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A MULTICRITERIA PREDICTION MODEL FOR PROJECT RISK CLASSIFICATIONS

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Abstract

Project distress predictions are essential in project management. Developing appropriate methods to classify projects and building prediction models for Multi-Criteria decisions requires empirical methods to minimize misclassification errors. This paper carries out Multi-criteria analysis to classify projects risks using a preference disaggregation method, UTilités Additives DIScriminantes-UTADIS. The UTADIS requires predefined classification which is implemented using critical path analysis. The methods are applied on three projects and results in a no misclassification error and an effective prediction model.

keywords: Project Risk, uncertainty, multi-criteria, classifications, UTADIS, critical paths, Decisions

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1 Introduction

In the implementation of projects, any individual or group of investors would want to examine the possibilities of identifying risky events and its consequences. This would enable the investors to prioritize the risks associated with the projects to establish a least-to-most critical importance ranking of the projects. Critically ranking projects into risk groups provides insights to the investors as to resource allocation to manage or mitigate the occurrence of high risky activities in the project. Risk assessment is vital in creating awareness on project exposures and negotiating with investors, thus working according to a credible project plan to fund the project. It has therefore become imperative to build reliable risk assessment models to assist project managers in classifying their projects into classes of risk in the course of managing their projects.

Project risk assessment models can be used in discriminating between failed projects and non-failed projects. Traditional optimisation, statistical and econometric analysis approaches often used in risk prediction models, for example the revenue maximizing model[1], the managers utility model[21] and the satisfying model[11] are often based on the assumption that the considered problem is well formulated and usually consider the existence of a single objective or evaluation criterion [20]. In such a case the solution to the problem is not far-fetched. However in reality, the modelling of such project risk prediction models is based on a different kind of logic taking into consideration the existence of multiple criteria, the conflicting situation between the criteria, the complex, subjective and ill-structured nature of the evaluation process and the introduction of the decision makers in the evaluation process [2].

Operation researchers have therefore adopted this innovative, comprehensive and realistic perspective, which overcomes the restrictive framework of optimisation and statistical analysis [13]. An example is for financial decision problems, such as the choice of investment projects, portfolio selection and the evaluation of business failure risk, it becomes an illusion to speak about optimality since multiple criteria must be taken into consideration [5]. Thus, due to the multi-dimensional character of such decisions, decision makers and operation researchers seek Multi-Criteria Decision Analysis (MCDA) methodologies and system tools to support their decision making processes. The advantages that the MCDA paradigm provides in financial decision making include the possibility of structuring complex evaluation problems, the introduction of both quantitative and qualitative criteria in the evaluation process, the transparency in the evaluation, allowing good argumentation in decisions and the introduction of sophisticated, flexible and realistic scientific methods in the decision making process. Most important of all MCDA enables the Decision Maker to participate actively in the decision making process and supports him in understanding the peculiarities and the special features of the real-world problem that he faces.[22].

2 Background to Classification Problems

Classification refers to the assignment of a finite set of alternatives into predefined groups. When considering a discrete decision making problem, there are four different kinds of analysis that can be performed in order to provide meaningful support to decision makers: to identify the best alternative or select a limited set of the best alternatives; to construct a rank-ordering of the alternatives from the best to the worst ones; to classify the alternatives into predefined homogenous groups and to identify the major distinguishing features of the alternatives and perform their description based on these features (Roy, 1985). Choice, ranking, classification leads to specific results regarding the evaluation of alternatives. Choice and ranking are based on relative judgements involving pair-wise comparison of the alternatives. Consequently, the overall evaluation result has a relative form, depending on the alternatives being evaluated. For instance, an evaluation result of the form “product X is the best of its kind” is the outcome of relative judgements, and it may change if the set of products that are similar to product X is altered (Doupoupos & Zouponidis, 2004). On the contrary, classification problems are based on absolute judgments. In this case, each alternative is assigned to a specific group on the basis of a pre-specified rule. The definition of this rule, usually does not depend on the set of alternatives being evaluated. For instance, the evaluation result “product X does not meet the consumer needs” is based on absolute judgements, since it does not depend on the other products that are similar to product X [20].

One of the most well-known classification problems is the bankruptcy risk evaluation problem used by Doupoupos & Zouponidis (2004) in the prediction of firms into healthy and non-healthy firms. This refers to problems where the groups are defined in an ordinal way, since it is obvious that the healthy firms are in a better situation than the bankrupt ones. Therefore classification problems do not only provide a simple description of the alternatives, but it also incorporates additional preferential information, which could be of interest to the decision making context. Thus in classifications, the groups are defined a priori and the analyst knows in advance what the results of the analysis should look like.

2.1 Problem Domain

Investors that examine the possibility of funding a project or knitting up the activities in the project to arrive at a decision on how viable the projects are, would be interested in its performance and means of predicting any possible problems that the project may face. In the course of managing a project, project distress may lead to the failure of a project. Operations researchers have explored this issue from different points of view considering the different forms of project distress including Project failure has a negative effect on organizations and project managers, as investors might lose trust in funding future projects. Particularly, developing economies are often quite vulnerable to project distress and failures especially when the project occupies a sensitive sector of the country’s economy. Also considering the globalization of the world economy, it is obvious that such project failures might be connected to other projects in other parts of the globe and thus has replicating consequences. It has therefore become imperative to build reliable project failure prediction

models to assist project managers, investors and stakeholders in classifying their projects into classes of risk in the course of managing their projects. Classifying projects into different categories involves uncertainties, because in operations research, assessments and forecasts often arrive from several different units of an organisation as separate entities that are not integrated thus becoming a big task for managers to even build a basis for decision making. There is therefore the need to derive methods for efficient classifications that would incorporate the present and future uncertainties in all economic variables so as to build an appropriate platform for corporate decision making.

2.2 Research Question

What is an appropriate classification method for the decision maker to develop a classification model which represents his preferences and decision policy?

