This is described in more details in this section. The second way is when the values for the independent and dependent variables are fed into a modeller and it uses fuzzy inference systems to statistically infer the best model that fits the data. The second use of fuzzy inference systems is explained in more details in section 5.2.3.

In a classical fuzzy model the inputs are fuzzified based on the membership functions, then the defined rules and an implication method will relate the inputs to the output space, the resultant outputs from each rule are aggregated and finally using a defuzzification method a single value is given as the final output. In a Mamdani fuzzy modelling the output membership functions should be defined by a membership function whereas in the Sugeno type a constant value or linear relationships of the inputs form the outputs. In the following paragraphs, some details on forming a fuzzy model are presented.

The first step is to define the membership functions for variables. Membership functions should be representative of the real characteristics of the variables. One of the most widely used membership functions is a Gaussian function which permits membership between 0 and 1 and it never actually reaches absolute 0 or 1. In case of using Mamdani fuzzy system, the membership functions of the outputs should also be defined. Then rules of the system should be defined which permit to connect the inputs to the outputs. If there are more than one input in the system, a fuzzy operator should be chosen for the model. The most common operators are Fuzzy intersection (And), fuzzy union (Or). Having the membership of each input to the relevant fuzzy sets and knowing the operators, it is now necessary to apply an implication method to find an output for each rule. An implication method gives out a final output for each rule. After this step, aggregation decides on how all the outputs from all the rules are being aggregated to give out one single fuzzy set. So it functions across the results of application of rules. As the last step of the fuzzy system aggregated outputs of the rules should be defuzzified into a single value. The most commonly used method is the Centroid where the centre of the resultant output fuzzy set curve is being calculated and presented as the output value. It is worthwhile to note that the definitions of membership functions, rules, implication and aggregation methods can be based on expert knowledge (as explained above) or data driven (section 5.2.3). Therefore depending on the existence of expert knowledge or real data on the subject a fuzzy model can be fitted to model the phenomenon under study. Figure 5-3 is a simple representation of a fuzzy model with two inputs, two rules and one output. The vertical upward arrows show finding the membership of each given input to the membership function defined in the model for each rule. The operators are defined to be “and”. The horizontal arrows show the implication implemented for each rule and the vertical downward arrow shows the aggregation of the rules to give the output fuzzy curve.

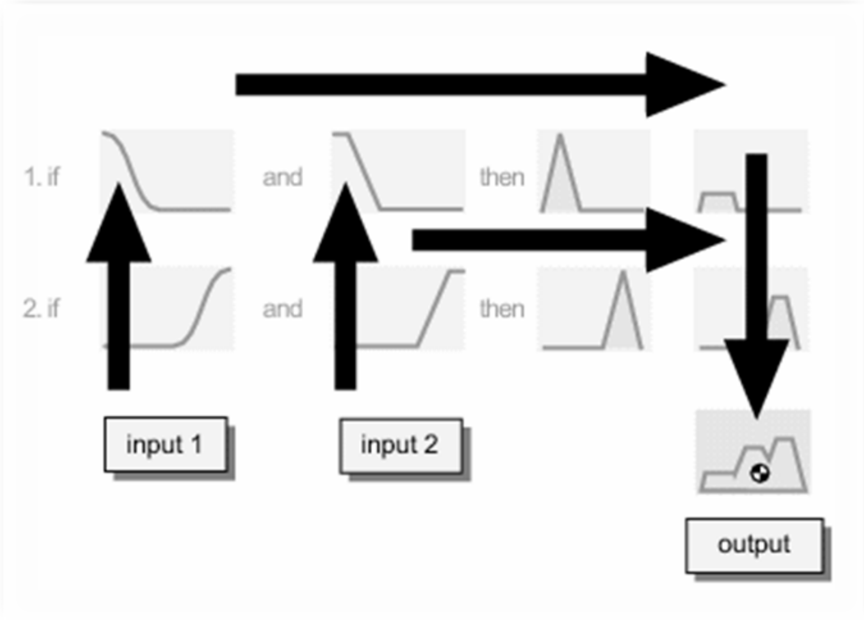


Figure 5-3 Fuzzy modelling with 2 input variables

This section was mainly discussed for two reasons. Firstly, because fuzzy modelling based on expert knowledge will be used in chapter 9 in this research. Second is that the foundations of fuzzy modelling needs to be explained because fuzzy inference technique is also to be used as a modelling alternative in this research. This technique is described in more details in the following section.

5.2.3 Adaptive Neuro Fuzzy Inference

In modelling complex phenomena such as assessment of one's impact or utilisation as we intend to do, the underlying relationship of the variables is not known. Therefore to capture the most representative model, various techniques could be tested. As explained in the previous sections, linear regression can be one of the best modelling techniques to use, If the relationship between the independent variables and the dependent variable are linear. However this underlying relationship is not known at the initial stages of the research. Therefore alternative modelling techniques which can capture a nonlinear relationship should also be considered. Adaptive Neuro Fuzzy Inference is one of the most acclaimed modelling techniques in recent years. It has been used to produce predictive or explanatory models in a variety of subjects. The method's winning points are its generalisability and its ability to overcome imprecision and to handle nonlinearity (Jain et al., 1996).

The method is first introduced by Jang (1993) as "Adaptive Network-based Fuzzy Inference System" and was developed and applied in a series of papers (Jang, 1994; Jang and Sun, 1995). It is based on the Sugeno type fuzzy systems (Sugeno, 1985) and a learning technique inspired from neural networks.

To understand the logic of this technique, consider a problem which has three inputs *(x,y,z)* ,each with two membership functions and one output with a Sugeno rule based as follows:

If x is A_1 and y is B_1 and z is C_1 then $f_1 = p_1x + q_1y + r_1z + s_1$

If x is A_2 and y is B_2 and z is C_2 then $f_2 = p_2x + q_2y + r_2z + s_2$

...

and

If x is A_n and y is B_n and z is C_n then $f_m = p_mx + q_my + r_mz + s_m$

n is the number of membership functions which in this example can be {1,2} and *m* is the rule number which in this example is 8. The structure of the adaptive neuro fuzzy inference system is presented in

Figure 5-4. The details of each layer are also described in this section.

Layer1: Each input has a membership value to each of the membership functions:

For example: $\mu_{A_x^i}(x)$ which is the membership of input x to the membership function A_n for the input x in the rule i.

Layer 2: Evaluating the rule premise using the product of the memberships which is equivalent to the intersection of the memberships (And):

$$w_i = \mu_{A_x^i}(x)\mu_{B_y^i}(y)\mu_{C_z^i}(z) \text{ , } i = 1,...,m$$

Layer 3: Calculating the ratio of the strength of each rule and finding the consequent result of each rule:

$$\overline{w}_i = \frac{w_i}{\sum_{i=1}^{m} w_i} \quad \text{and} \quad R_i = \overline{w}_i f_i \text{ , } i = 1,...,m$$

Layer 4: Aggregation of the rules' outputs

$$f(x,y,z) = \sum_{i=1}^{m} R_i$$

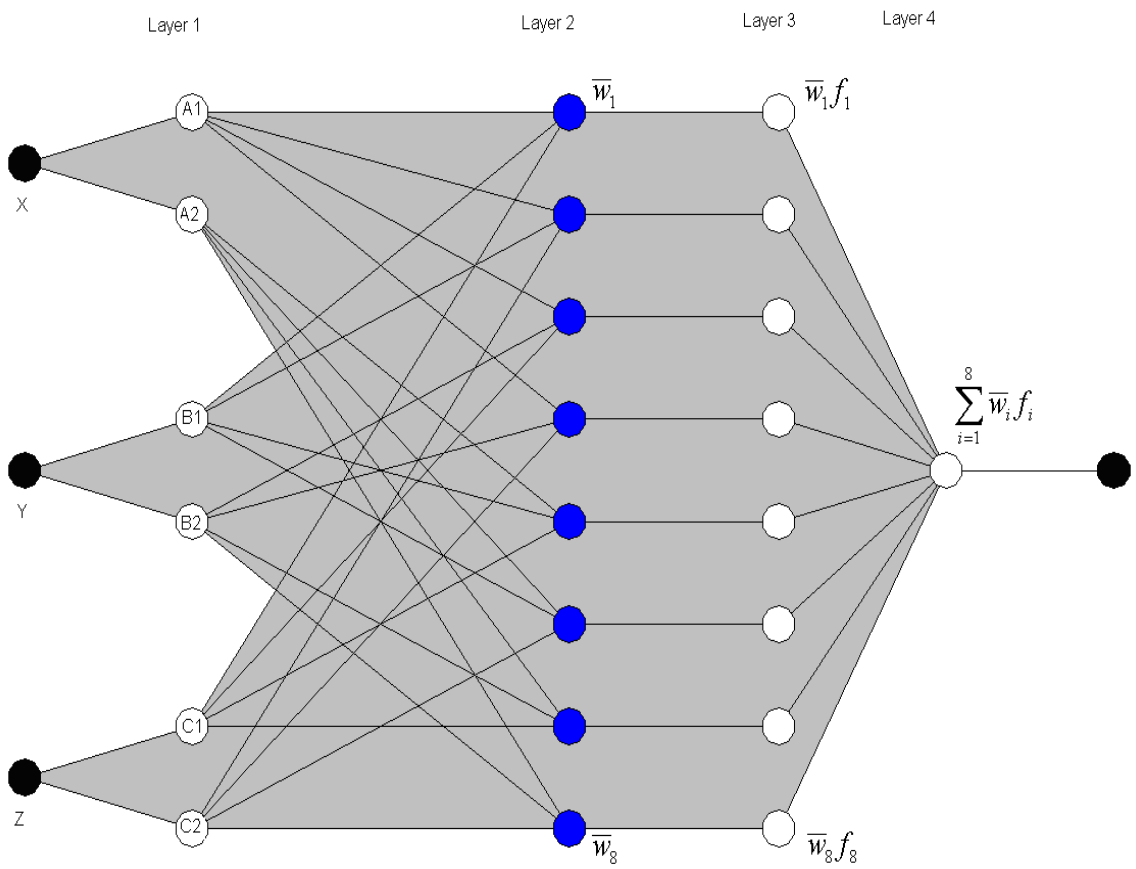


Figure 5-4 The structure of Adaptive Neuro Fuzzy Inference System (ANFIS)

This inference system was later renamed to Adaptive neuro fuzzy inference system (ANFIS). It uses gradient descent back-propagation neural networks to fine-tune the membership functions and least squared method for defining the output functions. MATLAB provides an interface for the ANFIS modelling. In this interface, inputs and outputs are fed to the software and using the above two techniques it fits the best model which can map inputs to the output. Number of membership functions, type of membership functions (Gaussian, Triangular…), type of outputs function (constant, linear) number of iterations to fine tune and some more option can be customised by the user (Mathworks, 2010).

5.3 Chapter conclusion

The chapter aimed to focus on the quantitative researches which have been done on the subjects studied in Chapter 2. This was done to identify the best possible modelling techniques which can be used in the current research.

The majority of the reviewed studies were trying to predict or assess conformance to specification, modelling people's well being or ranking the most suitable employee or contractor based on a set of criteria. Different types of data and aggregation methods have been used to relate the information obtained on those criteria to an outcome of choice. Different types of regression analyses, multiple criteria decision making tools, non linear modelling methods and other statistical methods have been used for the above purpose.

This chapter has concluded that multiple regression analysis and adaptive neuro fuzzy inference are suitable for the modelling purposes in this research. In modelling the case study in the research both approaches are going to be used to find the best model fitted to the data with the least error. Fuzzy logic has also been described in the section which is to be used in modelling the second case study in this research.

The next chapter focuses on the possible tools which can be used in a typical capability assessment practice. It also describes the design of the studies in this research.

Chapter 6
Study Design

This chapter explains the empirical data collection for the modelling purposes.

Firstly the design of the study is described and the frameworks of the main two surveys which have been done in this research are presented.

Secondly the details of the surveys used for examination of the concept are introduced. The first survey is aimed to build the main statistical model and formulations of this research. The second survey is a confirmatory model which uses expert knowledge in its model building. The main problem definition, settings, sources of information, data preparation and normalisation processes, scope and limitations of each survey are explained.

By the end of this chapter an example of capability assessment practice based on the provided theoretical background will be established. Conducting the surveys presented in this chapter would provide enough data to clarify a number of key issues on the conceptual and mathematical aspects of the model building.

6.1 The study design

Any research which uses observational or experimental data to test and validate a conceptual framework needs a clear statement of study purpose and design (Creswell, 2003). As stated before this research tries to model people's applied capability assessment using a set of criteria. The assessment would result in two different indices which to the author's belief could be used to describe one's applied capability. The conducted studies in this research are designed to contribute to the modelling and further clarify an optimum modelling choice which represents the outputs of the model most accurately. So the two studies in this research are designed for two distinctly separate purposes. The ethical approval has been gained for both surveys from “Brunel Research Ethics Committee” before conducting any data collection. A complete picture of the study design for this research is presented in Figure 6-1.

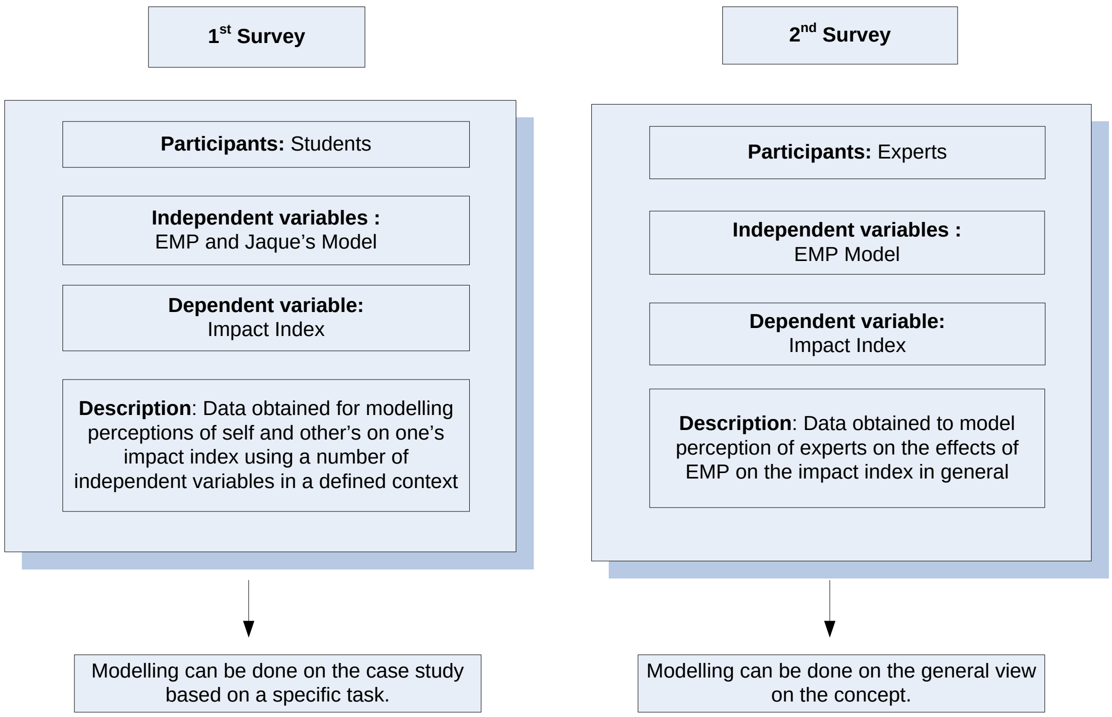


Figure 6-1 The study design

The first survey has been done primarily to obtain quantitative data from two groups of students at higher education level. The data are collected on the independent variables of the “EMP” and “Jaques” models and the tested dependent variable (Impact index). There are different scenarios that are included in the study to find the most representative model. Both conceptual models (EMP and Jaques) will be tested using different types of mathematical models in the future chapters to find the most robust model with the least error. So this will finally lead to a selected conceptual and mathematical model(s). The same combination of models, combination of variables and mathematical techniques are also to be tested using experimental (random) data which will extensively be discussed in chapter 8.

In the next part of the study (second survey) we collect the experts' views on the importance of each criterion in the EMP model and the effect of their interactions on the impact index. This has been done because many of the models on candidate selection procedures are based on expert knowledge. This study aims to specifically test the dynamics of the EMP model from their point of view. This data will also be modelled using different mathematical modelling techniques to find the best fit to the collected data from the expert knowledge viewpoint.

This study design is completed when the findings from the first survey, the experiment and the second survey are compared. This comparison would be the basis of the decisions about the validity and applicability of the results of the proposed models.

The details of the two surveys, together with the settings, data collection tools and their limitations are described in the following sections.

6.2 The First Survey

6.2.1 Settings and the sample

The first survey was conducted for the purpose of modelling the assessment of individuals' applied capability for a job. The survey intends to collect and process data based on the algorithm presented in chapter 4 which is based on job profiling, agent profiling, normalising the inputs and finally modelling the input to find indices. So data needs to be initially collected on the jobs and agents.

The survey was built around an assessment procedure for a hypothetical job. Although this job did not physically exist, it was selected because the pool of potential applicants for it was available.

Postgraduate engineering students who were reading “Engineering Management” or “Advanced Manufacturing Systems” for the degree of Master of Science took part in the survey. The sample consisted of 151 subjects and the study was conducted in two consecutive years (70 cases in the first year and 81 cases in the second year). Demographics of the sample are described in section 7.1 with more details.

This job was defined based on a module they take on as part of their course, “Simulation and System Modelling”. In order to complete this module, students are required to carry out one individual and one group assignment. The module outline and requirements of the assignments are attached in the appendix A. The outline of the module has helped in developing the main foci of the job, these are:

- Applying the theoretical concepts of system modelling to real world problems
- Good command of the System modelling software
- Conducting various software projects combining the theories and the applications
- Analysing ,interpreting and improving the results of the projects
- Conducting projects individually and in groups
- Writing executive reports on the projects based on the report requirements

In order to complete the assessment, the algorithm presented in chapter 4 should be done step by step. Therefore, the first step would be to do the job profiling and the next step is to profile the agents. The survey will then go through the normalisation process of the data which prepares the inputs which can be used in a number of modelling scenarios.

6.2.2 Job Definition

This process consists of defining the tasks within the job and listing the requirements of those tasks with respect to the enablers (the required skills and abilities to do the job), moderators (the required motivational aspects and personality characteristics to do the job) and performance (the required previous performance levels for this job). Since we aim to compare the "EMP" model with Jaques model, the requirements should also be stated in the form of required Complexity of information processes (CIP), skilled knowledge, values and identification of dysfunctional behaviours in the job.

6.2.2.1. Task Identification

Job can be broken down to its comprising tasks. In this survey the tasks are identified as:

Task 1: Use of Arena software

Task 2: Applying theories into practice

Task 3: Model and data analysis

Task 4: Report writing

Task 5: Conducting Individual and group work

The required resources for the above tasks with regards to enablers, moderators or performance together with a level of requirement should be assigned to each. This should be followed by identification of the environmental (organisational) requirements. As discussed in figure 3.2, the union of all these requirements form the job profile. The other question is where the information on the job profile is sourced from.

6.2.2.2. Defining the job and the tasks

The requirements and their levels for each of the tasks have been inquired from two experienced teaching assistant (TA) as experts in the job. Their experience as a teacher and as a previous student warrants their qualification to profile this job. Teaching assistants are giving the requirements and their perceived values in all the main categories for the job. In setting the level for each requirement, a set of rules are being adopted:

- The required level for each of the required resources is ranged between [0, 1].
- The experts should use the same gauge in assessing the requirement as it is to be used in the candidate assessment.
- Some requirements are assessed using established tests (e.g. English proficiency, Personality, CIP); in those cases the requirement would be set based on test scores.
- Some requirements are not assessed based on established tests (e.g. self assessment of some motivational factors), in those cases the guide in assessing the requirements should follow the scale provided in Figure 6-2.
- The above guide on the assessment should be clearly communicated with the agent and the expert (in this case the students and the teaching assistants). This is because people's individual judgements and interpretations in surveys could be different and should be minimised (Wellington et al., 2005).
- In case of having contradictory required resources for different tasks, considerations should be made to modify those requirements which are opposing in nature.

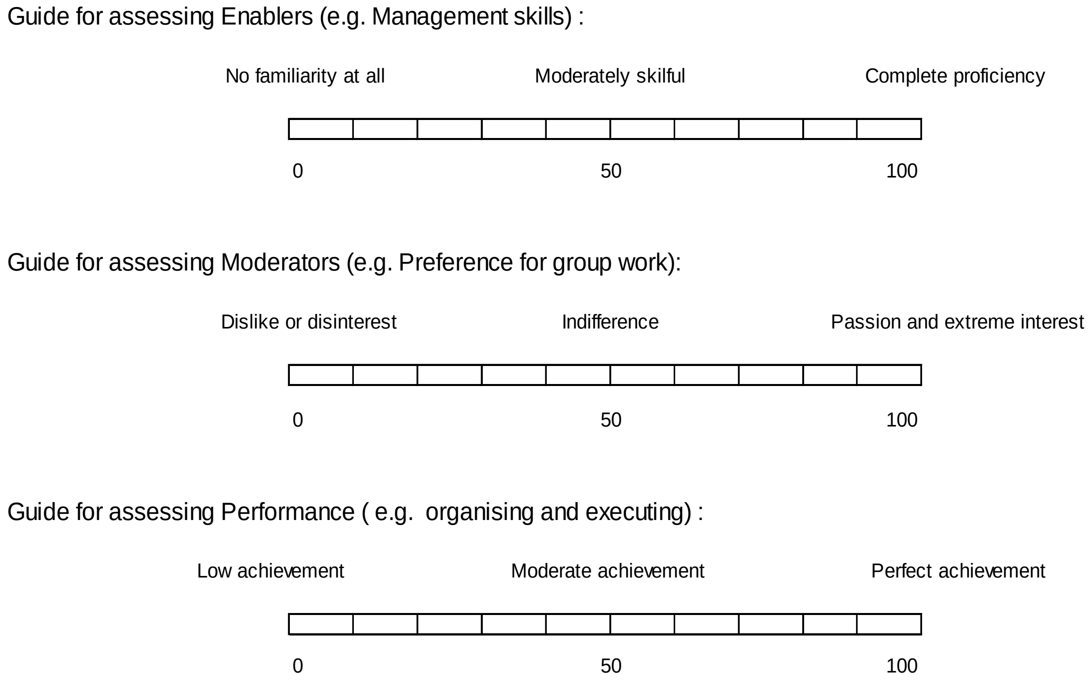


Figure 6-2 The guide for assessing the requirements

The organisational or environmental requirements of the task are also needed to be considered by the experts in defining the requirements and their levels. This is minimised in this research since the job was not physically placed within an organisational context.

The final job profile which is resulted from the union of all the requirements is formed. Figure 6-3 pictures all the requirements which are compatible with both conceptual models under study (EMP and Jaques Model). The requirements of the job are listed in the form of factors within each criterion with a value between [0, 1].

Enablers/ Skilled Knowledge

Code	Abilities and Skills	Required level	Source
E1	Team working ability	0.7	Self Assessment
E2	Management skills	0.6	
E3	Creativity skills	0.7	
E4	Communication skills	0.8	
E5	Maths and statistical abilities	0.8	
E6	Reading ability	0.8	IELTS or TOEFLTests
E7	Writing ability	0.8	
E8	Listening ability	0.8	
E9	Speaking ability	0.8	

Complexity of Information Processes

Code	CIP	Required level	Source
C1	CIP	3.25	Interview

Moderators / Values and Tempremental behaviour

Code	Values	Required level	Source
V1	Likes studying theories of conceptual issues	0.7	Self Assessment
V2	Likes studying theories of scientific issues	0.7	
V3	Likes strategic decision making	0.8	
V4	Likes data interpretation	0.8	
V5	Likes doing case studies	0.8	
V6	Likes problem solving	0.7	
V7	Likes studying management and leadership subjects	0.7	
V8	Likes working with a software	0.8	
V9	Likes simulating and modelling a real case study	0.8	
V10	Likes statistical analysis	0.8	
V11	Likes research	0.7	
V12	Likes innovation	0.8	
V13	Preference of assignment for assessment	0.8	
V14	Preference of Individual assessment	0.8	
V15	Preference of Group assessment	0.8	
V16	Preference of report writing	0.8	
V17	Values getting a good grade	0.8	
V18	Values developing connections and friendship	0.8	

Code	Personality (Temperaments)	Required level	Source
Pr1	Extroversion/Introversion	0.75	Myer-Briggs type Indicator Test
Pr2	Sensing/ Intuition	0.75	
Pr3	Thinking/ Feeling	0.77	
Pr4	Judging/ Perceiving	0.68	

Performance

Code	Record of Performance in	Required level	Source
P1	Interacting	0.8	Self Assessment
P2	Adapting and coping	0.8	
P3	Supporting and cooperating	0.8	
P4	Leading and deciding	0.8	
P5	Analysing and interpreting	0.7	
P6	Organising and Executing	0.7	
P7	Enterprising and Performing	0.7	

Code	Marks	Required level	Source
M1	Individual Mark	0.6	Manager Assessment
M2	Group Mark	0.6	

Figure 6-3 The list of requirements and their levels used in survey 1

More details of the requirements in Figure 6-3 and the way data is going to be collected from the candidates are described in the Section 6.2.3. However there are two basic points to be explained about Figure 6-3. Firstly CIP, is the only requirement which is not presented in [0, 1] range. The original CIP evaluations are in the range of [1, 9]. Since we are interested in the match of the individual to the requirements of the job (step 7 in the algorithm in Section 4.3) converting the scale to the [0, 1] scale would not have any effect on the processed inputs. Therefore the original scale of the CIP scores is used. Secondly the requirements set for the personality and the temperamental behaviours have been done using a simple algorithm which is described in details in Section 6.2.3.3.

The final step of the job profiling would be to assign weights for each of the factors within each of the criterion. As stated in the 5th step of the algorithm in Section 4.3 the experts should assign a weight to each of the resource requirements. This is done based on the criticality and frequency of use of that specific resource in the job (Levine, 1983). As stated in the algorithm the weights within each of the criterion (e.g. within the enabler domain) should add up to unity. This practice must be applied to each of the components of each model (EMP and Jaques) separately. Weights are not reported in this section to avoid multiple large tables.

The next section will focus on the agent profiling in the first survey.

6.2.3 Agent profiling

Having decided on the resource requirements of the job, a data collection strategy from the sample should be set out. This includes decisions about the tools and timelines in collecting the data with regard to the nature of the data and the acceptable variety of data collection methods. In fact the decision on the data collection tools and timelines and the decisions about the requirements of the job are made simultaneously. This is because the requirements of the job and the availabilities of the agents are to be examined using the same tools (step 6 of the algorithm in Section 4.3).

The data collection should be designed to obtain the most reliable data with regards to the available resources. Meanwhile it should respond to the following questions:

- What is the scale of measurement for the data in this survey?
- What would be the sources of the data? (Test based, self assessment, peer assessment or any other type of assessment)

The data collection tools vary based on the requirements of the research in terms of qualitative or quantitative data. Questionnaires, interviews, observations or personality tests can all be the means for measuring the types of data required in this research (Coolican, 2009) .As mentioned before the inputs and outputs to the models developed in this research are quantitative. This means that all the collected data using any of the above means should be scaled in order to be used in the algorithm presented in Chapter 4.

The following two sections describe the measurement of the data and the sources of information. This is followed by 6.2.3.3 which explains the data collection tools in more depth.

6.2.3.1. Measurement of data

In qualitative or quantitative research four types of measurements are used: Nominal, Ordinal, Interval or Ratio. Nominal and ordinal scales are normally used for data which belong to a category, a name or a ranking order. Interval and ratio scale gives a quantity for what they measure. Statisticians also divide numerical scales into dichotomous, discrete and continuous. Considering the nature of the data used in this research, the scale for the responses should be defined as discrete and interval. The way we asked the respondents to answer the questions is via a “thermometer scale” which is described in more details in Section 6.2.3.3. To read more about different types of scales and measurement Clark-Carter (2010) is recommended.

In this research the data is measured in the [0, 1] scale. In case of using questionnaires, respondent are asked to scale their response to the question in the continuum of [0, 1]. In case of using tests or interviews, the acquired data is also mapped in the [0, 1] interval. This is because the inputs of the model should go through a normalisation algorithm and could not be defined in a categorical format. Therefore using 5, 7 or 9 point scales such as Likert scales are contradictory with this requirement (Likert, 1932). Moreover, the outputs of the model are continuous ordinal measurements and can be any value in the [0, 1] space.

6.2.3.2. Data sources

The idea of multisource assessment is based on getting information from all the people who are familiar with the person in the aspects of job life. These people can be the person, managers, peers, subordinates, and in applicable cases customers. Self assessment proved to be a reliable tool however over rating and under rating can always happen in them (Yammarino and Atwater, 1993; Furnham and Stringfield, 1998). Peer ratings are also used as reliable assessment source of information. However the most contentious source of information is the subordinates which can become unreliable especially in cases where anonymity is endangered. Supervisors or managers ratings can also be used; however it is important to ensure that supervisor's ratings are diligent and fair (Phillips and Gully, 2009). In academia for instance, the marks given by lecturers, peers and student's self marking are shown to be very similar; although self assessments can be biased towards higher marks (Johnston and Miles, 2004). However in the same subject, Harvey (2002) believes that if students realise that their self assessment results are not threatening for them in any way then these would be a better reflection of the reality than other forms of assessment.

Therefore it seems essential to use a variety of sources in order to get a more robust picture of the required information. In the current survey, a combination of self assessment, peer assessment, manager assessment and self-administrated tests are used. Moreover there are other considerations in this survey which potentially enhanced the quality of the information obtained from all sources. These are:

- Participation in the study was completely voluntary.
- Participant's responses were not impairing their benefit in any form.
- Self, peer and manager assessment results are not communicated with none of the assessors (participants, peers and tutors).

6.2.3.3. Data Collection tools

This section gives some explanation on how each requirement within each of the main categories (enablers, moderators and performance) are measured. These range from one's abilities, skills, complexity of information processes, motivations and values, personality, previous performance and temperamental behaviour. Table 6-1 is a summary of the data collection methods and sources of the data for each of the criteria which have been assessed in each person for this job.

