UNIVERSITY OF GAZİANTEP
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DEVELOPMENT OF USER INTERFACE FOR CORRELATED COST RISK ANALYSIS MODEL (CCRAM) WITH VISUAL BASIC

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Development of User Interface for Correlated Cost Risk Analysis Model (CCRAM) with Visual Basic

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Supervisor
Assoc. Prof. Dr. Ahmet ÖZTAŞ

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This is to certify that we have read this thesis and that in our opinion it is fully adequate, in scope and quality, as a thesis for the degree of Master of Science.

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ABSTRACT

DEVELOPMENT OF USER INTERFACE FOR CORRELATED COST RISK ANALYSIS MODEL (CCRAM) WITH VISUAL BASIC

KAPLAN, Turgut
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Cost estimation can be considered as one of the most important tasks for construction projects. Various risk-factors affect the construction costs. Therefore, not only estimation of the costs but also the analysis of the uncertainty effect on the estimated costs is required. The widely used method of project cost estimation, i.e. predicting the construction costs and simply calculating the total, is deterministic and insufficient. This approach neglects the uncertainty and the correlation effects. In this regard, correlated cost risk analysis model (CCRAM) was developed by Ökmen [1]. This study presents a user interface developed by Visual Basic for correlated cost risk analysis model to easy data entry and to analyze the construction costs under uncertainty when the costs and risk-factors are correlated without simulation.

The aim of this study is to develop a user interface with Visual Basic program for correlated cost risk analysis model, and to evaluate the uncertainty effect on construction project estimated costs. This user interface assure data entry to the CCRAM and evaluate the uncertainty effect on construction project estimated costs without simulation for contractor or decision makers. The efficiency of the user interface for CCRAM is evaluated through hypotetical application in this study.

Key Words: User interface, cost analysis, uncertainty, risk management, risk analysis, Visual Basic, correlation

ÖZET

KORELASYONLU MALİYET RİSK ANALİZİ MODELİ (CCRAM) İÇİN VISUAL BASIC PROGRAMINDA KULLANICI ARABİRİMİ GELİŞTİRME

KAPLAN, Turgut
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Maliyet tahmini inşaat projelerinde dikkate alınması gereken en önemli konulardan birisidir. Çeşitli risk unsurları yapı maliyeti üzerinde etkilidir. Bu nedenle sadece maliyet tahmininin yapılması yeterli olmamakla birlikte, aynı zamanda belirsiz durumların maliyet üzerine etkilerinin de analiz edilmesi gerekmektedir. Proje maliyet tahmini için kullanılan en geniş metod olan birim fiyata dayalı basit matematiksel hesaplamalarla maliyet tahmininde bulunulması, deterministik bir yöntem olup maliyet tahmininde yetersiz kalmaktadır. Bu yaklaşım belirsizliğin ve korelasyonun etkisini ihmal etmektedir. Bu nedenle Ökmen tarafından korelasyonlu maliyet risk analiz modeli (CCRAM) geliştirilmiştir. Bu çalışma ise korelasyonlu maliyet risk analiz modeline data girişini kolaylaştırmak ve belirsiz şartlar altında maliyetlerin ve risk etkenlerinin korelasyonlu olduğu durumlarda yapı maliyetinin tahmin edilebilmesini sağlayan kullanıcı arabirimi geliştirilmesini, Visual Basic ortamında sunmaktadır.

Bu çalışmanın amacında, inşaat projelerinin erken maliyet tahmini üzerindeki belirsizliklerin değerlendirilmesinde kullanılabilmek üzere, korelasyonlu maliyet risk analizi modeli için Visual Basic programı ile kullanıcı arabirimi geliştirilmesi anlatılmaktadır. Bu arabirim CCRAM'e data girişini kolaylaştırmak ve müteahhit veya yüklenici firma için simulasyon yapmadan belirsiz şartlar altında yapı maliyetini tahmin edebilmek için tasarlanmıştır. CCRAM için geliştirilen bu kullanıcı arabiriminin verimliliği hipotetik bir uygulama ile bu çalışmada değerlendirilecektir.

Anahtar Kelimeler: Kullanıcı arabirimi, maliyet analizi, belirsizlik, risk yönetimi, risk analizi, visual basic, korelasyon

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CONTENTS

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LIST OF SYMBOLS/ABBREVIATIONS

CCRAM	Correlated Cost Risk Analysis Model
MCS	Monte Carlo Simulation
CPM	Critical Path Method
PERT	Program Evaluation and Review Technique
MSRN	Modified Second Random Number

CHAPTER 1

INTRODUCTION

1.1 Problem Statement

Cost estimating become important procedures for evaluating project budget. Construction activity costs are affected by the uncertainties in weather condition, productivity, design, scope, site condition, soil properties, material delivery time, equipment efficiency, and etc. Activity costs might deviate from the expected values due to such various risk-factors. Hence, deterministic approaches like unit cost estimation become insufficient in clarifying the uncertainty in costs.

