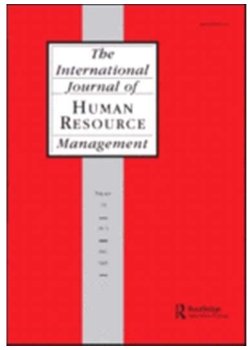

MEASURING CAPABILITY OF INDIVIDUALS AT WORK

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ON THE DEFINITION OF CAPABILITY IN THE WORKPLACE, A DIFFERENT PERSPECTIVE: APPLIED CAPABILITY

Abstract

A new perspective on the modelling and definition of an individual's capability in the work place is presented. A review of relevant literature has resulted in a definition of an individual's Capability. Capability in this context is defined as the ability of an individual to *utilise* a series of innate and acquired qualities and skills that lead to or impact on the fulfilment of a task. The proposed analytical model then acts as a predictor of capability in the work environment.

As proof of concept, an empirical study was conducted with different cohorts of postgraduate students over a 3 year period. The study was designed to emulate professional working environments where participants undertake individual and group tasks. The participants had professional employment history and had experience in undertaking projects at professional level. Statistical techniques were employed to validate the input data against the expected output, specifically Monte Carlo simulation was used to assess the robustness of the proposed model. Subject to minor heuristic adjustment, the results suggest that the proposed model is sufficiently robust as to be applied in wider industrial context.

The proposed model makes a contribution to the performance measurement and management of human resources within organisations.

Keywords: Capability, Effectiveness, Project, Planning, Job, Fitness

1. Introduction

Nearly 60% of the current UK employment opportunities are based on fixed term project-based contracts (Statistical Press Release, 2010). Project-based contracts traditionally recruit individuals or assemble teams for a particular task, project or programme of work. The members of these teams are employed on a short-term basis and are 'fit-for-purpose' in that they meet the skill profile for the work at hand. They are characterised by being technology savvy and are able to work independently or contribute to larger physical or virtual teams. Research, quick response teams for environmental/health disaster, aerospace (Mousavi, 2007) and healthcare organisations are good examples of this type of organisation. A recent application is being explored for healthcare research scientists and practitioners who are trying to find ways to assemble capable teams to address the needs of patient and reduce discharge times (Ministry of Health Canada, 2010).

Such task oriented challenges require individuals who possess innate qualities and skills (collectively referred to as their r*esources*) and have the ability to *utilise* those resources effectively and efficiently. Innate resources play a role and have an *impact* on the fulfilment of assigned tasks; the appropriate *utilisation* of those resources ensures the completion of those tasks. The *Capability* of an individual in this context is the measure of the relative *impact* and *utilisation* of resources in completing a task or a series of tasks.

The objective of this work is to propose a model, a systematic method for:

1. The definition of work as a process plan comprising a set of *tasks*,
2. The identification of *resources* possessed by an individual to be allocated to each task,
3. The definition of capability indicators, where frequently a subjective descriptor is used to measure a resources *impact* on fulfilling a specified task. The notion of *impact* is introduced to express the contribution a specific resource makes to the completion of a task,
4. The measurement of resource utilisation in terms of the ratio of actual expenditure to total available capacity (measured in time units) as the work progresses over time,
5. The definition of an individual's capability as a combination of the *Impact and Utilisation* of their innate and acquired resources during the lifecycle of the work.

The rationale for the proposed model of human resources capabilities is to match individuals to tasks. The ability to gain an appreciation of an individual's capability is a novel technique that will lead to a more balanced allocation of individuals to task.

In the following sections the authors provide a solid definition of capability in the context of the proposed approach that is based on an extensive lateral review of existing literature in economics, management science, business administration, human resource management, and industrial systems. For the sake of brevity this review is limited to the most relevant management sciences and human resource management findings in the literature.

As part of this paper we introduce the concept of *Capability Indicators* to represent the resource required to accomplish a given task. At the present time no phenomenological formulation is available for the physical measurement of such parameters, this deficiency has led to the investigation and development of self-assessment, peer-assessment and domain expert assessment survey type measurement techniques. By analysing the results obtained from surveys experts in the field (i.e. academics in this case) determine the capability indicators and necessary resources required to complete a given task. The relative contribution of each resource to the tasks completion is also determined by the experts. As the tasks were being performed, utilisation of each resource was estimated by observers (instructors and researchers) and by the individual's own self-assessment (i.e. the student in this case). Finally the authors present arguments why they believe the proposed approach is useful a tool when matching and mapping resources (an individual's traits and qualities) to a set of task descriptors as part of a job fitting exercise.

2. A Review of Existing Literature on Definition of Capability

In the past three decades the concept of 'Capability', its definition, evaluation and comparison have been the subject of discussion across a wide range of disciplines that includes economics, social sciences, engineering and management. Barney (1999) intimates that major business decisions are based on the assessment of an organisation's capability. Sen (1985) takes the view that from an economics stand point, capabilities are used to represent people's quality of life and "*what people are able to do or are able to be*". The psychoanalysts Jaques and Cason (1994) believe that an individual's capabilities can be assessed based on the complexity of the work they perform and levels of attainment achieved. From the Human Resource Management (HRM) standpoint, employee capabilities are evaluated on the basis of job descriptors and levels of fitness (Caplan, 1975; Carol, 1993).

However, from the existing literature one can conclude that there is an underlying consensus on the definition of "Capability" (Amit and Schoemaker, 1993; Cantamessa, 1999; Dosi *et al*, 2000; Helfat and Peteraf, 2003; Kogut and Kulatilaka, 2001; Pandza *et al*, 2003; Teece *et al*, 1997; Zehir *et al*, 2006).

In contrast, industrial engineers interpret capability as a potential that manifests itself through a set of enabling resources. A resource is an entity that is owned and controlled by an individual or an organisation. Put simply, capability is the ability to deploy a resource to achieve an end result (Helfat and Lieberman, 2002; Capron and Hulland, 1999). This *applied* view of Capability resonates with the methodology pursued in this paper as opposed to that taken by economists (Beckly, 2002; Gasper, 2002; Robeyns, 2005; Statistical Press Release, 2010).

Others describe the causal relationship that exists between capability and performance, as capability being a predictor of performance. This is the link between the potential and the application of capability that manifest itself as performance (i.e. degree of achievement). This differs from our interpretation of *"Capability"*, here we suggest that past performance can be expressed as the *"Level of Attainment"* measured against pre-set objectives, whilst capability cannot be realised unless an objective has actually been achieved. This view is closer to that of Amit and Schoemaker's (1993) interpretation of the causal relationship that exists between capability and performance. The implication is that performance can be considered as an indicator of an individual's capability (expressed as an independent variable in the proposed model).

The emergence of Capability Theorists (Jaques and Cason, 1994; Jaques, 1996) who link an individual's innate traits and qualities with the complexity level associated with a specific task has come to our aid in mapping/matching work to an individual. This approach asserts that the more capable an individual is, then the more complex are the responsibilities and the tasks they are able to undertake.

Capability theorists emphasise that the ability to process complex information is not sensitive to factors associated with the working environment (internal or external), but suggest that the deployment of one's capability is influenced by personal traits and values as well as knowledge and skill.

In the context of quantitative measurements, the experimental design used in this research puts this theory to test and concludes that not all the criteria suggested by Capability Theorists are adequate as predictors of an individual's capability. It is important to note that our limited empirical study reveals that an individual's *abilities, preferences,* and *attainments* could also reasonably act as predictors of *Capability*.

