ON THE APPLIED CAPABILITY OF INDIVIDUALS, EXPERIMENTAL DESIGN, EMPIRICAL STUDIES AND MODEL VALIDATION – PART 2

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Abstract

This paper reports on the findings of a case study undertaken over a two year period in academia to empirically verify, validate and test the robustness of the "Applied Capability" model (introduced in Part 1). A full implementation of the model is now discussed in the context of the collection and analysis of two data series, the first collected from cohorts of postgraduate students, the second collected from academics with domain expertise in education. Statistical techniques were implemented to validate the input data against the expected output. Additionally Monte Carlo simulation is also employed to assess the robustness of the models using larger randomised data series.

Within this limited academic study, results indicate that the Applied Capability model as applied in the work environment is robust when subjected to analytical testing. These results further suggest that the model is fundamental, in the sense that there is no reason to believe that with some minor heuristic adjustments, this same basic model could not be applied in other industrial sectors and domains.

Managerial Relevance Statement

In the current highly competitive marketplace many organisations both public and private are experiencing a shift in their recruitment pattern away from permanent to short-term contract. The need to sustain a competitive edge, to embrace flexibility and the stark realities of economic survival are forcing many companies to embrace alternative employment strategies and base their recruitment policies on a shorter-term project basis rather than the more traditional long-term and permanent employability. The ability to quickly identify the most capable individuals, individuals who could be rapidly deployed teams and into specified job roles is a key factor in ensuring the success of this policy.

1. Preamble

This paper is the second in a two part series reporting on the establishment of a basic definition for "*Applied Capability*" that is based on an analytical model for assessing an individual's capability in their work environment as an indicator for predicting future performance and potential success. The proposed method was reported in Part 1 titled: '*On the definition of capability in workplace, a new perspective – Part'*. In Part 2 of this series the intent is to validate the model using a real world case study from the education sector. This validation process consists of an experiment, designed to help connect the real world activities with the framework of the model. A cohort of 150 postgraduate students and 41 academic staff participated in multiple surveys, interviews and underwent direct observation as part of an empirical study carried out over a two year period. Statistical methods were used for validation purposes. In order to verify the model, a robustness test was designed based on Monte Carlo simulation and carried out to ensure that the results conform to the strict experimental design framework.

An interdisciplinary literature review allowed the proposition of a basic definition for applied capability in Part 1 of this two part series. Based on this review, a basic definition for Applied Capability within the context of *Work* was proposed. Here the context of work is borrowed from the job analysis; candidate evaluation and goodness of fit literature domains. This has resulted in a heuristic conceptual model.

In order to avoid repetition and complicated cross referencing to Part 1, a summary of the key definitions and parameters of the research work is presented in this section:

- ***Applied Capability:*** is expressed as the *impact* and *utilisation* of an individual's *resources* in completing a task or job (here a job is taken as set of tasks).
- ***Resources:*** are the innate or acquired (i.e. experience gained over time) qualities and traits an individual has and uses to complete a task or job. Through their resources an individual has an ***Impact*** on fulfilling the requirements of a job or task. The amount a resource is used to complete a job or task is called ***Utilisation***.

- ***Capability Factors:*** are the predictors of applied capability and are further classified into 3 categories. The ***Enablers (E)*** which represent an individual's cognitive abilities and skills. An individual's personality traits (i.e. drivers, motivations and values) are classified as their ***Preferences (P)***. Finally, ***Attainments (A)*** represents an individual's past relevant experiences and attainments in the workplace (i.e. their experience).
- ***The Applied Capability Modelling Algorithm:*** consists of 10 steps and covers three activities: 1. *Job Profiling*, 2. *Individual-Job Matching Process*, 3. *Resource Impact and Utilisation Measurement*. The job profiling process is broken down into tasks, associated tasks and the resources required; it then allocates the amount of resource required for each corresponding task. The individual-job matching process, considers the *availability* of the individual and a normalisation operation is then conducted to match the availabilities. Resource impact analysis is conducted and then based on that impact a prediction of utilisation is inferred. The Impact and Utilisation profile can demonstrate a comparative state of applied capability amongst individuals (refer to the appendix for the full algorithm).

2. The Research and Experimental Design Environment

The main objective of this paper is to report on the results of validation and verification tests conducted to validate the "*Applied Capability*" model. The data collected as part of the empirical study consists of two types. The first type of data was collected through a combination of direct observation of individuals (postgraduate students) in the workplace and a standardised individual survey; this data set is referred to as ***Data Series 1***. Data Series 1 is to build and validate the inferential statistical models derived from the data collected form the student cohort. The second data set is that collected from the academic participants using one-to-one interviews and a paper-based survey and is used to verify the inferential models. The second type of data is provided by academics who use their expert knowledge to define a set of capability parameters. These parameter are ultimately used in the prediction of the future success of '*Capable Students'*; this data set is referred to as ***Data Series 2***. In this context, one possible analogy is to compare the outcome of the capability model with a *"Reference Letter"* written by an academic tutor for a student who has applied for a job.

The 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.

The outcome of the first survey is to identify the most applicable combination of independent and dependent variables of *Enablers*, *Preferences* and *Attainments (EPA)*. The inferential models provide estimates for the impact indices of each resource. The purpose of the second survey is to validate the results from the first survey.

3. The Experimental Design

To the best of our knowledge this work represents a first attempt to establish an underlying theory or structure for human based network capability assessment. As part of this work in establishing benchmarks for the methodology a number of diverse physical and statistical models have been pursued. Direct external benchmarking is currently not possible, as the work offers a new perspective on capability evaluation. It should be noted that at the outset of this work the underlying relationship between the variables were unknown. 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. The principles and assumptions made were:

- The independent variables of the model are continuous.
- The dependent variables are continuous variables and not discrete.
- With respect to task or job requirements and an individual's availabilities, the independent variables need to be normalised.

- The exact nature of the relationship between the independent variables and the dependent variables (linear, curvilinear) is unknown.
- The independent variables may be related to each other.
- The independent and dependent variables are assessed using a variety of methods and statistical measures (e.g. self-assessment, expert knowledge …)

Multiple regression analysis is a widely used modelling technique that caters for a variety of different types of independent and dependent variables (categorical, continuous, quadratic variables, and interaction of variables etc.). Clearly multiple regression analysis is a candidate modelling technique for use in this research.

Of the data gathered from a sample size of 150 participating postgraduate students, 5 samples were discarded as being incomplete. The students were allocated two sets of assignments in the area of Systems Modelling and Simulation consisting of a series of tasks to be accomplished over a period of one academic term (October-February). The assignments were well-defined using assignment briefs. The expectations in terms of achieving the learning outcomes and the assessment criteria itself were also communicated to the student cohort. The success in achieving those outcomes is measured in the range 0 to 100%. This value is then used in determining whether the applied capability measurement for a particular individual is a reasonable predictor of their expected success level. In order to successfully implement the proposed capability evaluation algorithm, the implementation will be discussed as a series of experimental steps.

3.1 Data Series 1

As part of the implementation process, the Comprehensive Definition of Job (CDJ) is applied. The CDJ for measuring Applied Capability enables us to link the needs and expectations of the organisation and their selection strategies with the potential candidates. In Part 1 of this paper a comparison and explanation was made that contrasts this new perspective on the Job-Person fitting analysis method and its differences with that presented in the literature [2][5][14][16].

A. *Job Profiling:*

In the context of this research the work environment is academia; as such the type of data required to perform job profiling is extracted from module outlines, syllabus, assignment guidelines and interviews with the module leaders, the academics (i.e. the domain experts). There is no reason to believe that such profiling is not transferable to other work environments and could be applied in situations where the job and task definitions are different.

The profiling procedure used is based on the CDJ process and covers a set of activities that represent steps 1 to 5 of the capability modelling algorithm (see appendix 1):

Step 1: Breakdown the academic assignment (the job) into a number of discrete tasks (see appendix 2 for details of the assignment brief).