Early cost estimation procedures ignore the correlation between cost items or that not having risk based analysis approach produce unrealistic results. Unit cost estimation that utilizes deterministic unit cost values is the most widely used method among such procedures. Any cost estimation method that aim at producing this kind of information should approach the problem in a nondeterministic way and should not ignore the correlation between project variables (i.e. item costs). Moreover, the cost estimation should be considered within the risk management frame and risk analysis approach should be incorporated.

Correlated cost risk analysis model is one of the risk analysis technic under uncertainty when the costs and risk-factors are correlated. But, this model is not user-friendly and user interfaces are needed to develop. Use of the CCRAM are very complicated and the program format is not user friendly in terms of data input and calculations. In addition, guiding the user does not have an auxiliary grid, so the absence of user guides, is disadvantage of CCRAM. Data entry, data control, data transmission and data protection are necessary for a control analysis and model configuration.

1.2 Aim and Objectives

The aim of this study is to develop a user interface tool with Visual Basic program for correlated cost risk analysis model that can be used for facilitating data entry and computation and to evaluate the uncertainty effect on construction project estimated costs without simulation. This user interface facilitate data entry to the CCRAM and estimate early construction cost for contractor or decision makers. The correlation between item costs and risk-factors will be incorporated into the user interface tool for CCRAM. Furthermore, the tool will be designed such that they will be capable of providing risk-factor sensitivity information to support cost management. Probability will be the main mathematical theories that will be followed in building the theoretical logic of the tool.

The other objectives of the thesis:

- To learn (or accustome) the details of CCRAM model
- To computerize the developed user interface tool in Visual Basic
- To evaluate the tool through performing sensitivity analyses
- To carry out application for showing the applicability of the user interface

1.3 Scope

This study is composed of a user interface for CCRAM and an investigation on finding out the means of incorporating the uncertainty and correlation effects into early cost estimation. CCRAM is a candidate to be utilized as cost risk analysis tools through the risk analysis stage of project risk management due to its capability of capturing the uncertainty existing in construction costs. The whole analysis conducted throughout the thesis is user interface for CCRAM to be used facilitating data entry, computerization and uncertainity analysis in construction without simulation. The developed user interface is applicable to all kinds of construction projects either during the design stage or construction period. The scope of this study, design user interface for data inputs and calculations of CCRAM execution can be used to make easily and more understandable which is the method mostly utilized in construction sector in practice.

1.4 Method

The procedure followed in the thesis contains the development of user interface for correlated cost risk analysis model in a comparative manner. Sensitivity analysis will be frequently carried out to evaluate different features of the developed system. Hypotetical application will be conducted for showing the applicability of the user interface for CCRAM.

Probability theory is the major mathematical theories that will be followed in building the theoretical logic of the tool. The interface system will be computerized by designing Visual Basic program through formulas for CCRAM. The user-friendly interfaces will be produced with Visual Basic configurations to simplify the user's data entry and program usage. User interface for CCRAM consist of 31615 line code (671 pages) formulation in Visual Basic.

Furthermore, risk analysis full package software program, will be developed for adding simulation capability to the user interface of CCRAM.

1.5 Outline

The thesis consists of six chapters. The contents of the chapters are summarized below:

- Chapter Two: This chapter includes a brief theoretical background about the main subject matters of the thesis topic and a literature review about the existing methods associated with cost risk analysis.
- Chapter Three: Computerization of User Interface method is mentioned in Chapter Three. The logic, operation and computerization of the user interface tool are presented.
- Chapter Four: User Interfaces design at Visual Basic for CCRAM evaluated in Chapter Four.
- Chapter Five: A hypotetical application is performed on a construction project in Chapter Five.
- Chapter Six: Conclusion and Recommendations in Chapter Six.

CHAPTER 2

THEORETICAL BACKGROUND AND LITERATURE REVIEW

2.1 Introduction

This chapter contains a brief theoretical description about the main subject matters of the thesis and a literature review about the researches conducted over construction cost risk analysis. The corner points of the thesis subject include user interfaces, construction project management, risk management, cost estimation, simulation, uncertainty analysis.

2.2 Construction Project Management

The management of construction projects requires knowledge of modern management as well as an understanding of the design and construction process. While the relevant technology, institutional arrangements or processes will differ, the management of such projects has much in common with the management of similar types of projects in other specialty or technology domains such as aerospace, pharmaceutical and energy developments [2].

Specifically, project management in construction encompasses a set of objectives which may be accomplished by implementing a series of operations subject to resource constraints. There are potential conflicts between the stated objectives with regard to scope, cost, time and quality, and the constraints imposed on human material and financial resources. These conflicts should be resolved at the onset of a project by making the necessary tradeoffs or creating new alternatives. Subsequently, the functions of project management for construction generally include the following [3]:

- Specification of project objectives and plans including delineation of scope, budgeting, setting performance requirements, and selecting project participants.
- Maximization of efficient resource utilization through procurement of labor, materials and equipment according to the prescribed plan.
- Implementation of various operations through proper coordination and

control of planning, design, estimating, contracting and construction in the entire process.

- Development of effective communications and mechanisms for resolving conflicts among the various participants.