2.3 Aim

The aim is to build a classification model for project risk classification problems and to predict projects into risk categories. In classification problems, such as the assessment of bankruptcy risk, credit granting, country risk assessment, venture capital investments, portfolio selection and management, ranking a set of alternatives (i.e. firms, credit applications, countries, investment projects) from the best one to the worst one, does not necessarily provide a solution to the examined problem. In such cases, it would be more appropriate to sort the alternatives into homogenous predefined classes (i.e. bankrupt and non-bankrupt firms) in order to derive suitable decisions concerning the financing of a firm or a country, the granting of credit application or the implementation of an investment project[18]. The classifications are done based on criteria using information derived from the projects portfolio.

2.4 Objective

The paper has three (3) objectives. (a)To resolve data scheduling uncertainty problem, (b) present information on project risks to managers and (c) to classify the projects into risk categories with the least misclassification error considering the preferences of the decision maker. A Critical Path Analysis method [15] is used in achieving objectives (a) and (b). The output of the Critical Path method serves as a predefined classification for a Multi-Criteria Decision Analysis method, UTilités Additives DIScriminantes-UTADIS. The UTADIS is used in achieving objective (c).

2.5 Structure of the paper

Section 1 introduces the paper, section 2 dilates on the background to classification problems, the research domain, aim and objectives. Section 3 deals with the methodological

reflections of the paper whilst section 4 applies the methods to some cases. Section 5 concludes the paper.

2.6 Related Work and Research Motivation

This paper is motivated by the work of the Swedish International Development Agency(SIDA) in the assesment of the risk level of three projects. The managers of this project have received the schedules of overlapping activities(criteria) of the projects that are not integrated. This has presented a decision making problem for the managers of the project to classify the projects on risk levels. The managers are interested in not only classifying the projects on risk levels but would want to have clear information on what the actual risk of the individual projects are. This decision problem would require a classification scheme which would solve the uncertainty situation in the overlapping criteria of the projects and present a forecast of the risk levels of the projects to the managers of SIDA for decision making.

Notable amongst papers which have presented similar work on resolving uncertainty in project criteria values is the work of Laryea.R,2013 in *International Journal of Applied Decision Science, 2013* (in press) Project Outcome Classification with Imprecise Criteria Information, in which the author explored the use of linear programming in presenting information of project profit outcomes, resolve uncertainty in project criteria values and to preclassify projects for use in a Multi-Criteria Decision Analysis Method,UTilités Additives DIScriminantes- UTADIS. The paper on Project Outcome Classification with Imprecise Criteria Information further explored the use of the UTADIS to develop a Multi-Criteria Decision Model to forecast projects on profit outcome and to judge misclassification errors. In contrast to the paper on Project Outcome Classification with Imprecise Criteria Information, this paper would explore the use of a Critical path analysis method to identify the risk levels of the projects to present a platform for decision making to the managers of SIDA. Since the case of study in this paper does not have a profit making objective, but an activity risk level objective, the critical path analysis method would resolve the overlapping problems of project criteria and present clear information on the risk level of the three projects of study in this paper. This would futher present a predefined classification scheme for use in the UTADIS to develop a Multi-Criteria Decision Model for forecasting future project data into risk levels.

Other researchers in the paradigm of Multi-Criteria Decision Analysis have attempted to solve the problem of imprecision in decision making for classification problems, however the focus has been imprecision on the weights of the criteria [14][6]. Amongst the methods used for classification problems, the ELECTRE TRI and UTADIS are the useful and efficient ones among them[14]. The decision maker's dilemma in this paper is a classification problem which requires methods which would solve the problem of overlapping activity or criteria values, classify the projects on risk levels and build a classification model for classifying current and future projects. This calls for methods which would provide the managers with an idea of what the risk level of the projects are before the classification process is carried out. Notable amongst previous research that has researched into classifying problems for

decision makers is the work of Sergio Davalos et. al in the Bankruptcy classification of firms investigated by the US Securities and Exchange Commission[3] in which the authors used an evolutionary computing method and genetic algorithm, to generate an optimal set of if-then rules for bankruptcy classification of Accounting and Auditing Enforcement Release firms, the prediction of business failure using the UTADIS method[19] in which the authors classify greek sample firms and build a classification model with the UTADIS method in comparison with other methods. Other work by the these authors and others using the UTADIS method on practical applications follow the same routine [20] [16] [22][7][8] to cite a few of their work. Authors that have applied the ELECTRE TRI method on practical situations have focused their work on the variation of weights of the criteria[10][9][12].

The case of study in this paper would explore the use of the UTADIS method in presenting a Multi-Criteria Decision Model for classifying project risk levels. However, this paper would improve on the UTADIS method by using the critical path analysis method for the predefined classifications of the UTADIS method. The weakness in the use of the UTADIS method by the authors stated above is that the decision makers in predefining the classification for use in the UTADIS method for example, make the predefined classification decisions on some reference set according to their own subjective preference. The SIDA managers in the case of study in this paper would require a method to help them to know the risk information of the projects for predefined classification as the subjective ways of doing this may be misleading. Moreover, a variation of the weights as done by other authors stated above using the ELECTRE TRI method is of less relevance to this paper since the UTADIS method works out the required weights of the criteria in the Multi-Criteria Decision Model.

3 Methodology

The MCDA methodology that is used for the prediction of project failure originates from the preference disaggregation approach [7]. The preference disaggregation approach refers to the analysis of the global preferences of the decision maker in order to identify the criteria aggregation model that underlies the preference result. Preference disaggregation analysis uses common utility decomposition forms to model the decision maker's preferences and uses regression based techniques. With preference disaggregation analysis, the parameters of the utility decomposition model are estimated through the analysis of the decision makers overall preference on some reference alternatives. The problem is then to estimate a utility function (usually additive) that is as consistent as possible with the known subjective preferences of the decision maker [22].

In this paper, because we would want to minimise the misclassification errors between the subjective preferences of the decision maker and the utility function generated with the MCDA method, the subjective preferences of the decision maker which is fed into the MCDA method(UTADIS) as predefined classification would be guided with critical path analysis method instead. In this way, a more scientific and methodological way of estimating the decision makers preferences can be established and thus proceed with the UTADIS method to estimate the utility function and the utility threshold that classify the

alternatives in their original classes with the minimum misclassification error.

Figure 1: General outline of developing a method for classification problems.

