A Bayesian Belief Network Cost Estimation Model that Incorporates Cultural and Project leadership Factors

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***Abstract*— In this study an analysis is performed in order to explore whether and how culture and leadership factors have an impact on the accuracy of software effort and cost estimation. A survey on software development projects within government departments in the United Arab Emirates (UAE) was undertaken. A Bayesian Belief Network (BBN) cost estimation model incorporating organizational and intercultural factors was developed and evaluated. The results indicated that the inclusion of such data into explanatory estimation models such as BBNs could provide useful information and increase the accuracy of final estimates.**

***Keywords* — Software cost estimation; Bayesian Belief Networks; Culture and Leadership Characteristics.**

I. INTRODUCTION

Accurate and systematic estimation of the effort required for software development is recognized as a key factor for project success [5], [14]. Despite the studies conducted so far [1], [11] software effort estimation is an open research topic due to the diversity of cost factors and the lack of information in the early stages of software development. The most critical issue in this scientific endeavor is the agreement on the constituent elements of the problem [4]. In order to produce an estimate it is important to agree upon the main aspects that may affect the development effort. Environmental attributes (e.g. programming language, data base system), Project attributes (e.g. application domain), and Product attributes (e.g. function points, lines of code) are usually the main attributes that participate in software effort estimation models. Leadership and culture factors are scarcely used in estimation models despite the fact that several researchers have shown that the lack of leadership support within a project is often a cause of failure [10].

The main hypothesis of our research is that organizational culture and project leadership are significant contributing factors in the cost of software development. Organizational culture incorporates a set of assumptions, beliefs, and values [13], which guide the organization members' functions. On the other hand the leader of an organization sets the goals and the vision of the team [12] and promotes the productive cooperation and interaction between the members of the team. This paper examines the significant factors in organizational culture and project leadership for estimating effort and cost of software development. For our study, we selected the Arabian Gulf States [6]. In order to test this hypothesis, a survey of software development projects within government departments in the United Arab Emirates (UAE) was undertaken. The analysis of the survey highlighted several parameters affecting cost estimation in this area. Based on this analysis, new projects were monitored to ascertain the impact of organizational culture and leadership on software effort estimation.

The goal of the study was to develop a Bayesian Belief Network (BBN) estimation model that incorporates leadership and culture. This method was selected due to the nature of the data collected. Classical methods demand linear structures that are not observed in this analysis. It is generally accepted, and confirmed by managers and developers, that it is crucial to adopt estimation models that have both predictive and explanatory value, provided that estimates can be confirmed by intuition [3]. BBNs can point out potential dependencies among project factors and eventually can complement/supplement any predictions made by software managers [4].

The method has the ability to produce interval estimates for the dependent variable along with probability values that show the confidence on the estimate. In particular we selected Bayesian Networks as they can provide:

- A framework to model all project attributes and identify their interrelationships.
- Probabilities indicating confidence of the estimation.
- Results that can be easily interpreted and confirmed by intuition.
- A formal method that can be used alone/ combined / supplementary with EJ.

The final Bayesian Network proposed is constructed using the empirical data coming from the projects analyzed and is supplemented using expert judgment in order to insert dependencies that are not identified by the data analysis.

The paper is organized as follows: Section 2 presents the variables of the data set. Section 3 provides information regarding Bayesian Belief Networks, Sections

4 and 5 present the data analysis methodology and discuss the results correspondingly. In section 6 conclusions are provided.

II. PRESENTATION OF THE DATASET VARIABLES

In this paper we have analyzed data coming from more than 20 government organizations in the United Arab Emirates (UAE). The process of collecting information was conducted in three stages, each using a different survey. This posed research questions as to whether and how culture and leadership factors have an impact on the accuracy of software effort and cost estimation. The survey results indicated that the respondents from the organizations in the UAE concur with the significance of each of the cultural aspects covered by the survey in carrying out effort estimation. This shows that community, organizations and team members are intertwined. They are unable to escape their culture or background; they all affect each other.

The final version of the survey involved the collection of data regarding seven groups of parameters that were derived from the literature review, from interviews with administrators, managers and project leaders[5], [6]: Organization Line of Business, Application Type, Organization Type, Organization Culture, Project Leadership, Project Technical Environment and Year of Project Completion.