Table 6-1 Data collection methods and sources of data for each input

Criteria		Data collection method	Source
Enablers	English language skills	IELTS or TOEFL test result	Self Report
	General skills related to the job	Questionnaire	Self Assessment
Moderators	Personality	MBTI	Self Administrated Test
	Values	Questionnaire	Self Assessment
Performance	Task and contextual performance	Questionnaire	Self Assessment
	Marks	Reports	Manager assessment
CIP	CIP Level	CIP Interview	Manager assessment
Skilled Knowledge	English language skills	IELTS or TOEFL test result	Self report
	General skills related to each task	Questionnaire	Self assessment
Values	Values	Questionnaire	Self assessment
Temperamental behaviour	Personality	MBTI	Self Administrated Test

This table demonstrates the wide range of tools and sources used for collecting each data point in the first survey. The data collection methods displayed in Table 6-1 are to be explained in the following sections.

a) The Questionnaires

Questionnaires are one of the most established data collection methods which are used in a variety of research. Questionnaires can ask for the information via open ended or close ended questions. Use of abstract, difficult to understand or sensitive wordings will impair the validity of the results (Bailey, 1987). As stated before a [0, 1] continuum is used for the responses in this research. In order to define the scale more clearly; the concept of semantic differential scale is used in guiding the designers and respondents of the questions (Osgood et al., 1957). This format of response is also called the “thermometer scale” (Bailey, 1987). In this method the response to each question should be placed in a scale between a bipolar pair of two extreme answers. This scale is claimed to perform well in terms of concurrent validity (Coolican, 2009). Although in the original design of semantic differential scores, 7 points exist between the two poles; in “thermometer” scaling any scale can be used. In fact, Bailey (1987) believes that very few categories (e.g. 3 points) will limit respondents’ diversity of choices and too much categories (e.g. 20 points) will confuse the respondents. In this research, self administrated questionnaires have been used to assess some of skills, abilities, values and some aspects of performance of the agents. The skills, abilities, values and performance indicators which were assessed were based on the job profile which has been prepared by the experts. For the performance, the “great eight competencies” list has been used as the basis of choosing the required performance indicators. The original list of the “great eight competencies” as presented by Kurz et al. (2004), is provided in the appendix B. Once more It should be mentioned here that previous experience and previous performance are to be distinguished. Experience is normally measured using years or subjects of previous jobs.

However, great eight competencies inquire about all the aspects of individual’s previous performance.

b) The CIP Interviews

In order to incorporate Jaques model in to this study, interviews with the participants were designed to capture their complexity of information processes (CIP). As described in Chapter 2, there are four types of mental processes and four types of information complexities. A specific mental process occurring within a specific level of information complexity is described as a category of complexity of information processes. Although theoretically, each of the orders can happen in each of the types (16 situations), practically only seven situations are expected to be happening. A more complete explanation of the fundamentals of the concept was given in Section 2.1.4.

Complexity of information processes is assessed using especially designed “CIP Interview”. The settings of the interviews were instructed by a practitioner in the field, Mrs Christine Baker from Requisite Development Ltd. Interviews are done by asking respondents to elaborate their views on 2 different topics; one chosen by themselves with their own interest and the other by the interviewer. The list of the topics is attached in appendix C. They were required to talk about each topic for a minimum of five minutes and their voice was recorded for later analysis of their reasoning style. The interviews were transcribed and sent to Mrs Baker and CIP levels for each person are extracted. Their mental processes in answering the questions and the complexity of the information they use in their responses show their CIP level. CIP levels can be in the range of [1, 9]. It is also important to note here that the required CIP level for the job which was set in the previous section has been consulted with Mrs Baker. This level was set based on the complexity of the job and the longest time it takes to finalise the tasks. Participants’ extracted CIP levels are to be used in quantification of Jaques model in this research.

c) The Marks and Grades

One of the indications of student's performance comes from the grades they obtain from the assessments on their modules. In fact in many cases students' marks are used as a predictor of their future performance. Examinations, reports and presentations are all types of assessment which are normally marked based on fulfilment of some criteria in a module.

In the current study, the module assessment was based on the reports and the software models which students submitted on two projects (individual and group project). Each report and model was marked based on a set of detailed criteria and the marks were given for each person's individual and group project separately. It is believed that in addition to student's self assessment on task and contextual performances which have been discussed before, students' marks which represent manager assessment on some aspects of their performance is also important. That is why students' marks were included as an indicator of previous performance for students.

d) Personality test

Personality traits have been identified as one of the factors which should be considered in assessing one's applied capability in a job. In other words, they can act as a resource that someone may need in conducting a job. As stated in previous chapters, setting personality requirements of a job or an environment is widely used (Hogan et al., 1998; Raymark et al., 1997; Rolland and Mogenet, 1994). This is why it was included in the applied capability assessment approach.

Over years, different qualitative and quantitative approaches have been developed to examine personality traits. All the approaches aim to extract a number of personality variables and to assign people to those variables using a testing system. A number of these assessments are listed in Section 3.2.The analyses on pros and cons of different types of personality tests are out of the scope of this research. However two of the most commonly used personality tests, Myers-Briggs Type Indicator (MBTI) and Big Five Personality traits are explained.

MBTI is applied using a variety of self administrated tests which should be interpreted and conducted by the practitioners in the field (Jung, 1971; Myers and Briggs, 1926). The test attributes the respondents to one of the 16 different personality types. These types are extracted from the four dimensions of the personality in MBTI each of which has two extremes (example: Introversion, extroversion). Using a self administrated test, a number of questions with two possible answers are asked from the respondent. Based on the responses to the questions, the preference in each of the dimensions together with a preference score is extracted for each person.

Big five personality traits or NEO personality inventory has also a number of different versions of tests (Costa and Mccrae, 1976; Costa and Mccrae, 1985). A number of questions on five personality traits, each with six facets should be answered by respondent on a five point scale. An individual level for the respondent on each of the five main domains and 30 sub-domains are given.

Although both tests are being used widely, for the purpose of this research the MBTI has been chosen as the preferred personality test. This is mainly due to a more manageable number of traits and types it produces. Moreover the test has been conducted for the past 90 years and has a well established validity among practitioners. Test questionnaires and answer sheets have been purchased from the OPP institute, due to copyright issues the questions and answer sheets are not reprinted in this thesis.

How does MBTI work? MBTI is designed around 4 dimensions of personality each with 2 directions (traits). A detailed description of the meaning of each trait is provided in appendix D.

Extroversion (E)	$\longleftrightarrow$	Introversion (I)
Intuition (N)	$\longleftrightarrow$	Sensing (S)
Thinking (T)	$\longleftrightarrow$	Feeling (F)
Judging (J)	$\longleftrightarrow$	Perceiving (P)

(Jung, 1971; Myers and Briggs, 1926)

The type indicator used in this research was done using on a paper based test. The question booklets and self-scorable answer sheets were ordered from the OPP institute by Mrs Christine Baker, a practitioner in the field. In the question booklet, there are 88 questions each with 2 possible choices of answers for the respondent to choose from. Respondent's answer to each question will contribute a score to a specific trait preference for that person. The score each answer contributes could be 0, 1 or 2 depending on the question and the importance of its answer. Once the tests are completed, the preference of each individual to a specific trait in each of the dimension together with a preference score is calculated. There are 16 different types of personality which are shown by the preferred trait in each dimension and the preference scores (e.g. INTJ: 15, 15, 43, and 11).

The test scoring is structured such that the maximum scores in each of 16 different traits are different from one another as seen in table 6.2. Since this research is built around continuous scales, we need to make a quantitative sense for the preferred trait, its required level and each candidate's trait score.

Therefore, there is a need to interpret each personality dimension score into a one directional scale. For example for the Extroversion/Introversion dimension we get one scale which ranges from “0” to “67+67” (summation of the maximums of two directions). This means that a complete introvert will get a score of 0 and a complete extrovert will get a score of 134. This has allowed us to follow an algorithm to find test scores for each personality dimension in a one directional way. The algorithm which is provided below is the one used for assigning the required levels for personality traits. However its logic will also be used to prepare the preference scores of the individuals to go to the algorithm presented in Chapter 4.

Table 6-2 Maximum scores in each of the traits in MBTI

Trait	Maximum score
E	67
I	67
N	53
S	55
T	65
F	39
J	55
P	63

For assigning the personality requirements of the job profile and finding each agent’s personality score for the agent profile:

1. In each dimension, Get the maximum score for each trait.
2. In that dimension:
   a. Name one end “M” and the other end “N”.
   b. Assume that “M” is the final preferred trait to have for the job.

c. The required level of the trait (the preferred trait)is the midpoint of the trait in that dimension :

$$\text{Required level of trait } X_j = N_{max} + \tfrac{1}{2} M_{max}$$

d. Candidate's score in each dimension is :

$$A_j = \begin{cases} N_{Max} + Candidate's\ score & , where\ candidate's\ preferred\ trait\ was\ M \\ N_{Max} - Candidate's\ score & , where\ candidate's\ preferred\ trait\ was\ N \end{cases}$$

3. Now the required level and the available levels are set to be used in the algorithm in chapter 4 (Note that the scores are also normalised to be out of 1).

Example: As for the requirements of the tasks in our hypothetical job it is expected that the preferred personality type to conduct the job would be ESTJ. This is due to the characteristics of the job as a whole. According to previous research, engineers proved to have an ISTJ personality type predominantly and act best in this personality (Macdaid et al., 1986; Hill and Somers, 2008; Waner and Echternacht1993 from Johnson and Singh, 1998). The job we are defining is engineering and management based job which should be performed individually and in a group. Therefore it seems essential for people to have a more extroverted personality. That is why the preferred personality type for this position would be an ESTJ. As seen in the algorithm for each preferred trait the midpoint score of that trait is set as the required score. This is because the midpoints represent the score which shows that the person belongs to that trait while not representing extreme behaviour in that trait. The calculation of the required levels following the algorithm above would be:

Required level of E = I_{max}+1/2 E_{max}= 100.5

S = N_{max}+1/2S_{max}= 80.5

T= F_{max}+1/2T_{max}= 71.5

$$J = P_{max} + 1/2 J_{max} = 90.5$$

The above levels can then be transformed into a percentage along each dimension:

$$\text{Required percentage of E} = \frac{\text{Required level of E}}{I_{max} + E_{max}} = 100.5 / 134 = 0.75$$

The same rule applied to the other three traits and their required levels are:

S = *0.75,* T= *0.68 and* J = *0.77.*

For the agent, let’s assume that his/her personality type according to the responses to the test is INTJ (37, 9, 41, and 13). In order to interpret that into the one directional dimension (following step 2d), his scores will become:

Score in the EI dimension =67-37=30

Score in the SN dimension =55-9=46

Score in the TF dimension =39+41=80

Score in the PJ dimension =63+13=76

To get the percentage of each dimension, the above scores are divided by the sum of the maximums in each dimension:

Percentage score in the EI dimension =30/134=0.22

Percentage score in the SN dimension =46/108=0.42

Percentage score in the TF dimension =80/104=0.77

Percentage score in the PJ dimension =76/118=0.64

Now these figures can be compared with the required levels following the step 7 of the algorithm presented in Section 4.3. Please note that the part in which the scores turned into percentage has only been done to make the scores clearer and comparable.

The above explanations were necessary to understand the use of personality test scores in this research. Temperamental behaviour is another criterion which is used in Jaques model and is defined by personality traits. This is described in more details below.

e) The Temperamental behaviours

Temperamental behaviours are measured using the personality test questionnaire. Extreme behaviours in any personality dimension may represent temperamental behaviours, as advised by a practitioner in the field. Therefore, respondents were identified as having a temper in case they have a high level of preference (more than 75%) towards any of the personality traits. A person can have from one to all four personality dimensions in extremes or can be completely un-temperamental. Since temperamental behaviours are not actually part of the requirements and owning them by an agent is undesirable, this factor is called "not being temperamental" in the job resource requirement list and in job profiling. So, if "not being temperamental" is the j^{th} requirement for the job, the person A's availability is:

$$Aj = \begin{cases} 1 & z = 0 \\ 0.75 & z = 1 \\ 0.5 & z = 2 \\ 0.25 & z = 3 \\ 0 & z = 4 \end{cases}$$

Where $z \in \{0,1,2,3,4\}$ is the number of dimensions in which the person has tempers in. Apparently the requirement for this job would be not to have temperamental behaviour in any of the dimensions ($X_j=1$). The rest of the algorithm would be conducted the same.

For instance, a person with no temperament will get $A'_{ij} = \frac{\min(1,1)}{1} = 1$ and the one with temperamental behaviour in 3 dimensions will get an $A'_{ij} = \frac{\min(0.25,1)}{1} = 0.25$.

Personality test scores and temperamental behaviours were the only scores which go under a specific pre-processing as explained above, for them to be usable in the main algorithm in Section 4.3. The other data from the agents and the job requirements which were collected by the questionnaires, CIP interviews or marks do not need pre processing logic and go directly to the main algorithm in Section 4.3.

6.2.4 The data collection process; timelines and limitations

The information which was collected from the participating students and the expert are collected in the following order:

1. The data about the job, its constituent tasks, requirement of the tasks, their levels and their weights are acquired from the experts before the start of the module. This activity took 2 weeks to be completed.

2. The data on enablers / skilled knowledge (abilities and skills), values of participating students are obtained in the 3rd week of their course commencement using one questionnaire (see appendix E). This activity took 1 day to be completed in each group.

3. Personality and CIP levels of the participating students are assessed from the 4th week of the course using Myers-Briggs type indicators and interviews. This activity took 6 weeks to be completed.

4. The performance indicators of students are assessed with their final submission of the projects (17th week from the start) using one questionnaire (see appendix F). This activity took 2 weeks to be completed.

5. Marks are based on detailed module feedbacks by module leader and are collected after the course completion (17th week from the start).This data needs 3 weeks to be ready and passed on to the researcher.

6. The perceptions on the impact and utilisation values for each person are obtained at the end of the module from the person and the module tutor. This activity took 2 weeks to be completed.

Overall, data collection for the job profiling and agent profiling in one year have respectively required 2 weeks and 20 weeks to be completed. Agent profiling have been repeated for the second year to obtain a bigger group.

There are a number of factors to be considered in the sample selection and data collection in this survey:

1. Due to the nature of the study, an extensive amount of data was needed for each individual.

2. The data collection should be done in different stages and cannot be done in one step.

3. The project did not offer monetary reward to the participants.

4. The tests which could be used for the data collection were limited to the less costly ones.

5. The study could only be done in a setting where the job and its requirements are known and accessible for the researcher. Moreover a pool of possible candidate for the job was also needed to give enough data for modelling.

The above consideration has led the researcher to collect data from the student sample using the tools described in section 6.2.3.3. The key assumption is that the data will be sufficient to find the most representative model for students' applied capability assessment. Further steps for the modelling will be discussed in Chapter 8. The consent forms and questionnaires are provided in appendices E and F.

6.3 The second survey

6.3.1 Settings and the sample

The second survey is designed to extract expert views on the dynamics and importance of each of the three criteria in the EMP model on the perceived impact index. This means that regardless of the context of the job, the dynamics of the three criteria in EMP model and the impact index is to be modelled. This is mainly done to find a benchmark for the model which will be derived from the first survey. The sample for this survey is 41 lecturers and teaching assistants working in the School of Engineering and Design and Business School in Brunel University. More details of the sample characteristics will be given in Section 7.2. This sample was selected because:

1. They were from variety of academic backgrounds such as Enterprise engineering, System engineering, Organisational behaviour, Human resource

management and business modelling. Therefore they could identify with the subject of the study.

2. They are in contact with several students, companies and professional bodies which give them a good position to advise on the dynamics of the EMP model and the impact.

3. They were accessible for interviews and their close location helped in saving time and getting more respondents.

The sample is representative of the population of experts who can potentially be positioned as employers and decision makers in an appraisal or assessment process. Although they are physically based in an academic environment, their consulting and business activities, disciplines, age, gender, and ethnic backgrounds are diverse. This is helpful in generalising the results with a reasonable level of accuracy

6.3.2 The questionnaire design

An instrument used for the data collection of this survey was a questionnaire which was completed by the respondents in the presence of the researcher. This was done to ensure that the respondents are fully aware of the purpose of the research and understand the questions. The questionnaire design was based on the fuzzy logic rule based as it was decided that fuzzy inference system could be a suitable method to model the dynamics of the independent and dependent variables.

In the EMP model there are three major categories within which agent’s resources for a job can be placed (enablers, moderators and performance). The person can have different levels of match with each of the requirements of the given job. This is referring back to the step 7 of the algorithm in Section 4.2 (the A' values). The questionnaire seeks to study how the different levels of match in the three criteria can affect the overall impact of the people according to an expert viewpoint. Referring to the fuzzy rule based systems; it was decided to set three levels of match (Low, Medium, and High) for each of the three categories. Using these three ordered levels is a common approach in behavioural studies. The combination of the three variables each with three levels of match produces 27 different scenarios to be tested. Although the primary aim of this survey is to find the level of impact in all the 27 scenarios, the length and level of complication of the questionnaire would impair the quality of responses if all the 27 scenarios are asked. Newell et al. (2004) confirmed that one of the major reasons of low response rate to surveys is their length. In a study done by Moghaddam and Mousavi (2009), it is shown that people are more likely to respond more effectively to the questionnaires which take less than 10 minutes. Expectedly, 27 questions with small differences in their context can confuse the respondent. Therefore a compromise should be made between the comprehensiveness of the questionnaire and the quality of the responses. The decision was made to use a shorter form of the original 27 scenarios. A simple algorithm has also been developed to extract the answer to all the combinations (27 scenarios) from a fewer number of questions (10 scenarios). The validity of the conversion algorithm will be studied in chapter 8. The questionnaire used for this survey is attached in the appendix G. In the questionnaire respondents are asked to fill in a10 row table which corresponds to 10 different scenarios. They were asked to give their perceived level of person's impact in each scenario. They have also asked for their views on the weight of each criterion in the decision making. The following section describes the logic for using 10 scenarios instead of 27 and the algorithm to translate the 10 scenarios into the 27 scenarios.

6.3.3 Data preparation for the second survey

The three categories of resources (E, M and P) each with three different possible levels of match result in 27 scenarios. Figure 6.4 presents the 27 scenario and the simplified version which contains 10 scenarios. The 27 scenarios start from the scenario where the person's level of match with the three variables (E, M and P) is low and ends with the scenario in which the person has a high level of match in all the three variables. As seen in the figure the left table is lengthy and it may confuse the respondent in distinguishing between the scenarios. It seems to be reasonable to shorten the questionnaire provided this shortening does not impair the result. The mapping of the 27 scenarios into 10 scenarios is presented in Figure 6-4. In the shorter version, the respondents are only given the number of criteria which has that specific level of match. For example, consider the scenarios 2,3 and 4 in the left table. In all these cases the person has low level of match in two of the three criteria and a medium level of match with the third one. This has been translated to the scenario 2 in the right table. The numbers below the level of match columns in the right table in Figure 6-4 indicate the number of criteria which has that level of match.

Therefore the 27 scenarios are shortened into 10 categories of scenarios as displayed in Table 6-3.

	Level of Match		
Scenario	Low	Medium	High
1	E,M,P		
2	E,M	P	
3	E,P	M	
4	M,P	E	
5	E,M		P
6	E,P		M
7	M,P		E
8	P	E,M	
9	M	E,P	
10	E	M,P	
11	E	M	P
12	E	P	M
13	M	E	P
14	M	P	E
15	P	E	M
16	P	M	E
17	P		E,M
18	M		E,P
19	E		M,P
20		E,M,P	
21		E,M	P
22		E,P	M
23		M,P	E
24		P	E,M
25		M	E,P
26		E	M,P
27			E,M,P

	Level of Match		
Scenario	Low	Medium	High
1	3	0	0
2	2	1	0
3	2	0	1
4	1	2	0
5	1	1	1
6	1	0	2
7	0	3	0
8	0	2	1
9	0	1	2
10	0	0	3

Figure 6-4 The derivation of 10 scenarios from 27 scenarios

Table 6-3 Summary of the 10 scenarios

Categories (f)	Scenarios (*j*)
1	1
2	2,3,4
3	5,6,7
4	8,9,10
5	11,12,13,14,15,16
6	17,18,19
7	20
8	21,22,23
9	24,25,26
10	27

However, the shorter version at this stage ignores the fact that which criteria has which level of match and this may be important for the respondent in answering the questions. That is why an additional section has been added to the questionnaire in which the respondents are asked to give a weight (importance level) to each of the three criteria. Application of the given weights to the shorter version of the questionnaire will help in finding their possible answers to the full 27 scenarios. The logic used in conversion is as follows:

For

i= {1, 2, 3} where i shows the Criterion number

j= {1, 2… 27} where j shows the scenario number

f= {1, 2…10} where f shows the category to which the scenario belong to

$$C_j = \frac{C_f \cdot \sum_{i=1}^{3} F_{ij} \cdot w_i}{\frac{1}{3}\sum_{i=1}^{3} F_{ij}}$$

Where C_j is the calculated impact level for the j^{th} scenario, C_f is the given impact level for the f^{th} category, F_{ij} is the correspondent value of the i^{th} criterion's match level in the j^{th} scenario; w_i is the given weight of the i^{th} criterion. The response to each question in this survey were in the [0, 1] range. F_{ij} is needed to be calculated which requires interpretation of Low, Medium or High levels of match into quantitative values. In a continuum of [0, 1] the cut points for the concept of low, medium and high normally are:

$$\begin{array}{ll} \textit{Low} & 0 \le X \prec 0.33 \\ \textit{Medium} & 0.33 \le X \le 0.66 \\ \textit{High} & 0.66 \prec X \le 1 \end{array}$$

This means that for instance any X value between 0-0.33 is categorised as being low. Therefore the nominal values of F_i are set to be 0.165, 0.5 and 0.833 for Low, Medium and High match which are the midpoints of each.

The used logic made it possible to use a smaller questionnaire and yet to gain all the data needed for depicting the dynamics of the three criteria and the impact index. In chapter 8 the error of using this logic and its significance are calculated.

The data on the 27 scenarios can be calculated using the above logic and can be used for modelling the expert views on the relationships of the three criteria (E, M and P) with the perceived impact index. The modelling is to be done using Average Weight estimation, fuzzy inference and an ordinary least squared regression in Chapter 9.

6.3.4 Scope and limitations of the second survey

This survey aims to collect data in order to find the effect of different levels of match between the job and the agent on the impact as perceived by the experts. The survey was done in a generic format without focusing on a specific job. This survey could also be done to test the same concept using Jaques conceptual model. However this survey was designed in a later stage of the research by which time Jaques model has already been proved to be not usable in this type of assessment (chapter 8).

In studying the results of this survey several points should be considered regarding the sample and the setting. These are:

1. The sample of respondents were selected from people who have experience in dealing with different people and involved in assessing them. Even so, the

results from this survey may have limitations in application to all the jobs and all candidates since the respondents were mainly academics.

2. The survey was designed to be generic and without any reference to any particular job.

3. As mentioned before, in design of the survey a compromise has been made which made the questionnaire simpler. This could slightly impair the results of the study.

6.4 Chapter conclusion

In this chapter the foundation of the data collection and preparation for this study has been developed. The designs of each survey, its scope and limitations have been described. The tools and methods used in data collection or data preparation have also been discussed. The chapter has provided a complete view of the conducted studies and the data extracted from each study.

The chapter has provided a real case for modelling the applied capability assessment and clarifies the exact steps to be taken in order to get to the modelling stage.

The data obtained from these studies should now be tested and descriptive statistics on their characteristics should be checked. Therefore the next chapter will provide some initial analyses on the data before they can be used for the mathematical modelling.

Chapter 7
Sample characteristics, Data validity and reliability analyses

Any research which adopts empirical studies should go through a process of data validity and reliability analyses. The data collected from the participants of this research will be tested to determine the reliability of the data collection tools, validity of the collected data and the logics used in transforming them for modelling purposes.

In the first part of the chapter some basic information on the demographics of the first sample are presented. In this chapter, inter rater reliability analyses and questionnaire validity tests are conducted. Some basic descriptive information on the transformed data which are to be used for the modelling are also presented.

In the second part of the chapter sample characteristics for the second survey are presented. In this section a questionnaire validity test is conducted which examines the validity of the logic used in converting the results of the short questionnaire into the final results usable for modelling.

By the end of this chapter it is expected that fundamental information and statistics on the validity of the data produced by the surveys are presented.

7.1 Basic Analyses on survey one

7.1.1 Sample basic descriptive data

The sample for the first survey targeted from two groups of students in a post graduate degree course. The two groups were studying the course in two consecutive years (2008-2009). The total number of students attending the course was 151. Table 7-1 shows some basic demographic information on the sample in both years. The majority of the sample was male students. The minimum age was 21 and the maximum was 38 with a mean of 26 years of age. They were from a variety of ethnic backgrounds, most of whom from Asian countries.

Table 7-1 Basic demographic information on the sample for the 1st 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*
Group1	19	48	3	26.0	17	24	24	10	7	4	1
Group2	16	64	1	25.2	17	17	32	10	13	7	2
Total	35	112	4	25.6	17	41	56	20	20	11	3

61% of the students in the two groups took part in all parts of the data collection process. This is expected considering the voluntary nature of participation and also the length of data collection. Therefore, there are only 91 cases for whom all the required information for the modelling purposes in this research are available. Table 7-2 shows the study participation in the sample. The students who partially attended the study (36%) are those who did not attend the interview session for CIP identification and the personality test assessment. Those who did not attend in any part of the study were 3% of the total number of students.

Table 7-2 Participation in survey one

	Participants in survey one
	Count
Not attended in any part	5
Attended in some parts	55
Attended in all parts	91

In this study the modelling and statistical analysis were conducted on the participants for whom all the necessary data were available. This means that participants with missing data points were excluded from the modelling. The characteristics of the final sample which was used in the research are presented in Table 7-3. It provides basic demographic information on the 91 students who have participated in all the parts of the data collection.

Table 7-3 Basic demographic information for the participants in 1st survey

	Gender				Age		Ethnic Background											
							Asian, Far east		Asian, Middle east		Asian, Indian		European		African		South American	
	F	%	M	%	Mean	Range	Count	%	Count	%	Count	%	Count	%	Count	%	Count	%
Group 1	11	36.7%	19	63.3%	27	17	12	40.0%	7	23.3%	3	10.0%	4	13.3%	3	10.0%	1	3.3%
Group2	11	18.0%	50	82.0%	26	17	8	12.9%	28	45.9%	6	9.7%	10	16.1%	7	11.3%	2	3.2%
Total	22	24.2%	69	75.8%	26	17	20	22.7%	35	38.5%	9	10.0%	14	15.0%	10	11.0%	3	3.3%

Now that the sample is known, some basic analyses are to be done on the validity of the collected data and the instruments used in collecting them.

7.1.2 Questionnaire validity tests

Questionnaires, interviews and tests were used to collect the complete data set in the first survey in the research. Some of the main variables which are introduced in this research (e.g. enablers) are calculated from the answers which each respondent has given to a number of questions. Therefore, to be able to do further analysis on the collected data, It is important to test whether those questions were all correspond to the one variable which they were designed to measure. In other words the section aims at finding the internal consistency of questionnaires which ensures that the specified number of items are actually measuring the same variable (Salkind, 2008). Therefore the questionnaires are to be tested in terms of three main variables which they were designed to extract. These are:

- Skills and abilities: these are extracted in the first questionnaire and are forming the **Enablers** in the “EMP model” and also the Skilled Knowledge in “Jaques Model”.

- Values: these are collected in the first questionnaire and are forming a part of the **Moderators** in the “EMP model” and are also equivalent to the Values in “Jaques Model”.

- Self performance: these are asked in the final questionnaire and are forming a part of the **Performance** variable in the “EMP model”.

It is important to note that the rest of the data collected and used in the modelling were not obtained in the form of questionnaires. These include the personality type which are forming the other part of Moderators in “EMP Model” (assessed by MBTI test), CIP level in “Jaques Model” (assessed by interview) and Grades which are forming the other part of Performance in “EMP Model” (assessed with a marking scheme).

There are a number of methods which provide a measure of internal consistency of a construct such as split-half or Cronbach’s Alpha (Field, 2009). In this research we are using Cronbach’s α which was introduced by Cronbach in 1951 and is one of the most widely used measures of internal consistency for scales (Cronbach, 1951; Nunnally and Bernstein, 1994). The statistic is calculated using this formula:

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

Where N is the number if items measuring one construct (or variable), $\bar{c}$ is the average of covariance between the items in that construct and v is the average of variance within the items.

Reliability for the questionnaire which enquires one’s skills and abilities is high, Cronbach α = 0.78. These are 9 questions, answers to which make up the enabler. For several items to produce one scale the minimum accepted level of Cronbach α is about .7 (Nunnally and Bernstein, 1994). Therefore the level of Cronbach α for the first variable is acceptable. This means that these 9 questions are all measuring the same thing (i.e. enablers). Table 7.4 gives the value of the Cronbach’s α for the variable if any of the questions are deleted. Description for each item can be viewed in details in figure 6.3 using their codes (e.g. E5= Maths and Statistical ability).

It can be seen that except E5, deletion of any item will result in a lower Cronbach α. The first column of the Table 7-4 gives the correlation between any one items and the rest of the items within the variable. These correlations should not be negative or close to 0 and correlations around 0.2 and higher are acceptable (Everitt, 2002). These values are all in acceptable range in Table

7-4. It should also be decided whether to keep or to discard E5 from the measures. Since the correlation measure is acceptable and the difference in the Cronbach α if item deleted is not considerable the item remains for measuring enablers.

Table 7-4 Correlations of the items and Cronbach α if item deleted for Enablers

Item total statistics

	Corrected Item-Total Correlation	*Cronbach's Alpha if Item Deleted*
E1	0.535	0.755
E2	0.446	0.767
E3	0.383	0.781
E4	0.615	0.742
E5	0.325	0.803
E6	0.583	0.754
E7	0.571	0.752
E8	0.478	0.764
E9	0.603	0.752

E1= Team working ability;E2=Management skills; E3=Creativity skills; E4=Communication skills; E5=Maths and statistical abilities; E6=Reading ability; E7=Writing ability; E8=Listening ability; E9=Speaking ability

Values or interests are making up a part of moderator variable and they have been assessed using a questionnaire. For the values the Cronbach α equals 0.85 which is a very high value. There are 18 questions which measure this specific construct. The corrected item-total correlation is in the acceptable range (Table 7-5). Cronbach α for when the item deleted is also suggesting that all the items are actually measuring the same thing. This is because they are not getting any higher when any of the items is deleted which suggests keeping all the items for measuring this construct.