Step 2: Specify the resources required to perform the tasks and classify them as Enablers, Preferences or Attainments (EPA). In this particular case, the following *Resources* are required to achieve the learning objectives of the assignment brief:

- Knowledge of the underpinning theoretical science i.e. the mathematics, statistics and systems theory *(Enabler)*.
- A set of skills that encompasses use of specialist software and general IT tools required to complete the tasks outlined in the assignment brief *(Enabler)*.
- General problem solving, acumen, analytical and cognitive skills relating to the interpretation of results *(Enabler)*.
- Writing skills and competencies were also expected of the participants *(Enabler)*.
- Interpersonal competences, good motivation level, strong relationships with peers and other colleagues, strong values and preferences *(Preferences).*
- Past achievements and experience of the individuals in the subject area (i.e. evidence of previous group working at undergraduate levels or in other modules, past grades and marks in specific subjects … *(Attainments).* For example, the University admission criteria

(minimum requirements) and the student's attainments against those criteria were used as benchmarks.

Step 3: Assign a value $X_{ijt} \in (0 \rightarrow 1)$ representing a relative amount of resource j required for a given task *t.* A value of '0' indicates no resource is required, whereas a value of '1' indicates that all (the maximum) of the available specific resource is required to perform the task. This value is determined by domain experts; in our case the value is set by the lecturer and teaching assistants.

Step 4: Determine the levels of a resource required by the set of tasks by evaluating equation (3) (in Appendix 1).

Step 5: Determine the weighting of each resource using equation (4) (in Appendix 1).

Note that the domain experts should use the same measures in assessing this requirement as were used in the assessment of the candidate. While some of the requirements can be assessed using well established tests (e.g. English proficiency, Personality, CIP, etc.); in such cases the requirement would be based on the value of test scores. In other cases (e.g. self-assessment of a range of motivational factors), well established performance metrics and tests may not exist. In such instances the requirement measurement should be based on the semantic differential scale [12].

B. Availability Measurement

Step 6: Determining the individual's ability to provide the required resources. Table 1 summarises the assessment methods used, their criteria and their data soured.

Table 1: The resources required, methods used to ascertain their availability and the means used to collecting the required data.

With respect to *Enablers* and *Preferences,* the method to obtain the necessary data from the participating individuals (Postgraduate student cohort) was a self-assessment form. The information was collected in the 3rd week following the course commencement. A subsequent follow on survey and test was conducted on each individual in week 4 to ascertain their ability to process complex information using the Complexity of Information Processes (CIP) [7] method. The Myer-Briggs type indicators and interviews were used for this purpose. The CIP data collection and analysis phase required some 6 weeks to complete. The levels of previous experience and attainment (i.e. *Attainment)* of each individual were determined using their admission profile and previous work experience. Additionally, the results of the first assignment for the module were included as a component of their attainment calculation.

Steps 7 and 8: Calculate all availabilities using equations (5) and (6) (see appendix 1). These steps are performed to complete the individual's availability and task matching process. One of the more challenging data set acquisitions related to an individuals expected and actual values of resource impact. As part of this process individuals and the module leaders (domain experts) were asked to furbish an indicative value for the impact each set of resources has had on (from the individuals point of view) and should have had on (from the experts point of view) achieving the given tasks. They were asked to evaluate the degree to which their (an individual's) resources contributed to the fulfilment of the task requirements. Student profiling occurred over a period of 20 weeks in each year of the study, this data is combined with Data Series 2 and underpins the implementation of steps 9 and 10.

3.2 Data Series 2

As previously discussed the purpose of Data Series 2 is to establish the capability parameters used in determining an individual's applied capability. A total of some 41 domain experts (i.e. academics in this case) were consulted for this purpose, those interviewed as part of this survey came from a variety of academic backgrounds with differing perspectives of the subject area. A key attribute of those interviewed was that they all lecture and supervise students and additionally provide advice and consultancy services to industry and professional bodies. They are a representative sample of the population that in an academic context can be considered to be employers, employment advisors and decision makers in the appraisal or assessment of human resources. Their research activities, research management, their consulting and business activities, disciplines, age, gender, and ethnic backgrounds are diverse. This diversity, engagement with industry and professional bodies provides confidence in the incorporation of their suggestions into the proposed basic model.

The outcomes of this survey lead to an understanding of the importance and the 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 task.

This second data series also has another purpose, and that is to act as a reliability test for the models (interdependency of parameters) inferred from the data collected from the postgraduate students as part of Data Series 1.

A. Determine the Impact and Utilisation Measures as Indicators of Applied Capability

Steps 9 and 10: These steps relate to the statistical inferential model implementation that associates the availability of resources with impact. The impact factor is subsequently applied in the determination of the resource utilisation level using equations (7) and (8) (see Appendix 1).

The process of data modelling is based on a fuzzy logic rule based inference system; such an approach is conducive to modelling the dynamics of the subjective independent and dependent variables input by domain experts. The data describes how different levels of matching (individual tasks) could impact on the ability of an individual's resource to fulfilling a task. For the purpose of this survey, these levels of match were set to *low, medium,* and *high*. The combination of three resource Capability Factors (i.e. EPA) 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, we use 10 different scenarios [7][10] with the ability to extract the information for all possible 27 scenarios. The questionnaire used in this survey is available in appendix 3. The respondents are asked to fill in a 10 row table which corresponds to 10 different match compositions and to give their perceived level of an individual's impact in each of the scenario (e.g. low match in Enablers, medium match in Preferences and low match in Attainments). They were also asked to assign weights to each of the three resource types. The 27 possible scenarios covering all the possible combinations of individual's levels EPA and the shortened version with 10 scenarios are presented in Appendix 3 along with the rationale and method for this simplification.

4. Data Modelling and Analysis

The assumptions used in the validation process are:

1. A consensus exists amongst the participating domain experts that EPA is a predictor of the impact of an individual's resources.
2. The combine resource Utilisation and Impact is the true representation of individual's applied capability (verification).
3. The Applied Capability model is sufficiently robust be considered as a basic capability evaluation method for in work environments.

Figure 1 depicts a graphical representation of the roadmap to data taxonomy and the inferential modelling processing.

Figure 1: Data taxonomy and modelling

Data Series 1 is used to validate 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 (1994) model [7] is made to establish a baseline for the benchmarking. The verification process makes a comparison of the results with that of the inferences made from Data Series 2 (i.e. the Applied Capability predictors from the domain expert's point of view). The results of the validation and verification process determine the appropriateness of the proposed conceptual model.

A. *Input data validation*

In order to ensure the reliability and consistency of the measured data a series of tests were conducted. The internal consistency of Data Series 1 is checked by the inter-rater reliability (i.e. the degree of agreement among raters) of the weights and requirement levels assigned by domain experts for each resource. Data Series 2 is tested using the shortened questionnaire (see appendix 3 for details) to assess the error ranges resulting from the application of the process.

To verify the internal consistency of the questionnaire used to measure the independent EPA variables and Jaques's (Skilled knowledge and Values), the Cronbach α was calculated [4][11]. The results of the Cronbach α test are shown in Table 2. The α values are all above the acceptable level (α = 0.7). It should be noted that the Cronbach α is not universally applicable to all variables, only to those variables made up of several items, variables such as CIP for example are not calculated using this method. From these test results the authors concluded that the Data Series used for measuring internally consistent and the data obtained from surveying was valid for modelling purposes.

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

To further ensure the consistency of the data collected as part of the job profiling process, that is the domain experts view on the list of resources required and their weightings, an inter-rater reliability test was conducted [13][15]. The test 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 data capture part of the questionnaire was design to seek the rationale for the approximation to the real values, 2 random academics were requested to respond to the simplified questionnaire (10 scenarios) in addition to the full-length questionnaire (27 scenarios). The results from the full 27 scenario questionnaire were then compared with the approximated results obtained from the 10 scenario version. In total this represents a comparison of 54 scenarios. In order to compare the observed data with the predicted data and 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.

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

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. A resulting value of 0.96 indicates that the algorithm employed is reliable and is representative of the observed data, and the data is valid for modelling purposes.