Campbell *et al*. (1993) and Hough (2001) do not separate abilities from performance; in their view abilities and performance have a cause–effect relationship. In predicting performance, individuals are assessed based on a set of criteria that examines their abilities, skills and preferences over a number of tests, interviews and past experience (also see Kurz and Bartram, 2002). The results are subjective and objective models (e.g. weighted matrices) or managerial discretion in the form of subjective feedback (based on regular employee appraisals) are also used. Personality measures and interests can be used to predict an individuals' behavioural pattern (Schmitt and Chan, 1998). Behavioural patterns can sometime manifest themselves in an individual's choice of how much and for how long they choose to exert effort on a task (Campbell *et al,* 1993). The implication is that motivational factors have the potential to play a significant role in encouraging an individual to maximise the application of their innate and acquired resources. Differing situations may very well affect the way in which an individual use their knowledge, skills and habits (McCrae and Costa, 1996). This resonates with the approach proposed in this paper. We believe that creating the correct balance between one's resources and the levels of their utilisation is an important factor in fulfilling one's duties effectively and efficiently. For example deploying someone with high impact resources (i.e. highly qualified) to a menial job that under-utilises their abilities, is just as demotivating as is assigning someone with low resource impact (i.e. under qualified) to a job requiring high impact resources (i.e. the task is beyond their capability).

In the next section we analyse the literature on Job-Fitting approaches and select the most appropriate for the proposed *Capability* modelling. We borrow a number of definition and concepts from the person-environment-fit literature.

3. A Review of Existing Literature on Job Descriptors

In this section we appraise current techniques and tools used for job evaluation, assignment of individuals to jobs and fitness tests. The purpose of this analysis is twofold, firstly to extract the necessary parameters required for building the proposed *Capability* model, secondly to ensure that the proposed model meets with current practices and standards for job analysis in management and organisational sciences. This two way relationship allows us to perform a 'goodness' fit between the skill set and preferences of an individual with the desired values and the capabilities of the organisation. *"Work"* or a *"Job"* can be described as a logical assembly of one or more tasks. A task as "a quantity of things with a certain quality which should be done in a targeted time within the limits of available resources" (Jaques, 1996). The two most prominent methods adopted by industry for job evaluation are the Traditional Job Analysis (TJA) and Competency Modelling (CM).

The relevance of task breakdown in the context of the current research lies in the method for defining work and tasks. The TJA process uses 'experts' as the knowledge source for job definition, a source that may for example include the current job incumbent or a supervisor. The expert in the TJA approach decides on the type and levels of skills, knowledge, and personal qualities required to complete the job. The CM approach to job evaluation takes a different route, in this approach workers are evaluated based on the competencies required for the job with the objective of maximising the probability of successfully completing the task (Boyatzis, 1982; Phillips, and Gully, 2009).

Other researchers have expressed doubt as to whether there is a significant difference between TJA and CM (Ruggeberg, 2007). Equally Schippmann *et al* (2000) believe that CM is more congruent with the business goals of the organisation, whereas TJA is more accurate in developing a detailed job specification. The authors conclude that the most suitable definition for the purpose of capability evaluation is that suggested in Sanchez and Levine (2009), where both TJA and CM combine to achieve a more comprehensive hybrid job definition. The authors therefore suggest a Comprehensive Job Definition (CJD) as the first step in the proposed capability model. The CJD method simplifies and generalises the job definition process by allowing the analyst to breakdown the work (jobs) into task units and then mapping these units onto the individual's resources, and in doing so resource allocation becomes a substitute for the less quantifiable task definition. The resource allocation approach allows us to decouple the capability evaluation from being a task-specific to a more generalised resource-specific process. The method attempts to achieve a balanced approach to the job-person fitting practice. The principle is not about finding 'super-humans' to perform tasks, but to find the most suitable candidate for a job or vice versa.

Figure 1 lists some of the strengths and weaknesses of the current selection methods and demonstrates how the authors believe these procedures can be improved.

Put Figure 1 here:

As part of *Capability* evaluation, once a job is defined using the CJD method, a Candidate Suitability Test (CST) can be conducted to match individuals to appropriate jobs. This matching process results in a candidate-job suitability index, a value that can be used as a predictor in determining whether the level of an individual's capability indicator is sufficient to successfully meet the requirements of the given job.

4. The Capability Modelling

In order to build the basic form of the proposed *Capability* model, the surveys were conducted to inquire about three types of indicators. The *Capability Indicators* are the *Enablers, Preferences* and previous *Attainments*. For measuring the Enablers (E) an examination of to measure the cognitive abilities and skills of the individuals was conducted. The personality traits (i.e. drivers, motivations and values) of individuals were measured in a survey and classified as *Preferences (P)*. The third type of data to be acquired from the candidate is their level of attainment based on past experience; we refer to this data as *Attainments (A)*. For example, in academia previous experience in the successful publication of research outputs demonstrates a degree of attainment that could be used as an indicator of a researcher's capability. We believe the suggested usage of the term *attainment* allows us to use past performance as a predictor of an individual's capability. This differs from the approach taken in (Robertson and Smith, 2001; Viswesvaran and Ones, 2000).

The *Enablers, Preferences and Attainment (EPA)* are interpreted as a measure of an individual's innate or acquired *Resources that are* available for deployment in successfully performing a given task and act as the independent variables of the model. The information and levels of the independent variables are extracted from the questionnaires. The individuals provide their self and peer assessment values and are ratified against the expected levels as determined by the supervisor's. A min-max algorithm is then used to normalise the outcomes.

These resources have an associated *Impact* and *Utilisation* value (as discussed previously in section 1). They are expressed as indices whose combined value is an estimate of an individual's work *Capability,* the so-called dependent variables. Figure A1 (in appendix) shows the underlying logic behind the model and the elements of the *Capability* model per se. The *Impact (I)* and *Utilisation (U)* of the resources belonging to an *Individual (M)* for *Job (K)* is a function of the *E, P* and *A*.

$$(I, U)_{MK} = f(E, P, A) \tag{1}$$

In the first instance a given job is broken down into a set of tasks; $J = \{T_{1,..t}\}$. A resource-task matching specifies the capability indicator (C_{ijt}), where $i = [1,3]$ representing the capability factors *Enablers, Preferences, or Attainments.* $j = [1, R]$ is the index of the resource within the capability factors; $R \in C$, and $t \in T$ is the task number. Once the tasks and their corresponding resources are matched, the amount of resource required to complete the task is specified; $X_{ijt} = (0,1)$. If $X_{ijt} = 0$ then no resource *j* is required for task *t.* On the other hand, $X_{ijt} = 1$ indicates that all available capacity of the specified resource is needed to complete the task and there will be no spare capacity of using the specified resource for other tasks (e.g. operating at maximum capacity). When a resource is depleted and its utilisation is at maximum capacity, it cannot be used by or shared with other tasks or jobs.