Table 7-5 Correlations of the items and Cronbach α if item deleted for Values

Item total statistics

	Corrected Item-Total Correlation	*Cronbach's Alpha if Item Deleted*
V1	0.525	0.837
V2	0.44	0.841
V3	0.369	0.844
V4	0.606	0.833
V5	0.48	0.839
V6	0.523	0.838
V7	0.458	0.84
V8	0.33	0.847
V9	0.51	0.837
V10	0.534	0.836
V11	0.459	0.84
V12	0.566	0.835
V13	0.488	0.839
V14	0.509	0.838
V15	0.284	0.848
V16	0.535	0.836
V17	0.252	0.849
V18	0.225	0.851

V1= Likes studying theories of conceptual issues ;Likes studying theories of scientific issues; V3=Likes strategic decision making; V4=Likes data interpretation; V5=Likes doing case studies; V6=Likes problem solving; V7=Likes studying management and leadership subjects; V8=Likes working with a software; V9=Likes simulating and modelling a real case study; V10=Likes statistical analysis;V11=Likes research;V12=Likes innovation;V13=Preference of assignment for assessment;V14=Preference of Individual assessmen; V15=Preference of Group assessment; V16=Preference of report writing; V17=Values getting a good grade;V18=Values developing connections and friendship

The third collection of items to be tested are the performance self assessment which were collected through a questionnaire. This scale comprises 7 performance self assessment measures. The Cronbach α for these items equals 0.90. The correlation of the items are high and Cronbach α if item is deleted is also not higher that the overall Cronbach α. Therefore the data in Table 7-6 are all in acceptable range. This means that the all items in the scale are measuring the same construct.

Table 7-6 Correlation of the items and Cronbach α if item deleted for Performance

Item total statistics

	Corrected Item-Total Correlation	*Cronbach's Alpha if Item Deleted*
P1	0.686	0.884
P2	0.735	0.878
P3	0.695	0.884
P4	0.723	0.88
P5	0.785	0.874
P6	0.623	0.893
P7	0.683	0.885

Performance in :P1=Interacting; P2=Adapting and coping; P3=Supporting and cooperating; P4=Leading and deciding P5=Analysing and interpreting; P6=Organising and Executing;P7=Enterprising and Performing

It is concluded from this section that the items in the questionnaires which were asked to form a specific construct are in fact measuring that desired construct. In this research an algorithm will be used to normalise the absolute measurements resulted from each question using the required levels. These normalised values together with the weight associated with each of them will then be used to form a main variable (e.g. enablers) which enters the modelling. This algorithm can be viewed in more details in Section 4.3. This leads us to the next part of the reliability assessment which is the reliability of the main independent variables which will be used in the modelling. This means that at this point the data which are prepared by the by the end of step 8 of the algorithm is to be tested. This is done to ensure that the items which are included in each of the latent variables (e.g. moderators) are actually measuring the same thing before entering them into the modelling stage.

Table 7-7 Cronbach α for the inputs of both models

		Number of items	*Cronbach's Alpha*
EMP Model	Enablers	9	0.78
	Moderators	22	0.81
	Performance	9	0.85
Jaques Model	CIP	1	N/A
	Skilled Knowledge	9	0.78
	Values	18	0.84
	Not having Temperamental Behaviour	1	N/A

Table 7-7 reports on the Cronbach α for each of the variables which are made up of several items and are to be used in modelling in this research. These are all above the acceptable level (α = 0.7) which show the reliability of the structure of each variable. Apparently if a variable is not made up of several items (e.g. CIP or Not Having Temperamental behaviour) this measure is not applicable.

The next section tests the inter-rater reliability since there are two cases of using experts' judgement in the first survey, in setting the requirement levels for the job and the weights of the each requirement.

7.1.3 Inter-rater reliability

Inter-rater reliability is conducted to compare the results obtained from two or more experts on their judgment about the same issue. This will show their individual differences and their specific preferences (Sapsford, 1999). By examining the inter-rater reliability the degree of agreement between two or more people in rating the same principles is calculated (Salkind, 2008).

There are different methods in computing this reliability statistics. In this research correlation analyses are used to find the inter-rater reliability. This is because the weights and requirements are rated in a “thermometer scale” and are not categorical. The levels given to the requirements for the jobs and the weights given to each of them were not normally distributed. Therefore Spearman Rho or Kendall’s Tau can be used for finding the correlations. The results for both analyses are presented in Table 7-8 and Table 7-9.

Table 7-8 Correlation between the levels of requirements given by experts

		Rater 1	*Rater2*
Kendall's τ (sig 2 tailed)	*Rater 1*	1( )	
	Rater2	0.436 (0.001)	1( )
Spearman ρ	*Rater 1*	1( )	

Number of cases=40, Correlation is significant at the 0.01 level (2-tailed).

It is evident in Table 7-8 that the requirement levels for each item given by the two experts were correlated significantly, τ =.44, *p*<0.01; ρ= .52, *p*<0.01. In Table 7-9 the correlations between the weighting given by the two raters are even higher; τ =.92, *p*<0.001; ρ= .97, *p*<0.001. This shows that raters had agreement in the ratings they have given on the levels of requirements and their weights.

Table 7-9 Correlation between the weight levels given by experts

		Rater 1	*Rater2*
Kendall's τ (sig 2 tailed)	*Rater 1*	1( )	
	Rater2	0.915 (0.000)	1( )
Spearman ρ (sig 2 tailed)	*Rater 1*	1( )	
	Rater2	0.974 (0.000)	1( )

There is another correlation analysis called Intra-class correlation (ICC) which is also used to find consistency of the measurement by different experts on the same item (Shrout and Fleiss, 1979; Howell, 2010). This is a more comprehensive analysis of the rater's reliability of judgement. There are cases where the experts' ratings are correlated but they do not agree in their absolute values. ICC can capture the real correlation in those scenarios. It considers the amount of variance in the data which is due to variability between the items which are being measured rather than the variability between the experts (Wuensch, 2006). In this analysis we are interested to find the reliability of experts' ratings separately (Single measure) and also the reliability of the average of the ratings given by them (Average measure). The basic formulation used for finding ICC for single measures is:

$$ICC = \frac{MS_{items} - MS_{error}}{MS_{items} + (df_{Judges})MS_{error} + \dfrac{n_{Judges}(MS_{Judges} - MS_{error})}{n_{items}}} \qquad 7.2$$

The formula uses mean squared of variation between the items (MS_{items}), between the judges (MS_{Judges}) and the error (MS_{error}). It also uses the number of judges (n_{Judges}) and the number of items (n_{items}) and the degree of freedom for judges (df_{Judges}).

Different types of ICC can be calculated based on the scenario in which the raters are chosen and the type of agreement we are looking for (McGraw and Wong, 1996). As mentioned before in this research there are two raters which both rate the same items for two different purposes. We intend to find the reliability of their ratings and their agreement in the absolute values given to the items. The ICCs are calculated to find the answer to these questions. The results are reported in Table 7-10 and Table 7-11.

Table 7-10 ICC for ratings given by experts on the requirement levels

	Intra-class Correlation	*95% Confidence Interval*	
		Low Band	*High Band*
Single Measures	0.575	0.290	0.759
Average Measures	0.73	0.449	0.863

Number of cases=40, F test with True Value 0 = 4.298 , df=39, sig=.000

The results in Table 7-10 shows the ICC for one rater (single measure) and for both raters (average measure). Although the correlation is not very high in the single measure, it still shows that the single rater's judgements are correlated and reliable. Furthermore the average of the ratings shows a high ICC which confirms a high degree of reliability and absolute agreement in values given for the requirements. Table 7-11 shows the same statistics for the weightings given by the two raters. The ICC values are very high for both single and average measures. This shows a good degree of agreement between the two raters and also a reliable rating given by them.

Table 7-11 ICC for rating given by the experts on the weight levels

	Intraclass Correlation	*95% Confidence Interval*	
		Low Band	*High Band*
Single Measures	0.978	0.959	0.988
Average Measures	0.989	0.979	0.994

Number of cases=40, F test with True Value 0 = 87.35 , df=39, sig=.000

The questionnaire reliability and the inter-rater reliability test have been completed for the first survey; the data can therefore be used for the modelling purposes which will be further expanded in Chapter 8. The next section of this chapter will present some basic information and statistics on the second survey done in the research.

7.2 Statistics for the second survey

7.2.1 Sample characteristics

The second survey in this research as described in Section 6.3 is done to collect expert views on the combination of different levels of the three main independent variables in the “EMP” model on the perceived impact index. This survey has been done on a sample of 41 academics in Brunel University. Some basic demographic information on the participating sample is given in Table 7-12. The majority of the samples were male and they were between the ages of 25-34.

Table 7-12 Basic demographic information on the sample for the 2nd survey

	Gender		*Age Range*				*Education*	
	F	M	25-34	35-44	45-54	>=55	Master Degree	Doctoral Degree
Count	16	25	18	13	6	4	27	14
Percent	39%	61%	43.90%	31.70%	14.60%	9.80%	66%	34%

Recalling from the previous chapter, the data collected in the second survey is also to be used for a modelling purpose. A Logic was used to produce all the required responses for all the possible scenarios from a more simplified version of the questionnaire which did not include all the scenarios. It seems essential to check the reliability of the used algorithm before going to the modelling in the next chapter. The following section reports the error of the used logic in producing the data.

7.2.2 The error of the algorithm used

This section tries to report on how much the logic used in section 6.3 for the second survey can approximate the real values of all the possible scenarios. To do this, 2 random participants were asked to respond to the simplified questionnaire as well as the full-length questionnaire. Both questionnaires are attached in appendices G and H. The observed results from the full 27 scenarios were then compared to the approximated results using the logic presented in Section 6.3. This represents 54 scenarios for comparison. There is a need to compare the observed data with the predicted data and find the amount of variability in the predicted data which were accounted for by the logic used. R^2 which is a measure of fit and gives the squared correlation of the observed and predicted values can be used for this purpose. The formula used for R^2 is:

$$R^2 = 1 - \frac{SSE}{SST} \quad where:$$

$$SSE = \sum_{i=1}^{n} (y_i - \hat{y}_i)^2 \qquad 7.3$$

$$SST = \sum_{i=1}^{n} (y_i - \bar{y}_i)^2$$

SSE is the sum of squared error and the SST is the sum of squared about the mean. y_i is the observed value in case *i*, $\hat{y}_i$ is the predicted value in case *i*, and $\bar{y}_i$ is the mean of all the observed values.

The resulted R^2 is 0.96 which means that the used logic accounts for 96% of the variability in the data about the means. This shows that the algorithm used is very reliable and representative of the observed data and the results it produces can be used for modelling purposes.

7.3 Chapter conclusion

This chapter presented the validation and reliability tests which were conducted in this research. The results verified that the questionnaires, collected data and the transformed data are valid enough to be used for the modelling purposes. It has done that by looking into the basic demographics of the samples used in this research. The chapter checked the reliability of the questionnaires, the transformed data and the experts' ratings which were defined in the research using different statistical measures. It has also verified that in the second survey the logic which was used to produce all the scenarios is valid and reliable. Therefore it seems that the data is valid to be used for the modelling in the next chapter.

Chapter 8
Data Analysis and Results; First Survey

This chapter aims at modelling the empirical data obtained from the first survey and finding the most representative model. In order to do this, the chapter will clarify how the data on each of the variables can be aggregated to produce the impact index and how this process can be validated. A number of hypotheses have been presented in the chapter which will be tested.

In this chapter we would initially attempt to identify the best combination of independent and dependent variable as far as the mathematical modelling is concerned. This is together with testing two different estimation methods to model the variables. The most representative model(s) will then be further tested using experimental data which can testify which estimator produces the most robust and representative model. This means that the models and the produced indices are tested with the experimental data produced by Monte Carlo simulation.

By the end of this chapter, a model which can best connect the independent and dependent variables space and produce the most reliable estimation of the impact index; both empirically and experimentally; will be identified. The sensitivity of the impact index to each of the independent variables will also be tested.

8.1 Modelling and data analysis plan

The plan and sequence of data analysis and modelling is presented in figure 8.1. It is shown in figure 8.1 that in modelling the data from the first survey two conceptual models (EMP and Jaques) , three variations of dependent variable (impact index), different combination of independent variables and also two different estimation methods are to be tested.

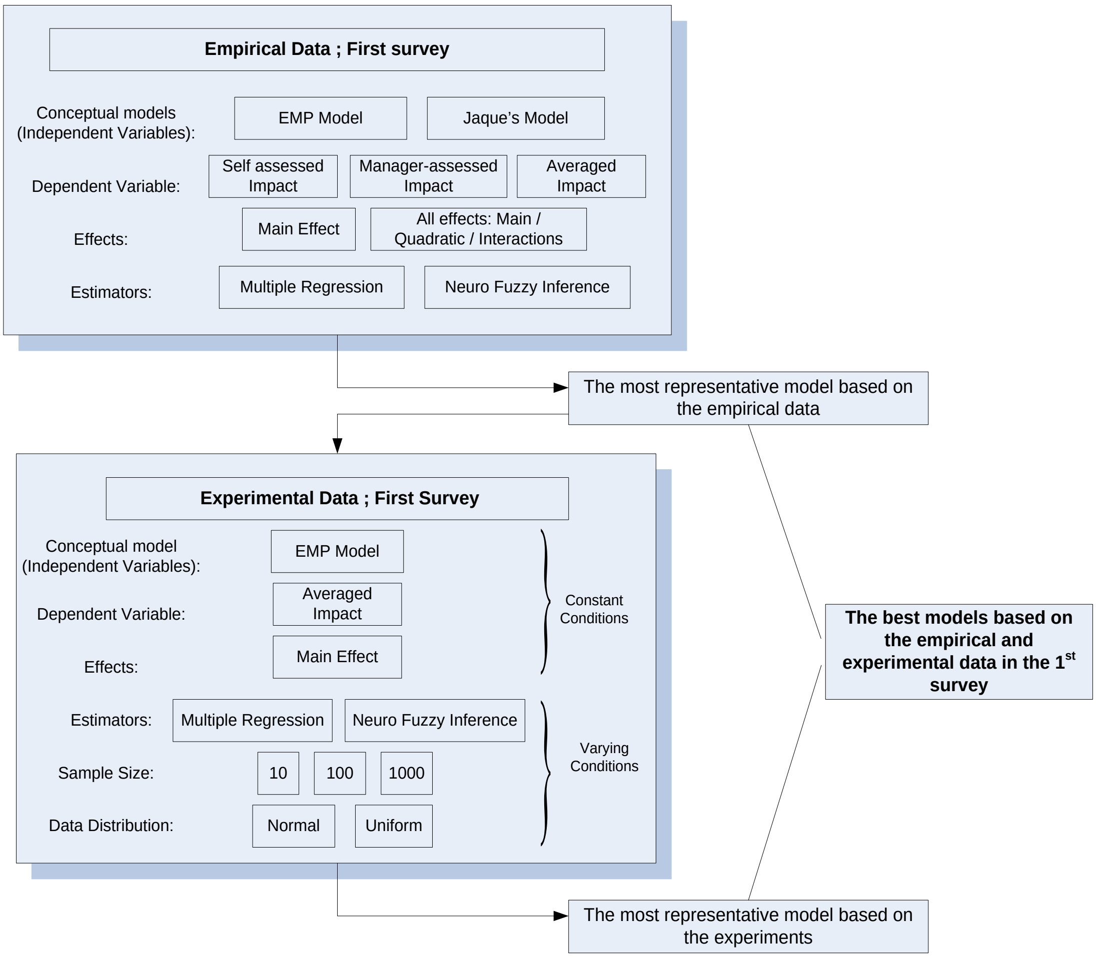


Figure 8-1 Plans for modelling the impact index

As stated in the previous chapters, the data used for modelling on this survey would be the data obtained from the first survey which has gone through steps 1-8 (independent variables) and also step 9 (dependent variable) of the model building algorithm in chapter 4. These data will be used in checking the predicative ability of the variables in each of the two conceptual models using two estimators; ordinary least squared (OLS) regression analysis and adaptive neuro fuzzy inference system (ANFIS). Main effects, quadratic effect and interaction (mediating) effects of the independent variable are tested in the analyses. The dependent variable as described in the Figure 8-1 would be self-assessed impact, manager-assessed impact or an average of these two given impact values. As stated before this modelling is mainly done on the impact index and its results will be used for the utilisation index in a later stage of this thesis. This will be discussed in more details in chapter 9. Modelling on the empirical data will be followed by an experimental study on the same two mathematical methods (OLS and ANFIS). The experiment is done to compare the performance of the two estimators in predicting the impact index in different experimental conditions. The main two conditions which are tested are the data sample size and the distribution of the data. The performance of the two estimators is compared in each experiment using several different tests such as the bias or the standard error of the model. Then the analyses on the empirical and experimental data are compared. This results in a selection of the most representative models.

8.2 Hypotheses of the research on the first survey

The hypotheses provide guidelines on the exact investigations that are going to be conducted in this chapter.

The conceptual and mathematical models that have been selected and developed in this research are to be tested. A set of hypotheses/questions are formed to test a number of issues regarding the conceptual and mathematical development of the model. The highlights of the hypotheses are presented below:

H1. Gender is not significant in determining levels of independent variables in EMP or Jaques models and Impact levels as dependent variable.

H2. Enablers, Moderators and Performance are significant predictors of one’s impact.

H3. Is EMP model a better predictor of one's impact (or utilisation) than Jaques model?

H4. Are the main effects of independent variables (E, M and P) on the dependent variable (impact) the most significant effect (compared to interaction effect or quadratic effect)?

H5. Is fuzzy inference a better modelling technique than multiple regression to model impact (or utilisation) indices in the survey condition (empirical study)?

H6. Is Regression a more robust and generalisable modelling technique than fuzzy inference (Experimental study)?

These hypotheses and questions are to be examined and responded to in the next sections.

8.3 Empirical data: Modelling for the first survey

The empirical data obtained from the surveys and processed using the algorithm in Chapter 4, are to be used for the modelling purposes in this section. Prior to the modelling practice, some basic statistics on the data which are to be used in this study are presented. Tables 8.1 give the basic descriptive data about the variables used in the modelling.

Table 8-1Basic statistics on the data used as variables in the modelling

	Variables	*Mean*	*Minimum*	*Maximum*	*Standard Deviation*
EMP Model	*Enablers*	0.87	0.41	1.00	0.09
	Moderators	0.82	0.56	0.99	0.10
	Performance	0.95	0.60	1.00	0.06
Jaques Model	*CIP*	0.90	0.69	1.00	0.11
	Skilled Knowledge	0.87	0.41	1.00	0.09
	Values	0.83	0.53	1.00	0.11
	Not having Temperamental Behaviour	0.96	0.25	1.00	0.12
Impact Index	*Self- assessed*	0.82	0.40	1.00	0.14
	Manager-assessed	0.77	0.40	1.00	0.16
	Average	0.79	0.53	0.93	0.09

The data used as independent variables are the weighted match levels with the requirements of the job. As expected, since the sample used for this study has similar professional profiles to each other and to the job, the match levels are relatively high. The same applies to the impact levels whether assessed by self or by the manager (tutor in this case) as shown in Table 8-1. It is evident that the mean of the self assessment levels is higher than the manger assessment. T-test would advise on whether or not this difference is significant.

Table 8-2 reports on the significance of the difference between the means of self and manger assessed impact levels. According to SPSS (2007) when the significance level of t value is lower than 0.05 and also the 95% confidence interval of the difference does not contain 0 in its range, the difference of the means of the two sets of data is significant. This means that based on table 8.2 the difference between the means of the self and manager assessed impact levels is significant. It should be noted that this test is different from the inter-rater reliability test. This is because the manager assessments are done by the same rater but the self assessments are done by 91 different raters.

The finding from this test shows that it would be informative to test both values (self and manager assessed impact) as dependent variables. This will allow us to understand which assessment of impact is best predicted by the independent variables and the estimators.

Table 8-2 T-test results for the differences between the means of self and manager assessment of impact

T Test		
T value (sig)	*95% Confidence Interval of the difference*	
	Low Band	*High Band*
2.24 (.026)	0.006	0.089

This T-test is to check whether the mean of the assessment of impact levels given by self and manager is significantly different or not.

Another test is on the possible gender effect on the values of any of the variables. This means that we have tested whether the means of the enablers, moderators, performance on the EMP model and the CIP, skilled knowledge, values and Temperamental behaviour on Jaques model and the self-assessed, manager-assessed and average impact levels are significantly different between male and female participants. The results are presented in Table 8-3.

Table 8-3 T-test results for testing the gender effect on all the variables

Variables		T Test		
		T value (sig)	*95% Confidence Interval of the difference*	
			Low Band	*High Band*
EMP Model	*Enablers*	0.0408 (.967)	-0.039	0.040
	Moderators	0.287 (.775)	-0.041	0.055
	Performance	0.0139 (.989)	-0.026	0.026
Jaques Model	*CIP*	0.600 (.55)	-0.037	0.069
	Skilled Knowledge	0.0408 (.967)	-0.039	0.040
	Values	0.958 (.34)	-0.024	0.069
	Not Having Temperamental Behaviour	0.144 (.885)	-0.052	0.060
Impact Index	*Self- assessed*	-1.48 (.148)	-0.094	0.014
	Manager-assessed	1.366 (.175)	-0.024	0.127
	Average	0.328 (.743)	-0.035	0.049

This T-test is to check whether the mean of the values on each of the variables is different between male and female particpants.

Table 8-3 shows that the t test results are not significant (all above 0.05) and also the range between the lower and upper band of the 95% confidence interval of the difference contains 0 for all of the variables. This means that the mean of none of the variables is significantly different between female and male participants. Therefore, the mean of the variables are not different as far as gender is concerned. This proves the first hypothesis presented in this chapter.

Now that the basic statistics on the data and some demographic effects have been studied, the first estimation of the index using multiple regression analysis is presented.

8.3.1 Regression Analysis

In this section a number of statistical tests are to be conducted. These tests are on a variation of independent variables, dependent variables and effects and the applicability of multiple regressions.

The first section examines the results of running an Ordinary Least Squared (OLS) regression with the main effects of enablers, moderators and performance as the predictor variables on the impact index. The self assessed impact, manager assessed impact and the average impact, are to be checked as the dependent variables in this section.

The next part in this section will run the regression while considering all the effects of the independent variables on the dependent variable (main, quadratic and interactions). The dependent variables will remain the same as the previous part.

The last section in the regression analysis, will briefly reports on having the independent variables inspired by the Jaques model. The self assessed, manager assessed and average impact are to be tested as dependent variables. The main effects of the independent variables are to be tested and modelled.

8.3.1.1. OLS regression on EMP and impact, main effects

The first analysis is on fitting a multiple regression model to the independent variables (Enablers, Moderators and Performance) and the dependent variable; the impact level. The independent variables are all pre-processed based on the algorithm presented in Chapter 4. The dependent variable will be the person's self assessment of his/her impact on the job, manager assessment of the impact and also the average of these two values.

The result of the regression analysis is presented in Table 8-4. The regression has been done on 91 cases and the R^2 shows the amount of the variations in the dependent variable which can be predicted by the regression model. The B coefficients are showing the change in the dependent variable with a unit change in any of the independent variables. A significance level (*p* values) is also attached to these coefficients which show whether each independent variable is significant in predicting the dependent variable.

Table 8-4 OLS regression results on main effects of E, M and P and impact levels

Dependent variables	*Self-assessed Impact*		*Manager-assessed Impact*		*Average of assessed Impact*	
Independent variables	Coefficient (*p*-value)		Coefficient (*p*-value)		Coefficient (*p*-value)	
Intercept	0.100		-0.667	***	-0.326	***
	(0.959)		(0.000)		(0.000)	
Enablers	-0.620		0.504	***	0.234	***
	(0.680)		(0.000)		(0.000)	
Moderators	0.550		0.811	***	0.436	***
	(0.685)		(0.000)		(0.000)	
Performance	0.859	***	0.346	**	0.585	***
	(0.000)		(0.035)		(0.000)	
n	91		91		91	
R^2	0.220		0.530		0.767	

***p < 0.01, **p < 0.05

As seen in the first column of Table 8-1, enablers and moderators are not significant predictors of people's self assessment of their impact on a job. Therefore changes in the enablers and moderators are not showing positive or high change in the dependent variables. The overall amount of variation in the self assessed impact predicted by this model is only 22%. This shows that the algorithm presented in Chapter 4 which calculates one's match to the resource requirement of a job using EMP models can not accurately predict one's own perception of their impact on that job.

The second column however shows an improvement in the predictive ability of the model. In this model student's match with the resource requirement of the job in the three criteria are modelled into the perception of manager from their impact on the job. The manager assessment is done by teaching assistants of the module since they get to know and interact with the students during their studies. This means that Enablers, moderators and Performance are all proven to be significant predictor of the manager assessment of one's impact in a given job. The value of R^2 is also showing that the predictive ability of the model is higher than the previous model.

The third column an average of the self and manager's assessment will be used as the modelled impact index. The results demonstrate the model with the highest R^2 which shows that this model can account for 76% of the variation in the dependent variable. In addition, a unit change in any of the three independent variables in this model has a positive effect on the dependent variable. Therefore based on the OLS regression results, if we find one's match with the resource requirements of a given job in the three given criteria using the algorithm in chapter 4, this match level is a good predictor of an average of what the person and his/her manager perceives of their impact level in that given job .

It is concluded from this section that enablers, moderators and performance are suitable predictors of the average impact index which is the proof for the second hypothesis presented in this chapter.

8.3.1.2. OLS regression on EMP and impact, all effects

Following the results from the first regression analysis, it is reasonable to check the model when adding other effects (quadratic and interaction) of the independent variables in to the model. A good example of use of different effects in a regression exercise is the work of Edwards and Cable (2009).

These effects have been studied on the independent variables from the EMP model and the self, manager and average given impact values. The results of this regression analyses is reported in Table 8-5.

Table 8-5 OLS regression results on all effects of E,M and P and Impact levels

	Dependent variables	*Self-assessed Impact*		*Manager-assessed Impact*	*Average of assessed Impact*
Independent variables		Coefficient (*p*-value)		Coefficient (*p*-value)	Coefficient (*p*-value)
Intercept		-0.684		0.813	0.068
		(0.757)		(0.684)	(0.934)
Enablers		0.915		-1.237	-0.345
		(0.638)		(0.482)	(0.636)
Moderators		3.675		-3.157	0.36
		(0.280)		(0.304)	(0.777)
Performance		-2.659		3.030	0.273
		(0.319)		(0.209)	(0.784)
*Enablers*Enablers*		1.426		-0.589	0.376
		(0.165)		(0.523)	(0.326)
*Moderators*Moderators*		0.523		-1.162	-0.213
		(0.670)		(0.295)	(0.643)
Performance Performance*		5.390	***	-4.963	0.135
		(0.001)		(0.001)	(0.826)
*Enablers*Moderators*		-0.829		1.136	0.154
		(0.652)		(0.495)	(0.823)
*Moderators*Performance*		-3.010		2.129	0.282
		(0.243)		(0.359)	(0.820)
*Enablers*Performance*		-3.889		5.009	-0.154
		(0.241)		(0.096)	(0.872)
n		91		91	91
R^2		0.320		0.597	0.770

***p < 0.01, **p < 0.05

The first column in Table 8-5 used different combination of Enablers, Moderators and Performance to model the self-assessed impact which has resulted in a slightly higher R squared (32%) than the same model with only main effects (Table 8-4). However, Table 8-5 shows that with inclusion of all effects to the model, almost none of the variables are proved to be significant in predicting the self-assessed impact index. This shows that in predicting one's self perception of impact in a given job, match in the three criteria of requirements (E,M and P) together with the quadratic effect or interaction of the requirement is not useful.

The second column tests the predictive ability of the same set of variables for the manager assessment of impact on the job. This exercise has shown that even though the variance explained by the model is considerably higher than the model in the first column of the table, none of the variables proved to be significant for this prediction.

The last column checks the OLS regression for all effects of the EMP model on the average of the assessment on impact level. In terms of the model fit, this model is a good predictor of the dependent variable with an R^2 of 77%. However the coefficients and their *p* values in the model show no significant contribution to the prediction of the variations in the dependent variable. Therefore it seems that entering quadratic or interaction effects into the modelling exercise does not improve the quality of the prediction made by the ordinary least squared regression.

A further comparison on the difference of the R^2 of different models is presented in Figure 8-2. Figure 8-2 presents R^2 of all the possible models from the combination the EMP independent variables and average of impact levels (self and manager) as dependent variable. Each row in the figure represents a different regression. The black boxes represent presence of that specific independent variable (which are named in horizontal axis) in the regression.

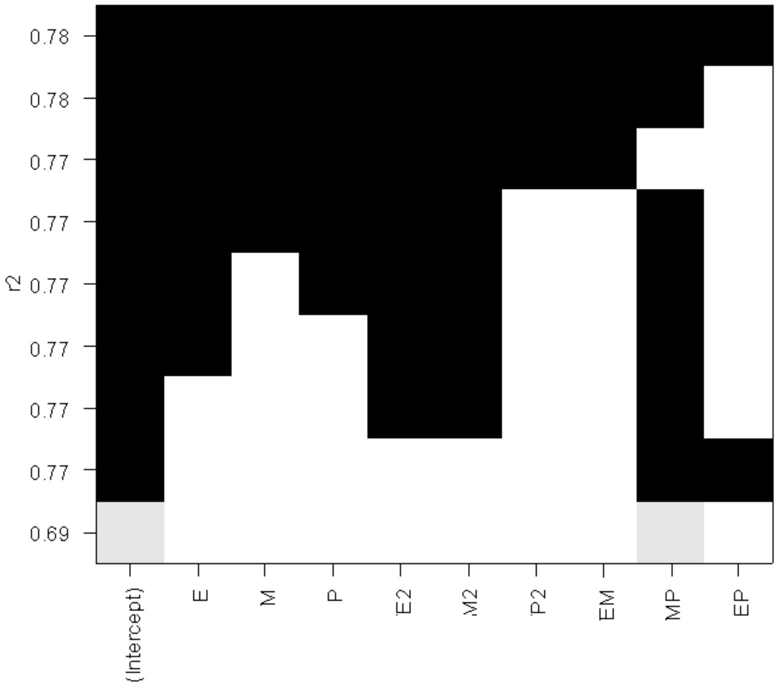


Figure 8-2 R squared of all the regression models on EMP and average-assessed impact

It shows that the R^2 is relatively high for all different combinations. Moreover the number of model which has high R^2 while having E, M and P as independent variables is high which verifies their predicative ability. It is evident that inclusion of other effects other than main effects does not improve the goodness of fit in the OLS regression on EMP model and impact levels. So the main effects of the EMP model are the only significant ones and other effects do not prove to be significant in predicting the impact. This is an indication that the fourth hypothesis of this chapter is in fact true which says that the main effect of the independent variables (E, M and P) on the dependent variable (impact) is the most significant effect (compared to interaction effect or quadratic effect). Appendix I contains two other figures which represent the comparison of the R^2 of the same independent variables with the self assessment of impact and also manager assessment of impact levels.