Figure 1 above was originally developed by Zouponidis & Doumpos, 1999 in their book *Multicriteria Decision Aid Methods* (chp.1 pg.18). In this paper, we modify the figure to include Critical Path Analysis to provide more information to decision makers on the risk levels of the projects and to guide the subjective preferences of the decision maker in the Reference Set. Based on the estimation of the Slack and the Free Slack with the Critical Path Analysis method, the number of Critical paths of a project or an alternative can be identified. With the number of Critical paths of the different projects known the managers are guided in classifying the projects into different risk categories. This would introduce empirical ways of predefining the alternatives into categories, before the MCDA method is applied, since the objective is to minimise the misclassification error in the training sample and the MCDA model.

3.1 Reference Set A classification method- Critical Path Analysis

One of the most challenging jobs that any manager can take on is the management of a large-scale project that requires co-ordinating numerous activities throughout the organisation. A myriad of details must be considered in planning how to coordinate all these activities, in developing a realistic schedule and then in monitoring the progress of the project. Fortunately, operations Research techniques such as the the Critical Path Method (CPM) is available to assist the project manager in carry out these responsibilities. This technique makes heavy use of networks to help plan and display the coordination of all the activities [15].

A project consists of a well-defined collection of activities, or tasks or criteria which all have finite durations. The project is completed when all of the tasks have been completed. An activity in a project whose delay would cause a failure of a project as a whole is referred to as a critical activity. Any such collection of tasks and orderings has a longest path(sequence of connected tasks) which takes as long or longer to complete than any other sequence in the project. This path is called the “Critical Path” of the network, and its length is the duration of the project [15].

Any task that is not on the critical path has some scheduling flexibility in that it may be delayed without increasing the length of the project. The amount of delay that a task may take on without increasing the length of the project is called the “slack” of the task. It follows then that all tasks on the critical path have zero slack [15].

The slack of an activity is the difference between its latest finish time (LF) and its earliest finish time (EF), or the difference between the latest start time (LS) and the earliest start time (ES)

$$\text{Slack} = LF - EF = LS - ES$$

It is common that although a task may have slack, delays in the task will cause delays in tasks that succeed it, even though the length of the project is not affected. Certain tasks, however (those on the last end of a sequence) may be delayed without causing delays in the project or in any other tasks. These tasks are said to have “free slack”. The free slack that a task may have is always less than or equal to its slack [15]. The “early start” of any task is the earliest date that it can begin, and its “early finish” is its early start plus its duration. The “late start” of any task is the latest date that it can begin without delaying the length of the project. That is, the date that the task can begin if it has been delayed until its slack has been exactly used up. The “late finish” of a task is its late start plus its duration[15]

There are software packages to deal with all the data needed to develop schedule information and then to monitor the progress of the project. This paper would use “Schedule” a critical path method software developed by Power Angle Software inc. to build its network . Let’s assume project Alternative 1 with the following project activities or criteria:

Activities A(4 days) and B(5 days) can start simultaneously.

Activities C(4 days) can begin once activities A and B are complete

Activity D(3 days) can begin once activity B is complete

Activity E(1 day) ends the project and can begin once activities C and D are complete

Num	Description	Start-Early-Finish	Start-Late-Finish	Slack	Free	Days	Delay	Cost	Labor	Units	Num
0	Start Project	12-19-12 12-19-12	12-21-12 12-21-12	2	0	0	0	0	0	0	0
1	Activity A	12-19-12 12-24-12	12-24-12 12-28-12	3	3	4	0	0	0	0	1
2	Activity B	12-21-12 12-28-12	12-21-12 12-28-12	0	0	5	2	0	0	0	2
3	Activity C	12-31-12 01-04-13	12-31-12 01-04-13	0	0	4	0	0	0	0	3
4	Activity D	12-31-12 01-03-13	01-02-13 01-04-13	1	1	3	0	0	0	0	4
5	Activity E	01-07-13 01-07-13	01-07-13 01-07-13	0	0	1	0	0	0	0	5
100	End of Project	01-07-13 01-07-13	01-07-13 01-07-13	0	0	0	0	0	0	0	100

Table 1: The different criteria-Activities in Project Alternative 1

In Table 1 for Activity A for example it is realised that the earliest start time is 12-19-12 and the latest start time is 12-24-12. The earliest finish time for Activity A is 12-24-12 and the latest finish time is 12-28-12. The slack time (Total Float) is 3 days and the Free (Free float) is 3 days. This shows that Activity A is not critical because there is enough available time of 3days to complete Activity A after the 4 days allocated to it. When it comes to Activity B, it is realised that the earliest start time is 12-21-12 and the latest start time is also 12-21-12. The earliest finish time for Activity B is 12-28-12 and the latest finish time is 12-28-12. It is also realised that for activity B the slack time is 0 and the Free is 0. This makes activity B a critical one and so does activity C and activity E. Therefore project alternative 1 has three critical paths. The idea is that based on the number of critical paths of the other project alternatives, the projects can be empirically classified in the reference set with some cut off points by the Decision Maker

The network diagram for the project is as shown in figure 2 below:

Figure 2: Network Diagram showing interconnectivity of activities or criteria within a project.

As shown above, Figure 2 depicts the interconnection between activities or criteria in project alternative 1. The activities marked red are the critical activities and are therefore on the critical path, and the activities marked green have some slack time to deliver and not on the critical path.

Let $T(p)$ represent the total number of critical paths of a project or an alternative

$$T(p) = \sum_{i=1}^n a_i$$

Where:

n = number of nodes

a_i = activities that are critical on project p

Figure 3: Cut off points used to classify the project alternatives based on the number of critical paths of the project.