B. <u>Data Analysis Estimating the Impact and Utilisation of Resources</u>

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 deduced that the most suitable method would be the linear multiple regressions (LMR). Table 3 summarises the ρ values and R squared values for each of the data variables.

Table 3: The statistical analysis for the EPA tests

These results confirm that EPAs are significant in terms of 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 model [7]. Table 4 provides a summary of the proposed predictors of resource Impact.

Table 4: Comparison of the proposed predictors of resource Impact compared to Jaques Model

The results demonstrate that in comparison with the EPA model the Jaques model is less desirable as a predictor of an individual's resources.

The conclusion from Data Series 1 testing is that the proposed EPA model is a good predictor of the average impact levels of resources with respect to the data obtained from both postgraduate students and academics. The results also demonstrate that the selection of the independent variables for the purpose of Applied Capability modelling is a true predictor of the resources impact. The deduced regression formula is:

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

E: Enablers, P: Preferences and *A: Attainments.*

A third test was conducted this time using the data collected from Data Series 2. Due to the nature of the data collected from domain experts (in this instance Academics), Fuzzy Interference models for "Approximate Reasoning" are employed [8][17]. The Individuals-Job matching levels for the EPAs are described as being Low, Medium or High; this arbitrary setting allows us to determine their degree of matching as inputs to the model. The conditional statements which relate the inputs to the outputs are determined by fuzzification rules [9]. 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. This relationship is modelled using the MATLAB® Mamdani fuzzy interface [8][9](also see MATLAB 7.1 software tool manual).

Figure 2: Output membership functions for the Mamdani model on the second survey.

Figure 2 shows all the 27 output membership functions for the model. The X axis shows the impact values and each curve represent one of the 27 scenarios with the standard deviation and the mean of the given impact level for each scenario (extracted from domain expert's views). In all cases the distributions are Gaussian distribution. The rest of the settings default to those used by of the MATLAB Mamdani fuzzy interface.

Figure 3 shows the resulting surface obtained from fitting a fuzzy Mamdani model using the information extracted from Data Series 2. 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 quite similar for both of the variables in each plot. The three plots have very similar appearance indicating that all of the independent variables act in a similar way with respect to their influence on the Impact index.

Figure 3: Changes of the Impact level with changes in Enablers, Preferences and Attainment matching levels

Figure 4 depicts 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), that predicted 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.

Figure 4: Observed and predicted Impact indices

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 the *Resource Utilisation* is defined as the levels that an individual uses their resources in fulfilling a task subject to available and is represented as a the ratio of the usage to the availability of a given resource.

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. [1].

However, the case of the current study where the modelling here relies on the 'study patterns' of postgraduate students, the environment is not well defined and does not lend itself to the application of such a standardised approach in measuring utilisation. In this respect it has been necessary of the authors to come to an accommodation and devise a method that uses the same basic principle of regression analysis to estimate Utilisation (A''_{mi}). The implementation of that method is described in steps 7 and 8 of the proposed algorithm (see Appendix 1 and Part 1 of this paper).

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 using the regression model are shown in Figure 5. 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 Utilisations (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.

Figure 5: The predicted Impact and Utilisation values.

C. Robustness Tests

Monte Carlo simulation has been conducted to analyse the changes in Impact and Utilisation levels under three different 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 listed in Table 5.

Table 5: Experimental design for robustness testing

Figures 6a–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.

Figure 6: The Impact and Utilisation levels resulted from the three experimental conditions

These results suggest that when the job requirements are high (Figure 6a), 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 6b), 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 6c), 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, there is a capability mismatch.

Since these results are realistic and conform to the expected, 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 deployed can conceptually represent their *Capability* to achieve/fulfil a given job or task – i.e. their *Applied Capability*.

5. Implementation and Implications

With the consent of the participants, Figure 7 shows a snapshot of the predicted capability profile for the 91 postgraduate students participating in the study.

Figure 7: The predicted capability profile of 91 individual.

The results show that Utilisation has a tighter distribution than Impact. This observation demonstrates the differences that exist between students in the cohort and in their ability to achieve the assessment benchmark (i.e. meet the learning objectives of the module as determined by the final grade) with respect to the levels of effort expended. It is noteworthy that in this particular instance there is a strong degree of homogeneity with respect to the age, abilities, values, personalities and experience of the individuals participating in the study.

The module leader sets the range of acceptance levels for the Impact and Utilisation values as being between 0.8 and 0.9. These individuals are identified as red dots in Figure 7 and represent the most promising individuals. Here the important achievement is to strike a 'balance' between an individual's qualities and how those qualities are utilised to accomplish a task and in doing so avoid the trap of creating super humans or super teams. For example such an exercise could potentially help the module leader to assess the capabilities of those graduating from the module with the view of selecting the most appropriate candidates for employment in the System Modelling domain.

The wider implication of this research is that the same models can be applied across various industrial sectors to study their systems and employees with a view to establishing generic acceptance boundaries for those industries.

6. Application and Potential Benefits in Engineering and Management of Systems

One of the primary benefits of this research and the proposed Applied Capability concept is that it facilitates the short term and strategic personnel needs of an organisation. The ability to identify individuals that posses certain skill sets and competencies, the ability to assemble teams of such individuals that collectively leaver those competencies to collectively delivering corporate objectives efficiently and effectively in a timely manner is an on-going corporate challenge. To meet these need an organisation must manage the process of acquiring, renewing, updating, and enhancing their capabilities, whilst at the same time ensuring the personal and professional needs of the individual are met and supported. There are three key groupings that have a major role in personal and organisational development. The first group is the individual themselves; people endeavour to choose opportunities that provide them with the educational, vocational and networked opportunities that address their personal and professional aspirations. The second group is made up of team managers and leaders, a key responsibility of this subset in highly skilled economies is to identify, protect and enhance key skill sets within their organisation. They need to understand the competencies and personalities in their group and be able to intervene and improve their operation. The third group is made up of the strategists and policy makers who have the responsibility of utilising and mobilising the socio-economical resources to create opportunities for development. The creation and facilitation of teams that empower both the individual and organisation to improve their separate and joint capabilities would be major step forward for strategists and policy makers, thus enabling leaders and managers to build and lead more effectively teams of highly capable individuals.

As part of the inevitable and natural evolution towards team based organisations, it is imperative that we employ the correct individual and then have the ability to continuously train and monitor their evolution in attaining, expanding and enhancing the necessary workplace based skill set. In fulfilling corporate objectives, managers need to understand and measure the impact of interventions such as training, motivating, promoting, in meeting their employees aspirations.

As an assessment tool *Applied Capability* can assist organisations in understand their employees capabilities and in the development of training plans to enhance those capabilities in meeting corporate objectives.

Moreover, the results of *Applied Capability* assessment can assist organisations in establishing the correct criteria and requirements for a given job, to allow them to systematically filter and search for the most appropriate candidate. It can also help organisations to determine if they have set the requirements of a job at a reasonable level, for example if candidates constantly demonstrate high levels of Utilisation and medium or low levels of Impact, one can conclude that the requirements are set higher than the capability of the type of candidate attracted to the job. At present these areas of assessment are not particularly well defined and in that respect the proposed technique for job profiling and measurement of an individual's capability will assist in achieving a better balance between an individual's capability and the job requirements. It will facilitate the elimination of scenarios where highly capable individuals are under-utilised within their organisation role, where individuals who are more capable than the job requirement feel underappreciated or indeed from the organisational perspective are '*over qualified and over paid*'.

7. Conclusions and Future Work

This paper reports on the tests conducted to verify and validate the proposed conceptual and mathematical model(s) for measuring and predicting an individuals' *Applied Capability* in their workplace environment. It achieves this by proposing and testing the validity of the effect of a set of independent variables on dependent variables using analytical methods. The results from these studies helped in determining a satisfactory and representative conceptual model which underwent robustness testing. The findings indicate that there is no reason to refute the thesis that: *Human Applied Capability in the work environments can be described as the product 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 capability. *Applied Capability* is itself a strong indicator of performance and the degree of achievability in performing a given a task.