The Project Management Institute focuses on nine distinct areas requiring project manager knowledge and attention [4]:

- Project integration management to ensure that the various project elements are effectively coordinated.
- Project scope management to ensure that all the work required (and only the required work) is included.
- Project cost management to identify needed resources and maintain budget control.
- Project quality management to ensure functional requirements are met.
- Project human resource management to development and effectively employ project personnel.
- Project communications management to ensure effective internal and external communications.
- Project risk management to analyze and mitigate potential risks.
- Project procurement management to obtain necessary resources from external sources.

2.3 Early Cost Estimation

Early estimation of costs in an accurate way is extremely important to the owner and contractor in construction projects. Inaccurate early estimates can lead to lost opportunities, wasted development effort and lower than expected returns. The accuracy of early cost estimation depends on quality of cost data, scope definition, preparation time and the skill of the estimator. As a project progresses, the time required to complete the estimate and the accuracy provided both increases. Project price is influenced by the size of the project, the quality of the project, the location, construction duration and other general market conditions [5].

The cost of a completed construction project to the owner includes both the initial capital cost and the subsequent operation and maintenance costs. Each of these major cost categories contains a number of cost components. The initial capital cost for a construction project includes the expenses related to the initial establishment of the facility as enumerated below:

- Land acquisition, including assembly, holding and improvement
- Planning and feasibility studies
- Architectural and engineering design
- Construction, including materials, equipment and labor
- Field supervision of construction
- Construction financing
- Insurance and taxes during construction
- Owner's general office overhead
- Equipment and furnishings not included in construction
- Inspection and testing

Unit cost estimation method has been the most frequently utilized method in cost estimation. If the design technology for a facility has been specified, the project can be decomposed into elements at various levels of detail for the purpose of cost estimation. The unit cost for each element in the bill of quantities must be assessed in order to compute the total construction cost. This concept is applicable to both design estimates and bid estimates [6]. The basic unit-cost formula can be described as follows:

Suppose that a project is decomposed into n elements for cost estimation. Let Q_i be the quantity of the i^{th} element and u_i is the corresponding unit cost. Then, the total cost of the project is given by:

$$y = \sum_{i=1}^{n} u_i Q_i \tag{2.1}$$

where n is the number of units.

Unit cost estimation method is a deterministic approach and does not take the uncertainty effect into account. In other words, it is not useful for deciding the contingency amounts. In this thesis, this deficiency will be tried to be eliminated by incorporating risk-factor based modeling approach into early cost estimation process.

Program Evaluation and Review Technic (PERT) can be used to estimate the probability of completing either a project or individual activities. PERT continues with the designation of three time estimates for each activity [7]: optimistic (o), pessimistic (p) and most likely (m). These values are assumed to be the determining parameters of beta distribution (see Figure 2.1) that is accepted as capable of describing empirical data in PERT application. The equations of this approximated computation are given below:

$$\mu = (o + 4m + p) / 6 \tag{2.2}$$

$$\sigma^2 = [(p - o) / 6]^2 \tag{2.3}$$

where μ = expected duration of an activity, σ^2 = variance and σ = standard deviation of the activity durations. However, it should be emphasized that there are some arguments in the literature about these approximated computation equations of the traditional PERT and some other equations are offered for the same process. Afterwards, the expected duration (μ_T) and variance (σ^2_T) of the project are obtained by summing the expected values and variances along the critical path.

$$\mu_T = \sum_{i=1}^{n} \mu_i \tag{2.4}$$

$$\sigma^2_T = \sum_{i=1}^{n} \sigma^2_i \tag{2.5}$$

where n is the number of the activities belonging to the critical path.

In fact, the basic theory upon which PERT is developed is the well-known central limit theorem. This theorem claims that the sum of means of random variables from identical distributions (regardless of shape) tends to follow normal distribution.

PERT can be considered as an improvement to CPM for its incorporation of uncertainty and risk analysis. Unfortunately, it has some limitations due to the inherent computational assumptions and its insufficient ability to analyze all of the paths along the network. The criticisms established about PERT in the literature can be summarized as follows [8] :

- It is difficult to estimate the optimistic (minimum), most likely and pessimistic (maximum) costs of an activity and the estimation process involves high degree of subjectivity.
- The application of beta distribution to all project activities leads to computation errors.