The process of allocating remaining capacity of any given resource continues until either the tasks are completed or the available capacity is allocated. For example, a new list of requirements for the resources C'_{ij} and the corresponding levels for X'_{ij}, then for all $T_{1\ldots t}$:

$$C'_{ij}, X'_{ij} = \begin{cases} \max X'_{ijt} & or\ all\ similar \qquad Cij \\ X'_{ijt} & for\ all\ dissimilar \qquad Cij \end{cases} \tag{2}$$

There may be an argument that every resource may have its own special weight, due to their impact on fulfilling the task. Therefore, if need be a weight allocation can be applied

$$\begin{aligned} &\text{For } i=1,\ \textstyle\sum_{j=1}^{e} W_{ij} = 1 \qquad e \in Enablers \\ &\text{For } i=2,\ \textstyle\sum_{j=1}^{p} W_{ij} = 1 \qquad p \in Preferences \\ &\text{For } i=3,\ \textstyle\sum_{j=1}^{a} W_{ij} = 1 \qquad a \in Attainment \end{aligned} \tag{3}$$

Once tasks-resource matching is completed, we determine the availability of every individual $M = 1, \ldots m$ for the job. The levels of *availability* (A_{mij}) for $\acute{C}_{ij}$. Where, A_{mij} is the availability of individual *m* for factor *i and* resource *j.* We normalise the levels of availability of individuals against the allocated resource (i.e. $\acute{X}_{ij}$), denoted by A'_{mij} and A''_{mij}, where:

$$A'_{mij} = \frac{\min(A_{mij}, X'_{ij})}{X'_{ij}} \quad \text{and} \quad A''_{mij} = \frac{\min(A_{mij}, X'_{ij})}{A_{mij}} \ \text{for } \forall\ i, j, k \tag{4}$$

Therefore, for all A'_{mi} and A''_{mi} for $\forall$ all Ms.

$$\text{For } i=1 \quad A'_{m1} = \textstyle\sum_{j=1}^{e} W_{1j} A'_{m1j} \text{ and } A''_{m1} = \sum_{j=1}^{e} W_{1j} A''_{m1j}$$

For *i=2* $A'_{m2} = \sum_{j=1}^{e} W_{2j} A'_{m2j}$ and $A''_{m2} = \sum_{j=1}^{e} W_{2j} A''_{m2j}$ (5)

For *i=3* $A'_{m3} = \sum_{j=1}^{e} W_{3j} A'_{m3j}$ and $A''_{m3} = \sum_{j=1}^{e} W_{3j} A''_{m3j}$

Finally, the impact level of an individual on completion of task I_m is applied to the model. The levels of impact will be based on an self or supervisor assessment, where $0 \leq I_m \leq 1$. A statistical model to infer the most suitable predictor of impact I_m with respect to A'_{mi}, for $i \in \{1,2,3\}$ and list of j resources.

$$I_m = f(A'_{mi}) \quad (6)$$

The statistical inference model estimates the closest possible function *(f)* for estimating the Impact index. For the measurement of *resources utilisation* (U_m) for an individual we suggest using regression of the Impact indices. For $i \in \{1,2,3\}$:

$$U_m = f(A''_{mi}) \quad (7)$$

By completing the three steps of task-resource matching, individual-resource matching, and incorporating resource Impact and Utilisation, a comparative measure of an individual's "*Capability"* against their peers is derived. A further example that demonstrates the feasibility of the proposed assessment method can be found in Figure A2 of the appendix to this paper.

Figure 2 summarises the findings and key definitions presented in this section:

Put Figure 2 here:

In section 5 the authors discuss the tests conducted to validate the method and verify the results.

5. Model Validation and Verification

5.1 The Project Environment

The study was carried out in the context of academia, where tasks, skills, preferences and outcomes are well defined. These attributes are not dissimilar to those found in other organisations who allocate tasks to individuals with specified skills and measurable outcomes.

The data collected as part of the empirical study consists of two types. Firstly data was collected using a combination of direct observation of the individuals (postgraduate students in this instance) in the workplace and the use of a standardised individual survey; this data set is referred to as ***Data Series 1***.

The purpose of this data series is to build and validate inferential statistical models relating to the data collected from the student cohort. ***Data Series 2*** targets the academic participants (the domain experts) using a combination of one-to-one interviews and a paper-based survey; this data is used to verify the inferential models. The academic participants were asked to use their expert knowledge to define a set of capability parameters required to complete an academic project (the job at hand). This is akin to a manger defining work, its associated tasks and the capabilities required to complete those tasks. These parameters are ultimately used in the prediction of '*Capable Graduates'*. Data collection was undertaken over a period of two years at Brunel University, in the United Kingdom. To protect participant anonymity the data is anonymised. The respondents of Data Series 1 are postgraduate students (reading a specific degree) whose capabilities were measured. The respondents of Data Series 2 are the domain experts, the academics and course directors who set the learning objectives, outcomes and assessment criteria (analogous to job descriptions).

The outcome of the first survey was to identify the most pertinent combination of independent and dependent *EPA* variables. The inferential models provide estimates for the impact indices of each resource. The purpose of the second survey is to validate the results of the first.

5.2 The Testing and Validation Process

To the best of our knowledge the work presented here represent a first attempt to establish an underlying theory or indeed a structure for human based network capability assessment. As part of this work benchmarks have been established for the methodology and a number of diverse physical and statistical models have been pursued. Currently direct external benchmarking is not possible, as the work establishes a new perspective on capability evaluation. As part of the programme of work to establish a framework for the experimental design, an extensive review of statistical and mathematical methods was undertaken. A number of assumptions were made: (i) The independent variables of the model are continuous, (ii) the dependent variables are continuous variables, (iii) with respect to task or job requirements and an individual's availabilities, the independent variables need to be normalised, (iv) the exact nature of the relationship between the independent variables and the dependent variables (linear, curvilinear etc.) is unknown, (v) the independent variables may be related to each other, and (vi) the independent and dependent variables are assessed using a variety of methods and statistical measures (e.g. self-assessment, expert knowledge etc.). Due to the number and variety of different types of independent and dependent variables, multiple regression analysis was adopted.

Students were allocated two sets of assignments in the area of Systems Modelling and Simulation that consisted of a series of tasks to be accomplished over a period of one academic term. The assignments were well-defined using assignment briefs. The expectations in terms of learning outcomes and the assessment criteria itself were also communicated to the student cohort. The success in achieving those outcomes is measured as a percentage. This value is then used in determining whether the applied capability measurement for a particular individual is a predictor in achieving the task. The implementation of the proposed capability evaluation algorithm will next be discussed as a series of experimental steps.

The job was broken down into a number of discrete tasks[1]. The resources required for the tasks were specified and classified into the EPA. Figure 3 demonstrates the list of resources required to fulfil the task.

Put Figure 3 here

The relative amount of resource *j* required for a given task *t;* $X_{ijt} \in (0 \rightarrow 1)$. Assigning a value of '0' indicates that no resource is required, while a value of '1' indicates that all of the available resource is required to perform the task. This value is determined by domain experts; in our case the value was determined by the lecturer and teaching assistants. The levels of resource required and their corresponding weight of each resource was determined.

In passing it should be noted that for consistency the domain experts should use the same measures in assessing requirements as were used in the assessment of the candidates themselves. While some of the requirements can be assessed using well established tests (e.g. English proficiency, Personality, CIP, etc.); in such cases the requirement is based on the value of the test score. In other cases (e.g. self-assessment of a range of motivational factors), well established performance metrics and tests may very well not exist. In such cases the requirement measurement should be based on the semantic differential scale (Osgood *et al,* 1957).

[1] For details of assignment brief see: http://brunel.ac.uk/~emstaam

The criteria to classify individual's ability to provide the required resources is summarised in Table 1.

Put Table 1:

With regard to *Enablers* and *Preferences,* the method used to determine the necessary data from participating individuals was based on a self-assessment form. The data was collected at two intervals; one at the beginning and the other in the third quarter of the term. To ascertain the participants' ability to process complex information the CIP method (Jaques and Cason, 1994) was used. The Myer-Briggs type indicators and interviews were used to inquire about the preferences, ideals and values of each individual.

One of the more challenging data set to acquire is related to determining an individuals expected and actual values of resource impact. As part of this process both the individual and the module leaders (supervisor/manager) were asked to supply an indicative value for the impact each set of resources has had on (from the individuals point of view) and should have on (from the experts point of view) with respect to achieving the given tasks. They were asked to evaluate the degree to which their (individual) resources contributed to the fulfilment of the task requirements. The individual profiling occurred over a period of 20 weeks in each year of the study, this data was then combined with Data Series 2 and underpins the utilisation and impact estimation.