Therefore two final conclusions can be made based on the result of the regression analysis to this point. Firstly the main effects of the EMP model are best predictors of the impact as compared to the other effects (interaction and quadratic). Secondly EMP model is a better predictor of an average of the perception of a person and their manager on the impact on a given job. This means that a known level of match for the people in the resource requirement of the job has adequately predicted the average of the perceptions of the person and a manager on the possible impact of the person on the job.

The next section will study the OLS regression on the Jaques model for the independent variables.

8.3.1.3. OLS regression on Jaques model

In this section we use Jaques model as the conceptual model for choosing the independent variables. The section aims at using students' match in the Complexity of information processes, skilled knowledge, values requirements of the job together with not having temperamental behaviours as independent variables. These four independent variables are regressed on the impact levels as given by self, manager and the average of both. This study is done to understand whether match in the resource requirement of a job using the Jaques conceptual model can satisfactorily predict one's self, manager or average impact of the person in that job.

The results of this regression analysis are reported in Table 8-6. The first column of this table shows the results of the independent variables regressed against the self assessed impact levels. The results for this practice were poor and the model was able to explain only 1% of the variations in the dependent variable. P values show that none of the independent variables were significant in predicting the variations in the self assessed impact levels. The second regression in the table is on the same set of independent variables and the impact value as assessed by the manager. This exercise has shows that match in the skilled knowledge and values of the students is a significant predictor of their impact in the job as perceived by the manager. However match in the required CIP levels or not being temperamental does not proved to be significant in this model. The third regression reported in the Table 8-6 is on the four independent variables and the average of self and manager assessment of impact. This model is a better one as it can be liable for 52% of the variation in the dependent variable (R^2= *.52).* As before, two of the independent variables (skilled knowledge and values) were proved to be significant predictors of the outcome whereas CIP and having no temper did not.

Table 8-6 OLS regression results on main effects of CIP, S/K, V and T on Impact levels

Dependent variables	*Self-assessed Impact*		*Manager-assessed Impact*		*Average of assessed Impact*	
Independent variables	Coefficient (*p*-value)		Coefficient (*p*-value)		Coefficient (*p*-value)	
Intercept	0.67	***	-0.254		0.189	
	(0.004)		(0.192)		0.069	
Complexity of Information Processes (CIP)	-0.056		-0.013		-0.024	
	(0.673)		(0.912)		0.695	
Skilled Knowledge (S/K)	0.090		0.642	***	0.374	***
	(0.585)		(0.000)		(0.000)	
Values (V)	0.097		0.642	***	0.371	***
	(0.454)		(0.000)		(0.000)	
Not Being Temperamental (-T)	0.037		-0.073		-0.019	
	(0.077)		(0.487)		(0.739)	
n	91		91		91	
R^2	0.017		0.480		0.523	

***p < 0.01, **p < 0.05

It can be seen in this section that using Jaques concept of applied capability in predicting one's impact in a job using the algorithm in this research is not feasible. This proves that EMP conceptual model is a better predictor of people impact in a job than Jaques model which proves the third hypothesis of this chapter.

8.3.2 Adaptive Neuro Fuzyy Inference System (ANFIS)

As describe in Chapter 5, ANFIS is one of the modelling techniques which has been used for predicitve or explanatory models in a variety of subjects. It can capture any non linear relationship between the independent and dependent variables. Its generalisability and ability to handle non linearity is two of its winning points (Jain et al., 1999). It is worthwhile using ANFIS to see how it can possibly better the fit in some of the modelling scenarios which have been done in this chapter so far.

ANFIS is to be tested on different combination of independent variables and dependent variables. Independent variables are from either EMP or Jaques conceptual model. The dependent variables are self, manager and average assessment of impact of the person on the job. ANFIS is not to be tested for effects other than the main ones (quadratic or interaction). This is because of the underlying logic of the ANFIS in modelling. Ni and Gunasekaran (1998) described ANFIS as a linear blend of a number of non-linear functions (the membership functions). This means that incorporation of the membership functions and the rule based caters for all the possible interaction effects of the independent variables. What is more, entering the quadratic effects into the fit deteriorated the goodness of fit in all the scenarios tested in the previous section. Therefore the inferences would be only on the two sets of independent variables (EMP and Jaques) and three dependent variables (self, manager and average).

We have accessed ANFIS through MATLAB’s fuzzy logic toolbox. The logic of the underlying formulation and method used in ANFIS has been explained in Chapter 5 in details.

8.3.2.1. Inference of Impact from EMP model using ANFIS

In this section we have used ANFIS to fit a model to how participants’ impact can be predicted by their match in the job requirements in three main criteria (enablers, moderators and performance) on the self assessed impact index. This has been done using a graphical unit interface in MATLAB, It allows the user to load the data on the independent and dependent variables in the current sample and it generates a model fitted to those data with the least error. A number of settings such as type of membership function, number of membership functions and number of trainings should be set before running each analysis.

In the first model there are three independent variables (E,M and P) and one dependent variable (self-assessed impact). Gaussian functions (normal distribution) are assigned for defining the memberships for each of the inputs. While in many cases the exact reasons for the Gaussian form of the functions are not clear, the use of the normal distribution is theoretically justified and widely used. Moreover, each input is defined to have two membership functions. This means that for instance for a person with a match value of *x* for enablers, he or she will have a membership value for each of the two functions defined for enablers. The two functions are estimated based on the data. This leaves the person with having $\mu_{A^1}(x)\ and \mu_{A^2}(x)$ which are his or her memberships to each of the two functions for the enablers. This procedure is done for all the cases and for all the variables. Having placed the required settings, training of the data is done which results in finding the mostly well suited Gaussian function to best regress the output from the inputs using least squared technique. Number of epochs (trainings) has set be 50. This means that the set of data (91 cases) will be trained 50 times which will result in fitting the best membership curves to the variables, defining the most representative rules describing the system and finally fitting the most accurate model to the data. Training error for the first model is presented in Figure 8-3. The training errors given in the ANFIS are the Root means squared error (RMSE) at each epoch. RMSE is the mean of the sums of squared differences between the observed outputs and the ones predicted by the model.

$$RMSE = \sqrt{\frac{\sum_{i=1}^{n}(y_i - \hat{y}_i)^2}{n}} \qquad 8.1$$

Where, *n* is the number of cases, y_i is the observed value in case *i*, $\hat{y}_i$ is the predicted value in case *i*. In fact RMSE is one of the measures for goodness of fit along R^2 or F statistics. According to Sweet and Martin (2008) a researcher may use all or one of them to test the goodness of fit. RMSE may be a good measure since it is an absolute measure of goodness compared to R^2 which is a relative measure. As far as RMSE is concerned, the lower level it has, the best a model fits the data.

Figure 8-3 shows how the error of the model decreases when a better model is fitted into the data. This is the training error for the model in which Enablers, moderators and performance are the independent variables and the averaged assessed impact is the dependent variable. Each new training is done to fit a better model to the variables which can predict the dependent variables with least error. It shows the error of the model produced by the first attempt in modelling the dependent variable using the independent variables to the error of the 50th model. It is seen that the error (RMSE) reached 0.039 at around the 45th epoch and stayed at the same level.

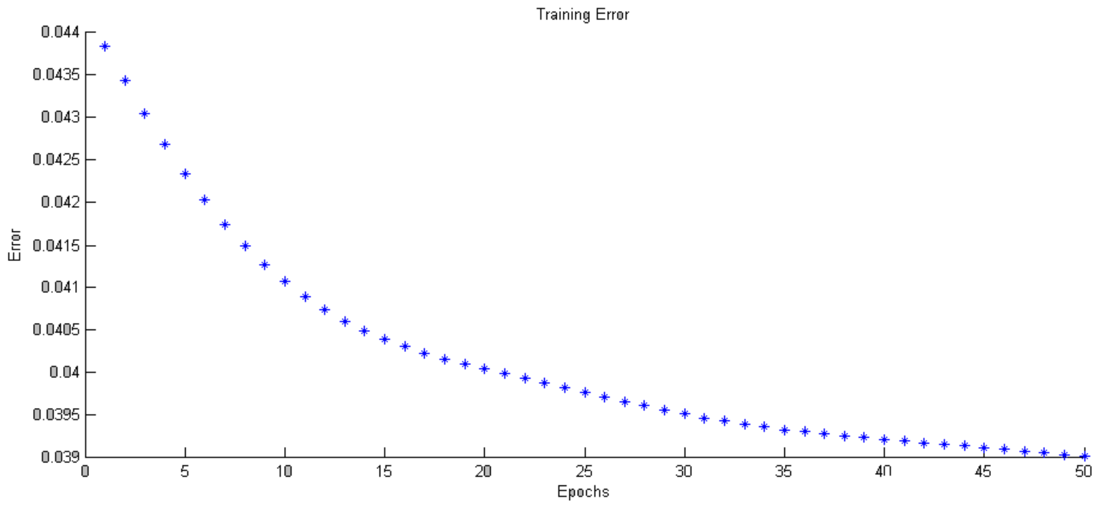
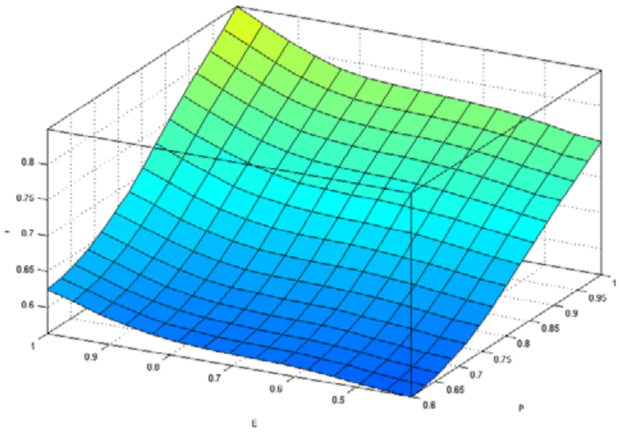


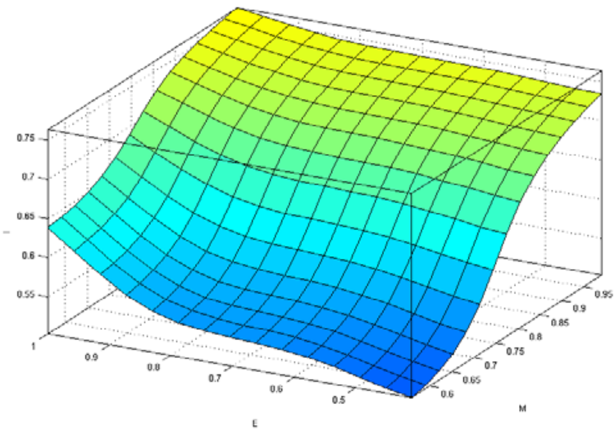
Figure 8-3 Training error for ANIFS on EMP and average-assessed impact

The graph for the training error for self assessed impact and manager assessed impact as the dependent variables are attached in appendix J.

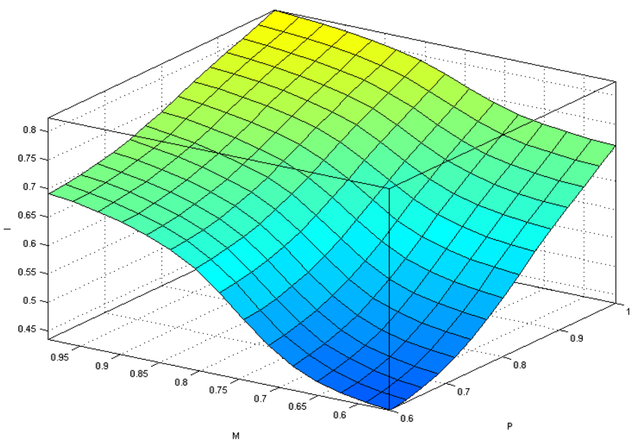
ANFIS does not provide the fitted model in the form of any equation. However the surfaces which are obtained from the best model (with lowest RMSE) are presented in Figure 8-4. The produced model predicts the average of the impact indices given by the person and the manager based on the match level in enablers, moderators and performance as depicted in Figure 8-4.



a) Enablers and Performance



b) Enablers and Moderators



c) Moderators and Performance

Figure 8-4 The results of the ANFIS modelling on the EMP and average-assessed impact

The plots presented in Figure 8-4 are showing how the predicted impact index is changing with respect to the changes in person's level of match in enablers, moderators or performance. The vertical axis represents the Impact index and the horizontal axes represent the independent variables.

Firstly it is notable in the plots that range in which the values for each of the variables are changing is in a limited range and not in the whole [0, 1] range which it can potentially be. The reason is that the model is fitted to the data obtained from the case study and the data in the case study was not covering the complete range of possible levels for each input. This is because the sample were homogenous to a great extent and they got high match with most of the requirements; therefore the final processed E, M and P levels are mostly above 0.5 which also results in high levels of impact index.

Secondly, the graphs reveal the combinatory effects of the independent variables on the dependent variable. For instance changes in the impact level is much sharper with increase in the match in performance levels compared to increase in the match in enablers' (Figure 8-4.a). The same comparison can be made between the moderators and enablers, where the matches in moderators are much influential in the changes of the predicted impact level (Figure 8-4.b). In fact moderators and performance show a somewhat identical behaviour; which can be seen in Figure 8-4.c. Overall increase in any of the three independent variables shows an increase in the predicted impact of the person in the job. The degree of this positive contribution is different among the independent variables.

The results from using ANFIS for modelling enablers, moderators and performance on the self assessed impact or manager assed impact are not included in this section. This is because the Root mean squared errors produced by those models were higher than this model. Therefore, they were not able to produce a model which can produce predictions of impact as close as possible to the observed levels.

The results of this section show that ANFIS is producing a good fit for the EMP model and the average impact index. Therefore it can be concluded that by using ANFIS as the inference method we can reliably predict the average of impact index given by the person and a manager for a given job using their match level in the requirement of the job as categorised in enablers, moderators and performance.

In the next section ANFIS is to be used to fit a model on Jaques input and the impact index as the dependent variable.

8.3.2.2. Inference of Impact from the Jaques model using ANFIS

This section aims at inferring one's impact level in a job from his/her match in the requirement of the job as described by Jaques conceptual model using ANFIS. The impact data used for this modelling was the average of the impact levels given by self and manager for each person. This choice is made to make the model comparable to the model produced in the previous section on the average assessed impact.

The logic of the ANFIS has been described in the previous sections. The settings for the model are similar to the previous modelling. This means that for each of the four independent variables (CIP, Skilled knowledge, Values and Not having Temperamental behaviour) 2 membership functions has been set and the number of training epochs set to be 50. Figure 8-5 demonstrated the training error for this inference. As it can be seen the RMSE after 25 epochs, approaches 0.055 which does not provide a better fit to the data compared to RMSE obtained from the modelling in the previous section.

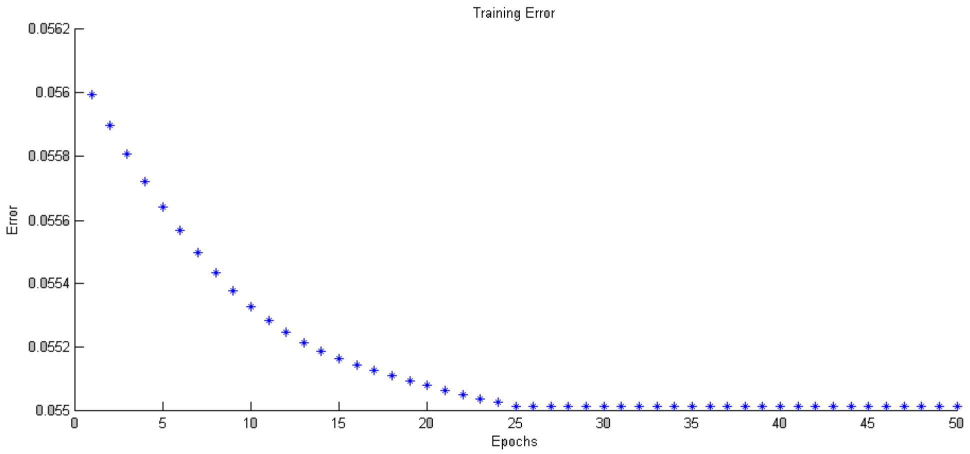


Figure 8-5 Training error for Jaques model and average-assessed impact

For this model, similar to the model in the previous section, a number of graphs for the relationship of independent-dependent variables have been produced. However the problem is that the graphs produced for the relationships of the input and output space is not representative of the input/output space.

This is because the accuracy of adaptive neuro fuzzy inference systems is dependent on the quality and quantity of the data set used in the modelling (Basheer and Hajmeer, 2000). This means that in the absence of enough underlying guidelines and rules in the pattern of the data the produced model will not be representative. In modelling with Jaques inputs, there are 91 cases based on which the underlying rules of the system for four independent variables should be derived. This makes the model more susceptible to producing larger errors or giving an unrealistic fit compared to the EMP model (which had 3 independent variables). Although the model produced by ANIFS well fits the exact given data points the trends of the independent variables and their relationship with the output as given by the fit are not generalisable to other data set.

Therefore it is concluded that ANFIS can not find a good fit between Jaques model of independent variables and the average impact index as the dependent variable. The models for the Jaques model and self assessed or manager assessed impact are not included as they had higher errors and not comparable to the other models.

8.3.3 8.3.3. Discussion on the empirical results

In this chapter, two mathematical techniques have been used to compare the predictive ability of the two conceptual models introduced in this research. The mathematical techniques are Ordinary Least Squared Regression and Adaptive Neuro Fuzzy Inference system and the conceptual models are EMP and Jaques model in predicting one's impact in a given job. This section reports on the main findings on the model fitting practice on the empirical data.

OLS regression shows that enablers, moderators and performance can be good predictors of the impact levels that a person has on a job. However, the predicted impact index using these methods is much more similar to the average of self and manager impact, than just the self-assessed impact or the manager-assessed impact. This can be due to the fact that the self assessments of the impact are different from the manager assessment as explained in Section 8.3.The reason behind this difference can be because agents sometime see themselves higher or lower than what they are. Models which are produced solely on the manager assessment of impact were more accurate than the models based on the self assessment of impact. However as mentioned before the models produced based on the average of the two have proved to be the most representative. What averaging does is that it gives a midpoint of the manager's and person's perception about the person's impact on the job. At the same time, OLS regression on E, M and P produces impact values which are more in accord with the average impact level. Another finding regarding regression on EMP is that the main effects are the most significant effects and inclusion of quadratic effects or interactions of the variables reduce the goodness of fit. Non significance of the interaction effects shows that combinatory effect of no two variables (e.g. enablers and moderators) affects the impact levels on the job.

The next regression models have used CIP, skilled knowledge, values and not having temperamental behaviour as independent variables and tried to predict the impact values given by self, manager or the average of both. Results of this regression were similar to the previous to some extent. This means that Jaques model is a better predictor of the average of the manager's and self perception on the impact than the self or manager perception separately. However, even in this model, CIP and not having temperamental behaviours were not confirmed to be significant predictors. This can indicate that quantification of certain predictors such as CIP or temperamental behaviours does not yield useful information for predicting one's impact level.

ANFIS has also been used because it can capture nonlinear relationships and imprecision in the data. ANFIS has also shown that using enablers, moderators and performance as predictors and the average impact index as the dependent variable produce a model with lowest error (compared to models with self or manager impact index as dependent variable).The graph illustrations of the model in figure 8.4 are also representative of the dynamics of the input/output space which show the effect of increase in each of the independent variables on the dependent variable. However ANFIS was unable to produce a representative model with Jaques inputs. This was due to the number of input variables and the insufficient number of cases in portraying a complete surface view. But even in this case, the error produced from fitting the Jaques model into the average of assessments was lower than the one produced by self assessment of impact.

All the models which were produced and tested in this section are presented in Table 8-7. In order to compare the models we have used root mean squared error as a measure for goodness of fit. The quadratic or interaction effects of the independent variables on the dependent variables are not included in this table as they have been proved to be not influential in the modelling.

Table 8-7 Comparison of the obtained models based on RMSE

Conceptual Model (Independet Variables)	*Estimation Methods*	*Dependent Variables*	*Root Mean Squared Error (RMSE)*
EMP Model (Enablers, Moderators , Performance)	*OLS Regression*	*Self assessed Impact*	*0.116*
		Manager assessed Impact	*0.106*
		Average of Self and Manager assessed Impact	***0.041***
	ANFIS	*Self assessed Impact*	*0.108*
		Manager assessed Impact	*0.091*
		Average of Self and Manager assessed Impact	***0.039***
Jaques Model (CIP, Skilled Knowledge, Values, Not having Temperamental Behaviour)	*OLS Regression*	*Self assessed Impact*	*0.13*
		Manager assessed Impact	*0.111*
		Average of Self and Manager assessed Impact	*0.06*
	ANFIS	*Self assessed Impact*	*0.124*
		Manager assessed Impact	*0.101*
		Average of Self and Manager assessed Impact	*0.055*

According to Table 8-7, as far as root mean squared error is concerned, EMP model is best predictor of the average of self and manager assessment on impact. This means that the deviation of the variance of the impact levels which is not explained by the model is lowest in this model as compared to the others. It is also notable that for each set of inputs and each of the modelling techniques, RMSE decreases when the output changes from self to manager to the average of self and manager. What can also be inferred from Table 8-7 is the proof of the 5th hypothesis in terms of the comparison of ANFIS and regression for empirical data.

In Figure 8-6 to Figure 8-8, the observed values of average impact for each participant are compared to some of the predicted values using the produced models. Figure 8-6 compares the observed values of average impact with the predicted levels by ANFIS and OLS regression on using the EMP model. It can be seen that ANFIS provides a very good fit to the observed data; regression also provide a very low residual. As expected from the Table 8-7 ANFIS produces a better fit to the observed data as compared to the Regression. This is because ANFIS uses an exhaustive learning process and it is expected that it fits the model to the exact data points which are used. However the main question would be whether or not, this issue jeopardise the generalisability of the models produced by ANFIS. This question is mainly answered in the next section.

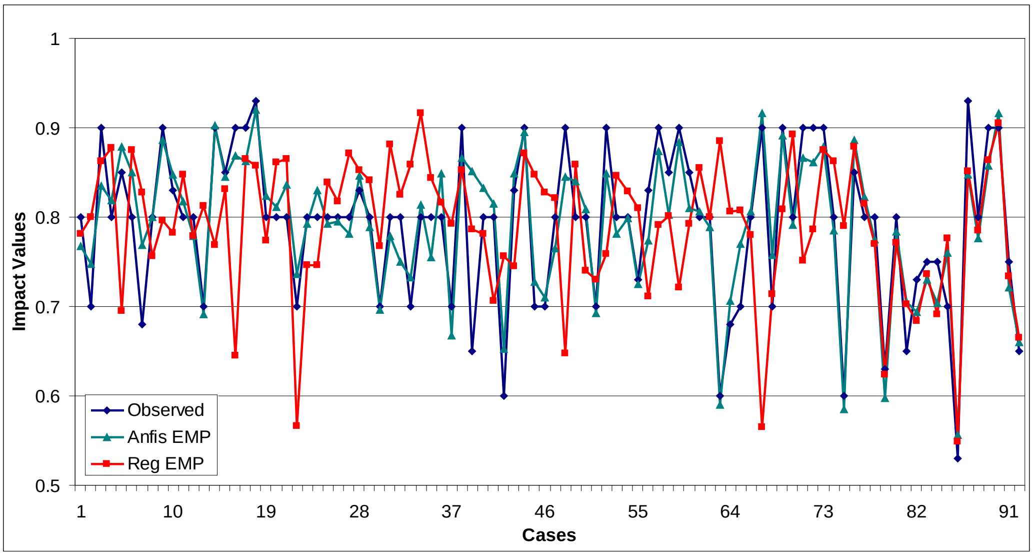


Figure 8-6 Comparison of the observed values with ANFIS and OLS regression with the predicted impact values using EMP conceptual model

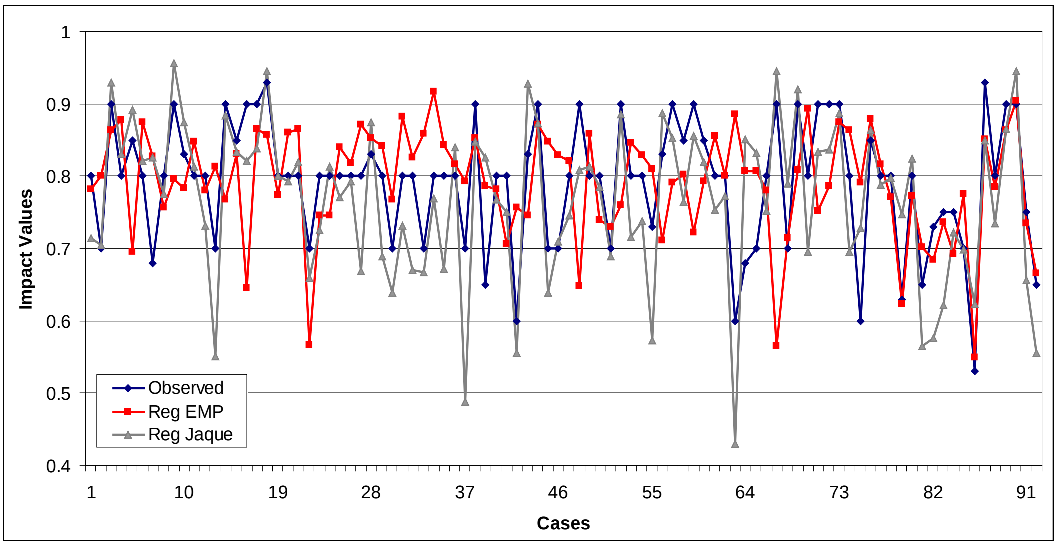


Figure 8-7 Comparison of the observed values with regression predictions of average impact index using EMP and Jaques conceptual models

Table 8-7 compares the predicted impact indices produced by Jaques or EMP conceptual models using OLS Regression. It is evident from Figure 8-7 that the predicted values of average impact from the EMP model are closer to the observed values compared to the predicted values using Jaques model. This was expected from the analyses done in the previous sections and also from Table 8-7. Figure 8-8 tries to compare the observed values of impact and the values produced from the two conceptual models using ANFIS. It is evident that the predicted values of impact using the EMP conceptual model are closer to the observed values of impact compared to the ones' predicted by Jaques model. This confirms that EMP provides better prediction of impact than Jaques model which approves the 3rd hypothesis in this research once again. However, as explained before since ANFIS use a learning algorithm to fit the best model to a given set of data, the predicted outputs are closely fit to the observed data regardless of the conceptual model behind them. Therefore the generalisability of the model produced by ANFIS are to be studied in the next section using experimental data.

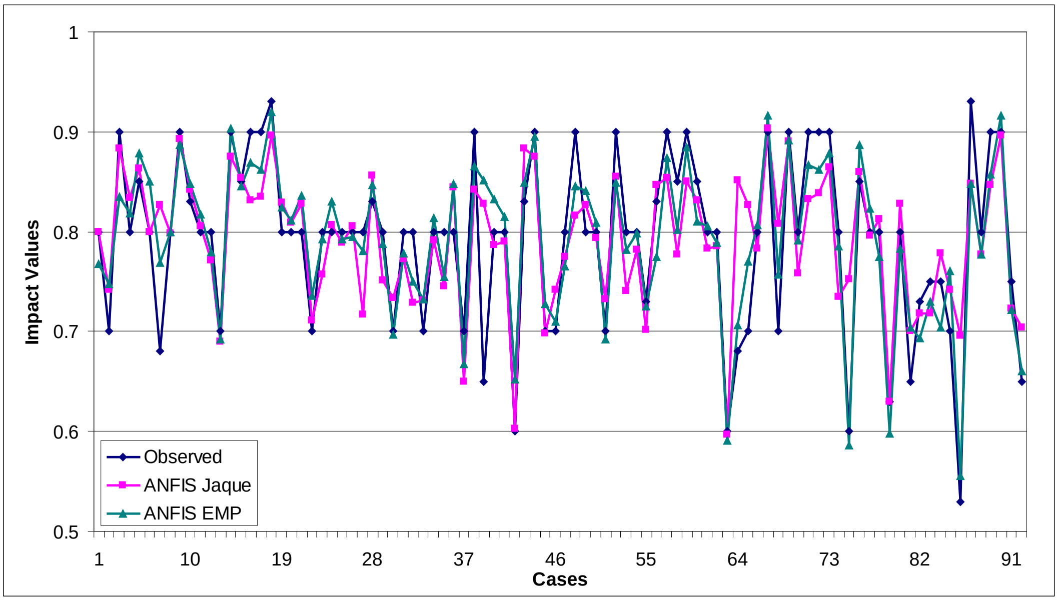


Figure 8-8 Comparison of the observed values with ANFIS predictions of average impact index using EMP and Jaques conceptual models

What can be concluded from the empirical data in the first survey is that EMP conceptual model can be a good predictor of the average impact levels given by the person and manager. This shows the best combination of independent and dependent variables for modelling in this research. However the main question to be answered is which mathematical method is a better one to model this phenomenon. This needs to be answered because OLS regression and ANFIS both showed high goodness of fit to this set data. Therefore to test the generalisability of the models, it has been decided to run a Monte Carlo experiment. This experiment would show the effect of several different factors (such as sample size, data distribution) on the goodness of the estimation methods which is measured using model bias, standard error and mean squared error of the variance.