Two Data Series sets were used, the first as the basis for analytical inferences and the second to confirm the model through approximate reasoning. The outcome confirmed that the observed and expected outcomes were close enough for verification purposes and had reasonable robustness.

Through a real world example reported in this paper, it has been demonstrated how the calculations and interpretation of results were made. There are no reasons to suggest that the underlying conceptual model is not of sufficient generality to form the basis of capability evaluation in other sectors.

The mathematical and conceptual models development as part of this research will be further extended and investigated across differing workplace job environments to not only further confirm their robustness, but to also identify usage patterns and standards for the more effective use of

Impact and Utilisation measures. Currently the models are being extended to measure human-network capabilities. The aim of this forthcoming research programme work, we attempt to explain how the collective capability of a team can be affected by the network characteristics of Skills Diversity, Homophily, and Past Experiences of its constituent members [6].

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On the Applied capability of individuals, experimental design, empirical studies and model validation – Part 2 (Shekarriz, Mousavi and Broomhead)

Figures

Figure 1: Data taxonomy and modelling

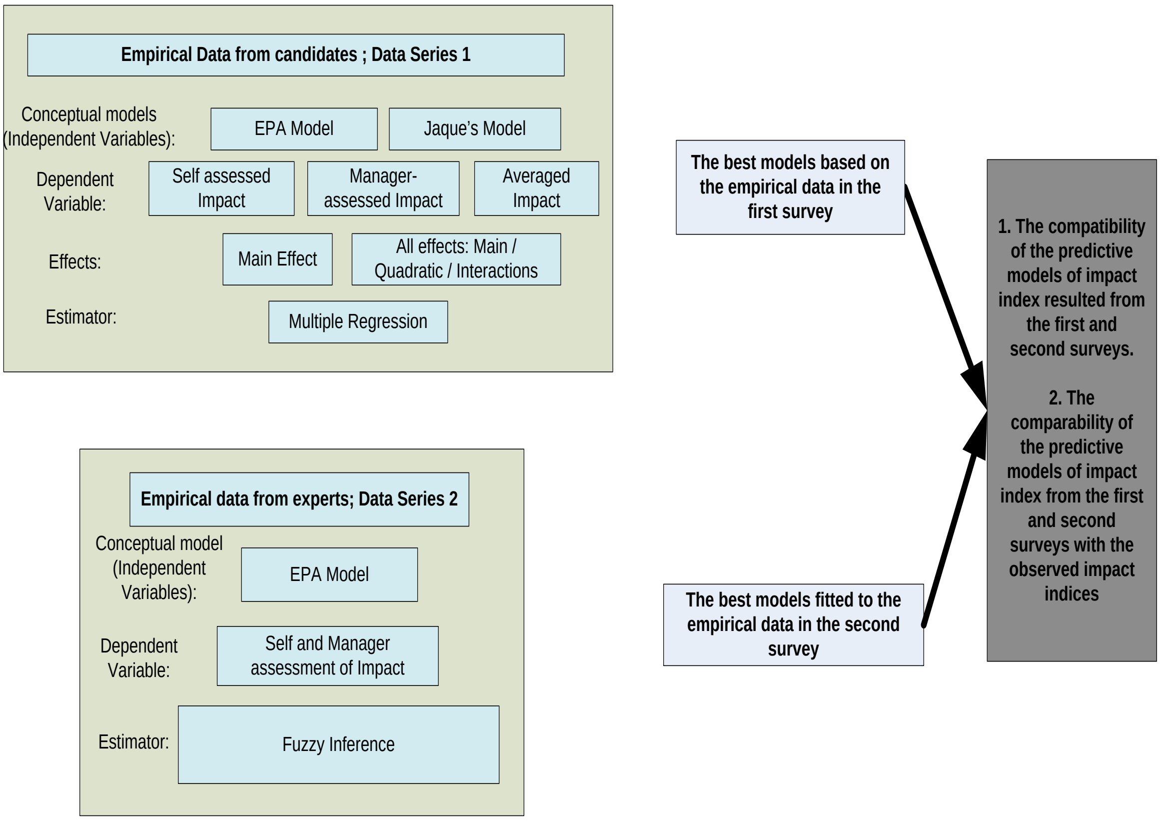


Figure 2: Output membership functions for the Mamdani model on the second survey.

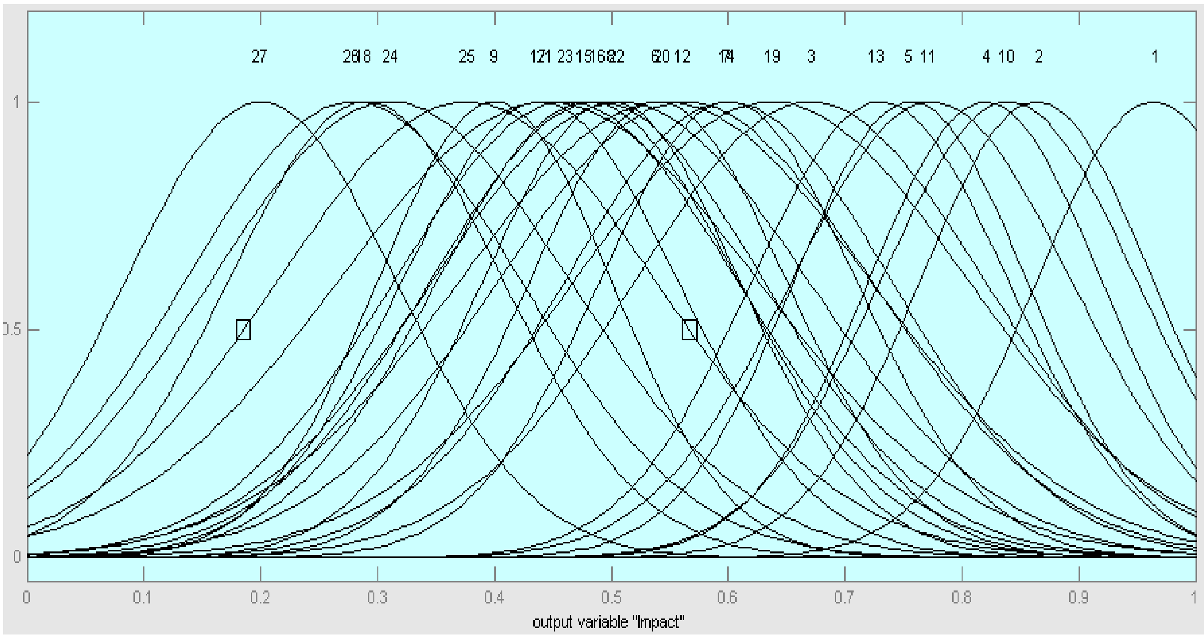
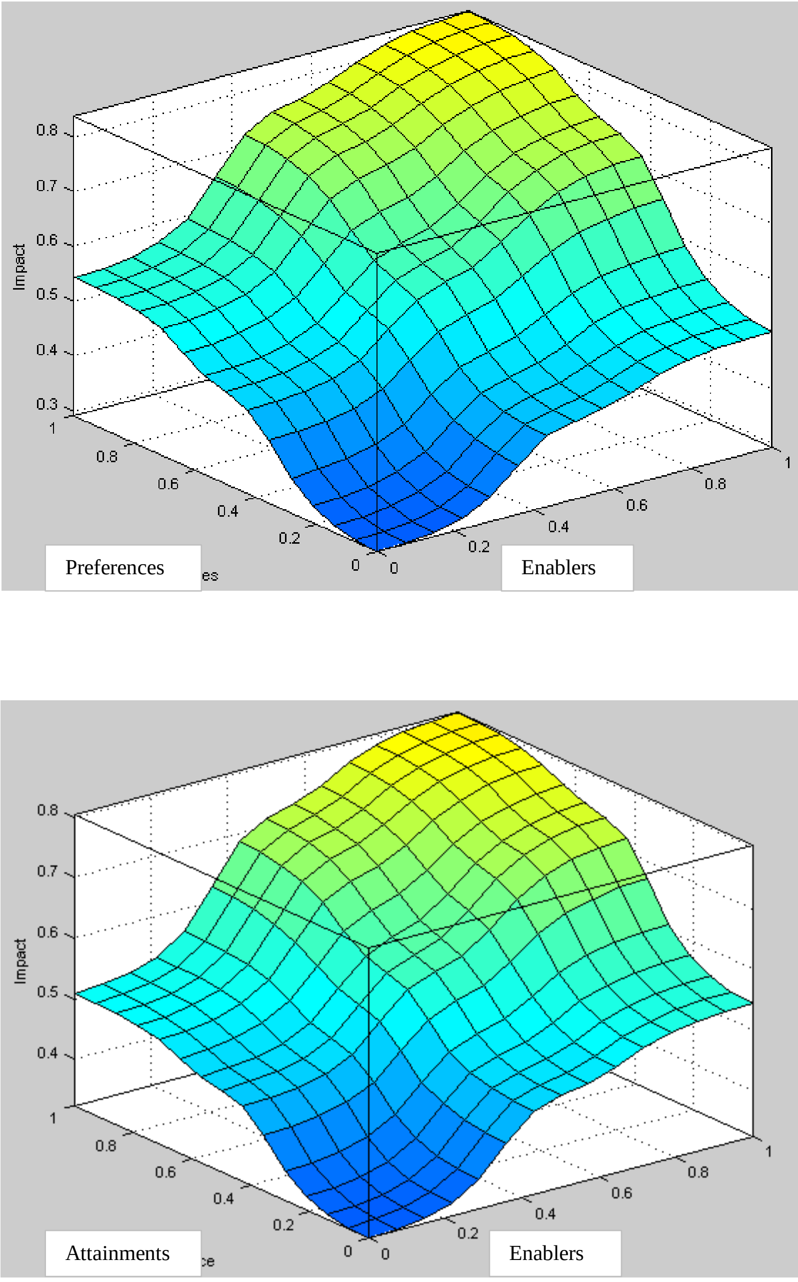