As previously discussed the purpose of Data Series 2 is to establish the capability parameters that are used to determine an individual's applied capability. A total of some 41 academic-practitioners who had the experience and responsibility of supervising or managing people were consulted. The backgrounds and the domains of activities of these supervisors were from various disciplines (i.e. IT, Modelling, Engineering, and Finance). A key attribute of all those interviewed was that they lecture, supervise or manage people and additionally provide advice and consultancy services to industry and professional bodies. As such they could be considered as representative sample of the academic and industrial population; a sample that typically is equivalent to employers, employment advisors and decision makers found in the appraisal and/or assessment of human resources. This diversity, engagement with industry and professional bodies provides a degree of confidence in the validity of their input into the proposed model.

The outcome of this survey has led to the understanding of the importance and interrelationship that exists between resources and how they affect an individual's capability to fulfil a given task. We refer to this as the *"Impact"* of the resource or alternatively as the impact the resource owner has on fulfilling the given task.

Data series 2 also serves another purpose, in that it acts as a reliability test for the models (interdependency of parameters) inferred from the data collected as part of Data Series 1 from the postgraduate students.

6. Determining the Impact and Utilisation Measures as Indicators of Applied Capability

A statistical inferential model that associates the availability of resources with impact has been presented. The impact factor is then subsequently applied in determining a resources utilisation level using equations (6) and (7).

Data modelling is based on a rule-based fuzzy logic inference system; an approach that is conducive for modelling the dynamics of the subjective independent and dependent variables input by domain experts. The data describes how the different levels of matching impact on the ability of an individual's resource to fulfilling a given task. For the purpose of this work, these levels were set to *low, medium,* and *high*. The combination of three types of resource each with three levels of match (*low, medium,* and *high*) results in 27 different scenarios. In order to maintain a good response rate from the respondents, 10 different scenarios were used to provide the ability to extract information for all possible 27 scenarios. The respondents were asked to fill out a 10 row table corresponding to 10 different 'match' compositions and to give their perceived level of an individual's impact on each of the scenario (i.e. low, medium or high). They were also asked to assign weights to each of the three resource types. The 27 possible scenarios covering all the possible combinations of an individual's EPA levels and the shortened version with 10 scenarios are presented in Figure A2 (in appendix).

6.1 Data Modelling and Analysis

The assumptions used in the validation process are: (1) the participating domain experts agreed that the suggested EPA is a predictor of the impact of an individual's resources. (2) The combination of resource

Utilisation and Impact is the true representation of an individual's capability (verification). (3) The *Capability* model is sufficiently robust to be considered as a basic capability evaluation method for deployment in working environments.

Data Series 1 is used to validate the EPA as a predictor of Applied Capability. A combination of dependent variables and their influence on the outcome of the model is tested using multiple regression analysis. A comparison with Jaque's (1996) model is made to establish a baseline for the benchmarking. The verification process makes a comparison of the results with those from the inferences made from Data Series 2. The results of the validation and verification process determine the appropriateness of the proposed conceptual model. Figure 4 shows a graphical representation of the data taxonomy and the inferential modelling roadmap.

Put Figure 4 here:

6.2 Input Data Validation

The internal consistency of Data Series 1 was verified using inter-rater reliability (i.e. the degree of agreement amongst raters (Salkind, 2008; Sapsford, 1999)) of the weights and requirement levels assigned by domain experts for each resource. Data Series 2 was verified using a shortened questionnaire to assess the error ranges resulting from the application of the process.

In order to verify the internal consistency of the questionnaire used to measure the independent EPA variables and the skilled, knowledge and values, the Cronbach α was calculated (Field, 2009; Nunnally and Bernstein, 1994). The results of the Cronbach α test are shown in Table 2. The α values are all in the acceptable range (i.e. above $\alpha = 0.7$). It should be noted that the Cronbach α is only applicable to aggregate variables made up of several items, variables such as CIP are not applicable. From these test results the authors conclude that the Data Series used for measurements is internally consistent and the data obtained from surveying was valid for modelling purposes.

Put Table 2:

The inter-rater reliability test as applied to the data supplied by domain experts (weights and requirement levels) reveals that the correlation in a single measure is 0.575, but the single-rater judgements are correlated and reliable. An intra-class correlation of 0.75 was evident with 0.97 for single and average measure of the resource weightings levels. These results demonstrate a high degree of absolute agreement between domain experts with respect to the levels of resource requirement.

In order to ensure the reliability of the Data Series 2, 2 random academics were requested to respond to the simplified questionnaire (10 questions) in addition to the full-length questionnaire (27 questions). The results from the full questionnaire were then compared with the approximated results obtained from the simplified version. In total this represents a comparison of 54 scenarios. In order to compare the observed data with the predicted data and to determine the variability in the predicted data that can be attributed to the methodology used. The coefficient of determination R^2 is used to check the goodness of fit between the predicted and observed parameters.

$$R^2 = 1 - \frac{\sum_{i=1}^{n}(y_i - \hat{y}_i)}{\sum_{i=1}^{n}(y_i - \bar{y}_i)} \qquad (9)$$

Where y_i is the observed value; $\hat{y}_i$ is the predicted value and $\bar{y}_i$ is the mean value of all observations. This yielded a result whose value of 0.96 indicates that the algorithm employed is reliable and representative of the observed data, and that the data is valid for modelling purposes.

6.3 Data Analysis Estimating the Impact and Utilisation of Resources

The validity of the assumption that the EPAs are true predictors of resource Impact was tested. Various regression methods were considered, but based on the nature of the data sets (qualitatively and quantitatively) it was concluded that the most suitable method would be to use Linear Multiple Regression (LMR). Table 3 summarises the ρ values and R squared values for each of the data variables.

Put Table 3:

These results confirm that EPAs are significant as resource Impact predictors. A second test was conducted to assess whether the proposed predictors are better representatives of Impact as compared to those of Jaques' (1996) model. Table 4 provides a summary of the proposed predictors of resource Impact.

Put Table 4:

The conclusion that can be drawn from the Data Series 1 testing is that the proposed EPA model is a good predictor of the 'average' impact level of resources with respect to (in this instance) the data obtained from both postgraduate students and academics. The results also demonstrate that the selections of the independent variables used for the purpose of Capability modelling are a true predictor of the resource impact. The deduced regression formula is:

$$I = -0.326 + 0.234I_E + 0.436I_P + 0.585I_A \quad (10)$$

The Data Series 2 provided the information for individuals-Job matching levels. The "Approximate Reasoning" Mamdani, 1977; Zadeh, 1975) was used to estimate the levels of match in the categories Low, Medium or High. The conditional statements which relate the inputs to the outputs are determined by fuzzification rules (Moghaddam and Mousavi, 2009). In the proposed model there are three inputs each with three different membership functions; as such 27 rules can be extracted that relate all possible inputs to the output space. The output is the level of impact specified by the domain experts for each of the 27 combinations of match level.

Figure 5 shows the resulting surface obtained. The surface demonstrates the resources Impact based on various levels of matching for Enablers, Preferences and Attainment for a given job or task. The surfaces clearly demonstrate that the Impact index increases as a function of increased levels of predictor matching; this increase is similar for both variables in each plot. The three plots have similar appearance indicating that all of the independent variables act in a similar way with respect to their influence on the Impact index.