8.4 Experimental results: Modelling on the first survey

Enablers, moderators and performance have proved to be good predictors of one's impact level in a given job as perceived by self and manager. This section aims to test the generalisability of the estimation methods which were tested in Section 8.3. This exercise seeks to study the models produced by OLS Regression and ANFIS in scenarios which are different in the distribution of data used for modelling and the sample size. This is because if the reliability of the estimation method is not restricted to a specific data distribution or sample size the method can be used more liberally without those considerations. A Monte Carlo experiment can check the performance of the estimation methods in different settings.

Consider that all the match levels of the person to the requirements of a job in the three criteria (enabler, moderators and performance) are given to predict one's impact on the job. The observed impact levels (average of self and manager assessment) are also known. In this section OLS regression and ANFIS are tested as the two estimation methods. This is done using Monte Carlo simulation which is known to be one of the most powerful methods in analysing complex systems (Rubinstein, 1981). Certain factors are being changed within experiments to test the changes on the reliability of the results produced by each of the two main estimation methods in use. This section describes the experimental design and the results of the experiment.

8.4.1 Experimental Design

The experiment is a factorial Monte Carlo which is designed by the work of Gentle (2003). Before running the experiment, we need to define the factors which are going to be different within experiments. These are presented in Table 8-8. It is important to note here, that the data which are generated randomly are defined to be in the range of the empirical data obtained in the first case study. This is to make the experimental results comparable to the empirical results.

Table 8-8 Design of the Monte Carlo experiment

Test Number	*Sample Size*	*Data Distribution*	*Estimations Methods to be tested*
1	*10*	*Normal*	*OLS Regression /ANFIS*
2	*10*	*Uniform*	*OLS Regression /ANFIS*
3	*100*	*Normal*	*OLS Regression /ANFIS*
4	*100*	*Uniform*	*OLS Regression /ANFIS*
5	*1000*	*Normal*	*OLS Regression /ANFIS*
6	*1000*	*Uniform*	*OLS Regression /ANFIS*

Table 8-8 shows that the data sample size (three levels) and the distribution of the variables (two levels) are going to be different which makes a total of 6 experiments to be conducted. In each experiment both estimation methods are to be used and compared. For instance, in the first experiment 10 random data (which are normally distributed) are used to run an OLS regression and an ANFIS modelling which result in estimations of the dependent variable (Average of self and manager assessed impact). The robustness of the estimation methods are being assessed using the variance, standard error, mean squared error and bias of the variance in the estimations. The logic behind this approach is to test whether the sample size or the distribution of the data can affect the robustness of the estimation methods.

Table 8-9 gives the means and variances of the impact indices produced by each of the methods in each experiment are given in.

Table 8-9 Means and variances of indices produced in the experiments

Test Number	Mean of Impact Index		Variance of Impact Index	
	OLS Regression	ANFIS	OLS Regression	ANFIS
1	*0.7962*	*0.7985*	*0.0016*	*0.0024*
2	*0.8243*	*0.8244*	*0.0004*	*0.001*
3	*0.7862*	*0.7875*	*0.0012*	*0.0041*
4	*0.8365*	*0.8367*	*0.0001*	*0.0003*
5	*0.7891*	*0.7905*	*0.0012*	*0.0003*
6	*0.8352*	*0.8354*	*0.0001*	*0*

It is evident that the mean of the impact is always estimated to be slightly higher using ANFIS than the OLS regression, although this difference is not major. The same difference exists in the variance of the estimated variable. However, the variance is low in all the experiments for both estimators. Moreover when the distribution of the data used for modelling is uniform the mean of the impact levels are higher and the variance is smaller than the case where normally distributed data are used.

The tests which are to be used in order to check the robustness of the estimates are described in the next section.

8.4.2 Measures of robustness

In this simulation bootstrapping is used which means that the initial sample was used to resample and produce pseudo-population (Martinez and Martinez, 2002) in each experiment. These are the population which are not completely random and are based on the characteristics of the main initial sample in each experiment. Bootstrapping provides enough data to calculate different measures of robustness of the estimation methods.

Different tests can be used to examine the robustness of the methods under study. Nurwaha & Wang (2008) have used mean and standard deviation, maximum and minimum of absolute errors, root mean squared error (RMSE) and the mean of absolute errors to examine the predictive ability of two different estimation methods. In this research, we will use standard error, bias and mean squared error of the variance as the measures of robustness for the two estimation methods as suggested by Martinez and Martinez (2002).

Standard error: To find the standard error of the variance, the variance of the output in each experiment is compared to the bootstrap estimate of the variance.

$$SE_B(\hat{V}) = \left\{ \frac{1}{B-1} \sum_{b=1}^{B} (\hat{V}^b - \bar{\hat{V}})^2 \right\}^{1/2} \quad 8.2$$

$$\bar{\hat{V}} = \frac{1}{B} \sum_{b=1}^{B} \hat{V}^b \quad 8.3$$

Where B is the number of bootstrap replications and $\hat{V}^b$ is the b^{th} bootstrap estimation of the variance.

Figure 8-9 shows the standard error of the variance as produced by the two estimators in each of the 6 experiments. It is visible that as the sample size increase the two methods are becoming more similar in terms of the standard error produced. However in the smaller sample sizes regression proves to be a better estimator as far as standard error is concerned. In each sample size uniform distribution of the data produces a smaller SE.

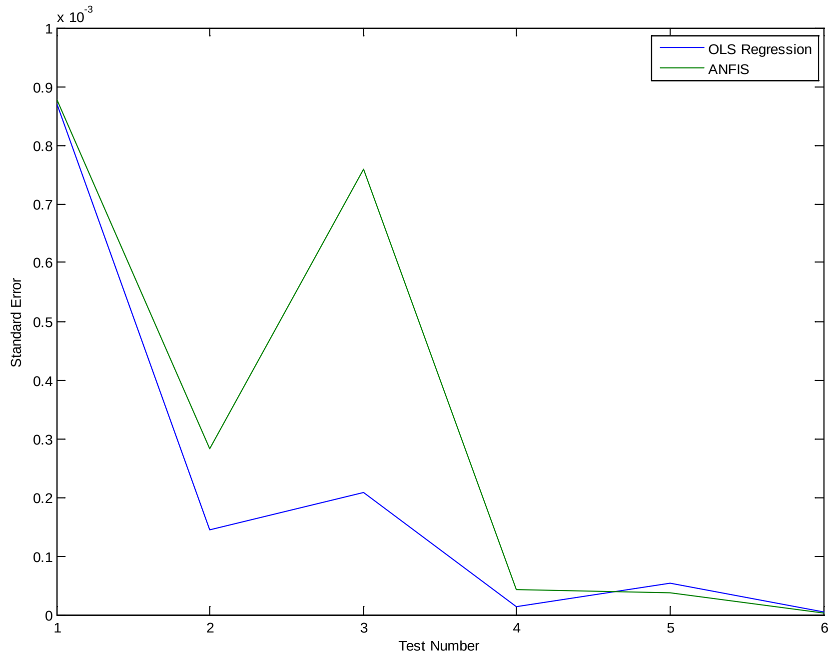


Figure 8-9 Standard error of the variance in each test

Mean Squared Error: This is calculated using the variance and the bias:

$$MSE(V) = Variance(V) + [Bias(V)]^2 \qquad 8.4$$

MSE is also following the same pattern as the standard error for both estimators in each of the experiments as seen in Figure 8-10.

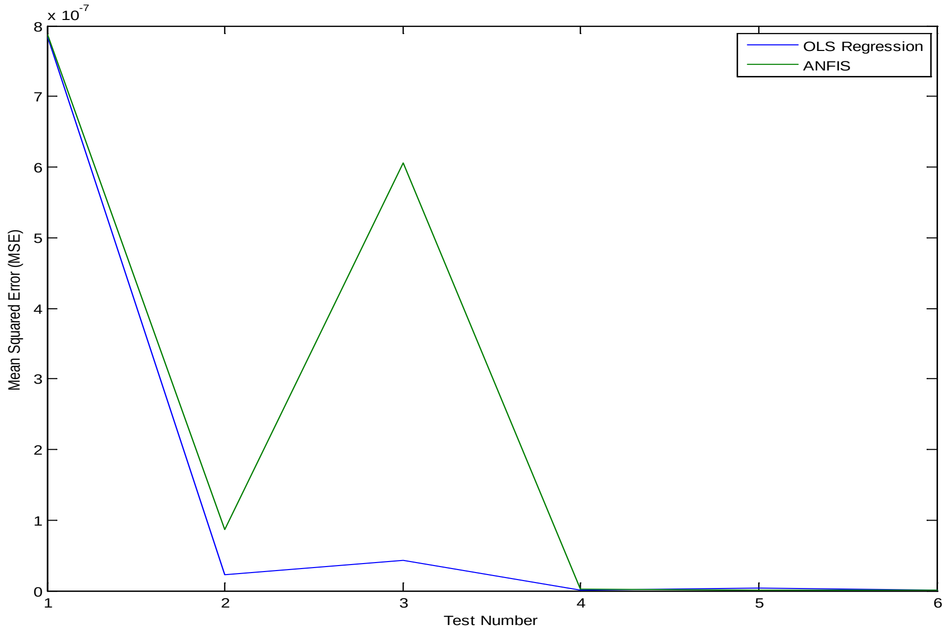


Figure 8-10 Mean squared error of the variance in each test

Bias: It gives the average error produced by the estimator; this means that it calculates the difference between the mean of the bootstrap estimations and the variance of the initial sample for each experiment:

$$Bias(V) = \overline{\hat{V}}^{b} - \hat{V} \qquad 8.5$$

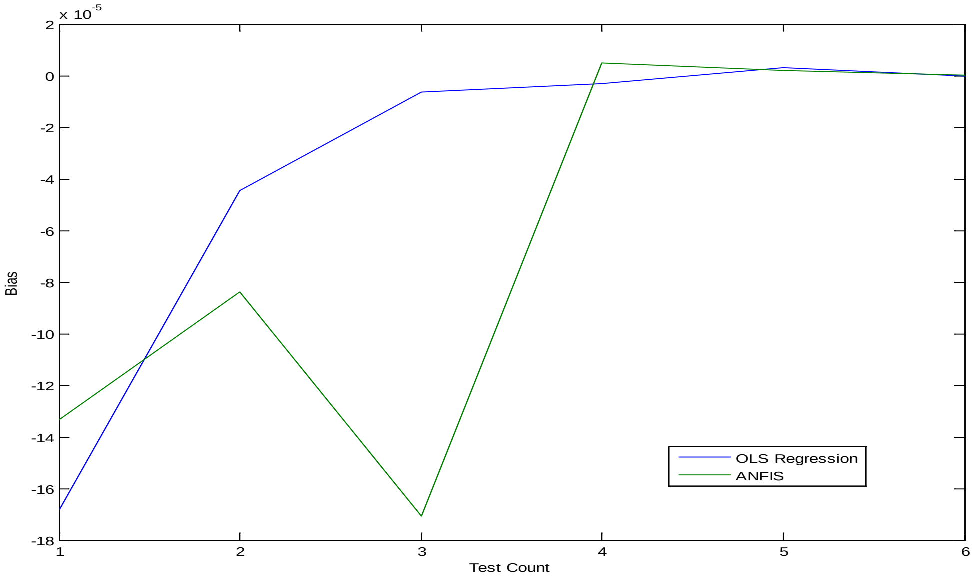


Figure 8-11 Bias of each of the estimators in each test

Figure 8-11 is a representation of the bias of each estimator in the experiments. The bias also gets closer to 0 as the sample size increases. Although bias is nearly 0 for both estimators in a large sample size, the small sample sizes respond better to OLS regression.

So it can be concluded that OLS regression is less sensitive to experimental conditions. Moreover in the experimental conditions more similar to the first survey OLS regression showed better results in terms of the errors it produces.

8.5 Discussions on the empirical and experimental results

In this chapter the author investigated empirical and experimental data to pursue the following objectives:

- Finding the most representative conceptual model; this model would contain the most representative independent variables and predict the impact index as the dependent variable.

- Finding the best estimation method; this means that the method which predicts the dependent variable by having the independent variables should be chosen. This method will also suggest the type of the effects of the independent variables on the dependent variable.

By achieving these objectives a decision can be made on whether EMP is a superior conceptual model to Jaques. We can also find out that independent variables are best predictors of what type of impact (self perception, manager assessment or average of both). The results of the empirical data showed that the best model is fitted on the EMP as the independent variables. It also showed that these are best predictor of the average of self-assessed and manager-assessed impact levels of the person on the job. ANFIS and OLS regression both proved to be good estimators of the impact index in the empirical data. However, the experimental results showed that OLS regression can be a more robust estimator and is less sensitive to the sample size and distribution of the data. The fact that OLS regression provides a better model than ANFIS can be due to several reasons as discussed below.

In previous research, ANFIS is shown to be a robust modelling technique especially in the presence of inexact data or unpredicted uncertainty (Malhotra & Malhotra, 2002). In fact, in many studies ANFIS proved to be a better predictor model than regression (Nurwaha & Wang, 2008; Kumanan et al., 2008). Other clinical studies have shown the superiority of fuzzy inference to logistic regression, multiple linear regression and partial least-square (Schwarzer et al. 2003; Buyukbingol et al., 2007; Aali et al. 2009; Ju and Ryu, 2006). Kumanan et al. (2008) believe that hybrid models such as ANFIS outperform individual models such as regression in terms of prediction and speed despite their computational complexity. However it is believed that one of the main advantages of using fuzzy inference is the incorporation of qualitative concepts and it may be utilised at its best in the presence of qualitative expert knowledge (Buyukbingol et al., 2007). Since the data used in modelling with ANFIS in this research are purely quantitative, this is believed to be the **first** reason for the results obtained in this research. **Secondly** inter-related inputs, nonlinear relationships in the model together with the lack of any other representative mathematical model can support the use of fuzzy logic (Tessem and Davidsen, 1994). De Kok et al. (1997) has also stated that for highly correlated input variables ANFIS works better than linear regression. This means that in the absence of such circumstances, use of fuzzy logic may not be beneficial which is the case in this research. **Thirdly**, Moreno (2009) pointed out that although ANFIS may have a more predictive power than linear regression, sample size is very important for ANFIS because of the number of parameters involved in building the model. The benefits of the big sample size for the ANFIS can evidently be seen in the experimental results. However in the empirical results this is not the case and could have damaged the usability of ANFIS.

Therefore to summarise the above, the superiority of OLS regression to ANFIS in this research can be due to several reasons:

1. Fuzzy systems work best when the qualitative expert knowledge on the variables and their relationships are used. This is not the case in this part of the study.
2. ANFIS is a better tool if we have interdependent inputs or inputs with non linear relationship, while in this research the inputs are not highly correlated and do not have non linear relationships.
3. ANFIS is not a great estimation method in small sample sizes because it should generate rules and membership function and small sample size limits its power in this sense.
4. OLS regression is a reliable prediction method which has been used for a variety of problems and works well with linear problem.

The results of this section also prove the validity of the 6^{th} hypothesis which believes that OLS regression is a more robust and generalisable modelling technique than fuzzy inference for modelling the impact levels. This is specifically true with regards to the sample size and the data obtained in the first survey. Therefore the most representative mathematical model for predicting one's impact level in a job can be formulated as:

*Impact (average of self and manager perceptions) = -0.326 + 0.234 * Enablers + 0.436 * Moderators + 0.585 * Performance*

8.5.1 Sensitivity analysis of the final regression model

Now that the use of the regression in a more generalised way has been ascertained, some complementary analyses on the variables in the model are to be done. Sensitivity of the estimated impact index to each of the independent variables (Enablers, Moderators and Performance) is to be checked in this section which is shown in Figure 8-12 to Figure 8-14. This will show how one's match to the requirements of a job in three criteria of enablers, moderators and performance affects the changes in the level of their impact on the job.

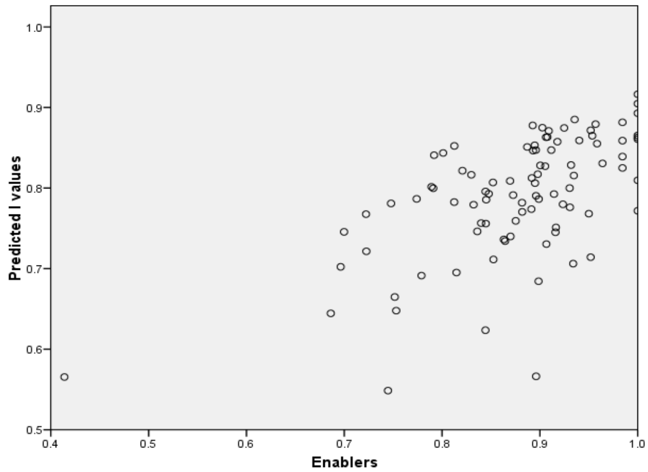


Figure 8-12 Sensitivity of Impact index to Enablers values

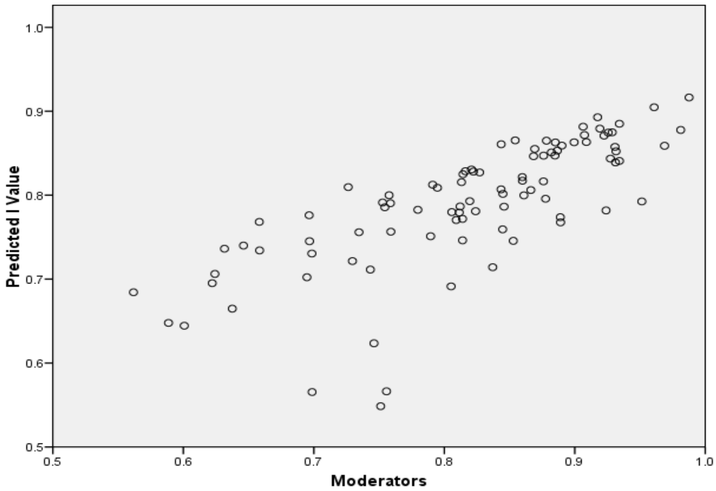


Figure 8-13 Sensitivity of Impact index to Moderators values

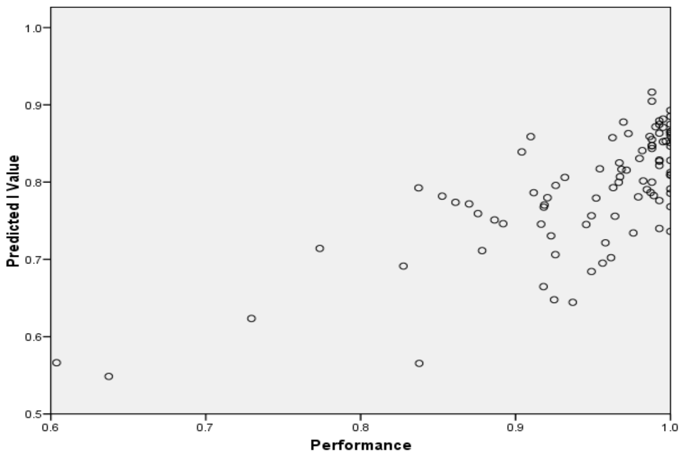


Figure 8-14 Sensitivity of Impact index to performance values

The above figures show the sensitivity of the impact index to all the components of the EMP model. Expectedly, Enablers, moderators and performance are all positively contributing to the impact values. This is clear from the variation in the impact index as any of these variables vary. For the sensitivity of impact to enablers and performance levels it can be seen that the concentration of cases are in the right end of the graph. This is because the cases had high values in these two variables. Even so increase in their levels increases the impact values.

8.6 Chapter conclusion

This chapter indented to choose the most representative conceptual and mathematical model(s) which can predict one's impact on a job. This has been done through investigating the different combination of independent variables (stemmed from two conceptual models), dependent variables (self and manager assessment of impact) and modelling them using two different estimation methods. The conceptual models and the estimation methods have been compared and contrasted using empirical and experimental data.

The results from these studies helped in finding the most representative conceptual model and the most robust estimation technique which can produce a good prediction of one's impact in a job. This means that the match levels of job requirements with the person's availabilities in three main criteria of enablers, moderators and performance can produce a reliable estimation of the person's impact on that given job as perceived by him and the manager. This is most reliably estimated using an OLS regression.

The findings of this chapter are to be tested using expert knowledge in Chapter 9. Moreover the combinatory estimation and use of impact and utilisation indices are to be discussed in more details in Chapter 9.

Chapter 9
Model Evaluation; Second Survey

This chapter is dedicated to the analysis of the data collected from the second survey. It essentially aims at modelling the impact index from an alternative perspective and use it to evaluate the results of modelling from the previous chapter. It also intends to finalise the overall picture of the applied capability assessment by estimating the utilisation index and showing an example of the joint use of impact and utilisation indices and their usefulness.

It is expected that experts' view on how different levels of match of people to job requirements in the three criteria proposed by EMP model can predict the level of impact they have on that job. That is why in this chapter a model(s) will be fitted to the data obtained from the experts which shows the dynamics of the inputs and outputs in assessing one's impact in a job.

Then the impact indices produced by the models derived from the data in the first survey and the second survey are compared. This will result in a final decision about the predictive ability of the mathematical and conceptual models which were studied.

As stated before, all the analyses so far were to be done for modelling the impact index and not the utilisation index. In order to complete the overall picture of the "applied capability assessment" there is a need to elaborate on the derivation of the utilisation index. This chapter will explain the reasons why the models produced for predicting the impact index can be extrapolated to find one's utilisation index. The overall dynamics of the impact and utilisation indices will then be studied. This is a crucial stage because the applied capability assessment will not be completed without both indices.

This chapter will be finished by giving an example of how the whole procedure of applied capability assessment (impact and utilisation indices) can be interpreted and used in the example scenario.

9.1 Confirmatory analysis plan

As stated before the second survey is done in order to examine the validity of the results from the first survey. Empirical data from the first survey have shown that people's match with job requirements in the three criteria proposed by EMP model is a better predictor of their impact on that given job (compared to the criteria proposed by Jaques). The experimental results have also shown the more robust estimation method for this prediction is the OLS regression. However it seems essential to further test the generalisability of the results using a different survey. The second survey's main aim is to examine the findings from the first survey. As it is said before, the survey asks experts to give their opinion on people's impact in a job while their matches to the requirements of the job are at different levels. Its main differences from the first survey is that

- It is not based on a specific job or environment or population.
- It does not aim at finding a profile for the immediate participants.
- It is only based on the EMP model and not the Jaques model.
- It asks for the expert's perception on the impact level in each scenario whether for self or for others.
- It seeks expert's view on the dynamics of the EMP model and the impact.

The details of the design of the second survey are presented in chapter 6. In this chapter initially different models are fitted to the findings of the second survey. The modelling is done using several different mathematical techniques. This will result in the possibility of comparing the models obtained from the first and second survey together with the actual observed data from the first survey. As a result not only the accuracy of the models for the second survey is tested but also the compatibility of the models from the first and second surveys can be analysed.

The organisation of these analyses is shown in Figure 9-1. The processes in blue boxes have been done in chapter 8 and the ones in pink are to be done in Chapter 9.

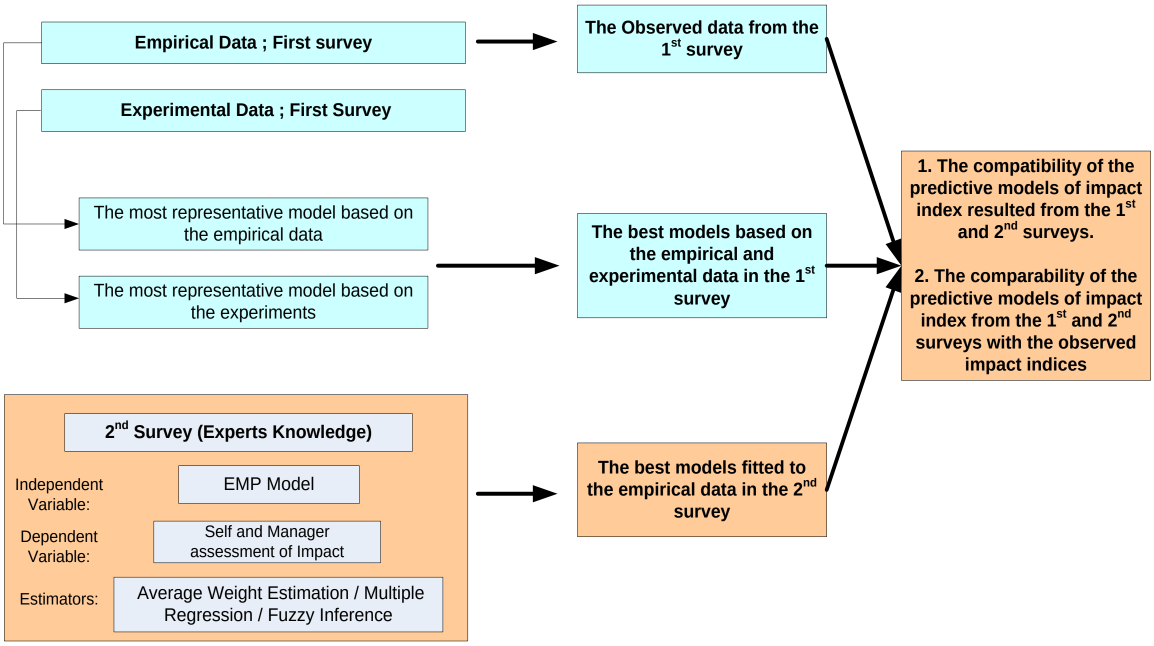


Figure 9-1 A picture of the modelling analyses done on chapter 8 and 9

Following the above, the final sections of this chapter are dedicated to estimation of utilisation and impact indices and their dynamics. Therefore subsequent to the first 6 hypotheses presented and proved in the previous chapter, the hypotheses and questions to be tested in this chapter are:

H7. Expert knowledge will confirm that the EMP model is an acceptable predictor of one's impact in a job within an environment.

H8. In using fuzzy inference to model Expert knowledge, Does Mamdani fuzzy modelling inference provides better estimations of the impact than ANFIS?

H9. Models resulted from experts' view on impact levels will be compatible with the observed data on the impact.

H10. Models obtained from the first and second survey will produce similar impact indices.

H11. Impact and Utilisation indices produce distinct yet complementary information about one's applied capability.

9.2 Modelling on the second survey

Before starting the modelling the expert's knowledge on impact, some basic information on the data are presented in this section. The details of the sample, its characteristics and some initial analysis on the usability of this survey were provided in Chapter 7. There were 41 experts participating in the study and the summary of their responses are presented in the table 9.1. The questionnaire asked them to give a value between 0 and 1 to what they perceive as one's impact in a given job in each of the scenarios. These scenarios are different on the combination of the level of match that person has with the job in each of the three criteria (E, M and P). In Chapter 6 a method was introduced on how the responses to the 27 scenarios were extracted while only a few numbers of questions were asked from the participants to avoid tiredness.

Table 9-1 Basic statics on the perceived impact level s given by the experts in each scenario

	Degree of Match with			Perceived Impact level		
	Enablers	**Moderators**	**Performance**	**Mean**	**Standard Deviation**	**Range**
1	High	High	High	0.946	0.105	0.4
2	High	High	Medium	0.864	0.111	0.448
3	High	High	Low	0.678	0.154	0.612
4	High	Medium	High	0.822	0.1	0.434
5	High	Medium	Medium	0.756	0.102	0.46
6	High	Medium	Low	0.543	0.119	0.484
7	High	Low	High	0.602	0.14	0.71
8	High	Low	Medium	0.505	0.117	0.465
9	High	Low	Low	0.403	0.106	0.421
10	Medium	High	High	0.84	0.117	0.48
11	Medium	High	Medium	0.774	0.129	0.627
12	Medium	High	Low	0.563	0.161	0.654
13	Medium	Medium	High	0.731	0.111	0.518
14	Medium	Medium	Medium	0.6	0.113	0.535
15	Medium	Medium	Low	0.48	0.129	0.545
16	Medium	Low	High	0.488	0.143	0.596
17	Medium	Low	Medium	0.439	0.118	0.386
18	Medium	Low	Low	0.291	0.118	0.474
19	Medium	High	High	0.637	0.169	0.775
20	Low	High	Medium	0.546	0.176	0.691
21	Low	High	Low	0.446	0.182	0.678
22	Low	Medium	High	0.508	0.161	0.671
23	Low	Medium	Medium	0.461	0.147	0.498
24	Low	Medium	Low	0.311	0.154	0.621
25	Low	Low	High	0.376	0.162	0.722
26	Low	Low	Medium	0.279	0.144	0.59
27	Low	Low	Low	0.201	0.116	0.4

It is important to note here that the order and numbering of the scenarios here onwards are different from the ones provided in chapter 6. This is firstly to ascertain that the order or number of the scenario does not affect the logic used. Secondly the order of scenarios in this chapter is based on the criteria and not on the level of match; therefore the order is changed to satisfy this logic. The details of each scenario, the mean, the range and the standard deviation of the given impact index for each scenario by all the experts are given in Table 9-2. For instance, in the fourth scenario where the person owns a high level of match with the job requirements in enablers and performance and a medium level of match in moderators, the average of the given impact indices by the experts for the person on the job is 0.822 (out of 1) with a standard deviation of 0.1 and the range of 0.434.

These 27 scenarios in Section 9.1 are extracted from the logic described in Chapter 6. In Chapter 7 the error produced from the logic has also been tested and proved to be negligible. The next three sections explain the main attempts on finding the best impact index estimation method using the expert knowledge based on the data obtained in the second survey.

In terms of the estimation techniques used for modelling purposes for this survey, the conclusions in chapter 5 on the effectiveness of OLS regression and Fuzzy Modelling is used here. The type of data obtained in the second survey is scale which makes OLS regression the first choice in the modelling. Adaptive Neuro Fuzyy Inference (ANFIS) has also been used for the modelling purposes as it has the ability to capture underlying nonlinear interactions within the variables. The existence of some elements of qualitative information in the questionnaire design has made Mamdani Fuzzy modelling another alternative because of its ability to model the qualitative expert knowledge. The next three sections will look at the produced model using the above techniques. However before proceeding to these models some basic analyses on the data resulted in a simple modelling which will be discussed in Section 9.2.1.