Figure 3 Based on managerial experience, $U_1 \dots U_{Q-1}$ represents cut off points which classifies the projects or alternatives into classes of risk $C_1 \dots C_Q$ based on the number of critical paths of a project

$$T(p) > U_1 \Rightarrow p \in C_1$$

$$U_k \leq T(p) < U_1 \Rightarrow p \in C_k$$

$$T(p) < U_{q-1} \Rightarrow p \in C_Q$$

3.2 Classification model MCDA method - UTilités Additives DIScriminantes(UTADIS)

Given a predefined classification of the alternatives(projects) in classes guided by the critical path analysis method, the objective of the UTADIS method is to estimate an additive utility function and the utility thresholds that classify the alternatives in their original classes with the minimum misclassification error [7] In this paper, this objective has been boosted by the fact that the predefined classification of the alternatives(projects) in classes in the reference set would be guided empirically using the critical path analysis method as compared to the subjective ways of classifying in the reference set in other papers. The estimation of both the additive utility function and the utility thresholds is accomplished through linear programming techniques.

If $g_1, g_2, \dots, g_m$ is a consistent family of m evaluation criteria and $A = a_1, a_2, \dots, a_n$ set of n alternatives to be classified in Q ordered classes $C_1, C_2, \dots, C_Q$ which are defined as priorities in the following way $C_1, PC_2, \dots, C_{Q-1}, PC_Q$ where P denotes the strict preference relation, between the classes.

The global utility $U(a)$ of an alternative $a \in A$ is of an additive form:

$$U(a) = \sum_{i=1}^M U_i [g_i(a)]$$

where $U_i [g_i(a)]$ is the marginal utility of the alternative a for the criteria g_i . The marginal utilities represent the relative importance of the evaluation criteria in the classification model. The marginal utilities have piece-wise linear form. For each evaluation criterion i the interval $G_i = [g_{i*}, g_i^*]$, where g_{i*} and g_i^* are the less and most preferred values respectively of the criterion i for $a \in A$. The interval G_i is divided into $a_i - 1$ equal intervals, $[g_i^j, g_i^{j+1}]$, $j = 1, 2, \dots, a_i - 1$ where a_i is defined by the decision maker as the number of estimated points for every marginal utility u_i . Each point g_i^j can be calculated using linear interpolation [22].

$$g_i^j = g_{i*} + \frac{j-1}{a_i-1} (g_i^* - g_{i*})$$

The aim is to estimate the marginal utilities in each of these points. Suppose that the evaluation of an alternative a on criterion i is $g_i(a) \in [g_i^j, g_i^{j+1}]$. The marginal utility of an alternative a , $U_i [g_i(a)]$ can be approximated through linear interpolation, in the following way :

$$U_i [g_i(a)] = U_i(g_i^j) + \frac{g_i(a) - g_i^j}{g_i^{j+1} - g_i^j} [U_i(g_i^{j+1}) - U_i(g_i^j)] \quad (1)$$

Supposing that the preferences of the decision maker on each one of the evaluation criteria are monotone, the following constraint must be satisfied [20]:

$$U_i(g_i^{j+1}) - U_i(g_i^j) \geq 0, \forall i$$

The monotonicity constraints can be converted into non negativity constraints through the following transformations [18]:

$$m_{ij} = U_i(g_i^{j+1}) - U_i(g_i^j) \geq 0, \forall i, j$$

$$U_i(g_{i*}) = 0$$

$$U_i(g_i^*) = \sum_{k=1}^{a_i-1} W_{ik}$$

$$U_i(g_i^j) = \sum_{k=1}^{j-1} W_{ik}$$

where $\sum_{k=1}^{j-1} W_{ik}$ is the summation of the marginal utilities on $U_i(g_i^j)$

Equation 1 can therefore be re-written as follows:

$$U_i[g_i(a)] = \sum_{k=1}^{j-1} W_{ik} + \frac{g_i(a) - g_i^j}{g_i^{j+1} - g_i^j} \left[\sum_{k=1}^j W_{ik} - \sum_{k=1}^{j-1} W_{ik} \right]$$

3.3 The misclassification errors:

The misclassification errors are accessed based on the global utility $U(a)$ and the utility thresholds:

Figure 4: Distribution of the classes on the assessed utility.

Overestimation error $\sigma^+(a)$: it is where an alternative according to its utility is classified to lower class than the class that it belongs to as shown in figure 4. Underestimation error $\sigma^-(a)$: it is where an alternative according to its utility is classified to a higher class than the class that it belongs to as shown in figure 4. The classification of the alternatives is achieved through the comparison of their global utilities with the corresponding utility thresholds[17]

$$\begin{aligned} U(a) &\geq U_1 \rightarrow a \in C_1 \\ U_k &\leq U(a) < U_{k-1} \rightarrow a \in C_k \\ U(a) &< U_{Q-1} \rightarrow a \in C_Q \end{aligned}$$

The assesment of both the marginal utilities $U_i[g_i(a)]$ and the utility thresholds U_k , is achieved by linear programming[18]

$$Minimize F = \sum_{a \in C_1} \sigma^+(a) + \dots + \sum_{a \in C_k} [\sigma^+(a) + \sigma^-(a)] + \dots + \sum_{a \in C_Q} \sigma^-(a)$$

s.t.

$$\begin{aligned}
 & \sum_{i=1}^M U_i [g_i(a)] - U_1 + \sigma^+(a) \geq 0 \quad \forall a \in C_1 \\
 & \left. \begin{aligned}
 & \sum_{i=1}^m U_i [g_i(a)] - U_{k-1} - \sigma^-(a) \leq -\delta \quad \forall a \in C_k \\
 & \sum_{i=1}^m U_i [g_i(a)] - U_k + \sigma^+(a) \geq 0 \\
 & \sum_{i=1}^m U_i [g_i(a)] - U_{q-1} - \sigma^-(a) \leq -\delta
 \end{aligned} \right\} \forall a \in C_k \\
 & \sum_{i=1}^m \sum_{j=1}^{a_i-1} W_{ij} = 1
 \end{aligned}$$

$$U_{k-1} - U_k \geq s \quad k = 2, 3, \dots, Q-1$$

$$W_{ij} \geq 0, \sigma^+(a) \geq 0, \sigma^-(a) \geq 0$$

Where δ is a small positive real number used to ensure the strict inequality of $U(a)$ to U_{k-1} ($\forall a \in C_k, K > 1$) and $U_{Q-1} (\forall a \in C_Q)$. The threshold s is used to denote the preference between the utility thresholds that distinguish the classes ($s > \delta > 0$).