Put Figure 5 here:

Figure 6 shows the relationship that exists between the observed and predicted Impact indices, the figure shows plots of the observed data (information provided by the individuals and their line manager or supervisor), data predicted by multiple linear regression of Data Series 1 and that predicted from the expert using the Mamdani model. Good proximity of the observed and expected resource Impact levels is illustrated for the proposed conceptual and inferential models.

Put Figure 6 here

Thus far we have discussed in some detail the determination of the resource Impact indices. The next step is to consider the estimation of the resource Utilisation factor. Recall that *Resource Utilisation* is defined as the level at which an individual uses their resources to fulfil a task subject to their availability and is represented as a given resources usage to availability ratio .

Typically the estimation of resource utilisation in industrial systems occurs in environments where jobs or tasks are defined in terms of standard units of work, where stations/machines have well defined capacities, processing times are well defined, and there are good estimates of the inter-arrival time of jobs etc. (Askin and Standridge, 1993).

However, in the case of the current study where the modelling relies on the ‘study patterns’ of postgraduate students, the environment is not as well defined and does not readily lend itself to the application of a standardised approach to utilisation measurement. To accommodate such circumstance the authors have devised a method that uses the same basic principle of regression analysis to estimate Utilisation (A''_{mi}), and whose implementation is described in steps 7 and 8 of the algorithm.

The independent variables (that represent the criteria for estimation), the coefficients (representing the interrelationships between parameters) and the estimation technique (in this case Ordinary Least Square regression) represent the parameters of the estimation model. Using the Impact factors the Utilisation of resource *“I”* for individual *m* can be estimated as:

$$A''_{mi} = -0.326 + 0.234A''_E + 0.436A''_P + 0.585A''_A \qquad (11)$$

The estimated values for resource Utilisation and Impact indices are shown in Figure 7.

Put Figure 7

The results show that the proposed model more than adequately differentiates between the participating individuals. This testifies to the fact that the EPA data collection process and the subsequent modelling approach can successfully discriminate between an individual's Impact and Utilisation (two components of Applied Capability) with respect to completing a given job or task. It also indicated that the same regression formulae (β coefficients) can be used to estimate the Impact and Utilisation levels for an individual as well as determine their fitness to perform a job based on the proposed data collection and modelling methodology.

6.4 Robustness Tests

Monte Carlo simulation has been conducted to analyse the changes in Impact and Utilisation levels under differing experimental conditions. The simulations are designed such that a random job, with a random number of requirements in each of the three main criteria (EPA) is assigned to subjects (individuals) with random capacities to meet those requirements and an estimate of their Impact and Utilisation is arrived at using equations 10 and 11. The constant parameters for the experiments are the number of resources types i.e. EPA. The variable parameters in the simulations are the levels of the job requirements which are set to High, Medium or Low. A summary of the simulation parameters and the run conditions is given in Table 5.

Put Table 5

Figures 8a–c shows the final value for Impact and Utilisation for individuals under three experimental conditions in which the requirements of a job are set to Low (0.25), Medium (0.5) and High (0.75) respectively.

Put Figure 8:

These results suggest that when the job requirements are high (Figure 8a), individuals would normally respond by more aggressively expending their innate resources in meeting that demand. The impact of such expenditure may very well be below average (0.5), despite responding to the increased demand; their impact is less than they may have wished. This is analogous to an individual expending too much effort on an activity and achieving little in response. In the second scenario (Figure 8b), the job requirements are medium and the difference between the Impact and Utilisation levels is decreased, but nevertheless individuals are still expending relatively high levels of resource whilst the resulting impact remains moderate. In the final scenario, when the job requirements are low (Figure 8c), individuals have greater impacts on the job they perform, but their utilisation level is lower. This is analogous to situations where the individuals are over qualified for the job they perform, and there is a capability mismatch.

As these results are realistic and conform to those expected, then they are suggestive that the proposed method for estimating an individual's Impact and Utilisation is appropriate. The combination of the resources an individual possesses and how they are *"applied"* can conceptually represent their *Capability* to achieve/fulfil a given job or task. We refer to this approach as *"Applied Capability"*.

7. Implementation and Implications

Figure 9 shows a snapshot of the predicted capability profile for the 91 postgraduate students who agreed for the results of their capability prediction to be reported in this study. The results show that Utilisation has a tighter distribution than Impact. This observation demonstrates the differences that exist between individuals in the cohort and in their ability to achieve the assessment benchmark with respect to the levels of effort expended. The module leader sets the acceptance levels for the Impact and Utilisation in the range 0.8 to 0.9. Individuals who meet the criteria are identified by red dots in Figure 9 and represent the most promising individuals. They are the individuals who possess the right combination of resources and who can effectively utilise them. In other words they are the capable individuals for systems modelling perspective and equally should perform well in future projects.

The wider implication of such finding is that it allows managers who lead such projects to identify the team members with highest capabilities with respect to completing similar tasks in the future. In this example out of a cohort of 91 who agreed their data to be used for capability prediction some 29 individuals are categorised as highly capable and can be recommended for future systems modelling projects. They are the individuals who have the necessary qualities and are able to deploy them effectively at the correct level.

Figure 9:

One underpinning assumption of this research is that we believe experts in various sectors are capable of setting the key requirements, usage levels and the impact each resource has on successfully achieving the objectives of a given task. In the context of our example, academic supervisors are capable of defining such parameters accurately and in our experience within the engineering field, a similar level of definition in terms of the required parameters can be achieved through project planning and resourcing.

8. Application and Potential Benefits for Organisations

One of the primary benefits of this research is that it facilitates the short term and strategic personnel needs of an organisation. To meet these needs, an organisation must manage the process of ensuring that the personal and professional needs of the individual are met and supported. As part of the natural evolution of an organisation, it is imperative that they employ the correct individual and then have the ability to grow that individual by entering into a process of continuously training and monitor the acquisition of their necessary workplace based skill set. As an assessment tool *Applied Capability* can assist organisations in understanding their employees' capabilities and in the development of training plans to enhance those capabilities in meeting corporate objectives.

Moreover, the results of *Applied Capability* based assessment can assist an organisation in establishing the correct criteria and requirements for a given job, leading to appropriate candidate selection. Furthermore it can help an organisation to determine if they have set the requirements for a given job at the appropriate level. For example, if candidates continually demonstrate high levels of utilisation and have medium or low levels of impact, then one can conclude that the requirements for the job are set too high in relation to the capability of the candidate performing the job. At present these areas of assessment are not particularly well defined and in that respect the proposed technique will assist in achieving a better balance between an individual's capability and the job requirements. Key factors when implementing the capability model are:

- The accuracy of self-assessment, at times individuals may over estimate or indeed exaggerate their skills and the levels of utilisation of their resources.
- The mechanism used for data collection is also a major consideration in such an approach – finding ways to automatically collect most of the data relating to project members EPA factors is a major challenge.

9. Conclusions

In this paper an attempt has been made to establish a basic definition for measuring the capability of an individual in the workplace. Review of the existing literature has allowed the authors to propose *"Applied Capability"* as a concept that relates to the innate and acquired resources and qualities of an individual to the way in which that individual utilise such resources in completing a given task. This perspective on capability assessment correlates the application of resources to the achievement of task objectives and we believe is a contribution to the existing body of knowledge.

Following on from the proposal of a systemic and analytical method for the assessment of capability, a series of tests were conducted to verify and validate the proposed model. The results from these initial studies helped in defining a conceptual model that underwent further robustness testing. These latter findings support the view that: *Human Applied Capability in the work environment can be described as a combination of the impact of one's resource and the levels at which those resources are utilised.* More succinctly that resource Impact and Utilisation are good predictors of an individual's capability. *Applied Capability* can be used as a good indicator of an individual's performance and to the degree of success that individual will have in achieving a given a task.