9.2.1 Average weight estimation

As seen in appendix G in the data obtained from the second survey two series of information are collected from the respondents:

- Their perception of the impact of an individual in any of the scenarios.
- The weight given to each of the criteria (E, M and P) in estimating the impact.

Their perceptions on the impact on each scenario showed a good correlation. This has been tested using reliability tests. Table 9-2 provide the information on the agreement of the 41 raters on each of the 27 scenarios. As it is evident in the table the correlation of the 41 respondents on the 27 items is high (α=0.993). The F test results have also confirmed that this correlation is significant.

Table 9-2 Intra-class correlation between the experts on the given impact levels

	Intra-class Correlation	*95% Confidence Interval*	
		Low Band	*High Band*
Single Measures	0.781	0.686	0.871
Average Measures	0.993	0.989	0.996

Number of cases = 27, F test with True Value 0 = 147.03 , df1=26, df2=1040, sig=.000

The same analysis has been done on the weights given to the three criteria (enablers, moderators and performance) by the 41 respondents. Table 9-3 shows the result of this analysis and the fact that the respondents were in high agreement in the weights they gave to each of the criteria. Based on intra-class correlation levels and F test value and its significance, the agreement is less than their agreement on the impact index. This can be due to the fewer number of items (3) in the second test compared to the first test (27).

Table 9-3 Intra-class correlation between the experts on the given weights for each criterion

	Intra-class Correlation	95% Confidence Interval Low Band	High Band
Single Measures	0.108	0.130	0.851
Average Measures	0.832	0.352	0.996

Number of cases = 3, F test with True Value 0 = 5.962 , df1=2, df2=80, sig=.004

The results of this analysis suggest that it is logical to use the average weights given to each criterion as the overall weight of that criterion in estimating the impact level. This means that an equation for calculating the impact index using the averages can be written as:

$$Impact = 0.35 * E + 0.38 * M + 0.27 * P$$

Where 0.35, 0.38 and 0.27 are respectively the average weights given to E, M and P by the respondents. This is the most simplistic interpretation of the results obtained in the second survey. This is because it ignores the impact values given to each scenario and it only relies on the weights given to the criteria. In the next sections other modelling techniques will be used which will also use the responses to each of the scenarios by the participants.

9.2.2 OLS regression

OLS regression has been used to find an equation in estimation of the impact index from the three main criteria, having the information on the 27 scenarios. Use of the OLS regression for the data requires a minor change into the data format.

The Low, Medium, High levels are translated into continuous variables. This means as stated in the questionnaire having a low match level in any of the criteria is equivalent of a uniformly random value between 0 and 0.33, Medium levels are uniformly random values between 0.33 and 0.66 and High level would be uniformly random values between 0.66 and 1. This translation of categorical variables into continuous ones is because the data for the E, M and P are defined to be continuous data and a model based on categorical data would be of no use. It is notable that the original data collection for the second survey could have not been done using continuous variables. This is because the questions and the required data needed to be formatted in some way which results in concise and communicable questions to get the most reliable data from the respondents. Therefore using the 3 levels of match for each of the criterion was used.

So for each response the Low, Medium, High levels were translated into a random data with the distribution and the range stated above. The 41 respondents each provided information on 27 different scenarios; this means that each person has given a value for the perceived impact in 27 different combinations of the match levels of the person with the requirements of a job in three criteria. This makes a total of 1107 (27x41) cases to be used for the OLS regression analysis. The results of the regression analysis are provided in the Table 9-4.

Based on the findings in Table 9-4 the independent variables explain 56% of the variations in the dependent variable. Table 9-4 also shows the coefficients for the model and it shows that all the independent variables are significant in estimating the dependent variable. It is also evident that the coefficients estimated here are very similar to the average values obtained in the previous section. However the difference here is that the regression analysis provided a constant term for the equation. Although the constant is not as significant predictor of the impact as the other variables, it is still significant enough to be included.

Table 9-4 OLS regression results for the second survey

	Dependent variables	*Impact*	
Independent variables		Coefficient (*p*-value)	
Intercept		0.042 (0.004)	***
Enablers		0.353 (0.000)	***
Moderators		0.399 (0.000)	***
Performance		0.308 (0.000)	***
n		1,107	
R^2		0.563	

***p < 0.01, **p < 0.05

The OLS regression results show that the match level of the person with the requirements of a job in the three criteria can explain more than half of the variations in the person’s impact on that job. Moreover an increase in the level of match in each of these criteria will increase the impact level. These data has also been modelled using fuzzy logic in the next section.

9.2.3 Fuzzy Modelling

Fuzzy modelling is to be used as the alternative modelling technique to fit an estimation method to the observed data in the second survey. As stated in chapter 6, fuzzy modelling is done using an inference from a set of data. This inference can be done by the user by defining membership functions for the variables or by using the adaptive neuro fuzzy inference directly by the software. The difference is that in the first one the outputs are defined by the user as membership functions; however in the second one using direct inference by the software the output functions are either constant or a linear combination of the inputs. The next two sections describe the above two modelling techniques and their results.

9.2.3.1. Mamdani

In modelling using Mamdani technique, input membership functions, output membership functions, rules, implication method, aggregation method and defuzzification method are to be set for the model. The details of the logic used in the Mamdani setting can be found in Section 5.2.2.

Inputs: The three inputs of this model, each are defined to be in three different levels of match (Low, Medium, and High). The membership function to the Low, medium and High levels is defined in Figure 9-2.

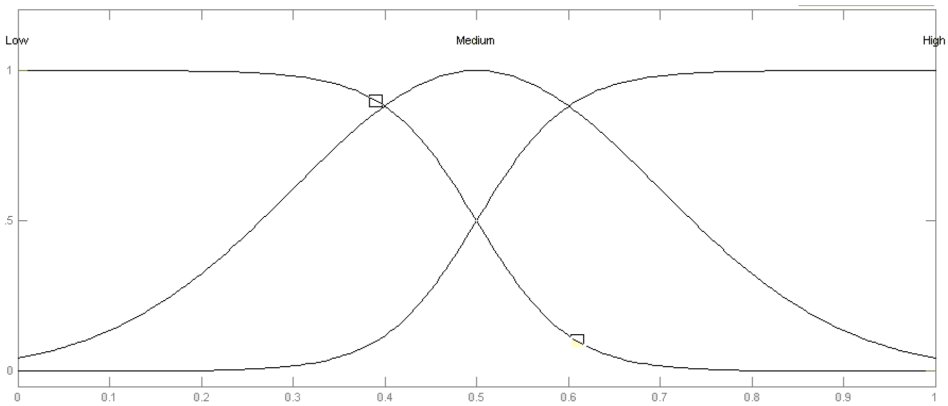


Figure 9-2 Membership functions defined for the inputs

The horizontal axis in the Figure 9-2 is the absolute value for the input variable (match with E, M or P) and the vertical axis is a membership value. For instance for an E value of 0.2, the membership to the low category is 1, the membership to the high category is 0 and the membership to the medium category is 0.35. This means that in case someone's match with the enablers in a job is 0.2, this is 100% low and 0% high and 35% medium. The membership functions are chosen to be Gaussian and the position of the curves are based on the values defined for the low, medium and high ranges (Low 0-0.33; Medium 0.33-0.66 and High 0.66-1).

Rules: Rules are the conditional statements which relate the inputs to the outputs. In our modelling there are three inputs each with three different membership functions. This means that 27 rules need to be defined to relate all the input combinations to the output space. This will become clearer as the output membership functions are explained.

Outputs: The distribution of the given impact index in each of the scenarios by the 41 cases are used as the output membership functions. The Figure 9-3 shows all the 27 output membership functions for this model. This means that for instance in the 4th scenario where enablers and performance are in high level and moderator is in the medium level, the distribution of the impact levels given by the respondents looks like the 4th distribution in Figure 9-3. This is based on the data obtained from the 41 respondents. The distributions are again chosen to be Gaussian for all the scenarios.

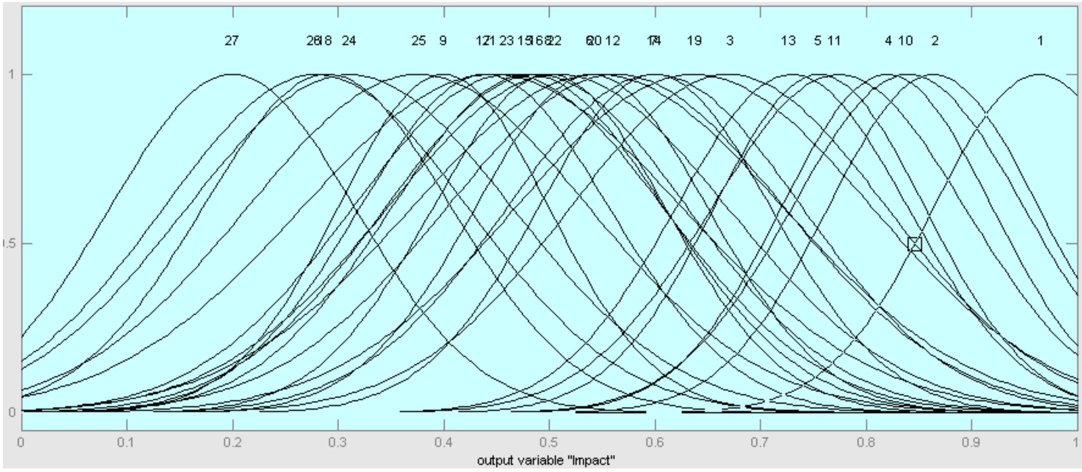


Figure 9-3 Membership functions for the output

Fuzzy operators, Implication, aggregation and defuzzification methods: Fuzzy operator is defined to be “And” since the statement used for asking the questions from the respondents have used “and”. The implication method to be used is the “prod” which scales the output of each rule based on the inputs given to it. The aggregation method is to be “sum” which is the sum of each rule’s output. The defuzzification method is the “Centroid” which gives the centre of the produced area by the aggregation method. These are some of the basic default settings in the fuzzy inference in MATLAB. What is more, in this example changing of some of these settings had a minimal effect on the outcome of the model. Therefore these default settings are used for the modelling purposes.

The resulted model: As mentioned in chapter 8, fuzzy inferences are not providing a mathematical formulation of the model and the exact underlying operations can not be detected. Figure 9.4 represents the resulting surface obtained from fitting a fuzzy Mamdani model into the data from the second survey. This surface shows how the changes in the match levels of Enablers and Performance with the requirement of a job affect the impact of the person on the job. The surface clearly shows that the impact index increases as the levels of E and P increase. It also indicates that the trend of this increase is quite similar in both of the variables.

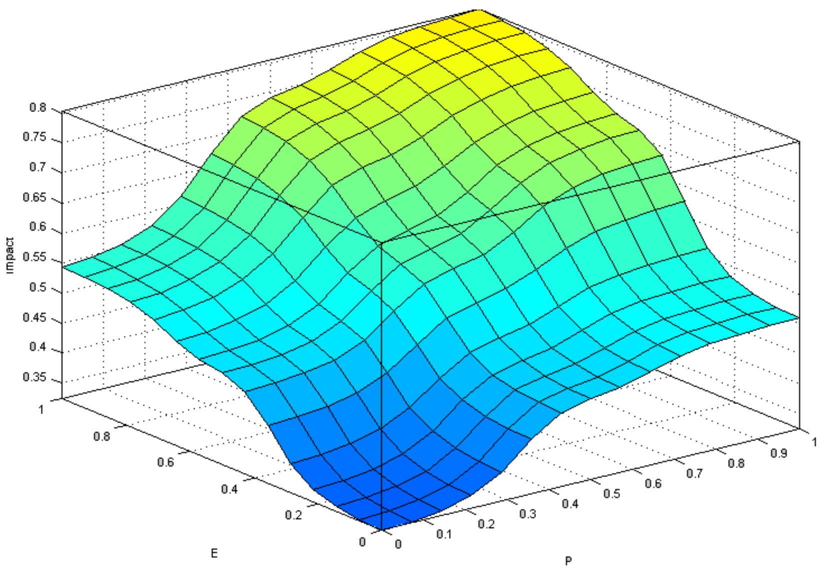


Figure 9-4 A representation of Impact, Enablers and Performance

The other two plots (E, M and Impact; M, P and Impact) are not presented being quite similar to Figure 9-4. This can be due to the fact that all the independent variables are acting in a similar way as far as their predictive ability for the impact index is concerned from experts' point of view. This is a similar result to what have been found out in the average weight estimation and OLS regression methods. A final estimation method using fuzzy inference will be shown in the next section.

9.2.3.2. ANFIS

An alternative way of using fuzzy inference in obtaining a model fitted to a set of data is to use Neuro Fuzzy Inference. The logic behind this method has been explained in details in chapter 5. Moreover, the data obtained in the first survey has also been modelled using ANFIS as seen in Chapter 8.

In order to use ANFIS as modelling technique the input variables and the output variable are to be defined and fed to the inference system. In the second survey, as discussed before, 41 respondents have given a perceived impact level for 27 different scenarios which produces 1107 data points. The dataset used for the ANFIS modelling is the same as the dataset used in the OLS regression section in this chapter. The membership functions for the variable defined to be 3 Gaussian functions. The data is trained for 50 epochs to find the best tuned membership functions for the variables. The training error plot is shown in Figure 9-5. This figure shows that around the 33rd training of the data the most fit membership functions to the data was identified which resulted in a Root Mean Squared Error of 0.1421.

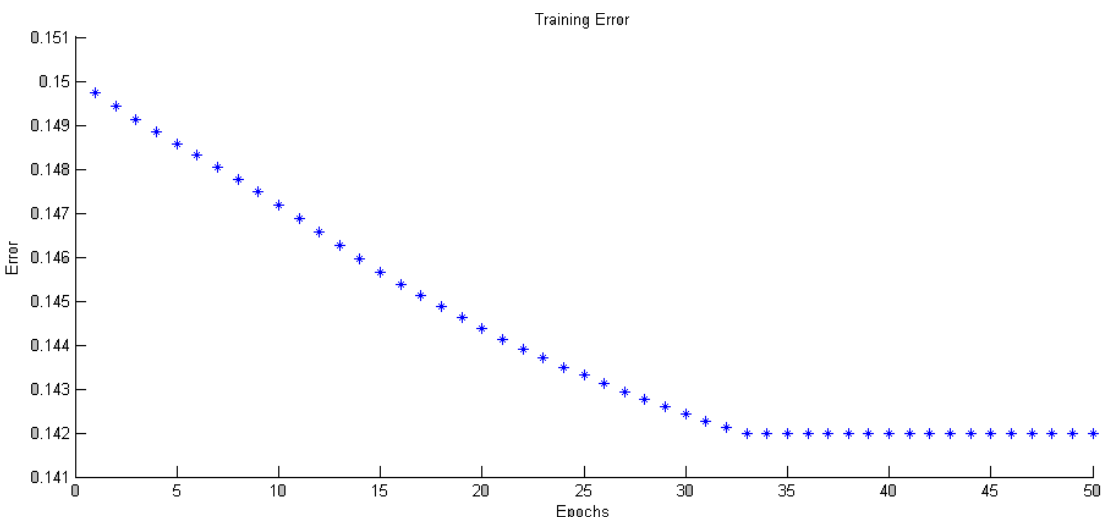


Figure 9-5 Training error of ANFIS for the second survey

After training the data the fittest estimation model was identified. Figure 9-6 shows one of the resulted surfaces of this model. It is clear that an increase in the levels of match in enablers and performance will increase the impact index given to the person. Similar plots have been obtained from the other combination of the inputs and their results on the impact levels.

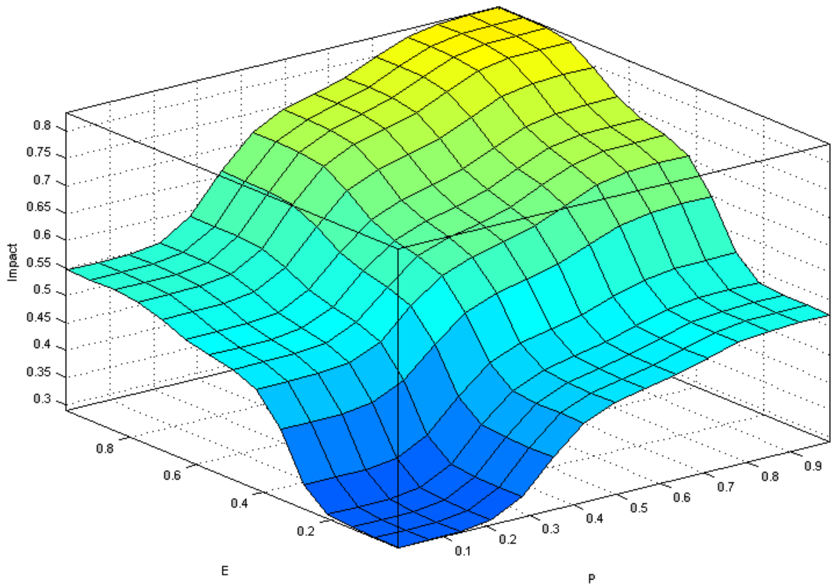


Figure 9-6 A representation of Impact, Enablers and Performance resulted from the ANFIS modelling on the second survey

Interestingly, the obtained surfaces from this estimation method are very similar to the results obtained from other modelling techniques. The next section will compare all the modelling techniques used for estimation of the impact values based on the data obtained in the second survey. This will result in decisions on the most representative model of the expert knowledge.

9.2.4 Analysis of fitted models

Four estimation methods have been used to fit a model to the data obtained in the second survey. These were all attempts to find the best estimation method fitted to experts' views on their perception of people's impact on a job while knowing their level of match to the requirements in three main criteria of enablers, moderators and performance.

Looking at the estimation model obtained from the average weights method, the coefficients obtained by the OLS regression, and the surfaces given by fuzzy inferences, it is clear that the three independent variables in the models are all having a positive relationship with the dependent variable. This means that according to experts not only people's match in the requirements of a job in the three main criteria proposed by the EMP model can predict their impact, but also the increase in this match level results in the increase in the impact level. All the modelling techniques used for this survey showed that enablers, moderators and performance have not much different power on the changes they create on the impact. This is evident from their average weight in the first model, coefficients in the regression model and also their similar patterns in the plots resulted from fuzzy modelling.

Considering the sample size used in this survey and the similar and significance results obtained from all the modelling methods, it is safe to say that this study confirms the validity of the use of EMP model in estimating impact index (proof for hypothesis 7). In the next section the most representative of the above four models is to be identified using the real data obtained from survey one.

9.3 Testing the models obtained from second survey

In order to check whether the resulted models from the expert knowledge comply with the observed real data, the data obtained from the cases in the first survey was fed into these four models and the predicted values of impact were compared to the observed values. The Root Mean Squared Error of each of the models is then calculated. The formulation for this error estimate is given in Chapter 8. Table 9.5 reports on the RMSEs resulted from using each of the estimation techniques in finding the impact level for the participants in the first survey. It is evident in the table 9.5 that using the average of the weights and the Mamdani fuzzy inference provide lower errors compared to the other two methods.

Table 9-5 Root mean squared error of the models done on the 2nd survey

Estimation Methods	*Root Mean Squared Error (RMSE)*
Average Weight Estimation	*0.0958*
OLS Regression	*0.1848*
Fuzzy Mamdani	*0.1004*
Adaptive Neuro Fuzzy Inference	*0.1731*

Independent Variables: Enablers, Moderators, Performance; Dependent Variable: Impact on the job. Models were created using expert knwoledge and their RMSE was derived using observed data in the first survey.

In addition to Table 9-5, it is worthwhile to look at Figure 9-7 which shows the observed values from the first survey and the predicted values for each case using the four above models presented in this chapter. It can be seen from the graph that all the models produced in this chapter are estimating the impact index with the same trend as the observed data. It is again clear that the Mamdani inference and average weights provide more accurate estimations than Anfis and the OLS regression.

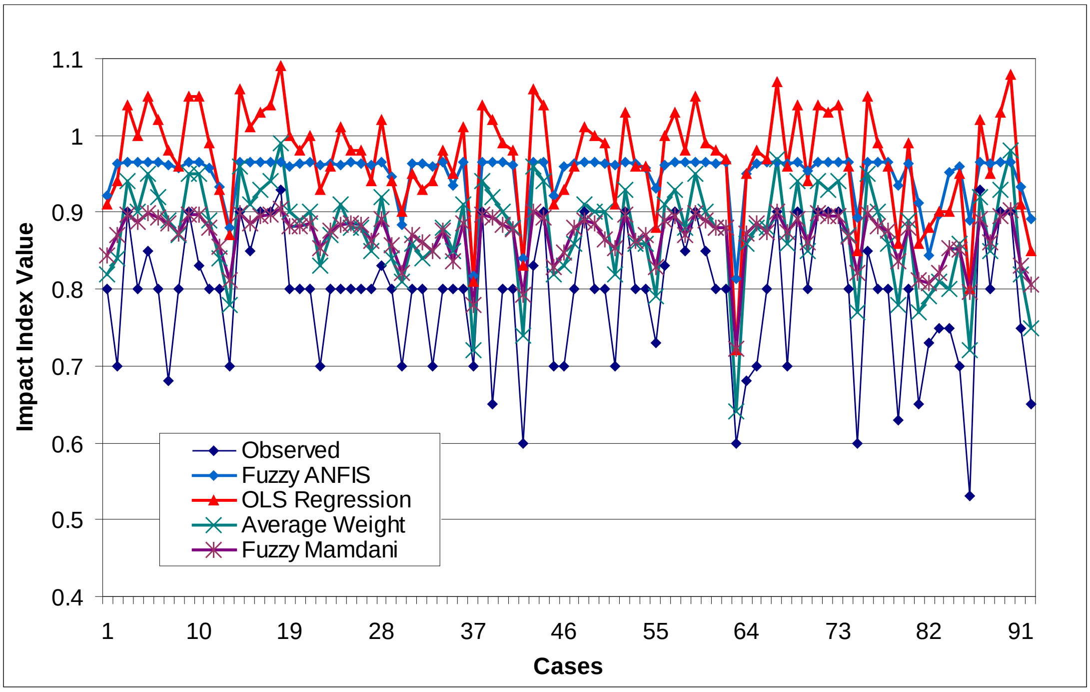


Figure 9-7 Observed Impact levels and predicted impact levels using different models derived from expert knowledge

In fact the estimated impact values produced by ANFIS are quite similar to each other for different cases, and they are not very close to the observed values of impact. This can be due to the fact that as stated in the previous chapter, ANFIS has the disadvantage of over-fitting the model to the exact data set it uses for modelling. Therefore it causes issues with the generalisability of the models and use of the resulted model for another set of data. Furthermore, in defining the output space in ANFIS (impact in this example), only constant values are used as representations of the outcome of each rule. So the outcomes of the one rule for the cases with similar membership functions to the input variables are identical. Since the observed values for enablers, moderators and performance in the first survey are mostly having a high match with the requirements, the estimated impact given for all the cases are quite similar. Now, if this result is compared to the estimations produced by the Fuzzy Mamdani modelling the advantage of the use of membership functions based on the distribution of the impact levels (which is what have been done in Fuzzy Mamdani modelling) becomes clearer.

In terms of the estimations produced by the OLS regression, although the trend is similar to the observed data, the values of the estimations are always higher than the observed values. This can be due to the fact that the sum of the coefficients of the model is slightly higher than unity. Therefore, high values of the independent variables cause high values of impact estimation and in cases the levels are even more than 1. If these values are compared to the values obtained from the model with the average weights of the variables, it can be seen that the average weight model follows the exact same trend but with a lower offset from the observed impact levels. Therefore Average weight model is a better estimator of the impact for the data in the first survey.

Overall from the results of the second survey, it can be concluded that:

- E, M, and P are valid estimators of one's impact in a job (This approves the 7th hypothesis in this chapter).
- Mamdani and Average weight are better modelling techniques in relating the EMP and the impact based on the expert knowledge (This approves the 8th hypothesis).
- The resultant modelling techniques from the second survey have been used for the data in the first survey and the estimated values were comparable to the observed values (This approves the 9th hypothesis).

The results of comparison of the first and second survey shows that the models obtained for the first survey is a representative model for estimating one's impact in a job. This has been tested on Chapters 8 and 9. Looking at the estimation of impact levels produced by models based on second survey (Figure 9-7) and the models based on the first survey (Figure 8-7) and the observed impact levels shows the models from the first and second survey produce similar estimates of impact levels.

For the purpose of comparison; the correlation of the observed values of impact in first survey, estimates of impact by the final regression model presented in Chapter 8 and estimates of impact using the average weight method presented in this chapter are presented in Table 9-6.

Table 9-6 Correlation of the observed and estimated values of impact

		Observed Impact	*Estimated Impact; Regression model in 1st survey*	*Estimated Impact; Average weight model in 2nd survey*
	Observed Impact	1()		
Spearman ρ (sig 2 tailed)	*Estimated Impact; Regression model in 1st survey*	0.253* (0.015)	1()	
	Estimated Impact; Average weight model in 2nd survey	0.837** (0.000)	0.208* (0.047)	1()

Number of cases=91,
* Correlation is significant at the 0.05 level (2-tailed).
** Correlation is significant at the 0.01 level (2-tailed).

It can be seen that the produced impact indices from the estimation methods are significantly correlated to the observed values and also to each other. This will approve the 10th hypothesis of this research.

This means that The EMP model can be used as a reliable estimator of the impact of one in a job. Moreover the use of regression model proposed in

Chapter 8 as the estimator of impact is once more approved by a confirmatory analysis in this chapter.

In the next section the generalisability of the modelling for the impact index are to be tested for the utilisation index; this is followed by the application of the resulted indices and their use.

9.4 Impact and Utilisation Indices

9.4.1 Estimation of Utilisation levels from Impact estimation models

The output of any estimation method is dependent on the modelling technique and the inputs. This section aims at explaining the reason why all the modelling so far has been done on one of the indices (Impact index) and not both (Impact and Utilisation).

Considering the two indices and the underlying concept, it is not easy for the participants to think of both concepts at the same time and give a value for both of them. This is because in one index the respondent are required to think of the job and fitness of themselves to the job and in the next they are asked to think of themselves when they respond to the question. This is based on the logic behind the definition of the indices which were explained in more details earlier in Section 4.1. In other words, expectedly people may arbitrarily think of one and not both. This has been tested in a pilot study done for this purpose discussed in Section 4.1.

Therefore it has been decided to do the data collection and modelling for one of the indices and to use the models for the other. This is because:

1. From the conceptual point of view, the difference between the indices is not in the criteria to assess them or their importance; they are different in the view points of who is the subject of the problem (the job or the person).

2. From respondents' point of view, it is unlikely that one person have different opinions in terms of the criteria or their importance when they respond to the two questions. Now considering the fact that we are defining these indices for a job and a person (The same job and the same person in any one instance) if different criteria or weights have been used this meant that in deciding about one's fit to a task, the two models are seeing the effect of each criteria in the fitting problem differently. Therefore, the same person and the same job would be treated differently in answering one question which is the fitting problem. It should be borne in mind that the main difference between the indices is in their prioritisation of the person or the job and not in their view on the Enablers, Moderators and Performance.

3. From survey design point of view, asking two questions which to the participants can look similar may confuse the respondent and surrender the accuracy of the response.

Moreover having done the data analyses and modelling in Chapters 8 and 9, two other reason can be added to the above:

4. According to the results from the first survey, the models show very good fit to the collected data. This shows that the phenomenon under study has strong links with the models. If the resultant models were not as good their generalisability would be limited.

5. According to the results of the second survey, the models produced from the first survey are valid. This makes the inference from this model even more valid.

The above points are providing evidence on why the 11th hypothesis in this chapter on the distinct yet complementary nature of the indices can be confirmed. Therefore the decision to ask the respondents either about the impact or about their utilisation on the job seems logical. This is understandably a compromise between the amount of information we obtain and their accuracy.

Now in order to use the model prepared for estimating the impact index for estimating the utilisation one must consider several points. What characterise the impact estimation model are the criteria (independent variables), the coefficients and the estimation technique (OLS regression). What can potentially switch the output of the model from impact to utilisation is the values which are entered as the inputs of the models. Going back to the logic used in data processing in chapter 4, for the k^{th} person and the i^{th} criteria A'_{ki} is used as the input values for the Impact index and A''_{ki} are used as the inputs to calculate the Utilisation index. So for calculating the utilisation index the same regression model with the same coefficients is to be used.

In the data collected from the student sample in the first survey, using the above instruction, the estimated values for Utilisation and Impact indices using the final OLS regression model (details in Section 8.3.1.1) are depicted in Figure 9-8.

It is seen in Figure 9-8 that impact and utilisation indices are quite different for each of the individuals. This shows how the logic used in Chapter 4 to prepare the inputs for finding the impact and utilisation indices differentiates the values obtained for these two concepts.