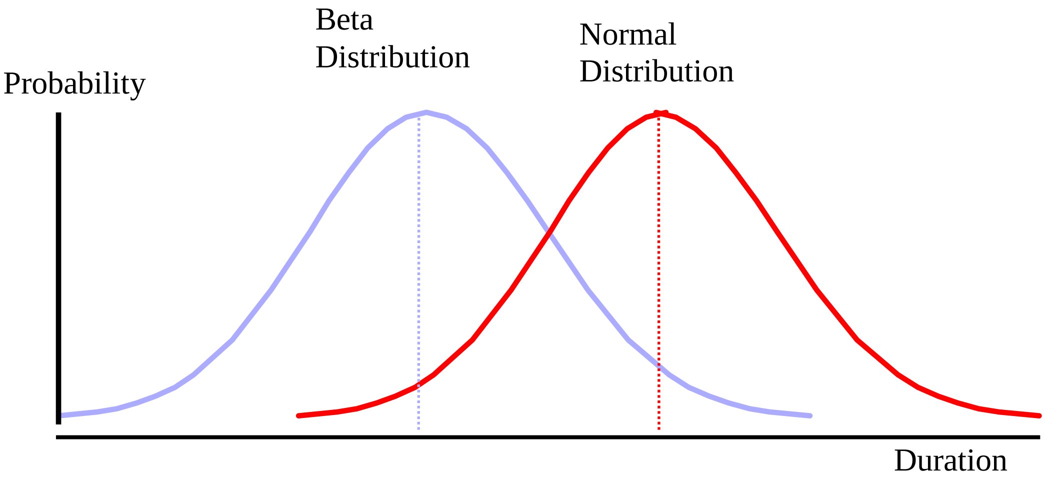


Figure 2.1. Beta and Normal Probability Distribution

2.4 Risk Management in Construction Projects

2.4.1 Risk concept

The concept of risk can be applied to nearly every human-decision making action of which the consequences are uncertain. Characteristic of decision making is its orientation towards the future (it uncertain). So, time is a central variable. Investors in financial markets recognize that risk plays an important role in their allocation of assets across different investments [9].

Some of the resources in literature propose the meaning of the word "risk" from the managerial point of view as follows:

- To give a broad overview of what is meant by risk and the way in which it influences decisions made in construction industry.
- To describe some of the tools and techniques used in risk management in a broad range of industries.
- To describe systems and techniques that could be used by design and construction team in management of risk on construction projects.
- A project risk is an uncertainty that may influence the implementation of the project. The influence may be negative - a threat risk - or positive – an opportunity risk.

All of these definitions share two common aspects: indeterminacy and loss. In other words, in order to discuss about the existence of risk; first, there must always be at least two possible outcomes and second, at least one of the possible outcomes must be undesirable.

Probability, which underlies many of the analytical approaches to risk. Decision–making in the construction industry & the role of the past in forecasting are considered.

There are many studies, both theoretical and empirical, which focuses on riskiness of situation, or focus on the willingness of people to take risks in certain situations.
The different type of risk studied include :

- Business risk
- Investment risk
- Economic risk
- Social risk
- Political risk

Certainty: When one can specify exactly what will happen during the period of time covered by the decision. This situation is not happen very often in construction industry.

Risk: Risk has a place in a calculus of probabilities and lend itself to quantitative expressions. Risk of success and cost of failure can be calculated by using probability of failure. Project risk is an uncertain event or condition that, if it occurs, has a positive or a negative effect on a project objective, uncertainty and the absence of information regarding occurrence, understanding risk requires some information [10].

Uncertainty: A situation in which there are no historic data or previous history relating the situation being considered by decision maker. Uncertainty occurs generally as a result of risk. For example, the completion time of a construction project is uncertain. However, the reasons leading to this uncertainty are the risks that affect the project aspects. Risk, in some manner, can be recognized as any result of uncertainty in any project affecting factor such as weather condition. This result may be a favorable or an adverse variation in the affected project aspect such as activity duration. For example, uncertainty in weather conditions may create the risk of variation in activity durations either in adverse or favorable direction, i.e. the actual activity durations may be more or less than the expected durations [11].

The major effects of common construction risks over a construction project are enumerated below:

- Failure to keep within the cost estimate

- Failure to achieve the required completion date
- Failure to achieve the required quality.
- Failure of the project to meet the required operation needs
- Failure of the project safety requirements
- Damage as a result of fire, flood, earthquake, etc.

2.4.2 Risk management

Risk management is a system which aims to identify and quantify all risks to which a business is exposed. A risk management system must be practical, realistic and must be cost effective. Risk management need not be implicated nor require collection of vast amount of data. It is matter of common sense, analysis, judgment, intuition, experience, gut feel and a willingness to operate a disciplined approach to one of the most critical features of any project in which risk is generated. Risk management is a discipline for living the possibility that future events may cause adverse effects.

Risk management can be defined as a systematic controlling procedure of risks that are predicted to be faced in an investment or project. Risk management can be applied to the entire project and can be used as a dynamic control system throughout the project life [12-14].

Process of risk management is broken down into below stages;

- Risk identification
- Risk classification
- Risk analysis
- Risk attitude
- Risk response

Risk identification and classification comprise the qualitative investigation of the risks. Risk response is the last risk management step at which the results of the preceding steps are discussed and suitable risk mitigation actions are taken in advance of risk occurrence.

2.4.2.1. Risk identification

To identify risk is rather like trying to map the world. Much of the world is not visible from where you stand. Some territory may familiar to you, but may not to others. Similarly, looking at a project from the top, with multiple layers of planning, complex vertical and horizontal interactions, and sequencing problems, resembles looking into the world map through a fog. Management's ability to influence the outcome is limited to what they can see. The great temptation is to focus upon what should happen, rather than what could happen. A clear view of the event is the first requirement, focusing on sources of risk and effect of the event. Sources of risk and effects of risk must be clearly distinguished.

Some risks are controllable: Co-ordination between the mechanical engineering services, specialist contractor, and the suspended ceiling specialist contractor.

Uncontrollable risks: Exceptionally inclement weather, So what? a contingency provision can be made by considering worst eventually.