Figure 3: Changes of the Impact level with changes in Enablers, Preferences and Attainment matching levels



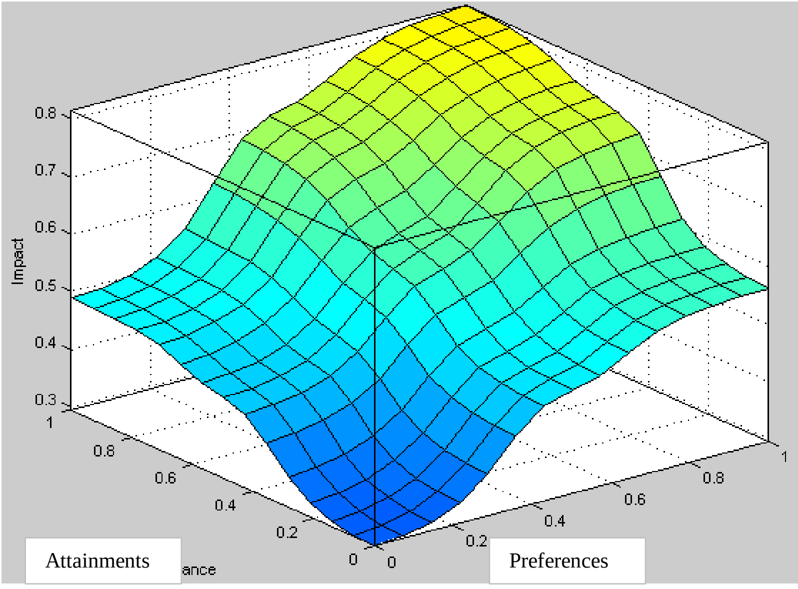


Figure 4: Observed and predicted Impact indices.

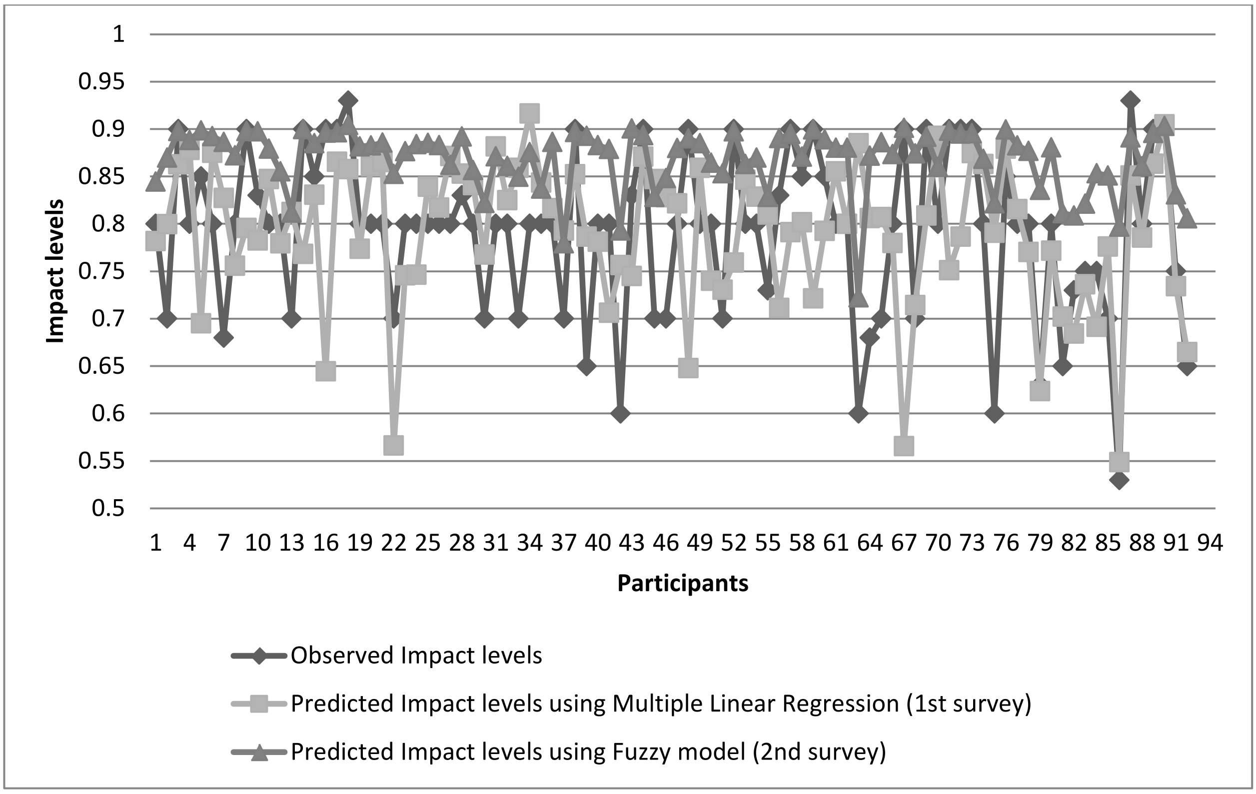


Figure 5: The predicted Impact and Utilisation values.