3.4 Sensitivity Analysis:

The optimal solution F^* achieved by solving the linear program:

$$Minimize F = \sum_{a \in C_1} \sigma^+(a) + \dots + \sum_{a \in C_k} [\sigma^+(a) + \sigma^-(a)] + \dots + \sum_{a \in C_Q} \sigma^-(a)$$

is examined by through a post-optimality analysis. The aim is to find, if possible, multiple or generally near optimal solutions corresponding to error values lower than $F^* + k(F^*)$ where $k(F^*)$ is a small portion of F^* . Therefore, the error object is transformed into a new constraint of the type [5]:

$$\sum_{a \in C_1} \sigma^+(a) + \dots + \sum_{a \in C_k} [\sigma^+(a) + \sigma^-(a)] + \dots + \sum_{a \in C_Q} \sigma^-(a) \leq F^* + k(F^*)$$

The new objective is thus to maximize and minimize the marginal utilities of each criterion and the utility thresholds U_k [4]. In this way the sensitivity analysis of the marginal utilities of the criteria is achieved, and at the same time one can have an idea of the sensitivity of the utility thresholds:

$$\text{Max} \left[\sum_{j=1}^{a_i-1} W_{ij} + \sum_{k=1}^{Q-1} U_k \right] \text{ and } \text{Min} \left[\sum_{j=1}^{a_i-1} W_{ij} + \sum_{k=1}^{Q-1} U_k \right] \forall i$$

The first two of the sums in the post-optimality analysis represents the marginal utilities of each criterion. Therefore, it is used to examine the sensitivity of the criteria's marginal utilities. On the other hand, the second sum is used to examine the sensitivity of the utility thresholds. Thus by maximizing and minimizing both the marginal utilities of each criterion and the utility thresholds, a range is defined within which there is an optimal or near optimal solution [17]

3.5 Connection between Critical Path Analysis and UTADIS method

The UTADIS method requires a predefined classification of the alternatives in classes [4]. In this paper, the managers of the case of study requires information the risk level of the projects. This calls for the implementation of the Critical Paths Method on the scheduling data presented in Appendix A. The project risk information obtained from the critical path method thus guides the managers in their predefined classification which serves as inputs for the UTADIS method to estimate an additive utility function and the utility thresholds that classify the alternatives in their original classes with the minimum misclassification error.

3.6 Data

The data used in this paper is obtained from the Swedish International Development Agencies (SIDA) projects in Uganda for 2012 (Andersson, Göransson & Sedola, 2012). The data is extracted from the detailed worked plan of three projects which are the alternatives. The considered alternatives are:

Evaluation of save the children Sweden's Support to partner organisations- ECS

Evaluation of the work on climate change adaptation and mitigation of Swedish Scociety for Nature Conservation in cooperation with partner organisations in the South- ECC

Mid-Term Review for the Quality Infrastructure and Standards Programme (QUISP) in Uganda

The criteria are the tasks in the project, see attached Appendix A for the tasks in the projects.

3.7 Research Ethics

Since this paper did not have to conduct interviews the need did not arise for the documentation of questionnaires and informed consent sheet. However, as researchers, we assigned references to our data sources and as the data is open source, we are of the view that the originators of the data source are wide aware of its use for research purposes.

4 Application

As explained in section 3.1 “Predefined Classification Method- Critical path analysis”, we are guided by the critical path analysis method to aid the managers in the predefined classifications. In this way a clear information on the project risk is presented to the managers for decision making and an empirical way for the predefined-classifications to minimise the misclassification error, before we use the UTADIS method to build our classification model. Based on the Data in Appendix A, a critical path analysis is used to determine the critical paths in project alternatives ECS, ECC and QUISP. The data for each project is obtained by calculating the number of days assigned to each activity or criteria in a project.

4.1 Critical Paths for Project QUISP

When the schedules for the activities for project QUISP as shown in attached Appendix A is used as input in a critical path analysis software “schedule”, it produces the network diagram below:

Figure 5: Diagram of the critical paths for Project QUISP.

It can be seen from the diagram in Figure 5 that Project QUISP has 10 critical paths, which are the nodes colored red with the exception of the start project and end of project nodes. Table 2 below shows the data that was used in arriving at the critical paths of Figure 5. The data was obtained by calculating the number of days assigned to each activity from the project QUISP data schedule as shown in attached Appendix A

Num	Description	Start-Early-Finish	Start-Late-Finish	Slack	Free	Days	Delay	Cost	Labor	Units	Sum
1	Start Project	01-14-13 01-14-13	01-14-13 01-14-13	0	0	0	0	0	0	0	0
2	Inception-Programme Documentation	01-14-13 01-22-13	01-14-13 01-22-13	0	0	7	0	0	0	0	1
3	Inception-Assessment and review of	01-14-13 01-31-13	03-25-13 04-11-13	49	49	14	0	0	0	0	2
4	Inception-Discussions with Ministers	01-23-13 01-31-13	04-03-13 04-11-13	49	49	7	0	0	0	0	3
5	Inception-Preparation of Inception	01-23-13 01-31-13	04-03-13 04-11-13	49	49	7	0	0	0	0	4
6	Inception-Submission of inception	01-23-13 01-31-13	01-23-13 01-31-13	0	0	7	0	0	0	0	5
7	Inception-Agreement with Side on I	02-01-13 02-11-13	02-01-13 02-11-13	0	0	7	0	0	0	0	6
8	Data collection-Briefing meeting 1	02-12-13 02-21-13	02-12-13 02-21-13	0	0	7	0	0	0	0	7
9	Data Collection-Interview with sta	02-12-13 03-04-13	03-25-13 04-11-13	28	28	14	0	0	0	0	8
10	Data collection-Debriefing meeting	02-22-13 03-04-13	02-22-13 03-04-13	0	0	7	0	0	0	0	9
11	Data Collection-Additional intervi	03-05-13 03-13-13	03-05-13 03-13-13	0	0	7	0	0	0	0	10
12	Reporting- Analysis and writing o	03-05-13 03-22-13	03-25-13 04-11-13	14	14	14	0	0	0	0	11
13	Reporting-submission of draft	03-14-13 03-22-13	03-14-13 03-22-13	0	0	7	0	0	0	0	12
14	Reporting-feedback from stakeholde	03-25-13 04-02-13	03-25-13 04-02-13	0	0	7	0	0	0	0	13
15	Reporting-writing of final report	04-03-13 04-11-13	04-03-13 04-11-13	0	0	7	0	0	0	0	14
16	Reporting-submission of final repo	04-03-13 04-11-13	04-03-13 04-11-13	0	0	7	0	0	0	0	15
100	End of Project	04-11-13 04-11-13	04-11-13 04-11-13	0	0	0	0	0	0	0	100

Table 2: Data and Result set for Project QUISP

Apart from the start project and end of project rows, the 10 zeros in the slack column of table 2 confirms the 10 critical paths of the QUISP project as shown in Figure 5.