2.4.2.2 Risk analysis

The next step after risk identification and classification is risk analysis in a risk management system. Risk analysis covers both quantitative risk measurement and qualitative risk assessment techniques and for this, statistical methods, simulating/ modeling capabilities of computers, engineering judgment and risk attitude are all taken into account and utilized. The importance of risk analysis is that it shows what happens if the project does not proceed according to the plan due to potential risks and warns the decision-maker or manager about the necessary responses to cope with risks. Furthermore, it captures all the feasible options and analyses the various outcomes of any decision [15-18].

Risk analysis techniques are grouped in two parts: quantitative and qualitative. All methods benefit from the data produced by risk identification and classification tasks but qualitative approach consumes the gathered information through direct judgment, ranking options, comparing options and descriptive analysis. In contrast, some of the quantitative risk analysis techniques, like Monte Carlo Simulation, are used in performing statistical models and simulations in order to reach numerical results that show the effects of risks. Whilst the most tools and techniques used in analyzing the risks provide quantitative solutions, they all contain subjectivity to some extent.

There are a number of quantitative risk analysis techniques emphasized in literature, which can be classified as classical techniques (e.g. sensitivity analysis and Monte Carlo Simulation). Some of the common qualitative and quantitative risk analysis techniques are enumerated below:

- Sensitivity analysis

- Monte Carlo Simulation
- Decision-tree analysis (stochastic or deterministic)
- Fuzzy-set theory
- Utility theory
- Multi-attribute value theory
- Probability theory
- Portfolio analysis
- Breakeven analysis
- Scenario analysis
- Delphi method

The quantitative risk analysis techniques can be further classified as deterministic and stochastic techniques. The stochastic methods such as Monte Carlo Simulation, stochastic decision tree analysis, delphi method and portfolio analysis produce probabilistic solutions instead of assuming %100 certainties for decision variables like deterministic analysis techniques. Deterministic techniques such as breakeven analysis and deterministic decision tree analysis produce fixed single-value results. In contrast, the variables in a stochastic risk analysis model can be represented by probabilistic terms or distributions so that the uncertainty surrounding the project is assessed. For these reasons, stochastic risk models and analysis techniques are becoming more popular among project managers and decision-makers.

The next subsections contain brief descriptions about sensitivity analysis, scenario analysis and Monte Carlo Simulation. These are the risk analysis techniques benefited throughout this thesis.

Sensitivity analysis: Sensitivity analysis is a kind of 'what-if' analysis. It aims to answer the questions like "How does the total project cost change if inflation rate increases 5%, 10%, 15%… above the estimated base inflation rate with the other cost affecting factors are kept constant?" In other words, sensitivity analysis is used to observe the impact of a change in the value of an independent variable on the dependent variable [19, 20]. There are two major uses of sensitivity analysis:

- It identifies the risky sides of the project in order for concentrating on these sides.
- It identifies risky variables that change the ranking order of the alternatives, so that effort is concentrated on these areas.

Scenario analysis: Scenario analysis is applied when testing alternative options. The options are regulated and then evaluated as different scenarios, but the scenarios are generally based on the most likely, the optimistic and the pessimistic forecasts. Besides, only key variables are identified with their values. Scenario analysis can also be used for optimization purposes.

Monte Carlo Simulation: Monte Carlo Simulation makes the assumption that parameters subject to risk and uncertainty can be described by probability distributions. That technique makes use of these probability distributions to generate a number of simulations of the desired overall cost estimate [21-23].

The simulation of a project uses uncertainty in the estimating process. Firstly, a project is broken down into activities or packages with an assessment of reasonably foreseable;

- optimistic (or lowest)
- pessimistic (or highest)
- most likely (this becomes peak value of distribution)

Seldom is it possible by the use of historical data or expert judgement to define more than these three points, nor is it even worth attempting. Estimating is a case where practicality of approach and sensitivity of results militate against analytical overkill. Most of us cope with the uncertainty in practice by describing it with words like 'between X and Y'. When we have to be more definitive we will include contingency sums to cover the unknowns we are dealing with. Uncertain things are fuzzy values, nor precise values.

MCS is a kind of stochastic and statistical experiment applied for practicing randomly generating events that cannot be formulated by even empirical means. For this reason, this technique is particularly useful when processes or events are too complex to be solved analytically.

The cost of construction work is a combination of what client is prepared to pay and the price at which contractor is prepared to undertake the work in order to show an acceptable level of profit. Prices can be considered as residing in a family of prices where there will be both extremes & a most likely price. The aim here is to describe a technique which identifies the probability distribution from which a price prediction has been taken. It can initially be used by the client and consultants in assessing a particular price prediction, and, eventually, in deciding upon the feasibility of the construction project to which the prediction refers. General methodology is applicable at any stage of the investment appraisal, development appraisal, or design process of a project.