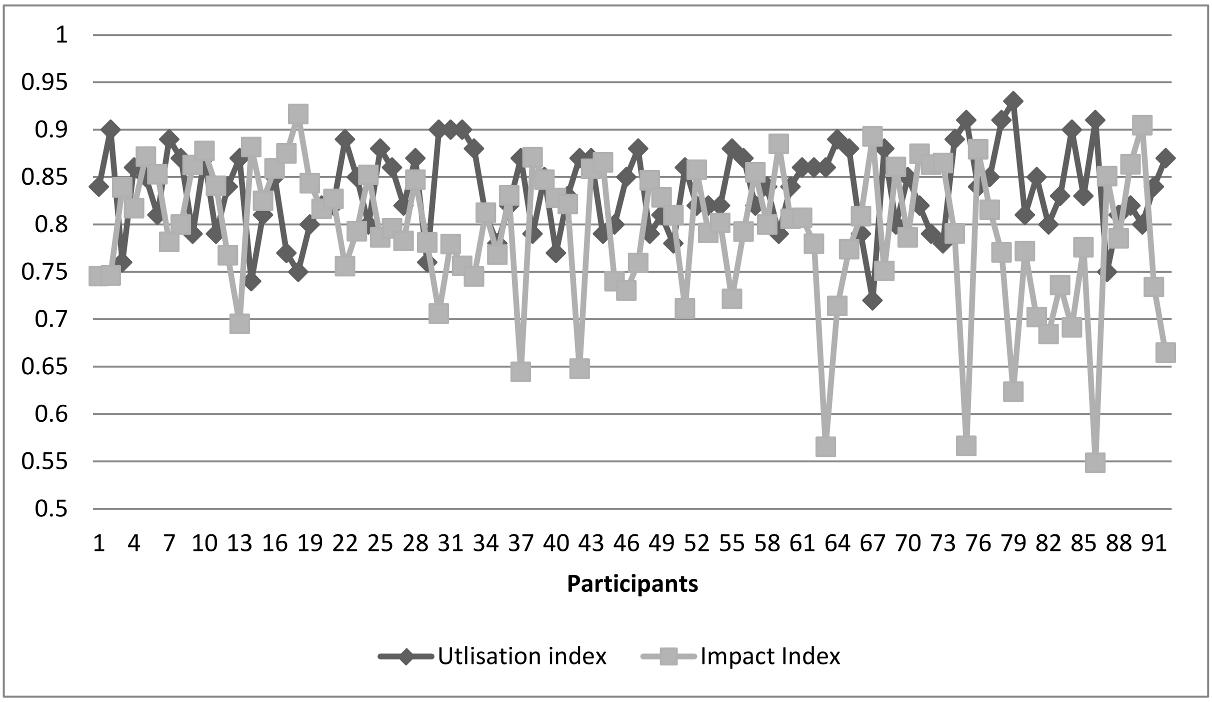
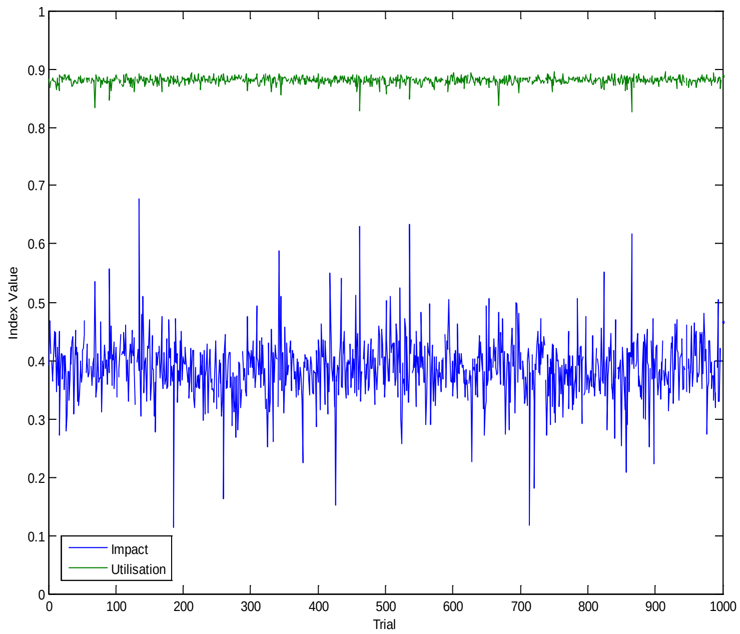
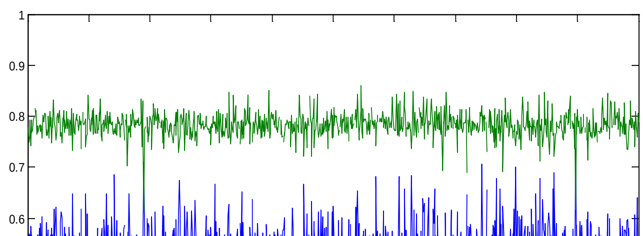


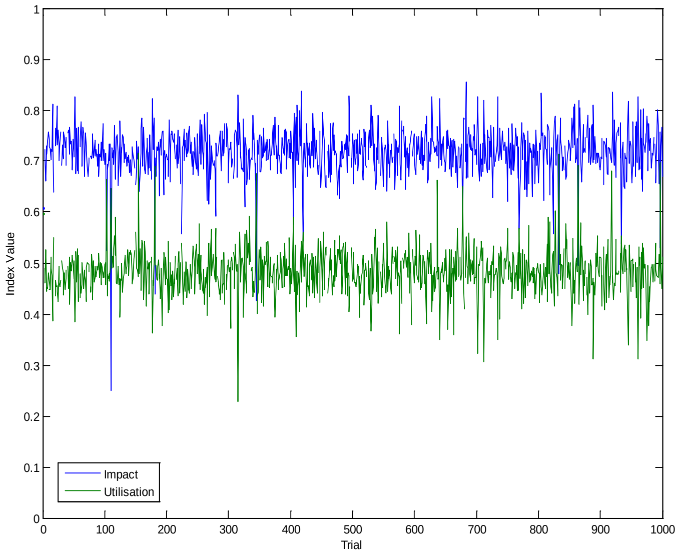
Figure 6: The Impact and Utilisation levels resulted from the three experimental conditions



6a: High Levels of Requirement

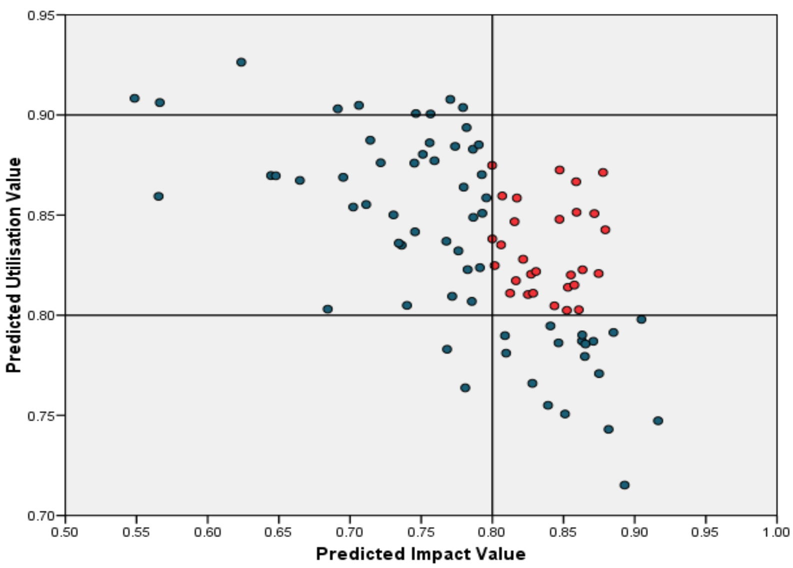


6b: Medium Levels of Requirement



6c: Low Levels of Requirement

Figure 7: The predicted capability profile of 91 individual


Predicted Utilisation Value
Predicted Impact Value
0.95
0.90
0.85
0.80
0.75
0.70
0.50
0.55
0.60
0.65
0.70
0.75
0.80
0.85
0.90
0.95
1.00

Tables

Table 1: Assessment methods and data sources

Criteria		Assessment method	Data Source
Enablers (E)	English language skills	IELTS or TOEFL test result	Report
	General skills related to the job	Questionnaire	Self-Assessed
Preferences (P)	Personality	MBTI	Self-Assessed
	Values	Questionnaire	Self-Assessed
Performance(Q)	Task and contextual performance	Questionnaire	Self-Assessed
	Marks	Reports	Manager Assessed
CIP	CIP Level	CIP Interview	Manager Assessed
Skilled Knowledge (S/K)	English language skills	IELTS or TOEFL test result	Report
	General skills related to each task	Questionnaire	Self-Assessed
Values (V)	Values	Questionnaire	Self-Assessed
Temperamental behaviour (T)	Extreme Personality traits	MBTI	Self-Assessed

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

		Number of items	*Cronbach's α*
	Enablers	9	0.78
EPP Model	Preferences	22	0.81
	Performance	9	0.85
	CIP	1	N/A
Jaques Model	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	-0.667 ***	-0.326 ***
	(0.959)	(0.000)	(0.000)
Enablers	-0.620	0.504 ***	0.234 ***
	(0.680)	(0.000)	(0.000)
Preferences	0.550	0.811 ***	0.436 ***
	(0.685)	(0.000)	(0.000)
Attainments	0.859 ***	0346 **	0.585 ***
	(0.000)	(0.035)	(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

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

Table 5: Experimental design for robustness testing

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

Appendix 1

The Applied Capability Algorithm

The *Impact (I)* and *Utilisation (U)* of the resources belonging to *Individual (M)* for *Job (K)* is a function of the *Enablers (E), Preferences (P)* and past *Attainments* (*A*).