4.2 Critical Paths for Project ECC.

Figure 6: Diagram of the critical paths for Project ECC.

Figure 6 shows Project ECC with 9 critical paths, which are the nodes colored red with the exception of the start project and end of project nodes. Table 3 below shows the data that was used in arriving at the critical paths of Figure 6. The data was obtained by calculating the number of days assigned to an activity from the project ECC data schedule as shown in attached Appendix A

Num	Description	Start-Early-Finish	Start-Late-Finish	Slack	Free	Days	Delay	Cost	Labor	Units	Num
0	Start Project	01-14-13 01-14-13	01-14-13 01-14-13	0	0	0	0	0	0	0	0
1	Inception- Initial meeting with SN	01-14-13 01-14-13	01-14-13 01-14-13	0	0	1	0	0	0	0	1
2	Inception-Preparation of inception	01-14-13 01-14-13	03-19-13 03-19-13	45	0	1	0	0	0	0	2
3	Inception-Desk study of reports	01-15-13 01-18-13	03-20-13 03-25-13	45	45	4	0	0	0	0	3
4	Inception- Development of methods	01-15-13 01-18-13	03-20-13 03-25-13	45	45	4	0	0	0	0	4
5	Inception-Submission of inception	01-15-13 01-22-13	01-15-13 01-22-13	0	0	6	0	0	0	0	5
6	Inception - agreement with side on	01-23-13 01-23-13	01-23-13 01-23-13	0	0	1	0	0	0	0	6
7	Data collection - interviews with	01-24-13 01-24-13	01-24-13 01-24-13	0	0	1	0	0	0	0	7
8	Data collection - outcome mapping/	01-25-13 02-13-13	03-06-13 03-25-13	27	27	14	0	0	0	0	8
9	Data Collection - analysis and file	01-25-13 02-13-13	01-25-13 02-13-13	0	0	14	0	0	0	0	9
10	Reporting - drafting of synthesis	02-14-13 03-01-13	03-14-13 03-01-13	0	0	11	0	0	0	0	10
11	Reporting - submission of draft	03-04-13 03-04-13	03-22-13 03-25-13	14	14	2	0	0	0	0	11
12	Reporting - Meeting with side and	03-04-13 03-04-13	03-04-13 03-04-13	0	0	1	0	0	0	0	12
13	Reporting - Feedback from stakeholder	03-05-13 03-05-13	03-25-13 03-25-13	14	14	1	0	0	0	0	13
14	Reporting - Finalisation of the report	03-05-13 03-05-13	03-05-13 03-05-13	0	0	1	0	0	0	0	14
15	Reporting - Submission of final report	03-06-13 03-06-13	03-22-13 03-22-13	12	0	1	0	0	0	0	15
16	End of Project	03-06-13 03-25-13	03-06-13 03-25-13	0	0	14	0	0	0	0	16
17	End of Project	03-07-13 03-07-13	03-25-13 03-25-13	12	12	1	0	0	0	0	17
100	End of Project	03-25-13 03-25-13	03-25-13 03-25-13	0	0	0	0	0	0	0	100

Table 3: Data and Result set for Project ECC

The zeros of the slack column in table 3, excluding the start project and end of project rows, confirm the 9 critical paths as shown in figure 6. The data used in table 3 was obtained from the schedules of the ECC project in the attached appendix A

4.3 Critical Paths for Project ECS

Figure 7: Diagram of the critical paths for Project ECS.

In figure 7, project ECS has just 1 critical path, the node colored red with the exception of the start and end of project nodes. Table 4 below shows the data that was processed to arrive at the critical path diagram in figure 7. The data was extracted from the project ECS data schedule in the attached appendix A

Num	Description	Start-Early-Finish	Start-Late-Finish	Slack	Free	Days	Delay	Cost	Labor	Units	Num
0	Start Project	01-14-13 01-14-13	01-14-13 01-14-13	0	0	0	0	0	0	0	0
1	Briefing meeting with SCS and Sida	01-14-13 01-22-13	02-05-13 02-13-13	16	0	7	0	0	0	0	1
2	Meeting with SCS	01-14-13 06-20-13	01-14-13 06-20-13	0	0	112	0	0	0	0	7
3	Meta analysis of past evaluations	01-23-13 02-21-13	05-22-13 06-20-13	84	84	21	0	0	0	0	3
4	Drafting of inception report and p	01-23-13 02-21-13	05-22-13 06-20-13	84	84	21	0	0	0	0	4
5	Desk Review	01-23-13 02-11-13	02-14-13 03-04-13	16	0	14	0	0	0	0	2
6	Feedback on inception report	02-12-13 02-12-13	03-07-13 03-07-13	16	0	1	0	0	0	0	6
7	Drafting of inception report	02-12-13 02-12-13	06-20-13 06-20-13	90	90	1	0	0	0	0	5
8	Stakeholder interviews, field visit	02-13-13 04-03-13	03-08-13 04-25-13	16	0	35	0	0	0	0	8
9	Debriefing workshop of preliminary	04-04-13 04-04-13	06-20-13 06-20-13	54	54	1	0	0	0	0	9
10	Drafting of evaluation reporting	04-04-13 05-02-13	04-26-13 05-24-13	16	0	21	0	0	0	0	10
11	Submission of Draft Report	05-03-13 05-03-13	05-28-13 05-28-13	16	0	1	0	0	0	0	11
12	Feedback from Sida	05-06-13 05-06-13	05-29-13 05-29-13	16	0	1	0	0	0	0	12
13	Drafting of final report	05-07-13 05-24-13	05-30-13 06-18-13	16	0	14	0	0	0	0	13
14	Presentation seminar	05-28-13 05-28-13	06-19-13 06-19-13	16	0	1	0	0	0	0	14
15	Submission of final report	05-29-13 05-29-13	06-20-13 06-20-13	16	16	1	0	0	0	0	15
100	End of Project	06-20-13 06-20-13	06-20-13 06-20-13	0	0	0	0	0	0	0	100

Table 4: Data and Result set for Project ECS

The slack column of table 4 has just one zero apart from the start project and end of project rows. This thus confirms the 1 critical path observed in figure 7.