The total cost of a project cannot be calculated exactly by formulas in advance, because of the complex market conditions, human factors, physical environment and many other risks. However, it can be estimated statistically by MCS because it is a random process. MCS enables the risky project parameters to vary simultaneously according to the assigned probability distributions which are explored from previous data. As the iteration number of simulation is increased, more regular and consistent results are provided related to the variable sides of the project. Furthermore, the risk model on which the MCS is performed can be further developed by necessary formulas and correlation elicitation techniques before the simulation. The most sensitive issues of MCS are the determination of probability distributions and correlation elicitation technique that will be implemented. Three approaches to the definition of the distributions exist in the literature: subjective definition of the distributions by expert judgment, objective definition of the distributions from the historical data and objective/subjective definition from a small sample of data extracted from previous similar projects. All of these approaches are valid in different circumstances because the amount and consistency of historical data is the key criteria that determine the way to be followed.

The followings are some of the common probability distribution types that can be assigned to variables in MCS:

- Uniform
- Triangular
- Poisson
- Binomial
- Lognormal
- Exponential
- Geometric
- Hypergeometric
- Weibull
- Beta

It is sometimes difficult to determine the appropriate distribution for a variable. In order to overcome such difficulties, the properties of the distributions and the factors surrounding the variables should be properly investigated. The following list consists of the basic principals to be followed in selecting probability distributions.

- The distribution should be easily identifiable from a limited set of data.
- The distribution should be easily updated as additional historical data are introduced to the analysis.
- The distribution should be flexible in shape i.e., it should be capable of taking a variety of shapes.
- It is better for the analysis that the distribution has finite end points.

Some of the distributions are more suitable in particular conditions. For instance, discrete functions are seldom used in construction cost risk analysis, whereas positively skewed triangle, beta and lognormal distributions are the most frequently used types for this purpose.

MCS uses random numbers chosen from the predefined value ranges of variables. These random numbers are generated by random number generators of computer programs and consumed to generate outcomes from the probability distributions in correspondence with their statistical properties and shapes.

Although it seems very important to choose the right probability distribution type for the project variables in MCS, the fact is not like this. The reason is that the errors in selection of distribution types are compensated by the effect of central limit theorem. Central limit theorem mentions that when a range of distribution shapes are simulated many times, there will, as the number of simulations increases, be a tendency for the output distribution to tend to the normal distribution shape. Therefore, selection of the precise distribution type is not more important than establishing the correlation effect in the model. This fact is more evident in particular areas. For instance, it is relatively more important to investigate and allow correlations between the costs of sub-components of construction cost estimates than to select the best-fit distribution to represent cost elements in MCS. Correlation between the variables may be positive or negative and this can be represented by correlation coefficient values between 1 and –1. Relevant computer programs are capable of incorporating the correlation coefficients between the variables if the coefficients are entered to the program.

Furthermore, they can warn the user if there is some inconsistency between the entered coefficients. However, estimating the correlation between the variables is not so easy. It depends on deep experience and the amount of previous data in hand. Instead, elicitation of the correlation indirectly through qualitative analysis techniques seems more logical and practical. The procedure that is followed throughout this thesis in developing the risk models is the indirect correlation elicitation method.

The results of MCS may be arranged in different forms according to the purpose. Some of these forms are tabular summary lists, frequency diagrams and cumulative frequency diagrams. Summary lists may show the probability ranges of the required resultant variable such as project duration or total cost, statistical properties of the results or they may provide the critical parameters of the risk model.

2.4.2.3 Risk response

The last action of systematic risk management process is responding to risks. The results of the risk analysis step are evaluated and accordingly, the strategies to cope with risks are determined during this stage. Contracts, insurance and surety are the common means of risk response by which the determined strategies are documented and carried out. Although, some of these means are expensive reactions they should not be considered as wasted costs. In contrast, they are the precautions to generate the desired returns [24, 25].

The risk response strategies can be categorized in four groups;

- Risk retention (absorption)
- Risk reduction (prevention – mitigation)
- Risk transfer
- Risk avoidance

Risk retention: Risks that produce individually small, repetitive losses are those most suited to retention. On a motor insurance policy many people will bear the cost of the first 50 pounds in return for reduction in the premium. Some people may choose to pay the first 200 pounds in return for a larger reduction, the level of retention is dictated by the financial circumstances and likelihood of loss. Not all risk can be transferred but even if they were capable of being transferred it may prove to be economical to do so. The risk will then have to be retained. Besides, it is preferable to retain a portion of the risk in certain circumstances. In summary, the relevant factors are:

- the cost of the insurance premium
- the maximum probable loss

- the likely cost of the loss
- the likely cost of paying for the loss, if uninsured

Risk reduction: One of the ways of reducing the risk exposure is to share risks with the other parties. For instance, the international banks syndicated loans to third world governments or the stock market investor spreads his risk over many securities. Risk reduction falls into 4 categories;

- *Firstly*, education and training to alert the staff to potential risks.
- *Secondly***,** physical protection to reduce the likelihood of loss.
- *Thirdly***,** systems are needed to ensure consistency and to make people ask the what if questions.
- *Finally***,** physical protection can be taken to protect people & property

Preventive (at early project stages);

- Utilize quantitative risk analysis techniques for accurate time estimation
- Depend on subjective judgment to produce a proper program
- Produce a proper schedule by getting updated project information
- Plan alternative methods/options as stand-by
- Consciously adjust for bias and add risk premium to time estimation
- Refer to previous and ongoing similar projects for accurate program

Mitigation (during construction);

- Increase manpower and/or equipment
- Increase the working hours
- Change the construction method
- Change the sequence of work by overlapping activities
- Coordinate closely with subcontractors

Risk transfer: Risk transfer is the action of transferring the responsibility of risks to another party using a contract, insurance, an indemnity, a bond or a surety. It is a widely utilized risk response strategy but important point to be cared about is that the party to whom the risks are transferred must be capable of controlling and affording the risks. Otherwise, the whole project may be affected negatively [26].