Through the use of a real world example the method has been demonstrated by illustrating how the calculations were made and how the results were interpreted.

The key contribution of this research work is in defining a means to measure an individual's capability and an objective method for doing so. The follow on project that the research team has embarked on is measuring the collective capability of human networks (teams). The researchers are investigating the potential for predicting human networks capabilities based on network dynamics and types of relationships between team members.

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MEASURING CAPABILITY OF INDIVIDUALS AT WORK

Figures

Figure 1: The current selection procedures and the possible improvements

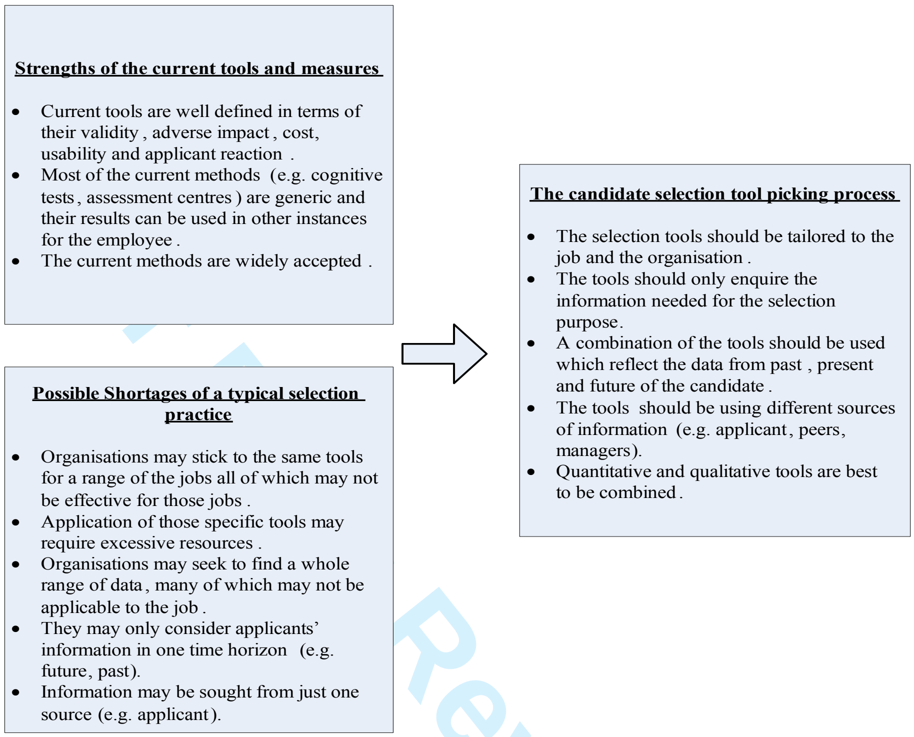


Figure 2: Summary of findings and key definitions for the proposed Capability Model

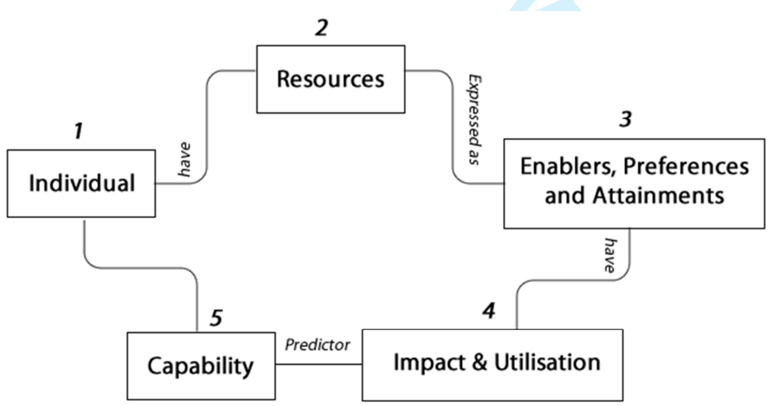


Figure 3: The resources required to complete the Systems Modelling assignment

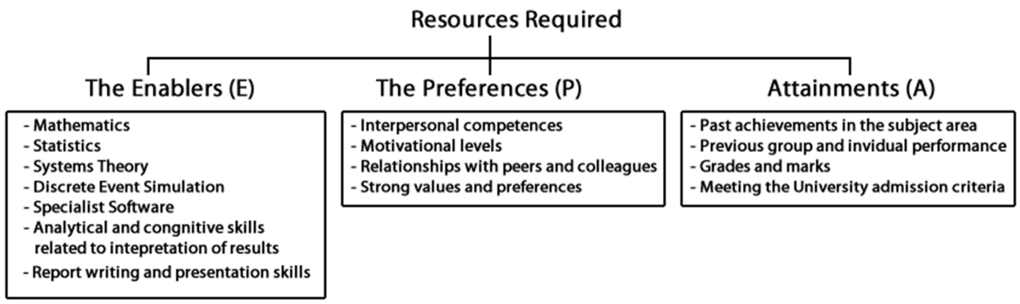


Figure 4: Data taxonomy and modelling

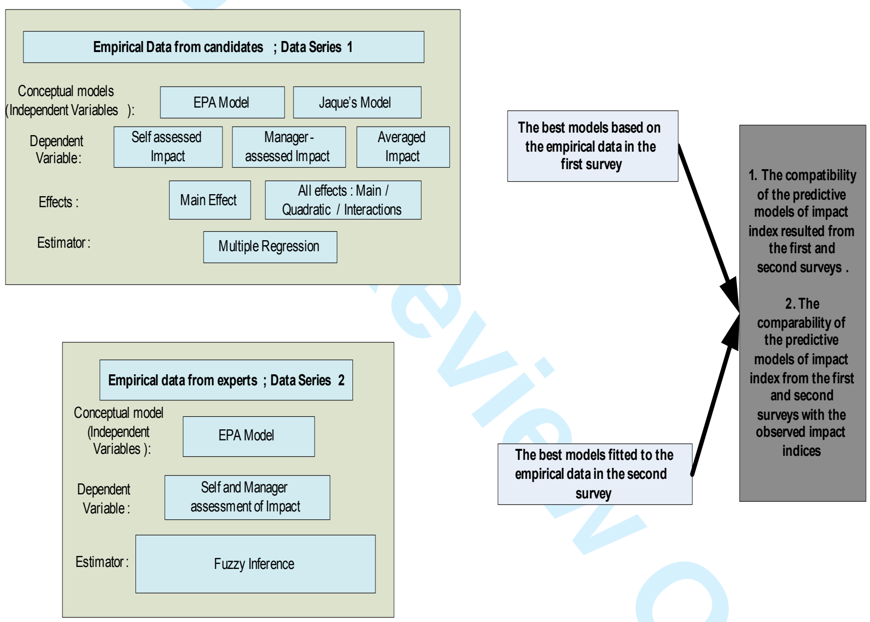


Figure 5: Impact levels against enablers, preferences and Attainment

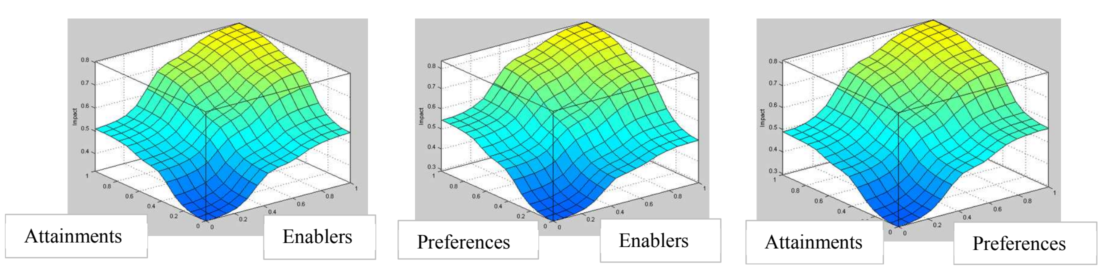


Figure 6: Observed and predicted impact indices.