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

The Applied Capability modelling algorithm is applied in 10 steps across 4 separate activities.

Activity 1 - Job Profiling:

Step 1: Breakdown jobs into tasks. A job may consist of 1…n number of tasks ($J = \{T_{1,..t}\}$.

Step 2: Select the resources relevant to each Capability Factors denoted by $i = 3$ (i.e. *Enablers, Preferences, and Attainments (i=3).* And *j* is the resource required:

$$i = \begin{cases} 1, & Enabler\ for \quad j = 1, \dots e \\ 2, & Preferences\ for \quad j = 1, \dots, p \\ 3, & Attainment\ for \quad j = 1, \dots, a \end{cases} \quad (2)$$

Denote each Capability Factor *i*, Resource *j* allocated to Task *t* as C_{ijt}.

Step 3: Assign a value $X_{ijt} \in (0 \rightarrow 1)$ representing a relative amount of resource *j* required for task *t*. A value of *"0"* means no amount is required and the maximum value of *"1"* means that all the available resource is required for this task. For example in the game of Volleyball, the level of *"agility"*, a resource in the Enabler category required for a specialist receiver of opposition service or spike could be $X_{ijt} = 0.7$ whilst the *"digging technique"*, another Enabler, when defending a service/spike should be $X_{ijt} = 1.0$ or close to that value.

Step 4: Do a number of simultaneous tasks in a job require the same resource. If "No" go to next step, if "Yes" then assume the maximum level of the resource required is the sum of all levels as required by those tasks. Start with the first task requirement for capability factor C_{ijt} , for $i = 1, j = 1, t = 1$ check if there is any other task that requires the capability factor.

A new list of required set of resources C'_{ij} and the corresponding levels to be X'_{ij}, then for all $T_{1\dots t}$:

$$C'_{ij}, X'_{ij} = \begin{cases} \max X'_{ijt} & or\ all\ similar \quad Cij \\ X'_{ijt} & for\ all\ dissimilar \quad Cij \end{cases} \quad (3)$$

For example the required agility levels for a receiving specialist in Volleyball might be 0.8, but at the same time the same player may be required to take part in attack (i.e. spike in front of the net), in the levels of *agility* required for spiking (attack) could be 0.2. Therefore, the overall agility required for this player is 0.8, since this is maximum agility required for the two rendered tasks, or in other words the job of a “defence specialist” in Volleyball.

<u>Step 5:</u> Allocate weight to each resource, if required.

$$\text{For } i=1,\ \sum_{j=1}^{e} W_{ij} = 1$$
$$\text{For } i=2,\ \sum_{j=1}^{p} W_{ij} = 1 \qquad (4)$$
$$\text{For } i=3,\ \sum_{j=1}^{a} W_{ij} = 1$$

Activity 2 – Determine the levels of Individual’s Availability for a job – the Matching process:

<u>Step 6:</u> For every individual $M = 1, \dots m$ determine the level of *availability* (A_{mij}) for $\acute{C}_{ij}$. A_{mij} is the availability of individual *m* for factor *i* and resource *j*.

<u>Step 7:</u> Normalise A_{mij} for each individual for $\acute{X}_{ij}$ of resource requirement for the set of resources $\acute{C}_{ij}$, and call them A'_{mij} and A''_{mij}, where:

$$A'_{mij} = \frac{\min(A_{mij}, X'_{ij})}{X'_{ij}} \quad \text{and} \quad A''_{mij} = \frac{\min(A_{mij}, X'_{ij})}{A_{mij}} \text{ for } \forall\ i, j, k \qquad (5)$$

<u>Step 8:</u> Calculate all A'_{mi} and A''_{mi} for ∀ all Ms.

$$\text{For } i=1 \quad A'_{m1} = \sum_{j=1}^{e} W_{1j} A'_{m1j} \text{ and } A''_{m1} = \sum_{j=1}^{e} W_{1j} A''_{m1j}$$
$$\text{For } i=2 \quad A'_{m2} = \sum_{j=1}^{e} W_{2j} A'_{m2j} \text{ and } A''_{m2} = \sum_{j=1}^{e} W_{2j} A''_{m2j} \qquad (6)$$
$$\text{For } i=3 \quad A'_{m3} = \sum_{j=1}^{e} W_{3j} A'_{m3j} \text{ and } A''_{m3} = \sum_{j=1}^{e} W_{3j} A''_{m3j}$$

Activity 3 – Determine the resource Impact and Utilisation indices

The levels of impact of an individual on completion of a task I_m can be queried through a self-assessment or an assessment made by their supervisor. Where I_m is a number between *0* and *1*.

<u>Step 9:</u> Define 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.

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

The statistical inference model will estimate the closest possible function *(f)* for estimation of the Impact index.

Step 10: In order to predict the *utilisation of resources (U_m)* for an individual we suggest using regression of the Impact indices; for $i \in \{1,2,3\}$:

$$U_m = f(A''_{mi}) \quad (8)$$

Steps 1 to 9 of the proposed algorithm are designed to estimate the Impact and Utilisation of one's resources to complete a job. The job-individual matching process with respect to the availability of resources was achieved by proposing a minimum function in step 7. The final part of the algorithm uses the inputs to predict the applied capability. Step 10 infers the levels of utilisation of resources based on the impact they have on completing jobs, thus purporting the application of one's capability.

By implementing all 10 steps, we arrive at a comparative measure of individual's '*Applied Capability'* against their peers.

Appendix 2

Assignment Brief

BRUNEL UNIVERSITY
SCHOOL OF ENGINEERING AND DESIGN

SYSTEMS MODELLING & SIMULATION
Dr A. MOUSAVI

GUIDELINES FOR THE ARENA ASSIGNMENT AND PROJECT
For details on submission date refer to lecture notes No. 1 on:
http://people.brunel.ac.uk/~emstaam/ or the Course Officer at TPO

Individual Assignments (for All Students)

Reports for the assignment and project comprise the following three elements:

1. Main body of assignment
The key issues to be addressed in the main body of the assignment are in brief the following:

Flowchart Description: A clear explanation of how the model was built should be provided. This should mainly refer to the modules that were used and their exact place in the flowchart. This part should also provide an indication of how the major parameters of these modules have been set. One good way to achieve this is by using screenshots of the windows/dialog boxes presenting the modules' parameters.
→**Note:** You are not expected to describe how you literally built the model using Arena. Descriptions of how the modules were selected from the project bar and then placed on the model window or of how the property dialog boxes of each module were accessed so as to enter data are considered to be obvious and therefore should be omitted.

Run Setup Parameters: Based on the requirements of each specific problem/exercise, you are expected to make decisions on how the simulation run setup parameters should be determined. The simulation run setup refers mainly to the number of replications, replication length, time units and in general all the parameters included in the Replication Parameters tag appearing in the Setup option of the Run menu. The determination of setup parameters that conform to the requirements of the assignments is a key point. Incorrect selection of the run setup parameters will result in findings different from those expected (regardless of the fact that the model can be absolutely correct).