Risk transfer can be realized through the following routes;

- Client to contractor
- Contractor to sub-contractor
- Client, contractor, sub-contractor to insurer

- Contractor or sub-contractor to surety

Transferring risk does not reduce the critically of the source of risk, it just removes it to another party. In some cases, transfer can significantly increase risk because the party to whom it is being transferred, may not be aware of risk they are being asked to absorb. Example, the general contractor (when entering into a contract with a sub-contractor) may impose a liquidated and assessment of loss suffered by the general contractor. The sub-contractor may not be aware of additional risk being transferred and he may well not be in the financial position to carry risk. The common form of risk transfer is by means of insurance which changes an uncertain exposure to a certain cost. In the construction industry obtaining insurance cover is becoming more expensive. On construction projects, fault-free building cannot be guaranteed and defects may be discovered long after practical completion.

Risk avoidance: Risk avoidance is the risk refusing action unlike the risk retention or risk reduction. The best examples are the refusal of the whole project or avoiding only its risky parts. Risk avoidance can be experienced through the following ways:

- Avoiding to bid on the Project
- Bidding very high prices
- Using exemption clauses
- Bidding on the less risky portions of the contract
- Ignoring the project (by owner/client)

Risk avoidance is a more consistent and realistic way of risk struggle in fuzzy situations instead of taking unconscious decisions simply for the aim of winning the tender. Investing on different alternatives and projects would be more logical than dragging the company into an adventure if the company did not have enough resources and capacity. Otherwise, terrible events may occur like bankruptcy.

2.5 Probability Theory and Uncertainty

Probability theory was shown among the risk analysis methods. In other words, this well known theory becomes an excellent mean for determining the extent of uncertainty inherent in construction schedules and cost estimations. For this reason, probability theory and its concepts are frequently utilized in improving in this thesis. The main definitions and descriptions regarding this theory are presented below [27, 28]:

Probability: Probability is the degree of likelihood that something will happen. More precisely, probability is used for modeling situations when the result of an experiment, realized under the same circumstances, produces different results (typically throwing a dice or a coin). Probabilities are expressed as fractions 1⁄2, 1⁄4, 3⁄4), as decimals (0.5, 0.25, 0.75), or as percentages (50%, 25%, 75%) between 0 and 1. For example, a probability of 0 means that something can never happen; a probability of 1 means that something will always happen. The probability of an event is calculated as follows:

$$p(a) = \frac{\text{No. of outcomes favorable to the occurrence of the event}}{\text{Total no. of possible outcomes}}$$

For example, the probability of getting heads in one toss is: p(heads) = 1/(1 + 1) = 1⁄2. In any experiment there are certain possible outcomes; the set of all possible outcomes is called the sample space of the experiment (denominator in the above equation). To each element of the sample space (i.e., to each possible outcome) is assigned a probability measure between 0 and 1 (0 is sometimes described as corresponding to impossibility, 1 to certainty). Furthermore, the sum of the probability measures in the sample space must be; 1

Probability theory: Probability theory is the mathematical study of phenomena characterized by randomness or uncertainty. In engineering applications, this theory is widely used. For instance, the duration of an activity randomly generates in even exactly similar conditions. Through identifying the effective factors and the shape of affection, this kind of uncertainty can be modeled by using probability theory.

Statistics: Statistics is the branch of mathematics dealing with gathering, analyzing and making inferences from data. It has applications in all the sciences. Statistical tools not only summarize past data through such indicators as the mean (mean, median and mode) and the standard deviation but can predict future events using frequency distribution functions. Besides, statistics provides ways to design efficient experiments that eliminate time- consuming trial and error. Statistics is directly related with probability theory in application.

Arithmetic mean: The arithmetic mean is the "standard" average of a set of, often simply called the "mean". Its equation is:

$$\bar{x} = 1/n \sum_{i=1}^{N} x_i \qquad (2.7)$$

The mean may often be confused with the median or mode. The mean is the arithmetic average of a set of values, or distribution; however, for skewed distributions, the mean is not necessarily the same as the middle value (median), or most likely (mode). The mean of a function also exists. It can also be defined as the average value of the function over its domain.

$$\bar{f} = 1/(b\text{-}a) \int_{a}^{b} f(x)\, dx \qquad (2.8)$$

Standard deviation and variance: Standard deviation (s) and variance are the two statistics used as a measure of the dispersion or variation in a distribution; variance is equal to the arithmetic mean of the squares of the deviations from the arithmetic mean, standard deviation is the square root of variance.

$$\bar{s} = \sqrt{[1/(N\text{-}1) \sum_{i=1}^{N} (x_i - x)^2]} \qquad (2.9)$$

The advantage of a standard deviation calculation over a variance calculation is that it is expressed in terms of the same scale as the values in the sample. For example, for a population of distances in meters, the standard deviation is also measured in meters, whereas the variance is measured in square meters.