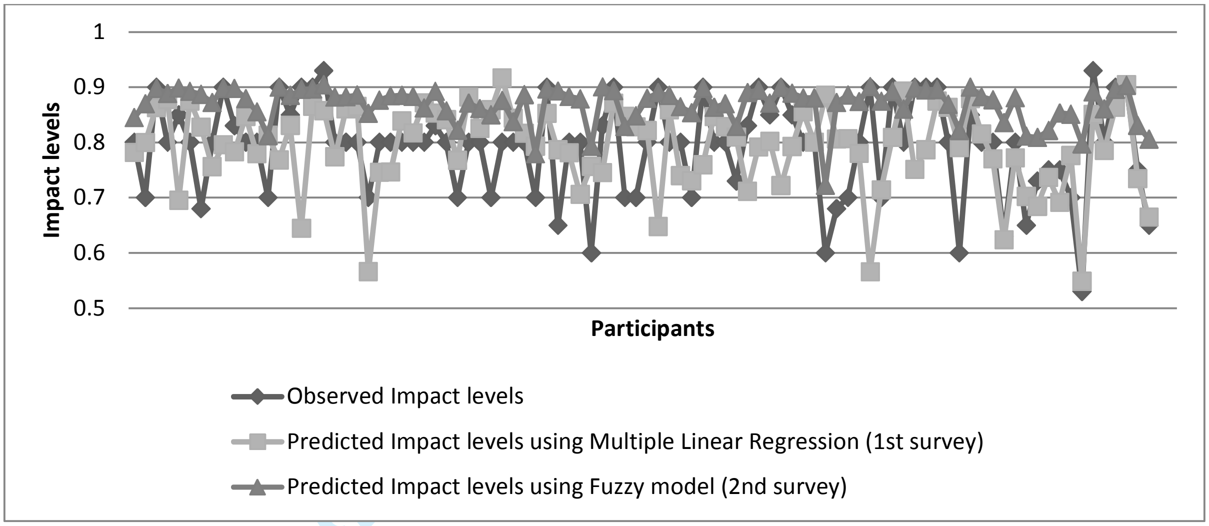


Figure 7: The predicted Impact and Utilisation values for all participants.

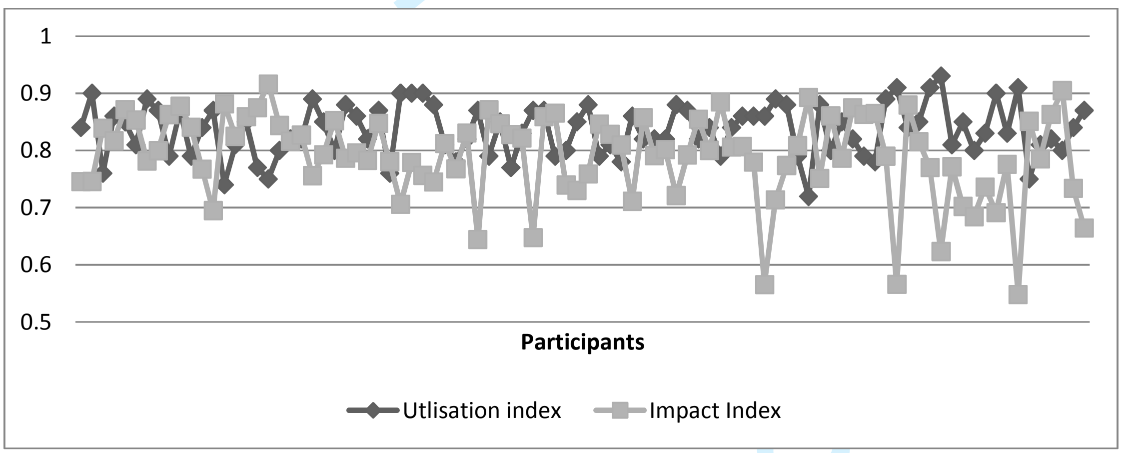
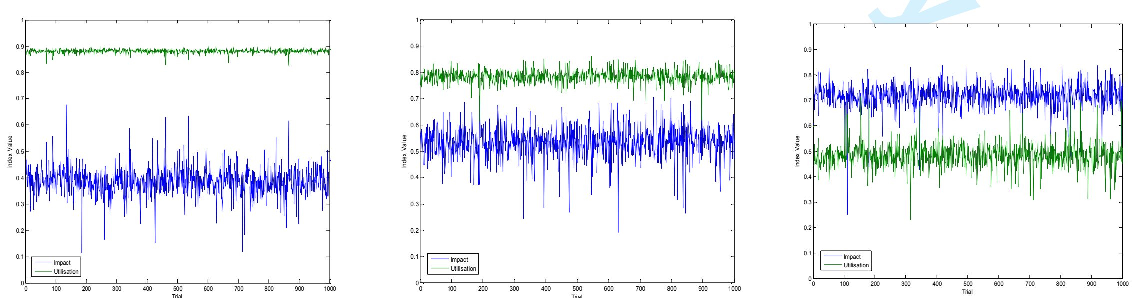
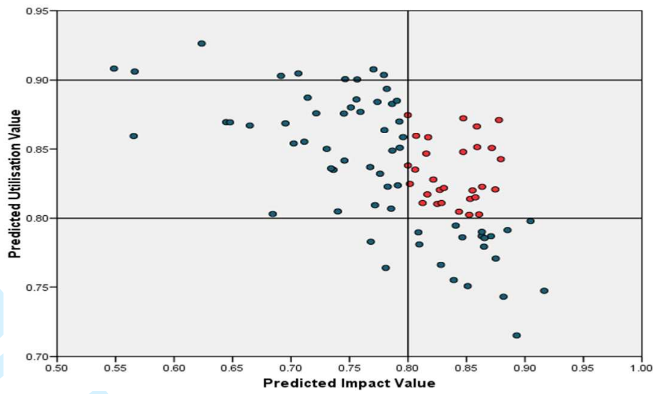


Figure 8: The Impact and Utilisation levels resulted from the three experimental conditions