One of the key factors that most studies eliminated is the impact of the organization culture on software development effort. The organization culture has been considered thoroughly in this study. Several parameters have been analyzed, such as timeliness, collaboration, job stability, intercultural intelligence, reward and communication. According to the literature review, they were the most important parameters issues in the fields of education, sociology, leadership and administration.

In the survey, conducted a 1-9 scale (1 represents the absence of a certain attribute and 9 represents the dominant existence of a certain attribute) was used to accommodate the majority of respondents and their responses regarding organizational culture and leadership data.

Seven factors were used to measure cultural characteristics. Timeliness means respecting time and the individual understands the general perception of time (event or relationship). This attribute measures the consistency in time or whether the individual slacks or has frequent absences. Collaboration (impersonal relations) means that the leader does not allow personal relationships to affect work. Job stability means that the leader is a team player holds no grudges against team members and his relationship is based on mutual trust and respect. Intercultural Intelligence (impersonal relations) represents the ability to understand another culture's world view. Reward (Incentives) means that the leader encourages and supports team professional development and rewards.

Decision making means that the leader encourages team members to communicate effectively. Team experience means that the team has worked on similar projects and has skills and knowledge.

The leadership ontology categorizes several attributes. Interaction (Behavior) and relationship with team members means that the leader creates learning experiences, and treats team members with respect. Decision Making of Leadership means the leader creates the right decisions and consults with teams about the organization's direction. The Ability to Motivate Team members means that the leader shares goals and appropriate instructions and support.

The ability to understand the project and the Organization's Culture means that the leader is able to understand and manage multicultural teams. Active thinking means that the leader enhances team contributions and sets feasible targets. Communication Skills means that the leader uses communication among team members effectively.

A more detailed analysis of the survey and the data collected can be found in [7].

III. BAYESIAN BELIEF NETWORKS

Bayesian Belief Networks are Directed Acyclic Graphs (DAGs), which are causal networks that consist of a set of nodes and a set of directed links between them, in a way that they do not form a cycle [8]. Each node represents a random variable that can take discrete or continuous finite, mutually exclusive values according to a probability distribution, which can be different for each node. Each link expresses probabilistic cause-effect relations among the linked variables and is depicted by an arc starting from the influencing variable (parent node) and terminating on the influenced variable (child node). The presence of links in the graph may represent the existence of direct dependency relationships between the linked variables (that some times may be interpreted as causal influence or temporal precedence). The absence of some links means the existence of certain conditional independency relationships between the variables.

The strength of the dependencies is measured by means of numerical parameters such as conditional probabilities. Formally, the relation between the two nodes is based on Bayes' Rule [7]:

$$P(A \mid B) = \frac{P(B \mid A)P(A)}{P(B)} \qquad (1)$$

For each node A with parents B1, B2,…, Bn there is attached an NxM Node Probability Table (NPT), where N is the number of node states and M is the product of its cause-nodes states. In this table, each column represents a conditional probability distribution and its values sum up to 1.

IV. METHODOLOGY

The initial number of projects that participated in the study was 38. The recipients were asked to relate the relative importance of each item to particular project size (e.g. a large project may impact on the organization in terms of resources such as person- power to a greater extent than a small project).

In order to evaluate the estimation model we excluded several projects from the initial set in order to use them as a validation set. Several studies indicate that 66.7% of the initial set should be used as a training set and the rest 33.3% as a test set. Taking into consideration this assumption 11 projects were randomly excluded from the

initial set and were used for the evaluation of the estimation model. As a consequence the models presented were built from 27 projects.

In the definition of the BBN it is mentioned that each node represents a variable that takes discrete or continuous finite values. This restriction requires the mapping of the values of the continuous variables into a limited number of classes (discretization). Two issues arise in the discretization of continuous variables: the number of classes and their range. Due to the small number of projects in the training set we considered three possible mutually exclusive intervals for each variable. We used equal frequency binning that divides the range of values into a predetermined number of intervals (three in our case) that contain equal number of instances. Sometimes a variable presented repeated values that did not allow the participation of exactly the same number of projects in each interval. The variables whose values were initially continuous and then were assigned into intervals are presented in table 1 along with the borders of the intervals.