4.4 Predefined Classification guided by Critical path analysis

It is observed from our critical path analysis that Project QUISP has 10 critical paths, ECC has 9 critical paths and ECS has just 1 critical path. The involvement of the Critical path analysis in the predefined classification has presented information of the risk levels of the projects for managerial decision making. At a high risk level of 10 and 9, Project QUISP and Project ECC belongs to classification category 1 and project ECS belongs to classification category 2 with a low risk level of 1 as depicted in table 5 below:

Project	Classification Category
QUISP	1
ECC	1
ECS	2

Table 5: Predefined classification of project alternatives guided by critical path analysis method

The output of the Critical path analysis would be fed as input for the UTADIS method as a predefined classification of the alternatives. This presents an improved and empirical means for pre-classification for the UTADIS method as shown in Reference Set A of figure1.

4.5 UTADIS METHOD CLASSIFICATION

As explained under section 3.2, given a predefined classification of the alternatives (projects) in classes guided by the critical path analysis method, the objective of the UTADIS method is to estimate an additive utility function and the utility thresholds that classify the alternatives in their original classes with the minimum misclassification error [17].

The projects are considered the alternatives and the activities which go into the scheduling of the projects form the criteria. The data values for the criteria are the addition of the schedules that forms the criteria in a particular project. After a careful analysis of the activities or criteria of the three projects, five common criteria is identified for all three projects and the scheduling days for all five criteria of the three projects is aggregated. This forms the data for the predefined classification of the UTADIS method with the predefined ranking from the critical path analysis as shown in table6 below:

Project	Meetings	Reports	Evaluations	Agreements	Interviews	Results	Ranking
QUISP	21	77	0	0	21	0	1
ECC	11	25	10	1	28	11	1
ECS	113	57	35	0	0	0	2

Table 6: Project with associated criteria values for UTADIS processing

The data in table 6 is thus implemented in the UTADIS method with the predefined classifications from the critical path analysis.

The scores from the optimisation solver using the UTADIS method provided the following global utilities as shown in table 7 below:

Project	Scores
QUISP	0.4989
ECC	0.7157
ECS	0.1633

Table 7: Scores for project alternatives after UTADIS processing

With a utility threshold of 0.2975, the output of the UTADIS method for classifying the projects is as follows:

$0.4989 > 0.2975 \rightarrow$

category 1 QUISP

$0.7157 > 0.2975 \rightarrow$

category 1 ECC

$0.1633 < 0.2975 \rightarrow$

category 2 ECS

Project	Classification Category
QUISP	1
ECC	1
ECS	2

Table 8: classification of project alternatives based on the UTADIS method

Thus the predefined classification using the critical path analysis as shown in table 5 perfectly agrees with the UTADIS method linear programming classification as shown in table 8 with no misclassification error. This paper therefore presents a much improved method for classification problems. The Additive utility model for our Multi Criteria Classifications thus consists of the marginal utilities of the criteria in the linear programming and is presented as follows:

$$0.0817u_1(g_1) + 0.1777u_2(g_2) + 0.0817u_3(g_3) + 0.1747u_4(g_4) + 0.3095u_5(g_5) + 0.1747u_6(g_6)$$

Where the coefficients represent the relative importance of the criteria or the weights of the criteria. This model can thus be applied in the classification of projects into risk classes. The Managers at SIDA can thus assess the risk impact of their projects and allocate resources efficiently in the execution of these three projects. Project failure can be avoided where necessary because the paper presents a detailed information in the predefined classification process on which activities are critical to the success of the considered projects and more attention can be allocated to these activities which have a high rate of failure. As the risk levels and risky activities in the projects are known, the managers at SIDA can strategise to if possible avoid some of the activities which present a high rate of failure to project QUISP for example which recorded the highest risk estimate.

5 Conclusion and future studies

The primary objective of this paper is to create a Classification model for Multi-Criteria Decisions and to minimize the misclassification errors. The paper considered three projects,

QUISP, ECC and ECS. The Critical Path Analysis Method is used to predefine the alternatives into risk categories with the objective of eliminating the traditional intuition based preclassification procedure used by decision makers. The paper thus improved on a model originally adopted by Zouponidis & Doumpos, 1999 in their book *Multicriteria Decision Aid Methods* (chp.1 pg.18) with the critical path analysis method. The projects were predefined based on the number of critical paths identified and a utility threshold identified by the decision maker. The Multi –Criteria Decision Analysis(MCDA) method employed in this study is a preference disaggregation technique dubbed the UTADIS method. The UTADIS method only requires a predefined classification of alternatives in this case our three projects as compared to other MCDA methods which requires information regarding the weights, existing trade-offs and veto thresholds. It was observed in our study that the use of the critical path analysis in the pre-defined classification resulted in no misclassification error and correctly predicted the classification in the UTADIS method. The UTADIS method was also used in developing the additive utility model for Multi-Criteria Classifications. The advantage with this is that, once this model has been developed, it can be applied in the classification of new projects into one of the predefined classes. For future perspectives, exploring the use of the Model for testing future data sets is an area of interest for this research.