Answers to the exercises' questions: Following the presentation of the model, the main part of the assignment should serve the purpose of identifying the questions that need to be answered for each problem/exercise. Furthermore, it is expected that a **complete** and **clearly stated** answer should be provided for **each** of these questions. Whenever the problems' questions are related to one or more of the collected statistics, the answers presented should be in accordance with those appearing in the statistics reports (see section below for the appendix).

In some cases the problems/exercises require, in addition to a number of statistics, information on e.g. the system performance under a number of alternative scenarios or a number of plots, animations etc. It is important to note that you will be assessed against all the required information.

2. Report Appendix
In the appendix you are expected to provide the Statistics Reports. You are advised to prefer the Summary Statistics Reports, which are considerably shorter than those appearing in the Reports Panel (in the Project Bar) of the Arena interface. The Summary Statistics Reports are generated automatically by Arena after each simulation run and are saved in the form of a text file (*.out) in exactly the same folder where you saved the model. In order to be able to get such (*.out) files you may need to make appropriate changes in the fields Default Report and Display SIMAN summary report (*.out file) in the Reports tag appearing under Tools >Options.

There are a number of issues that will be checked during the marking. Apart from the correctness of the collected statistics attention will also be paid to the:

- Run set up parameters that should be consistent with those presented in the main body of the assignment,
- Analyst's name that in turn should point to the student submitting the assignment.

3. Submission of models on CD
Along with the assignment you are also expected to submit a CD where you should have saved the *.doe file/s containing your model/s.
More specifically, the **CD** should:

- be accessible,
- include only the final version of the file/s that correspond to the required model/s,
- contain files that the Arena software **can** run and can thus generate results (bear in mind that even using unacceptable filenames can result in Arena being unable to run the model in spite of the fact that the latter can be absolutely correct. In such cases it is also impossible to collect any statistics reports). Failed runs during assessment will result into **F**.
- Contain files which correspond to the models that have been presented in the assignment (both main body and appendix). In other words, it is unacceptable to discover that running the model contained in the CD generates different results from those presented in the assignment report.
- Contain the student's (submitting the assignment) name as well as the reference number of the assignment on the label of the CD.
- Be attached to the assignment so that it should not get lost or examined separately from the assignment.

Students are also requested to provide their email so that they will be contacted in case there are problems with accessing their CDs.

Assignments' Submission Deadlines
The submission of the assignments should not under any circumstances exceed the relevant submission deadlines (For the dates please refer to Lecture Notes No. 1 on http://people.brunel.ac.uk/~emstaam/ and following the links to the module webpage). However, when special cases apply (e.g. whether there are mitigating circumstances) justifying late submission, assignments will be accepted and marked

beyond the submission deadline only when they are accompanied by the late submission cover sheet bearing the Module Coordinators' signature.

Marking scheme

INDIVIDUAL ASSIGNMENT SYSTEMS MODELLING AND SIMULATION

MARKING SCHEME[1]

Section		Description	Total Mark
A	**Overall Modelling Approach**	1. Model organisation	10
		2. Data accuracy	
		3. Run Setup	
		4. Bonus[2]	
B	**Entity Modelling and Routing**	1. Accurate generation entities and assignment of attributes	10
		2. Accurate assignment of variables and changes required during simulation run	
		3. Accurate process planning and sequencing	
		4. Accurately routes different types of components according to given plan	
		5. Bonus[2]	
C	**Resources and Stations**	1. Used stations and routes well	10
		2. Used schedules well	
		3. Modelled resource failures well	
		4. Used sets	
		5. Use of expressions and variables	
		6. Queue priorities	
D	**Animation**	1. Has animation	10
		2. Displays statistics	
		3. Animation works well	
		4. Bonus[2]	
E	**Results and Analysis**	1. Achieving expected results (output)	20
		2. Interpretation of results	
		3. Identification of problems (e.g. bottlenecks, congestions, imbalanced lines, layout, etc.)	
		4. demonstrate full understanding of the simulation results of current system	
G	**Improvements & Analysis**	1. Providing proposal for improvements and change (what if scenarios)	30
		2. Modelling and Simulation of proposals	
		3. Providing reasonable arguments for proposed system in the form of comparisons between original and new models	
		4. Arguments related to specified performance measures	
I	**Conclusions**	1. Detailed conclusion closing argument, reflection on the approach and what could have been done better	10

[1] Note that this scheme is adjusted every year based on the type of the assignment. But the essence of assessment scheme remains universal. This is just a sample guide.
[2] Bonus marks (normally between 1-3% in the corresponding section) is for relevant initiative and innovative approaches)

Group Project (For Full Time Students Only)

All the rules of report writing and submission described in the previous sections (the assignment submission) apply to the project submission.

In addition for the group project, all members of each group MUST make equal contributions to the development of the models, simulation project, project management and group analysis).
All group reports must include a page label "Group member assignment" which **clearly shows** the name of each group member and which part of the project he/she contributed to, each member would be responsible for writing and compiling that part of the project. This must also be indicated in the body of the report.
The introduction and conclusions where improved models are discussed should have equal contribution by each member.

Remember that the group performance can affect individual performance.

The group project consists of the purchase of a chosen artefact (by group members) not exceeding £20 which upon submission of the purchase receipt it would be reimbursed by AMEE.

The project would then consist of breaking the product into its components and development of a production process plan. The production process plan should include the methods, pathways, sequences of the production process. Also a research into the number of orders can be made by estimation. For example for a remote control toy car the number of weekly, monthly or annual orders needs to be made. A proper production plan and schedules should be created. The assembly line should be designed based on the sequence of work, system capacity, schedules, possible breakdowns, line-balancing and plant layout design.
Process times for each work-station can be defined through time and motion studies. This can either be done by practically using a stopwatch to assess the time or usage of techniques such as Maynard Operation Sequence Technique (MOST) for time studies.
This exercise is designed for you to appreciate the work and effort required to conduct a full plant layout design, creation of a workable production process and deal with system limitations. And above all utilising the capabilities of Systems Modelling and Simulation to plan and design a real system.
The assessment criteria would also include intuitive problem solving, approaches to problem definition, system design, and usage of the main subject covered in this module to solve the problem.

Additional Help

For further support you can contact my Teaching Assistants at designated times and with prior arrangements.

You can also always contact me.

Appendix 3:

Figure A3 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 each of the three Capability Factors (EPA) is low and ends where the person has a high level of match in all the three. In the shorter version (right box in Figure 1), the respondents are only given the number of resources which has that specific level of match. For example, consider scenarios 2, 3 and 4 in the left box. In all these cases the person has low level of match for two of the three resources and a medium level of match for the third. This has been translated to the scenario 2 in the right box. The numbers below the level of match columns in the right box in the figure indicate the number of resources which has that level of match. Therefore the 27 scenarios are shortened into 10 categories of scenarios as displayed in figure 1 – where? Does she mean A3?. Why do we use EMP in figure 3 when it's EPA?

Figure A3: The original and the summarised version of the possible scenarios levels for EPA of each individual.

27 scenrios in the roiginal questionnaire and their details

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

Guide of corresponding scenarios in the shortened questionnaire

	Number of resources in each match level: High	Medium	Low
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

Respondents have then provided a weight (importance level) to each of the three resources. Application of the given weights to the shorter version of the questionnaire will help in finding the possible answers to the full 27 scenarios. The logic used in the conversion is as follows:

For

i= {1, 2, 3} where i is the number of resources

j= {1, 2… 27} where j is the number of the scenario (figure 1, left table)

f= {1, 2…10} where f is the scenario category in the shortened version to which the scenario belongs to (figure 1 right table)

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

Where C_j is the calculated impact level for the j^{th} category, C_f is the given impact level for the f^{th} category, F_{ij} is the correspondent value of the i^{th} resource's match level in the j^{th} scenario; w_i is the given weight of the i^{th} resource. 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:

Low	$0 \le X < 0.33$
Medium	$0.33 \le X \le 0.66$
High	$0.66 < X \le 1$

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

The logic used makes it possible to use a smaller questionnaire and yet to gain all the data required to depict the dynamics of the three criteria and the impact index. 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 EPA with the perceived impact index.