The predictive performance of the cost models was based on the calculation of well-known accuracy measures proposed in the literature [9]. More precisely, one measure of local accuracy, which uses the actual (y_A) and estimated (y_E) effort, was evaluated for each project in the validation set, namely the magnitude of relative error (MRE).

$$MRE = \frac{|y_A - y_E|}{y_A} \quad (2)$$

This local accuracy measure was combined, for each project, to produce a global predictive accuracy measure of the entire validation set. Note that the term "local" refers to the error of each project's estimation, while the term "global" refers to the error from all combined estimations within a validation set. More specifically, the two global accuracy measures that were computed are:

$$MMRE = \frac{1}{n}\sum_{i=1}^{n}\frac{|y_{A_i} - y_{E_i}|}{y_{A_i}} \quad (3)$$

$$Pred25 = \frac{\#(\text{projects with } MRE \le 0.25)}{\#(\text{projects})} \quad (4)$$

For the interval comparisons the hit-rate was calculated. This is the percentage of estimated intervals containing the actual effort.

V. RESULTS

The initial BBN was derived automatically by a software tool [2] and is presented in figure 1. In the BBN we can see three groups of dependencies. The first one involves product attributes (AppArch_2, Lang_2, DBMS_2, OS_2). The other group involves attributes that affect the size of a project (UFP) most of them relevant the Organization Size (OrgSize, Organization_2, AppType), with one exception TeamExperience. The final group of variables involves cultural and communication attributes. There are many dependencies among these attributes many of them coming from Interaction.

The BBN of figure 1 indicates JobStability as the sole variable that directly affects effort. There are also several other variables that indirectly affect effort, given that the value of JobStability is unknown and each hierarchical parent node, such as TimeRespect, Motivation, Interaction, Lang, DBMS.

The structure of this BBN does not show any dependency between the values of UFP and the effort values, which is an unusual finding. This absence may be interpreted by the nature of the projects analyzed or may be a simple coincidence. The fact that several studies in effort estimation concluded that the size of a software project is relevant to the effort required for its completion forced us to further observe the nodes that are directly linked to UFP. The two nodes are Team Experience and Organization_2. Organization_2 shows whether the projects come from a public or a private organization and usually takes the first value.

Initially we evaluated the BBN of figure 1 using the values of JobStability; the NPT is presented in table 2. The first column of table 2 states that if the value of Job Stability is less than 6.65 then there is 31.1% possibility that the value of effort will be less than 272.5, 24.4% possibility that the value will be between 272.5 and 619, and 44.44% possibility that the value will be more than 619 hours.

TABLE I
DESCRIPTION FOR THE NEW DISCRETE VARIABLES

Variable name	Classes	Borders
Interaction	1, 2, 3	<6.25, 6.25-7.9, >7.9
Decision-Making	1, 2, 3	<6.4, 6.4-7.9, >7.9
Motivation	1, 2, 3	<6.15, 6.15-7.9, >7.9
Understanding Project Culture	1, 2, 3	<6.9, 6.9-8.15, >8.15
Active-Thinking	1, 2, 3	<7.25 ,7.25-8.15, >8.15
Communication-Skills	1, 2, 3	<6.9, 6.9-8.15, >8.15
Time-Respect	1, 2, 3	<6.25, 6.25-7.9, >7.9
Impersonal-Relationship	1, 2, 3	<7.4, 7.4-8.4, >8.4
Job-Stability	1, 2, 3	<6.65, 6.65-7.4, >7.4
Intercultural-Intelligence	1, 2, 3	<7.15, 7.15-8.15, >8.15
Reward-Mechanism	1, 2, 3	<6.15, 6.15-7.15, >7.15
Communications	1, 2, 3	<6.5, 6.5-8.5, >8.5
Team-Experience	1, 2, 3	<6.4, 6.4-7.4, >7.4
UFP	1, 2, 3	<480, 480-1299, >1299
effort	1, 2, 3	<272.5, 272.5-619, >619
duration	1, 2, 3	<8, 8-16.5, >16.5