a **b** **c**

Figure 9: The predicted capability profile of 91 individual



Appendix

Figure A1: The proposed Capability relational model

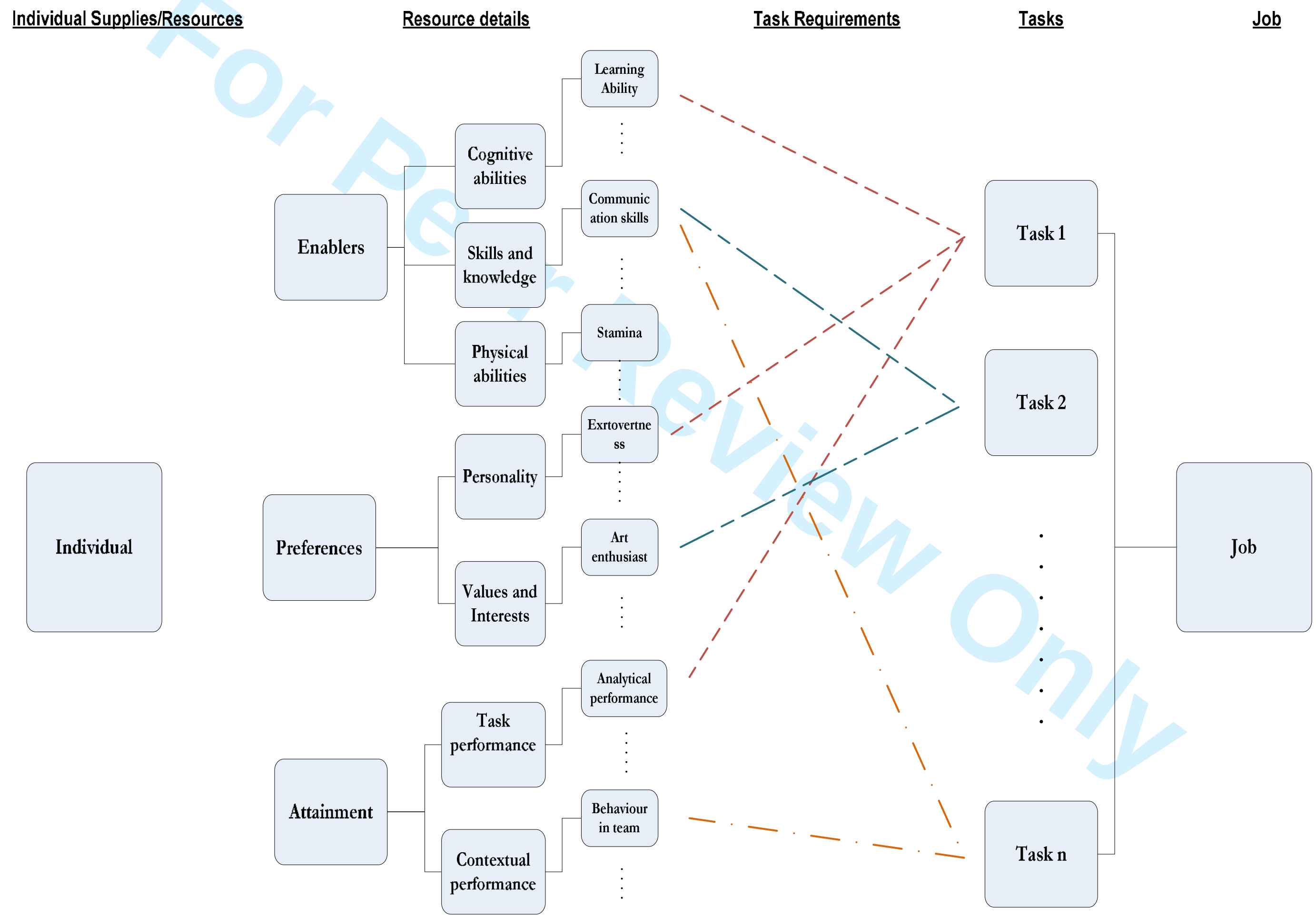


Figure A2: An example of using the algorithm in a simple job and candidate evaluation scenario.

Task-Resource Matching | Weighting | Individual Availability

Job	Task 1	C_{111}	Writing skills	X_{111}	0.7
		C_{121}	Language skills	X_{121}	0.6
		C_{211}	Extrovertness	X_{211}	0.5
		C_{221}	Likes working in teams	X_{221}	0.8
		C_{311}	Analysing and Interpreting	X_{311}	0.7
		C_{321}	Adapting and Coping	X_{321}	0.5
	Task 2	C_{112}	Writing skills	X_{112}	0.5
		C_{122}	Analytical ability	X_{122}	0.7
		C_{132}	Language skills	X_{132}	0.8
		C_{212}	Intuition	X_{212}	0.5
		C_{222}	Likes working with software x	X_{222}	0.8
		C_{312}	Interacting	X_{312}	0.7

C'_{11}	Writing skills	X_{11}	0.7	W_{11}	0.3	A_{111}	0.7	A'_{111}	1.00	A''_{111}	1.00
C'_{12}	Language skills	X_{12}	0.8	W_{12}	0.6	A_{112}	0.5	A'_{112}	0.63	A''_{112}	1.00
C'_{13}	Analytical ability	X_{13}	0.7	W_{13}	0.1	A_{113}	0.9	A'_{113}	1.00	A''_{113}	0.78
C'_{21}	Extrovertness	X_{21}	0.5	W_{21}	0.2	A_{121}	0.8	A'_{121}	1.00	A''_{121}	0.63
C'_{22}	Likes working in teams	X_{22}	0.8	W_{22}	0.2	A_{122}	0.7	A'_{122}	0.88	A''_{122}	1.00
C'_{23}	Intuition	X_{23}	0.5	W_{23}	0.4	A_{123}	0.5	A'_{123}	1.00	A''_{123}	1.00
C'_{24}	Likes working with software x	X_{24}	0.8	W_{24}	0.2	A_{124}	0.4	A'_{124}	0.50	A''_{124}	1.00
C'_{31}	Analysing and Interpreting	X_{31}	0.7	W_{31}	0.3	A_{131}	0.8	A'_{131}	1.00	A''_{131}	0.88
C'_{32}	Adapting and Coping	X_{32}	0.5	W_{32}	0.4	A_{132}	0.4	A'_{132}	0.80	A''_{132}	1.00
C'_{33}	Interacting	X_{33}	0.7	W_{33}	0.3	A_{133}	0.5	A'_{133}	0.71	A''_{133}	1.00

Normalisation | Impact/Utilisation | Statistical Inference

A'_{11}	**0.78**	A''_{11}	**0.98**
A'_{12}	**0.88**	A''_{12}	**0.93**
A'_{13}	**0.83**	A''_{13}	**0.96**

Impact	Utilisation
0.75	0.9

Use of statistical methods to approximate the model

Indices using one of the resulted models

Impact	Utilisation
0.72	0.87

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Tables

Table 1: Assessment methods

Criteria		Assessment method	Means
Enablers (E)	Language skills	IELTS/TOEFL/A-Levels	Report
	General skills	Questionnaire	Self-Assessed
Preferences (P)	Personality traits	MBTI	
	Values	Questionnaire	
Attainments(Q)	Past performance		
	Marks	Reports	Lecturer/Manager
CIP	CIP Level	CIP Interview	Lecturer/Manager
Skilled Knowledge (S/K)	Language skills	IELTS/TOEFL/A-Levels	Report
	General skills	Questionnaire	Self-Assessed
Values (V)	Values		
Temperamental behaviour (T)	Personality traits	MBTI	

Table 2: Internal consistency tests for the questionnaires used to measure the independent variables

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

Table 3: The statistical analysis for the EPA tests

Dependent Variables	***Self-assessed Impact***	***Manager Assessed Impact***	***Average Impact***
Independent Variables	**Coefficient (*p*-value)**	**Coefficient (*p*-value)**	**Coefficient (*p*-value)**
Intercept	0.100 (0.959)	-0.667 *** (0.000)	-0.326 *** (0.000)
Enablers	-0.620 (0.680)	0.504 *** (0.000)	0.234 *** (0.000)
Preferences	0.550 (0.685)	0.811 *** (0.000)	0.436 *** (0.000)
Attainments	0.859 *** (0.000)	0346 ** (0.035)	0.585 *** (0.000)
n	145	145	145
R^2	0.220	0.530	0.767

$*** \, p < 0.01, \quad ** \, p < 0.05$

Table 4: The proposed predictors of resource Impact compared with Jaques' Model

Properties of the Experiment	
Criteria Used	E, P, P
Estimation method used for calculating U and I indices	The OLS Regression equation from survey 1
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
Variations within the three Experiment	
Level of each of the requirements	0.25/0.5/0.75

Table 5: Experimental design for robustness testing

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