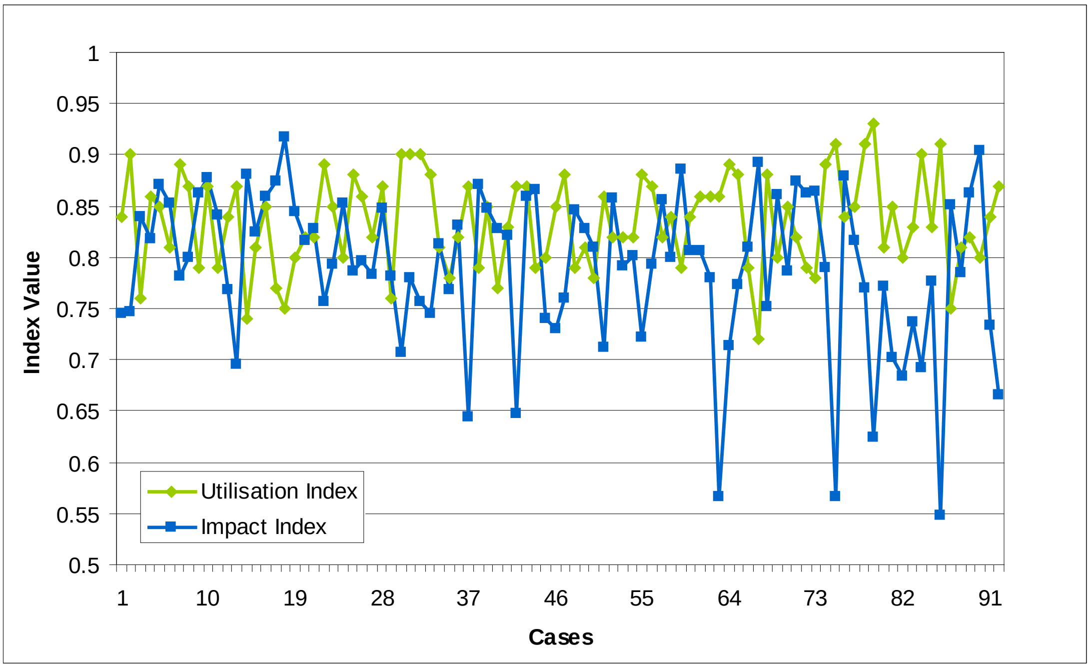


Figure 9-8 Predicted Impact and Utilisation index for the 1st survey

9.4.2 Dynamics of the Impact and Utilisation indices

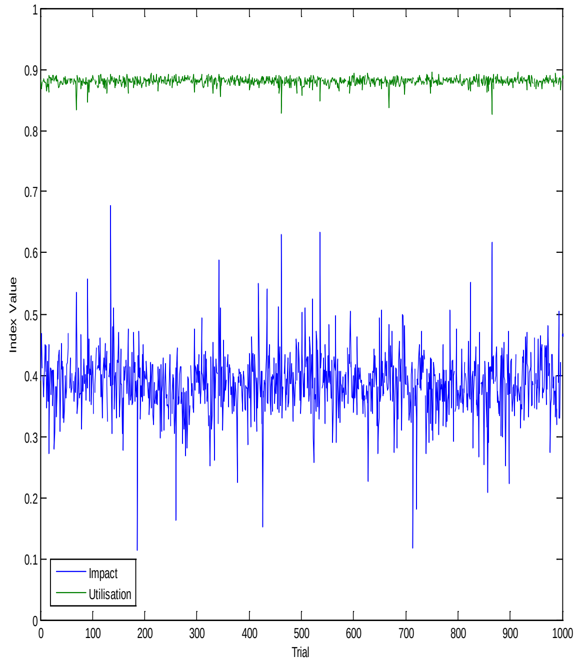
As a final analysis on the utilisation and impact indices, a simulation has been done to observe the dynamics of the two in three different experimental conditions. The experiments are designed in a way that a random job, with random number of requirements within each of the three main criteria and agents with random availabilities for those requirements are being tested and their impact and utilisation indices are extracted. What is constant in all the experiments is the use of the three criteria (E, M and P) and the OLS regression estimation model derived in Section 8.3.1.1. What specifically changes within the three experiments is the value of the level of the job requirements (three levels). It is useful to relook the algorithm used in chapter 4 to better understand the design of the experiment. The basic characteristics of the experiment are in Table 9-7.

Table 9-7 Design of the simulation for testing the dynamics of I and U indices

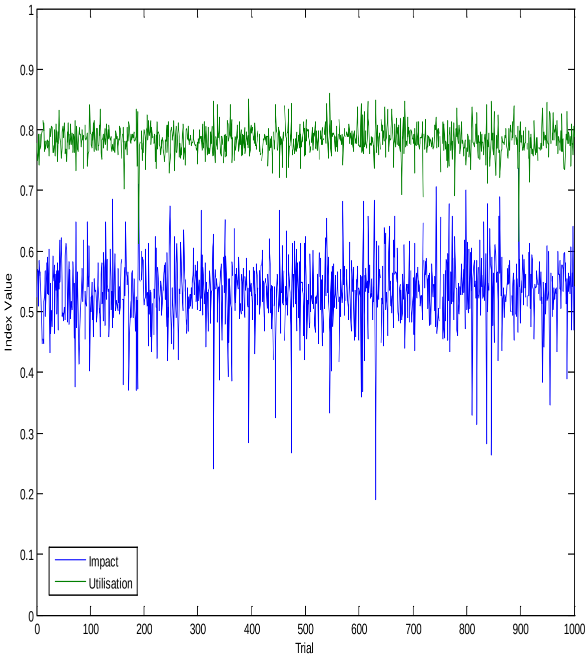
Constants within the three Experiment	
Criteria Used	*E, M, P*
Estimation method used for calculating U and I indices	*The OLS Regression equation from the 1st survey*
Number of required factors in each of the criteria	*Random number between 0-100*
Agent's availability in each of the factors	*Random value between 0-1*
Variation within the three Experiments	
Level of each of the requirements	*0.25 / 0.5 / 0.75*

For each of the three criteria (E, M and P) a random number of requirements for the example job are set. The levels of these requirements (X_{ij}) are set to be in one of the three main levels which correspond to high, medium and low requirement level. The weights of the requirements are not considered in this experiment. This is because the requirement levels are set to be the difference between the experiments and in case of assigning random weights to the requirements, the clarity of the distinction between the experiments will disappear (having two experimental conditions mixed). The availabilities of the agents in each of the requirements is also set to be a random number (A_{kij}). In order to use the estimation model the normalisation logic introduced in chapter 4 is applied to the A_{kij} s to convert them into A'_{ki} s and A''_{ki} s. The estimation of the impact and utilisation is then done using the final regression equation obtained in Chapter 8.

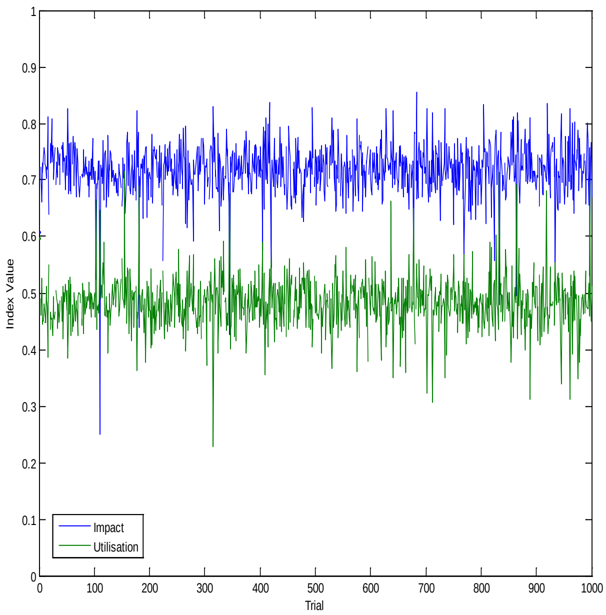
Therefore the results show the final value for the indices for completely random jobs and agent when the requirements of the job are set to be either Low (0.25), Medium (0.5) or High (0.75). Figure 9-9 (a-c) shows the estimated Impact and Utilisation levels in each scenario having random number of requirements and random availabilities for people. Looking at the Figure 9-9 , as expected when the requirements are high, agents would normally experience a very high utilisation of themselves; however the impact they would have on the job would be below average (0.5). This means that although they are almost fully utilising themselves in all the required aspects they are still not impacting the job. When the requirements of the job are on medium level, the difference between the two indices becomes less. However, on average people would still have a higher utilisation of themselves compared to the impact they could have on the job.



a) High level of requirements



b) Medium level of requirements



c) Low level of requirements

Figure 9-9 results for the dynamics of I and U indices

In the last scenario where the job requirements are low, it can be seen that mostly people will have high impact on the job but they would not utilise themselves in that job to a great extent. This is an expected situation to have. These results confirm that the used algorithm and model for estimating the impact and utilisation are logical and produce anticipated results. Therefore it can be concluded that the two indices are representing what they are designed to stand for and can be used in practice. They are assessing the persons' applied capability with two different viewpoints which are different yet complementary. This again confirms the hypothesis 11 in this chapter.

9.5 An example of the use of the indices

Going back to the initial idea of the applied capability assessment and its characteristics as described in Figure 3-8 in Chapter 3, the author is confident that the conceptual and mathematical modelling conducted throughout the research are conforming to the initial logic of the assessment.

In Chapter 8 and 9 several different modelling techniques were used to examine the conceptual and mathematical characteristics of the applied capability assessment. In this section we aim to demonstrate how the resultant Impact and Utilisation indices can be used in practice.

Figure 9-10 shows the estimated Impact and Utilisation indices for each of the 91 cases in the first survey. This calculation was based on the EMP model and the OLS regression formulation which was presented in Section 8.3.1.1.

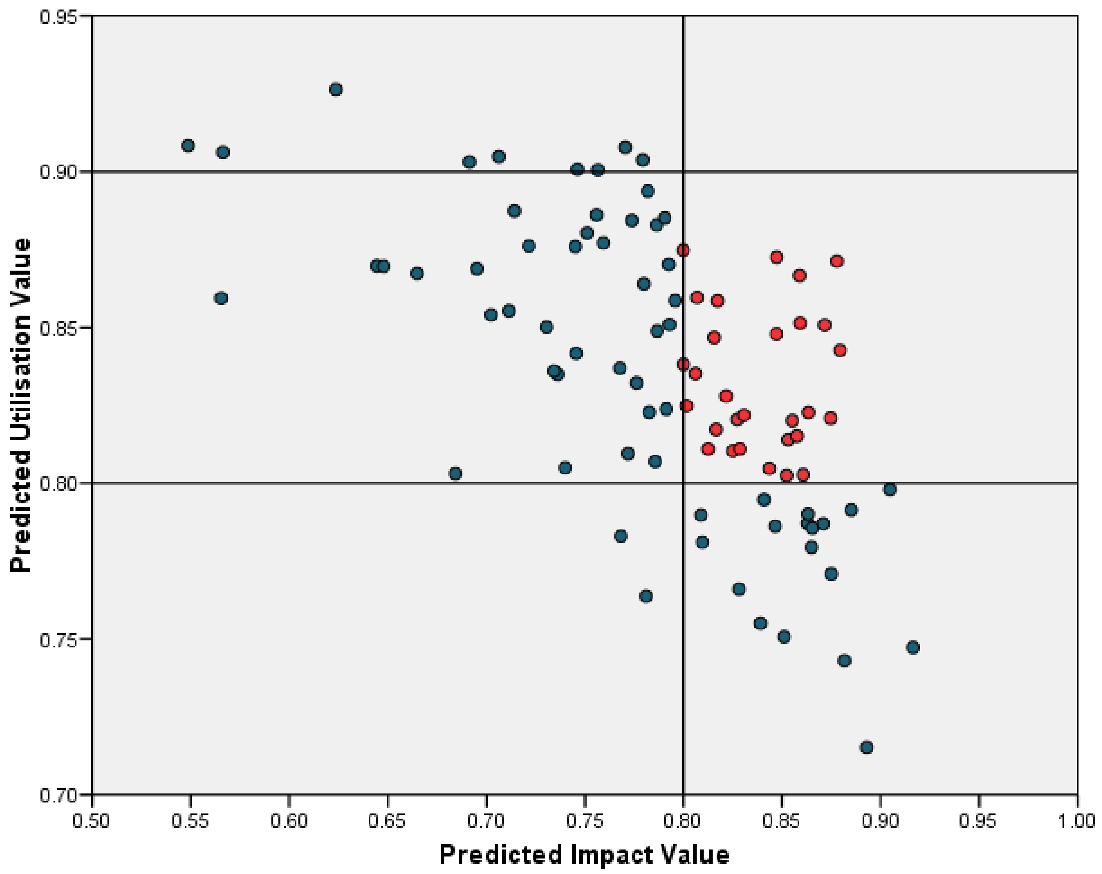


Figure 9-10 The Impact and Utilisation indices; possible uses

As it can be seen in the figure the spread of the impact index is in a bigger range compared to the utilisation index. This can be due to the fact that the requirements of the job and its environment were not low and although the agents are utilising themselves to a high extent, their impact is not as high. This has been also discussed in details in the previous section. Nevertheless, the homogeneity of the agents under study in terms of their abilities, values, personalities and previous performance makes them very close to each other in the final indices calculated for them. Now the indices should enable the decision maker to find the most appropriate people for this job based on the indices (I and U) resulted from applied capability assessment. The decision maker can put some minimums and maximums for the acceptable range of the indices.

Looking at

Figure 9-10 the acceptable level for the impact index was set to be 0.8. This also happens to be the mean of this index among the agents. Moreover the utilisation below 0.8 is not acceptable to the decision maker. In addition, the person should not be over utilised, so a maximum for the utilisation was also set to be 0.9. Setting of these boundaries can be based on the organisational norms and should be reviewed as the success of the previously set boundaries is constantly monitored. This boundaries result in a number of agents being marked in the desirable space. These people are shown in red dots in the figure.

Now, it is assumed that the procedure is been done to select the best possible agent(s) for this job in this environment. As expected in the presence of a group which are homogenous and very much suited for the requirements of the job and environment the decision making is difficult. Therefore it is much recommended that the use of impact and utilisation indices should be complemented by other methods. Going back to the literature in chapter 3, the selection process was comprised of screening and evaluative stages (Phillips and Gully, 2009). The indices are helping in the screening process and finding proper candidates. It is suggested that a qualitative method to be used in the evaluative stage which will enhance the assessment and selection practice further. This is because the quantitative nature of the assessment could be mitigated. However the initial quantitative screening is beneficial in focusing on the people who fit in the criteria defined for the project. This fit is based on the applied capability assessment logic which considers the benefit of both the person and the job environment.

A number of concise points on the implications of each of the aspects of the model, strengths and limitations of the approach and the final instruction for its possible use will be presented in the next and final chapter of this thesis.

9.6 Chapter conclusion

This chapter firstly looked into a confirmatory study on the findings of the previous chapter. In order to use this confirmatory study it required to be mathematically modelled, therefore a number of estimation methods were tested to explore the most suitable method which can be fitted into the data obtained from this survey. Then the estimations produced from these selected models were compared with observed data and the estimations obtained from the models based on the first survey. The results showed that the model obtained from the second survey confirms the estimations resulted from the models on the first survey and are also compatible with observed data. This can verify the generalisability of the models to a great extent considering the differences in the design of the two studies.

Secondly this chapter have expanded the discussion on the calculation of impact and utilisation indices. The estimation of the utilisation index from estimation models used for deriving impact index and also the dynamics of both indices using random numbers were specifically studied. The chapter has also presented a simple example of how the indices can be used and interpreted. The findings of this chapter conclude this research as all its objectives have been met.

Chapter 10 will give a summary of the findings, limitations, future research and final instruction for the possible use of applied capability assessment.

Chapter 10
Conclusions and Implications

This Chapter intends to recap the main attributes and findings of this research. For this purpose, the research will be summarised and its uniqueness, the limitations in its approach and also its findings will be presented in this chapter. The chapter will then explain the implications of the findings and their practical use. The possibilities of furthering the current research to extend its usability will also be discussed in the final section of this chapter.

10.1 Research Summary

This research has looked into the concept of capability assessment in a variety of subjects. This review has revealed that in industry, economics, social science and management there are different views, factors and considerations in assessing companies , people, countries or in general systems' capabilities. However an analysis of these approaches has resulted in a framework for assessing applied capabilities for individuals which is particularly helpful for human resource practitioners in selection procedures. This approach, "Applied Capability Assessment", is conceptually inspired by the capability assessment literature in one hand and the notion of person-environment fit in human resource management on the other. Figure 10.1 depicts a simplified explanation of how this research can solve the decision making problem on a selection practice.

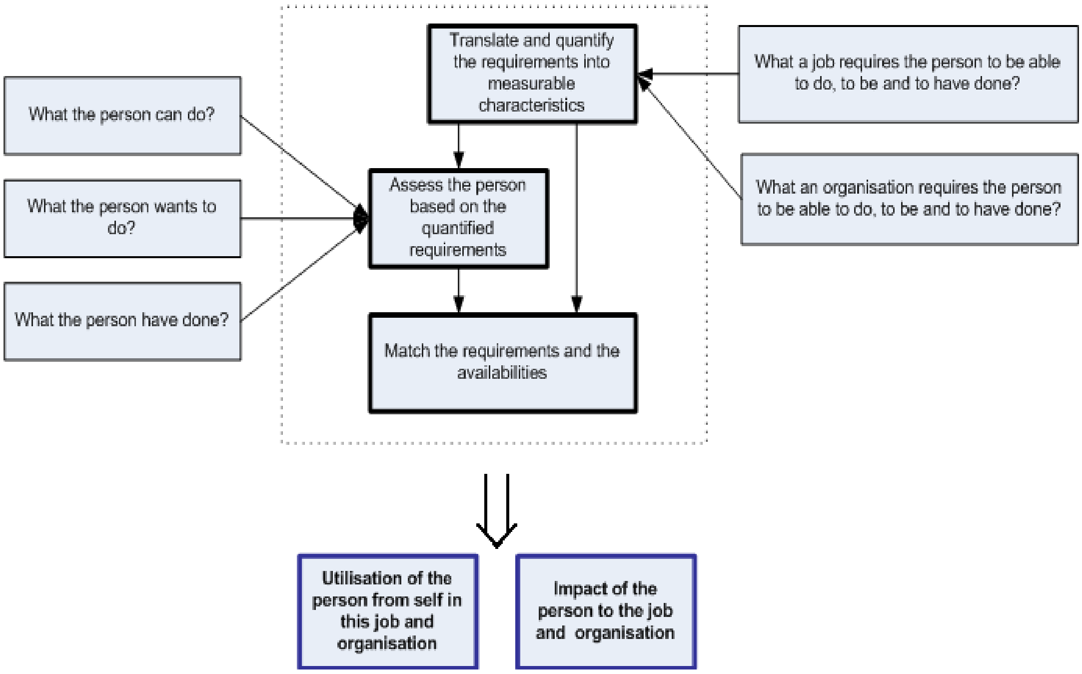


Figure 10-1 A picture of the conceptual background of the research

This conceptual infrastructure has led into development of an algorithm which is to be used for assessment of individuals for a certain job within a certain environment. In developing the algorithm a number of other conceptual considerations which have been emerged throughout the literature review were also included (e.g. job definition logic). Using this algorithm the assessment of one's applied capability for a specific job within a specific environment is done using a number of criteria which will then give out two indices.

This research then entered its next level which was focused on finding the most representative mathematical method to capture the applied capability assessment in estimation of its outcomes (indices). For this purpose, the possible mathematical techniques have been studied, a number of which have been selected. Two surveys have been conducted which were different in their setting, samples and designs. The selected mathematical techniques have been applied to the data from the surveys in order to uncover the estimation method which can give the most accurate prediction of the indices. The results of the mathematical modelling in both surveys were then compared. Analysis and comparison of the results showed that people's applied capability can be quantitatively assessed using the conceptual development of "Applied Capability Assessment". A number of other experimental data and also a different conceptual model have been used all of which further approved the reliability of the mathematical and conceptual robustness of "Applied Capability Assessment".

10.2 The uniqueness of the research

This research has approached an existing body of knowledge with a new look and has proposed a decision making mechanism for a prevalent problem. This section will highlight the unique features of this research. The power of this research is on its generalisable nature which permits applicability in different contexts and different levels (individual, organisational) and also its breadth and inclusiveness in terms of its used criteria and the resultant indices. Although the main focus of the surveys and analyses were on selecting the most suitable person for a job in a defined environment, the findings of this research can also be used in appraisal procedures.

The major distinctions of the "Applied Capability Assessment" from any other human resource selection or appraisal method are as follows:

1. **The three Criteria**: In assessing people applied capability, three main criteria of Enablers, Moderators and Performance have been set to be used when fitting person availabilities and job requirements. The three criteria are in fact assessing what a person can do, want to do and have already done in a job and environment similar to the one he/she is being assessed for. The three criteria which are used in the applied capability assessment are not only based on the literature surveyed in the second chapter but also have sound logical explanation and coherence.

2. The combined approach in job analysis: As discussed in the third chapter of this research, a new approach for job analysis have been proposed which has combined the existing approaches (Sanchez and Levine, 2009; Jaques, 1994). This approach is described in the third chapter and has been extensively used in other chapters. It is unique in several ways:

- Breaking down the jobs into tasks
- Setting the Requirements for the job and for the environment / organisation
- Combining the two sets of requirements
- Defining requirements which are translatable into personal attributes (abilities, values…)
- The requirements are associated with one of the three criteria at any time.

3. Data collection tools: One of the unique features of the findings of this research is that they are derived with using a reasonable number of tools. This means that compared to current practices the data collection does not require use of various tools which need a lot of resources to be conducted. However, tools which are to be used in assessing the candidates or the requirement levels for the job should:

- Be chosen based on the job and environment requirements
- Use variety of sources in data collection (self/others/tests)

4. Use of Great Eight Competency framework for assessing previous performance: It has been used to assess a task's and individual's requirements in terms of the expected task and contextual performance level. This is unique since in all the studied research, the use of task and contextual performance frameworks have been in previous performance assessment and not in setting future performance requirements for individuals (Kurz and

Bartram, 2002). Therefore a new use for an established framework has been developed.

5. The fitting algorithm: The algorithm which was proposed in chapter four for normalising the data for applied capability assessment is unique because :

- It considers the benefit of the assessor (organisation) and the assessed person by producing two complementary indices.
- It considers three criteria in fitting the person availabilities and job requirements.
- It links three of the main concepts in human resource selection: job analysis, candidate selection and person-environment fit. This link did not exist in the studied literature.

6. The estimation methods: OLS regression and Fuzzy Inference systems have never been compared for a human resource selection or assessment problem previously. The usability of the methods has also been tested using an experimental practice and a second survey using expert knowledge.

7. The resultant indices: Utilisation and Impact indices would represent the perfect candidate for the job (both in assessor's interest and the person's interest). These two indices are obtained from the same models using different inputs.

10.3 The contributions of the research

The main contributions of this research can be listed as the following:

1. Comparison of the definitions of capability in different subjects and extrapolation of a universal definition (the three criteria)

The second chapter of this thesis is dedicated to a thorough investigation of how do different fields of knowledge define and use capabilities. This conceptual analysis on the subject is furthered by reviewing the quantitative capability assessment which is done in the fifth chapter. One of the main contributions of this thesis is presenting this collective look on the subject.

2. Defining the three main criteria using which applied capability can be assessed

As a result of the studied literature on the applied capability, three criteria were identified which are believed to be the main decisive elements in assessing one's applied capability. These criteria were named Enablers, Moderators and Performance (EMP model); chapters two and four are dedicated to defining these three main criteria.

3. An algorithm to capture the applied capability using two different views.

The algorithm provided in chapter four is representative of the logic which was inspired from the reviewed literature and the gaps identified in the current practices. Especially the logic behind the normalisation process used in the algorithm is shown to be representative of the phenomenon under study. This was a new resolution to the selection problem.

4. Quantification and refusal of Jaques capability model using the proposed algorithm.

The model proposed by Jaques (1996) on defining applied capability is quantified using the algorithm provided in this thesis. The quantified model was then compared to the conceptual model inspired from the literature which showed that it can not provide an accurate estimate of the phenomenon under study as compared to the three criteria model (EMP model) quantitatively.

5. Estimation of the Impact and Utilisation indices using statistical models.

Impact and Utilisation indices which were introduced in this research are good indicators of one's applied capability in a job and a specific environment. This has been tested using a variety of empirical and experimental data. The indices are to be used in parallel yet they provide distinctive and useful information on the person's applied capability.

10.4 The limitations of the final models and the study

This research proved to produce reliable conceptual and mathematical models; however a number of limitations existed in conducting the research and in the application of its findings.

1. Limitations in conducting the research

- Sample sizes in both surveys were limited. This is because in the first survey the nature of the study necessitates a good knowledge of the job and the environment and this limited the researcher to focus on her specific field of expertise. What is more the amount of data required for each person required time and resource to be collected. In the second survey the respondents should have been approached individually which limited their numbers. Moreover they were required to have a level of managerial experience and have worked with a number of different people to b able to respond to the questionnaire.

- Source of data in many instances were self assessment (skills, performance, values). Self assessment in the context of this research was a reliable method; because being a voluntary study there was not much basis for participants to consciously over or underestimates themselves. Therefore the acquired mathematical models are based on accurate data and are valid to a good extent. However overuse of self assessment in a real selection practice is not recommended. The evaluations should use diverse methods of (self, peer, manager, tests) to guarantee the quality of the data used for applied capability assessment.

- The data analysis and statistical modelling could be improved with the use of limited dependent variable since the dependent variables in the models are bound to be in the range of 0-1. However this has not been done because the current models proved to be highly reliable. Therefore use of extra software which was not free to use was not feasible. This possibility can be further explored in future research.

2. Limitations in Application of the research findings

- The resultant model is probably best suited when the agents under study own a relatively high match with the requirements of the job and environment. This should be considered because the participants in the survey under study have such characteristics. Even though the results from the second survey confirmed the behaviour of the model, this provision should be considered.

- The model 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.

10.5 "Applied Capability Assessment" in Practice

10.5.1 Instructions for the use

It seems essential to recap on how the applied capability assessment approach can be used in practice in a typical selection procedure. The following steps are required to be taken in order to do the assessment:

1. **Job profiling:** This requires having experts with the knowledge of the job and organisational requirements and then interpreting them into measurable characteristics within the three criteria (EMP) considering the available tools. All the requirements should be assigned with a required level and an importance level (steps 1-5 of the algorithm).
2. **Agent profiling:** All the applicants are to be measured on the same characteristics as defined in the job profile using the same tools. Therefore there is a profile for each person which will have the availability level for each of the requirements for the person (step 6 of the algorithm).
3. **The normalisation process:** The information regarding the required levels and available levels obtained in the past few steps are to be fed into the normalisation process which prepares the required data to produce the impact and utilisation indices (steps 7 and 8 of the algorithm).
4. **Use of the proposed estimation:** The regression model which was verified in section 8.5 can be used to estimate agent's impact and utilisation on this job within this organisation. Having set acceptable levels of impact and utilisation, the decision maker can decide on whether or not the agents are fit enough in this occasion.

5. **Final decision:** The agent(s) who have an acceptable level of impact and utilisation would then go through a further qualitative assessment which will help finalise the decision on their suitability.

10.5.2 Interpretation of each part of the model

This section tries to portray how the applied capability assessment approach can be useful for organisations to use. These are some benefits that an organisation can gain from using this approach are presented.

1. Entering organisational requirements in selection practices: According to the organisation's strategy and vision in terms of selection and long term investment these details can play decisive roles. For instance whether companies are very concerned with people's values and company's vision or people's previous contextual performance or people's abilities, job profiling in this assessment method can accommodate their specific views.

2. Testing the validity of job profiling: The results of applied capability assessment can show the company whether they have set right requirements for the job that they are looking to select candidates for. This means that if applicants are constantly meeting the required levels in values and lack the required levels on enablers or performance levels this can be an indicator of incongruous requirement in the role. In another level the indices can also show the organisation whether they set reasonable level for the requirements of the job or not. For instance if applicants constantly have high utilisation and medium or low levels of impact this means that the job requirements are set higher than the average availability of its potential incumbent.

3. Final selection decisions using indices and the criteria: The results and the process of applied capability assessment as outlined in this research can be useful for organisations in many levels. In using the impact and utilisation indices, organisation's visions can affect their definitions of the acceptable levels of impact and utilisation indices. For instance Google has recruited "overqualified" employees because it gives them enough room for multiple promotions and they can grip the differences in job duties and their constant change (Delaney, 2006). This can be well projected in the application of the indices, and is equivalent to preferring people with high impact and low utilisation. These are the people who own more than what is needed but the organisation favours them because it contributes to its strategy of ever expanding and flexible staffing practice. In another level knowing the details of the match levels in the three criteria separately, organisations may prefer to circumvent the use of indices and work directly with the separate match levels. For instance they may wish to acquire people with high match levels in enablers; using the algorithm in this research people's fit (from their own and organisation's perspective) in that specific criterion is computable and can be used on its own.

10.6 Future work

The current piece of research is a fundamental work which displayed how one's impact and utilisation on a specific job in a defined context can be measured on a conceptual background of different subject areas. As stated before, the proposed conceptual and mathematical model in this research does not restrict changes or alternative application of its structure. There are a number of evident potentials for furthering the findings and application of this research which are named in this section.

- Inclusion of additional factors and renaming current criteria

Despite all the considerations which were foreseen in assessing one's applied capability there might be other factors which could affect one's applied capability and are disregarded in the current research. In fact these issues are outside the scope of this research and are considered to be supplementary to the findings of the research. For instance one's Socio-Economic Situation or general wellbeing may become important in their applied capability in a context. Moreover unforeseen circumstances for the person or within the job environment could also be crucial. There are numerous ways of including the above factors in the assessment such as adding constants, using stochastic terms or other solutions. Further study into the dynamics of inclusions of such factors is essential for expanding the usability of this research.

What is more the name “moderators” used for one of the criteria can be changed. The criterion was initially named as “moderator” since it was expected to have moderating effect on other criteria. This was proved to wrong in later chapters, however the name remained the same throughout the thesis to avoid any confusion. The name can be changed to *preferences* or *choices* in future research.

- Capability in Networks

The conceptual and mathematical findings of this research can be extended to a broader level. This extension can be on assessing the impact and utilisation of a network of people as opposed to an individual. Evidently, what needs to be added to the current framework is an indication of the network dynamics which can affect the individual or collective applied capability. However this inclusion should not have any effect on the fundamentals of the applied capability assessment as described in this research.

- A collective use of the indices

The produced indices (Impact and Utilisation) can be examined further to be used in a single indicator which is an overall nominator of one’s applied capability in a context. This can be in the format of a “production function” which illustrates one’s suitability in a specific context based on their impact and utilisation $(ACA = f(I, U))$. Therefore the indices would have a collective manifestation. However, this requires further examination on the generalisability of the results, their use in different circumstances and producing norms for acceptable impact and utilisation levels.