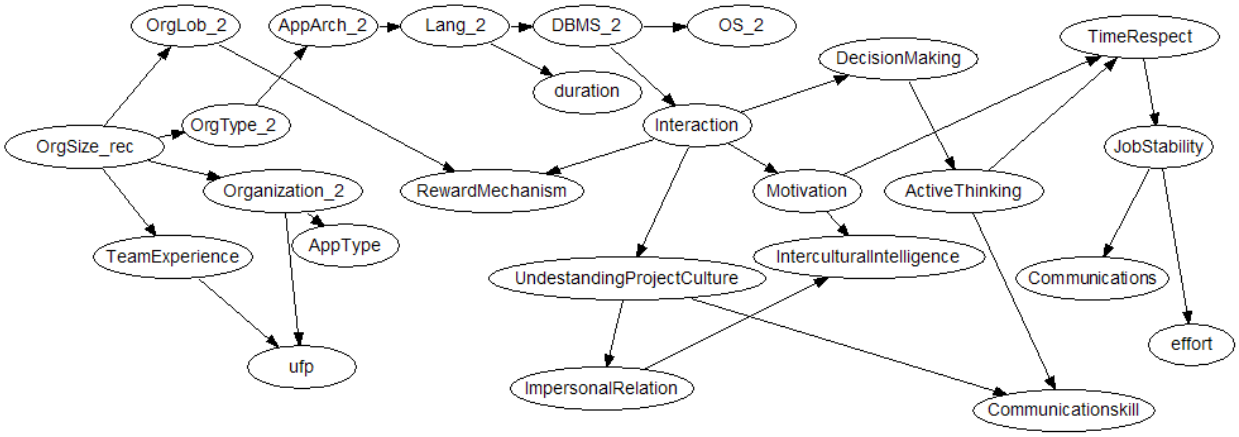

Figure 1. An automated BBN for software effort estimation

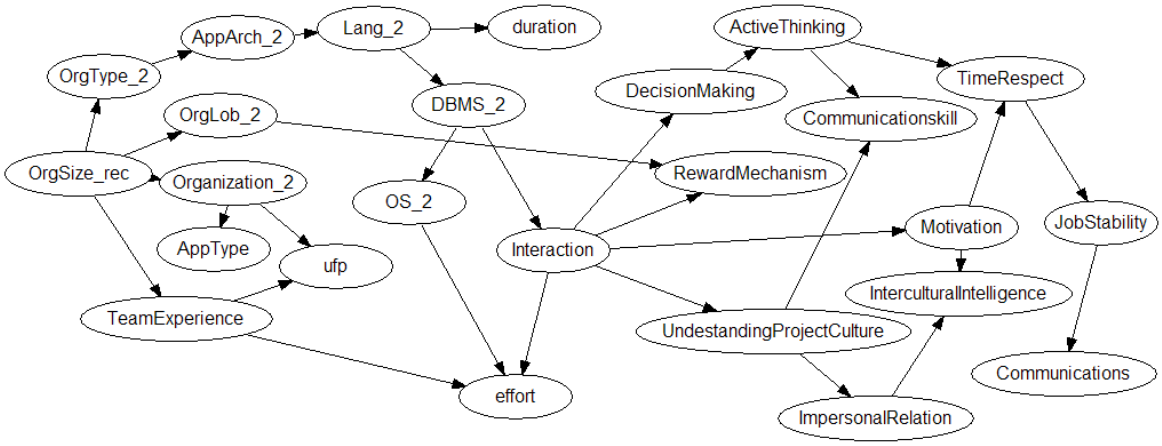

Figure 2. A BBN for software effort estimation based on intuition

TABLE II
NPT EFFORT ESTIMATION (JOB STABILITY)

Job Stability	1	2	3
1	0.31	0.48	0.24
2	0.24	0.42	0.42
3	0.44	0.10	0.33

TABLE III
EVALUATION METRICS

	hitrate	MMRE	pred(25)
training set	51.85%	79.15%	44.45%
test set	27.27%	116.66%	9.09%

The most probable estimate for this case would be the third interval (>619) keeping in my mind the low possibility that indicates that the estimate is weak. In order to estimate the effort values of the 11 projects in the test set we used the NPT of table 2 and we evaluated the model. The results of the evaluation of the model on both training and test set are presented in table 3. The MMRE and Pred(25) are calculated using the median value of the suggested interval.