References

- [1] W.J. Baumol. *Business behavior, value and growth*. Macmillan, 1959.
- [2] M. Cummings, J. Marquez, and N. Roy. Human-automated path planning optimization and decision support. *International Journal of Human-Computer Studies*, 70(2):116–128, Feb. 2012.
- [3] Sergio Davalos, Fei Leng, Ehsan H. Feroz, and Zhiyan Cao. Bankruptcy classification of firms investigated by the US Securities and Exchange Commission: an evolutionary adaptive ensemble model approach. *International Journal of Applied Decision Sciences*, 2, 2009.
- [4] J.M. Devaud, G. Groussaud, and E. Jacquet-Lagrez. UTADIS: Une methode de construction de fonctions d'utilite additives rendant compte de jugements globaux. In *European working group on MCDA, Bochum, Germany*, 1980.
- [5] M. Doumpos and C. Zopounidis. *Multicriteria Decision Aid Classification Methods*, volume 73 of *Applied Optimization*. Springer, Formerly Kluwer Academic Publishers, Boston, Dordrecht, London, 2002.
- [6] Min Guo, Jian-Bo Yang, Kwai-Sang Chin, Hong-Wei Wang, and Xin-Bao Liu. Evidential reasoning approach for multiattribute decision analysis under both fuzzy and interval uncertainty. *Trans. Fuz Sys.*, 17(3):683–697, June 2009.
- [7] E. Jacquet-Lagrèze. An application of the UTA discriminant model for the evaluation of sc R&D projects. In P. Pardalos, Y. Siskos, and C. Zopounidis, editors, *Advances in Multicriteria Analysis*, Nonconvex Optimization and its Applications, pages 203–211. Kluwer Academic, Dordrecht.
- [8] E. Jacquet-Lagrez and J. Siskos. Assessing a set of additive utility functions for multicriteria decision-making, the uta method. *European Journal of Operational Research*, 10(2):151–164, 1982.
- [9] V. Mousseau, J. Figueira, and J. Ph. Naux. Using assignment examples to infer weights for electre tri method: Some experimental results. *European Journal of Operational Research*, 130(2):263–275, 2001.
- [10] V. Mousseau and R. Slowinski. Inferring an ELECTRE TRI model from assignment examples. *Journal of Global Optimization*, 12(2):157–174, 1998.
- [11] Allen Newell, J.C. Shaw, and H.A. Simon. Empirical explorations with the logic theory machine: A case study in heuristics. In *Proc. Western Joint Computer Conference*, volume 15, pages 218–239, 1957. Reprint:Feigenbaum and Feldman, Computers and Thought, 1963, luger.
- [12] A. Ngo The and V. Mousseau. Using assignment examples to infer category limits for the ELECTRE TRI method. *JMCDA*, 11(1):29–43, November 2002.

- [13] R. Slowinski and C. Zopounidis. Application of the rough set approach to evaluation of bankruptcy risk. *International Journal of Intelligent Systems in Accounting, Finance and Management*, 4:1:27–1:41, 1995.
- [14] J. Wang. Multi-criteria classification approach with polynomial aggregation function and incomplete certain information. *Journal of Systems Engineering and Electronics*, 17(3):546–550, 2006.
- [15] Jerome D. Wiest and Ferdinand K. Levy. *A management guide to PERT/CPM / Jerome D. Wiest, Ferdinand K. Levy*. Prentice-Hall, Englewood Cliffs, N.J. :, 1969.
- [16] C. Zopounidis. Multicriteria decision aid in financial management. *European Journal of Operational Research*, 119(2):404–415, 1999.
- [17] C. Zopounidis, D.K. Despotis, and E. Stavropoulou. Multiattribute evaluation of Greek banking performance. *Applied Stochastic Models and Data Analysis*, 11(1):97–107, 1995.
- [18] C. Zopounidis and M. Doumpos. Developing a multicriteria decision support system for financial classification problems: The FINCLAS system. *Optimization Methods and Software*, 8((3-4)):277–304, 1998.
- [19] C. Zopounidis and M. Doumpos. Business failure prediction using the utadis multicriteria analysis method. *Journal of the Operational Research Society (JORS)*, 50(11):1138–1148, 1999.
- [20] C. Zopounidis and M. Doumpos. Multi-criteria decision aid in financial decision making: Methodologies and literature review. *Journal of Multi-Criteria Decision Analysis*, 11(4-5):167–186, 2002.
- [21] C. Zopounidis, Ch. Hurson, and M. Doumpos. *Risque-Pays: Evaluation des Aspects Economiques, Sociaux et Politiques*. Economica, Paris, 2000.
- [22] Constantin Zopounidis and Michael Doumpos. A multicriteria decision aid methodology for sorting decision problems: The case of financial distress. *Comput. Econ.*, 14(3):197–218, December 1999.

Preliminary work plan		MIDTERM REVIEW FOR THE QUALITY INFRASTRUCTURE AND STANDARDS PROGRAMME (QUISP) IN UGANDA																							
Phase	Task	JA	SS	GS	August					September					October										
					31	32	33	34	35	36	37	38	39	40	41	42	43	44							
Inception	Programme documentation made available to consultants							13-aug																	
	Assessment and review of relevant programme documentation	3	2	-				X	X																
	Discussions with Ministry and Swedish Embassy	-	-	-					X																
	Preparation of inception report	2	1	1					X																
	Submission of Inception Report	-	-	-						24-aug															
	Agreement with Sida on Inception report	-	-	-							31-aug														
Data collection	Briefing meeting in Kampala (incl. international return travel)	3	3	-									17-sep												
	Interviews with stakeholders in Kampala	7	7	-									X	X											
	Debriefing meeting in Kampala	1	1	-										27-sep											
	Additional interviews	1	-	-														X							
	Analysis and writing of draft report	7	6	4														X	X						
Reporting	Submission of Draft Report	-	-	-															12-oct						
	Feedback from stakeholders on draft report	-	-	-																		26-oct			
	Writing of final Report	2	2	1																				X	
	Submission of Final Report	-	-	-																				30-nov	
	Presentation of final Report to stakeholders in Kampala (incl. international travel) (date to be decided)	5	-	-																					
	Total days	31	21	6																					
Initials: JA = Jens Andersson, SS = Stefano Sedola, GS=Gunilla Göransson																									

Figure 10: Detailed scheduled sheet for project QUISP.