Appendix A

Module Outline

<table>
<tr><td colspan="6">Module Syllabus</td></tr>
<tr><td>Module Code:
MN5543</td><td colspan="2">Module title
Systems Modelling & Simulation</td><td>Module Leader:
Dr Alireza Mousavi</td><td>Credit value:
15</td></tr>
<tr><td>Level:
M</td><td>Pre-requisites</td><td>Co-requisites</td><td>Additional Tutors:</td><td>School responsible for teaching:
Engineering and Design</td></tr>
<tr><td colspan="6">MAIN AIMS OF THE MODULE:
To encourage systematic thinking and acquiring knowledge and skills to model and analyse modern complex systems.</td></tr>
<tr><td colspan="6">MAIN TOPICS OF STUDY:
This module deals with the principles of manufacturing systems, modelling and simulation.
Principles of systems engineering. Modelling and analysis of Discrete Systems,
Material Flow systems (assembly lines, transfer lines, serial systems, shop scheduling, Flexible Manufacturing, Group technology, Facility layout)
Machine setup and operation sequence; Material Handling systems
General Modelling approaches (Queuing Models)
Process Simulation and data analysis, enterprise operations
Supply chain and logistics-reverse logistics modelling concepts.</td></tr>
</table>

LEARNING OUTCOMES FOR THE MODULE

At the end of this module, students will be able to:

- A1. Critically evaluate and implement principles of systems approach and analysis.
- A2. Describe, evaluate and appropriately apply manufacturing concepts to real world industrial systems and to design, plan and solve arising problems that day-to-day management of such systems encounter.
- A3. Gain the required skills for modelling, simulating and critically analysing performance of deterministic and stochastic systems.
- A4. Acquire the skills to recognise the elements and rules governing supply chains/logistics and reverse logistics for better management and engineering of these systems.

TRANSFERABLE SKILLS DEVELOPED

- B1. Apply key tools and techniques for planning and evaluating the design of enterprise systems
- B2. Modelling of interactions and negotiations between components of enterprise systems
- B3. Demonstrate integrated modelling of key processes within manufacturing systems
- B4. Use simulation and optimisation techniques to identify improvements for Enterprise integration
- B5. Preparation of written reports

TOTAL NUMBER OF HOURS SPENT IN:

Contact Time: 30 (FT/PT)

Directed Study: 40 (FT/PT) / 70 (DL)

TEACHING/ LEARNING METHODS/STRATEGIES USED TO ENABLE THE ACHIEVEMENT OF LEARNING OUTCOMES:

FT/PT: Lectures/ laboratory exercises. Directed exercises using the latest modelling, simulation techniques and software. A simulation project using real world examples and data.

DL: Guided study of lecture & laboratory exercises via course notes & Web Vista. Directed exercises using the latest modelling, simulation techniques and software. A simulation project using real world examples and data.

ASSESSMENT METHODS WHICH ENABLE STUDENT TO DEMONSTRATE THE LEARNING OUTCOMES FOR THE MODULE:	WEIGHTING:
Simulation and modelling Individual Project and Report	50%
Simulation and modelling group Project and Report	50%

INDICATIVE READING LIST: 1 ESSENTIAL READING [* Purchased advised] D. Kelton, R. Sadowski and D. Sturrock (2004), Simulation with Arena 3rd Edition, McGraw-Hill . ISBN: 0-07-285694-7. A. Mousavi, A. Komashie, A. Moeen Taghavi, and V. Pezeshki (2006); Introduction to Simulation Modelling and Value Chains; Course Book. 2 RECOMMENDED READING Course Notes, Web-based material and other supporting documents provided by lecturer R. G. Askin and C. R. Standridge (1993); Modelling and Analysis of Manufacturing Systems; John Wiley & Sons, Inc. ISBN: 0-471-51418-7 M. P. Groover (2001); Automation, Production Systems, and Computer Integrated Manufacturing; Second Edition; International Edition; Prentice Hall International, Inc. ISBN: 0-130089546-6	
Date approved by AMEE Group	Version 1 - 15-June-2007

The following information is optional:

COMPULSORY module on the following programmes (please list):	MSc Engineering Management MSc Advanced Manufacturing Systems
OPTION module on the following programmes (please list):	

Appendix B

Performance Domain

1. Leading and Deciding
    - 1.1 Deciding & Initiating Action
        - 1.1.1 Making Decisions
        - 1.1.2 Taking Responsibility
        - 1.1.3 Acting with Confidence
        - 1.1.4 Acting on Own Initiative
        - 1.1.5 Taking Action
        - 1.1.6 Taking Calculated Risks
    - 1.2 Leading and Supervising
        - 1.2.1 Providing Direction and Coordinating Action
        - 1.2.2 Supervising and Monitoring Behaviour
        - 1.2.3 Coaching
        - 1.2.4 Delegating
        - 1.2.5 Empowering Staff
        - 1.2.6 Motivating Others
        - 1.2.7 Developing Staff
        - 1.2.8 Identifying and Recruiting Talent

2. Supporting and Cooperating
    - 2.1 Working with People
        - 2.1.1 Understanding Others
        - 2.1.2 Adapting to the Team

2.1.3 Building Team Spirit

2.1.4 Recognizing and Rewarding Contributions

2.1.5 Listening

2.1.6 Consulting Others

2.1.7 Communicating Proactively

2.1.8 Showing Tolerance and Consideration

2.1.9 Showing Empathy

2.1.10 Supporting Others

2.1.11 Caring for Others

2.1.12 Developing and Communicating Self-knowledge and Insight

2.2 Adhering to Principles and Values

2.2.1 Upholding Ethics and Values

2.2.2 Acting with Integrity

2.2.3 Utilizing Diversity

2.2.4 Showing Social and Environmental Responsibility

3. Interacting and Presenting

3.1 Relating & Networking

3.1.1 Building Rapport

3.1.2 Networking

3.1.3 Relating Across Levels

3.1.4 Managing Conflict

3.1.5 Using Humour

3.2 Persuading and Influencing

3.2.1 Making an Impact

3.2.2 Shaping Conversations

3.2.3 Appealing to Emotions

3.2.4 Promoting Ideas

3.2.5 Negotiating

3.2.6 Gaining Agreement

3.2.7 Dealing with Political Issues

3.3 Presenting and Communicating Information

3.3.1 Speaking Fluently

3.3.2 Explaining Concepts and Opinions

3.3.3 Articulating Key Points of an Argument

3.3.4 Presenting and Public Speaking

3.3.5 Projecting Credibility

3.3.6 Responding to an Audience

4. Analyzing and Interpreting

4.1 Writing and Reporting

4.1.1 Writing Correctly

4.1.2 Writing Clearly and Fluently

4.1.3 Writing in an Expressive and Engaging Style

4.1.4 Targeting Communication

4.2 Applying Expertise and Technology

4.2.1 Applying Technical Expertise

4.2.2 Building Technical Expertise

4.2.3 Sharing Expertise

4.2.4 Using Technology Resources

4.2.5 Demonstrating Physical and Manual Skills

4.2.6 Demonstrating Cross Functional Awareness

4.2.7 Demonstrating Spatial Awareness

4.3 Analyzing

4.3.1 Analyzing and Evaluating Information

4.3.2 Testing Assumptions and Investigating

4.3.3 Producing Solutions

4.3.4 Making Judgments

4.3.5 Demonstrating Systems Thinking

5. Creating and Conceptualizing

5.1 Learning and Researching

5.1.1 Learning Quickly

5.1.2 Gathering Information

5.1.3 Thinking Quickly

5.1.4 Encouraging and Supporting Organizational Learning

5.1.5 Managing Knowledge

5.2 Creating and Innovating

5.2.1 Innovating

5.2.2 Seeking and Introducing Change

5.3 Formulating Strategies and Concepts

5.3.1 Thinking Broadly

5.3.2 Approaching Work Strategically

5.3.3 Setting and Developing Strategy

5.3.4 Visioning

6. Organizing and Executing

6.1 Planning and Organizing

6.1.1 Setting Objectives

6.1.2 Planning

6.1.3 Managing Time

6.1.4 Managing Resources

6.1.5 Monitoring Progress

6.2 Delivering Results and Meeting Customer Expectations

6.2.1 Focusing on Customer Needs and Satisfaction

6.2.2 Setting High Standards for Quality

6.2.3 Monitoring and Maintaining Quality

6.2.4 Working Systematically

6.2.5 Maintaining Quality Processes

6.2.6 Maintaining Productivity Levels

6.2.7 Driving Projects to Results

6.3 Following Instructions and Procedures

6.3.1 Following Directions

6.3.2 Following Procedures

6.3.3 Time Keeping and Attending

6.3.4 Demonstrating Commitment

6.3.5 Showing Awareness of Safety Issues

6.3.6 Complying with Legal Obligations

7. Adapting and Coping

7.1 Adapting and Responding to Change

7.1.1 Adapting

7.1.2 Accepting New Ideas

7.1.3 Adapting Interpersonal Style

7.1.4 Showing Cross-cultural Awareness

7.1.5 Dealing with Ambiguity

7.2 Coping with Pressure and Setbacks

7.2.1 Coping with Pressure

7.2.2 Showing Emotional Self-control

7.2.3 Balancing Work and Personal Life

7.2.4 Maintaining a Positive Outlook

7.2.5 Handling Criticism

8. Enterprising and Performing

8.1 Achieving Personal Work Goals and Objectives

8.1.1 Achieving Objectives

8.1.2 Working Energetically and Enthusiastically

8.1.3 Pursuing Self-development

8.1.4 Demonstrating Ambition

8.2 Entrepreneurial and Commercial Thinking

8.2.1 Monitoring Markets and Competitors

8.2.2 Identifying Business Opportunities

8.2.3 Demonstrating Financial Awareness

8.2.4 Controlling Costs

8.2.5 Keeping Aware of Organizational Issues

(Bartram, 2005; Kurz et al., 2004, p. 1202-3)

Appendix C
Examples of interview topics for finding CIP

1. In general, people are living longer now. What are the causes of this phenomenon?
2. "People work because they need money to live." Do you agree?
3. Is it better to marry someone of the same cultural background?
4. "Having a child is essential for every family." Do you agree?
5. Does the fashion industry exist mainly to persuade people to spend money on things they do not really need?
6. Do you agree or disagree on drug legalisation?
7. Should the law limit the number of fast food restaurants in our towns?
8. Should governments act to control the Internet or should it be uncensored?
9. Some say: "*the poor* are poor because they are lazy." Do you agree?
10. Do you have a vision of a better society? What changes would you make to have it?
11. "Parents should not buy toy guns or war toys for their children." Do you agree?
12. Why do you think people go to higher educations?
13. What are the causes of unemployment and how is the problem solved in your country?
14. Should people of between 60 and 65 be obliged to retire from their jobs in order to make way for younger workers or should they not? Why?
15. "Living in another country for a while is an essential experience for any individual." Do you agree?

Appendix D
Myer-Briggs 4 dimensions of personality

Extroversion/Introversion

Extroversion:

Tendency to focus the attentions and get the energy from the outer world, people and things.

Introversion:

Tendency to focus the attentions and get energy from one's inner world of ideas and images.

Sensing/Intuition

Sensing:

Paying more attention to the information which comes through the five senses.

Intuition:

Paying more attention to the patterns and possibilities that one sees in the received information.

Thinking/Feeling

Thinking:

Focusing on objective principles and impersonal facts in making decisions.

Feeling:

Focusing on personal concerns and people involved in the situation when making decisions.

Judging/Perceiving

Judging:

Preference of a more structured and decided lifestyle and orientation to the world.

Perceiving:

Preference of a more flexible, adaptable and haphazard lifestyle and orientation to the world.

(Myers and Briggs, 1926)

Appendix E

Self assessment Questionnaire

Values*

A) Please choose (from 0 to 100) how much you value the following:

1. Studying theories of conceptual issues

0	10	20	30	40	50	60	70	80	90	100

2. Studying theories of scientific issues

0	10	20	30	40	50	60	70	80	90	100

3. Strategic decision making

0	10	20	30	40	50	60	70	80	90	100

4. Data interpretation

0	10	20	30	40	50	60	70	80	90	100

5. Doing case studies

0	10	20	30	40	50	60	70	80	90	100

6. Problem solving

0	10	20	30	40	50	60	70	80	90	100

7. Management and leadership studies

0	10	20	30	40	50	60	70	80	90	100

8. Working with a software

0	10	20	30	40	50	60	70	80	90	100

9. Simulating and Modelling a real case study

0	10	20	30	40	50	60	70	80	90	100

10. Statistical analysis

0	10	20	30	40	50	60	70	80	90	100

11. Research

0	10	20	30	40	50	60	70	80	90	100

12. Innovation

0	10	20	30	40	50	60	70	80	90	100

B) In terms of type of assessment, to what extent you prefer:

13. Assignments and projects

0	10	20	30	40	50	60	70	80	90	100

Examination

0	10	20	30	40	50	60	70	80	90	100

14. Individual assessment

0	10	20	30	40	50	60	70	80	90	100

Group assessment

0	10	20	30	40	50	60	70	80	90	100

15. Writing report

0	10	20	30	40	50	60	70	80	90	100

Doing an oral presentation

0	10	20	30	40	50	60	70	80	90	100

C) How much you agree with the following statements? When attending a course, you consider yourself successful if you:

16. Get a good grade

0	10	20	30	40	50	60	70	80	90	100

17. Learn a lot from the process of attending the course and doing the coursework

0	10	20	30	40	50	60	70	80	90	100

18. Develop lots of connections and friendships in that environment

0	10	20	30	40	50	60	70	80	90	100

Skills self-assessment

A) How would you rate your **

19. Team working ability

0	10	20	30	40	50	60	70	80	90	100

20. Management skills

0	10	20	30	40	50	60	70	80	90	100

21. Creativity

0	10	20	30	40	50	60	70	80	90	100

22. Communication skills

0	10	20	30	40	50	60	70	80	90	100

23. Mathematical and statistical abilities (if you have done any test and know the score please provide)

0	10	20	30	40	50	60	70	80	90	100

B)

24. Is English your first language?

Yes ☐ (Go to question 25)

No ☐ (Go to question 26)

25. Rate your English Verbal abilities

0	10	20	30	40	50	60	70	80	90	100

Writing

0	10	20	30	40	50	60	70	80	90	100

Reading comprehension

0	10	20	30	40	50	60	70	80	90	100

26. Rate your English proficiency (IELTS or TOEFL grades)

Reading	Writing	Listening	Speaking
☐	☐	☐	☐

*** As a guidance for Values self-assessment, take the following example:**

Studying theories of conceptual issues

0	10	20	30	40	50	60	70	80	90	100

Dislike or disinterest Indifference Passion and extreme interest

**** As a guidance for skills self-assessment, take the following example:**

Team working ability

0	10	20	30	40	50	60	70	80	90	100

No familiarity at all Moderately skilful Complete proficiency

Availability

The second part of the test entails a personality indicator questionnaire (30 minutes) and a short talk (5-10 minutes). So we need about 40 minutes of your time to come to Room H300 in Howell building. Please provide your availabilities.

1. Which days do you prefer? Please circle all the days you are available (at least 5)

	October			November						December	
Monday	12	19	26		2	9	16	23	30		7
Tuesday	13	20	27		3	10	17	24		1	8
Wednesday	14	21	28		4	11	18	25		2	9
Thursday	15	22	29		5	12	19	26		3	10
Friday	16	23	30		6	13	20	27		4	11
Saturday	17	24	31		7	14	21	28		5	12
Sunday	18	25		1	8	15	22	29		6	13

2. Please circle the time of the day which is more suitable for you? (If you are available both times please circle both)

Mornings **Afternoons**

Please state your:

Name		**Age**	
Email			

An email will be sent to you to inform you about your allocated time slot.

Thank You

Consent Form

Researchers

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Research Title: Human Capability Evaluation

A method to measure the capabilities of a system in fulfilling tasks is a desirable feature for industry and academia. The resultant capability concept will give an index which is based on the Ability, Choice and Performance of a system. An application of this theory can be tested on human agents. This case study will consider past, present and future data of the participants for the purpose of its analysis.

Information for the participants:

This study requires the participants to fill out three questionnaires and attend a short (ten minutes) interview. Interviews are recorded and transcribed for the purpose of further analysis. The study also may entails observation of students' group meetings for the assignment. **Participants will be given their personality type indicator, Complexity of Information Processes, career development map and a capability profile.** This result can help them in self development and also forming more effective groups in future. The study will have no harm or risk to the participants. This study is completely separate from the module. Students should be informed that participation, not participation or withdrawal will not affect their marking in the module in any manner. Any information collected in the study will remain strictly confidential and students' identities will be secured. **Data with participants' identity will only be accessed by principle researcher for the purpose of relating interviews**

and questionnaires. Nameless data will also be analysed by academic and industrial supervisor. There will be no other use or access to the data other than this study. **Students are ensured that their personal information will be destroyed upon the completion of the study.** In case of publication of the 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 to willingly take part in the study.	☐	☐

Signature of the participant:

Name: **Date:**

For researcher's use:

I am satisfied that the above person has given informed consent.

Witnessed by: Date:

Appendix F
Performance Self-Assessment

A) In doing this module, how would you rate yourself in*:

1. Interacting (Networking, Shaping Conversations, Negotiating)

0	10	20	30	40	50	60	70	80	90	100

2. Adapting and Coping (In different situations, balancing life, handling criticism)

0	10	20	30	40	50	60	70	80	90	100

3. Supporting and Cooperating (Adapting to the team, Building Team spirit, Supporting and respecting others, Forming a successful team)

0	10	20	30	40	50	60	70	80	90	100

3. **Leading and Deciding** (Making Decisions, Taking responsibility, providing direction, motivating others)

0	10	20	30	40	50	60	70	80	90	100

5. Analysing and Interpreting (Writing engaging and expressive reports, Applying learned expertise, analysing information)

0	10	20	30	40	50	60	70	80	90	100

6. Organising and Executing (Managing time, attending lectures, deriving results for assignments)

0	10	20	30	40	50	60	70	80	90	100

7. Enterprising and Performing (Pursuing Self development, Working Enthusiastically)

0	10	20	30	40	50	60	70	80	90	100

B) Overall:

How much you think your capabilities will contribute to fulfilment of the requirements of **this job (module) in this environment in future**?

0	10	20	30	40	50	60	70	80	90	100

*** As a guidance for performance self-assessment, take the following example:**

Interacting (Networking, Shaping Conversations, Negotiating)

0	10	20	30	40	50	60	70	80	90	100

Low achievement Moderate achievement Perfect achievement

Appendix G
Questionnaire used for second survey

To predict how an individual may be able to apply his or her capabilities in a task, we need to base our judgement on three main criteria:

Criterion A. Does the individual have the required level of specific abilities and skills?

Criterion B. Does the individual have motivations and personality characteristics matched to that task?

Criterion C. Does the individual have the required record of a degree of previous achievement in similar tasks?

Please answer the 2 parts below:

1. We have 10 individuals who are being asked to do a certain task in an organisation.

In doing that task, these people have different level of match with each of the above three criteria. Their levels of match can be High (H), Medium (M) or Low (L)*.

Please fill in the empty column in the table with **a rating from 0 to1** for answering this question:

In what level the individual would be able to contribute to (impact) the fulfilment of the requirements of this task in this environment? (0= Very Low, 1=Very High) in each of the following scenarios (the number shown in each cell is the number of criteria which match the requirement in that specific level)

	Low	Medium	High	Level of impact
Person 1	3	0	0	
Person 2	2	1	0	
Person 3	2	0	1	
Person 4	1	2	0	
Person 5	1	1	1	
Person 6	1	0	2	
Person 7	0	3	0	
Person 8	0	2	1	
Person 9	0	1	2	
Person 10	0	0	3	

***** Low ~ <33% , Medium ~ %33-%66 , High ~ > %66

2. How would you weight each of the three criteria regarding their importance in answering the first question?

	Weight
Factor A	
Factor B	
Factor C	
Total	100

Appendix H
Full version of the questionnaire used in second survey

To predict how an individual may be able to apply his or her capabilities in a task, we need to base our judgement on three main criteria:

Criterion A. Does the individual have the required level of specific abilities and skills?

Criterion B. Does the individual have motivations and personality characteristics matched to that task?

Criterion C. Does the individual have the required record of a degree of previous achievement in similar tasks?

Please answer the 2 parts below:

1. We have 27 individuals who are being asked to do a certain task in an organisation.

In doing that task, these people have different level of match with each of the above three criteria. Their levels of match can be High (H), Medium (M) or Low (L)*.

Please fill in the empty column in the table with **a rating from 0 to 10** for answering this question:

In what level the individual would be able to contribute to (impact) the fulfilment of the requirements of this task in this environment? (0= Very Low, 10=Very High) in each of the following scenarios:

						Level of Impact
Criterion 1	**H**	Criterion 2	**H**	Criterion 3	**H**	
Criterion 1	**H**	Criterion 2	**H**	Criterion 3	**M**	
Criterion 1	**H**	Criterion 2	**H**	Criterion 3	**L**	
Criterion 1	**H**	Criterion 2	**M**	Criterion 3	**H**	
Criterion 1	**H**	Criterion 2	**M**	Criterion 3	**M**	
Criterion 1	**H**	Criterion 2	**M**	Criterion 3	**L**	
Criterion 1	**H**	Criterion 2	**L**	Criterion 3	**H**	
Criterion 1	**H**	Criterion 2	**L**	Criterion 3	**M**	
Criterion 1	**H**	Criterion 2	**L**	Criterion 3	**L**	
Criterion 1	**M**	Criterion 2	**H**	Criterion 3	**H**	
Criterion 1	**M**	Criterion 2	**H**	Criterion 3	**M**	
Criterion 1	**M**	Criterion 2	**H**	Criterion 3	**L**	
Criterion 1	**M**	Criterion 2	**M**	Criterion 3	**H**	
Criterion 1	**M**	Criterion 2	**M**	Criterion 3	**M**	
Criterion 1	**M**	Criterion 2	**M**	Criterion 3	**L**	
Criterion 1	**M**	Criterion 2	**L**	Criterion 3	**H**	
Criterion 1	**M**	Criterion 2	**L**	Criterion 3	**M**	
Criterion 1	**M**	Criterion 2	**L**	Criterion 3	**L**	
Criterion 1	**L**	Criterion 2	**H**	Criterion 3	**H**	
Criterion 1	**L**	Criterion 2	**H**	Criterion 3	**M**	
Criterion 1	**L**	Criterion 2	**H**	Criterion 3	**L**	

Criterion 1	**L**	Criterion 2	**M**	Criterion 3	**H**	
Criterion 1	**L**	Criterion 2	**M**	Criterion 3	**M**	
Criterion 1	**L**	Criterion 2	**M**	Criterion 3	**L**	
Criterion 1	**L**	Criterion 2	**L**	Criterion 3	**H**	
Criterion 1	**L**	Criterion 2	**L**	Criterion 3	**M**	
Criterion 1	**L**	Criterion 2	**L**	Criterion 3	**L**	

2. How would you weight each of the Criteria regarding their importance in answering the first question?

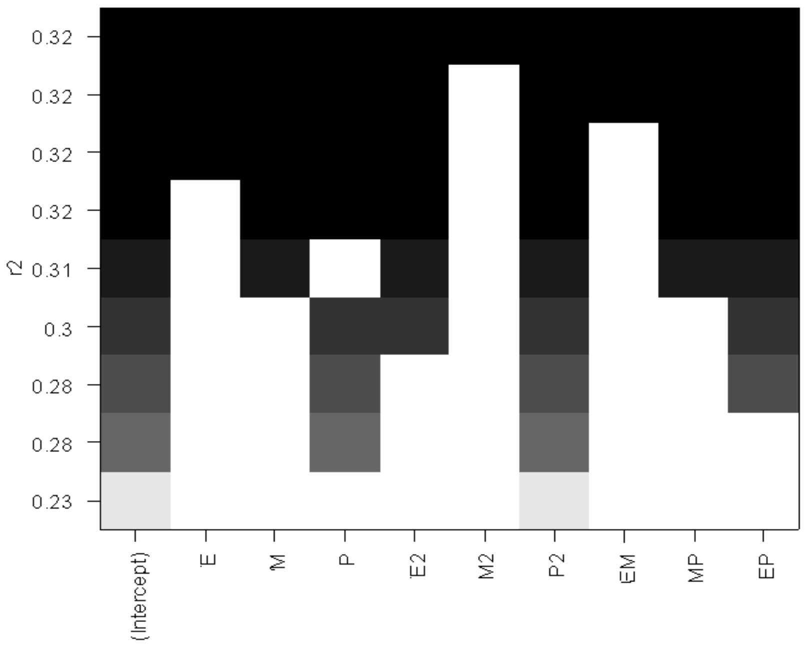
	Weight
Criterion A	
Criterion B	
Criterion C	

Total 100

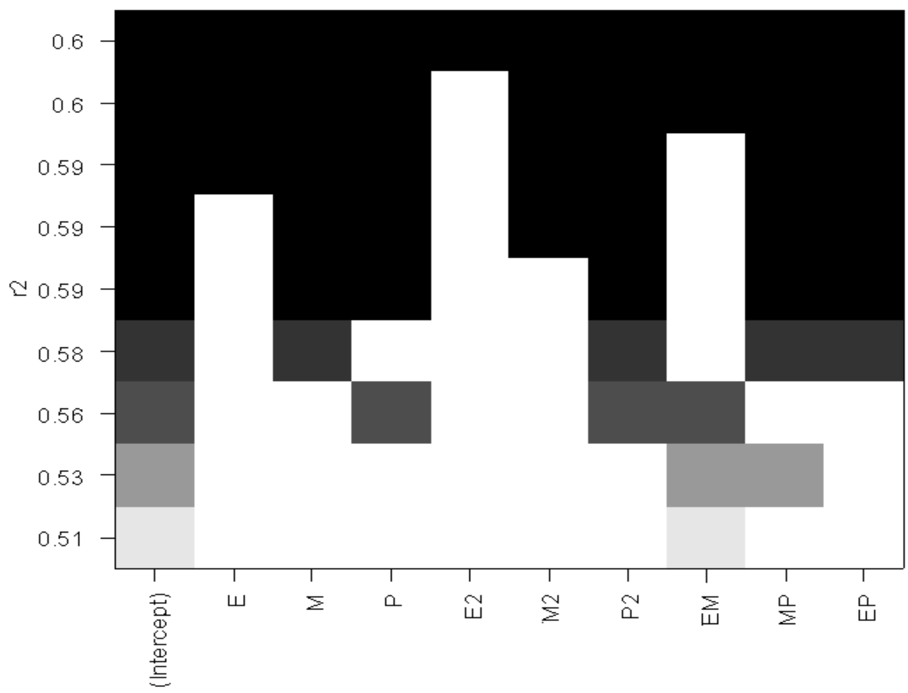
Appendix I
Further regression results on EMP Model

R^2 in using EMP model for independent variables and a) self assessment of impact and b) manager assessment of impact as dependent variables:

a) EMP and self-assessed impact:



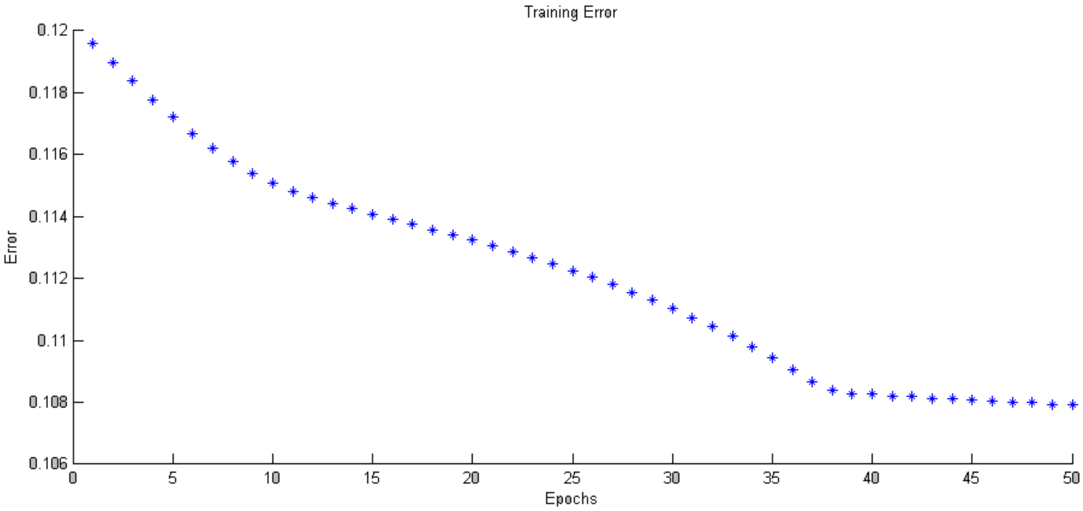
b) Manager-assessed impact:



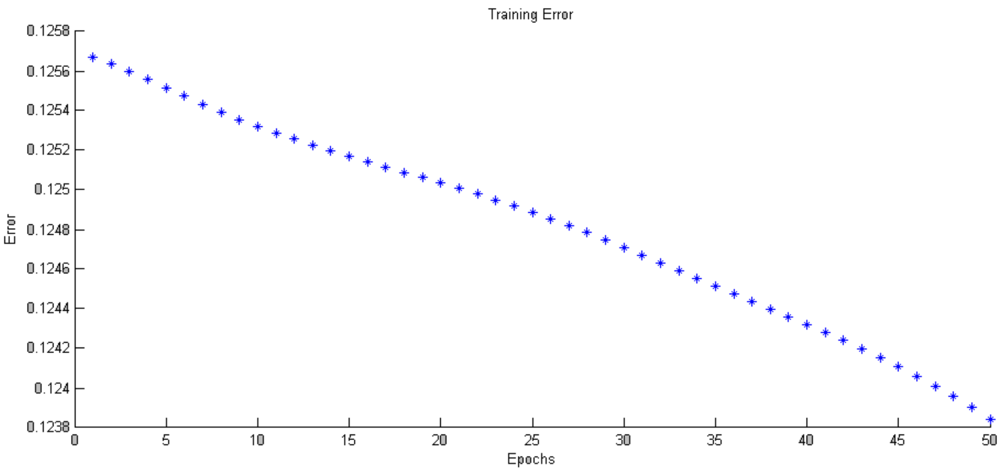
Appendix J
Training errors from ANFIS on EMP

Training errors for ANFIS when using EMP model for independent variables and a) self assessed impact and b) manager assessed impact as the dependent variable

a) Self assessed impact



b) Manager assessed impact



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