The BBN that was automatically derived presents poor estimation accuracy as all metrics in table 3 take values below a certain acceptable threshold especially in the test set. This can be explained by the fact that the effort estimation depends only on the values of a single variable that does not seem to have a considerable effect on other variables. For this reason we empirically considered three new variables as the parent nodes of effort each one coming from the three group of variables considered earlier. We chose these three variables based on a common concept behind software project management, namely the "three P's" [12]. It is believed that Process, Product and People are the basic building blocks of software projects. Therefore, we chose one variable from each "P". The first variable represents the Product attributes and is OS_2. The second one, namely Interaction, represents Process and comes from the project leadership attributes. The third one, namely TeamExperience, represents people and belongs to the intercultural attributes.

We selected these variables because they can be early estimated during the lifecycle of a software project and also they represent three different types of difficulties, technological (OS_2), lack of knowledge (TeamExperience) and cooperation problems (Interaction). The suggested network in this case is presented in figure 2. The NPT used for the estimation of effort along with the estimation accuracy of the BBN of figure 2 are presented in tables 4 and 5.

TABLE IV

NPT TABLE FOR EFFORT ESTIMATION BASED ON OS_2, INTERACTION, TEAMEXPERIENCE

OS_2	0	0	0	0	1	1	1	1	1	1	1	1
Interaction	1	1	2	3	1	1	1	2	2	2	3	3
TeamExperience	1	2	3	3	1	2	3	1	2	3	2	3
1	0.28	0.46	0.28	0.44	0.33	0.38	0.44	0.24	0.24	0.46	0.21	0.44
2	0.28	0.33	0.44	0.28	0.21	0.24	0.28	0.52	0.52	0.21	0.46	0.28
3	0.44	0.21	0.28	0.28	0.46	0.38	0.28	0.24	0.24	0.33	0.33	0.28

TABLE V

EVALUATION METRICS

	hitrate	MMRE	pred(25)
training set	70.37%	42.27%	48.15%
test set	72.72%	52.31%	45.45%

Some interesting conclusions can derive from the BBN while observing the effect of the values of certain variables on the rest. When TeamExperience takes high values it seems that the functionality implemented is also relatively high (second interval) but the effort required is low. High values of TeamExperience are usually presented in Organizations of relatively big size. It is evident that the three variables we used act as proxies for wider groups of variables (Product, Process, People). More conclusions of this kind can be drawn through further analysis of the suggested dependencies.

VI. CONCLUSIONS

Culture and leadership have been recognized as important factors affecting cost estimation. The results indicate that leadership and intercultural attributes affect in many ways the effort required for the completion of a software project. The experience of the team that develops a software project along with the interaction of the members of the team are the most important factors that affect the effort. Also based on the results we can see an interdependency among most cultural and leadership characteristics and the final effort a fact that indicates that the inclusion of such data into estimation models could provide useful information and increase the accuracy of final estimates.

Some variables showed more importance than others. Leadership characteristics and cultural intelligence were believed by the respondents not to be significant attributes. This is probably due to the fact that this is an innate attribute which is built in the character of the individuals. Their character hasn't been shaped by the outside environment, and perhaps later he/she would acquire it from life experience in the community.

Concluding, our study presents only a first step towards a holistic approach to software effort estimation. Such approach dictates the investigation and employment of all aspects of software development (Product, Process, and People) to be able to produce both fairly accurate and intuitively appealing estimates. Because a holistic approach may involve an excessive number of variables, it is necessary to work with the most representative variables of each project dimension.

Further work includes the investigation of other analysis methods (e.g. Neural Networks, Principal Component Analysis) to isolate representative variables or build composite variables. Further empirical analysis is also needed to exploit the wealth of information that is provided by soft factors, such as culture and leadership. In addition, the effect of such factors on software quality must be investigated. We encourage other researchers to build empirical datasets with data similar to ours in order to produce estimation studies of that kind.

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