Standard deviation is the most common measure of statistical dispersion, measuring how the values in a data set are spread out. If the data points are all close to the mean, then the standard deviation is close to zero. If many data points are far from the mean, then the standard deviation is far from zero. If all the data values are equal, then the standard deviation is zero. At least 75% of the values in any population are within two standard deviations away from the mean. 95% of the values in a population having normal distribution are within two standard deviations away from the mean.

Covariance: Covariance is the statistical term for the correlation between two variables multiplied by the standard deviation for each of the variables. A positive covariance indicates that the two variables tend to move up and down together; a negative covariance indicates that when one moves higher, the other tends to go lower. Covariance is in relation with correlation.

Correlation coefficient: Correlation coefficient is a statistic representing how closely two variables co-vary; it can vary from -1 (perfect negative correlation) through 0 (no correlation) to +1 (perfect positive correlation). In probability theory and statistics, correlation, also called correlation coefficient, indicates the strength and direction of a linear relationship between two random variables. In general statistical usage, correlation refers to the departure of two variables from independence. The basic formulas and further descriptions regarding the correlation concept will be introduced in the next chapter.

Coefficient of variation (standard deviation-mean ratio): The coefficient of variation represents the ratio of the standard deviation to the mean, and it is a useful statistic for comparing the degree of variation from one data series to another, even if the means are drastically different from each other. In other words, the coefficient of variation is a dimensionless number that allows comparison of the variation of populations that have significantly different mean values.

Confidence interval: Confidence interval is a statistical range with a specified probability that a given parameter lies within the range.

Probability distribution: Probability distribution is a function of a random variable yielding the probability that the variable will have a given value.

Common probability distributions used in simulation applications regarding uncertainty analysis was mentioned. Normal, triangle and uniform probability distributions are the main distributions utilized through the thesis and necessary information about them are presented within the related sections.

Every random variable gives rise to a probability distribution, and this distribution contains most of the important information about the variable. If X is a random variable, the corresponding probability distribution assigns to the interval $[a, b]$ the probability $\Pr[a \leq X \leq b]$, i.e. the probability that the variable X will take a value in the interval $[a, b]$. The probability distribution of the variable X can be uniquely described by its cumulative distribution function $F(x)$, which is defined by;

$$F(x) = \Pr [X \leq x] \tag{2.10}$$

A distribution is called *discrete* if its cumulative distribution function consists of a sequence of finite jumps, which means that it belongs to a discrete random variable X: a variable which can only attain values from a certain finite or countable set. By one convention, a distribution is called *continuous* if its cumulative distribution function is continuous, which means that it belongs to a random variable X for which Pr[$X = x$] = 0 for all x in R.

Central limit theorem: The normal distribution has the very important property that under certain conditions, the distribution of a sum of a large number of independent variables is approximately normal. This is the central limit theorem. The practical importance of the central limit theorem is that the normal distribution can be used as an approximation to some other distributions. This theorem is particularly used in PERT.

2.6 Risk Analysis and Uncertainty into Early Cost Estimation

The method developed to evaluate uncertainty in construction project and early cost estimation utilize quantitative and qualitative modeling techniques. MCS based cost analysis models follow a similar procedure. The main shortcoming of PERT and MCS based CPM is that these methods neglect the correlation between the variables, considering as if they are all independent, and so they produce inaccurate results.

Qualitative models use qualitative terms (e.g. very effective, effective, expected, worse) instead of quantity values for modeling uncertainty. The algorithm of the model then converts these qualitative values into quantities. Moreover, the approach in qualitative models is generally factor-based, i.e. the factors creating the uncertainty and their occurrence likelihood are required in these models. The main superiorities of the models that use solely qualitative or both qualitative and quantitative techniques are their correlation capturing capabilities and factor-based analyzing capability. The user interfaces that are developed within this thesis use qualitative and quantitative techniques in conjunction according to CCRAM.

The methods incorporating risk analysis and uncertainty into early cost estimation is briefly described in the following paragraphs:

MUD (Model for Uncertainty Determination) which is a simulation-based model was developed to evaluate project networks under uncertainty. The MUD simulation by Carr and Padilla was further refined into a component of the *DYNASTRAT*

(DYNAmic-STRATegy) model for dynamically allocating resources. The evaluation of uncertainty in *MUD* is factor-based and uncertainty is treated as having both favorable and adverse effects. Moreover, correlation between activities is modeled indirectly and calendar- dependent risk-factors such as weather are taken into account with considering their planned dates on the calendar [29].

JRAP (Judgmental Risk Analysis Process) which is a simulation based model was developed by Öztaş and Ökmen, to evaluate uncertainty in construction activity networks. It follows a systematic risk analysis procedure. The evaluation of uncertainty in *JRAP* is factor- based and correlation between activities is modeled indirectly. However, uncertainty is treated as having only adverse effect [30].

Exact Simulation, MSRN (Modified Second Random Number) and *Factored Simulation* are all MCS based models which requires correlation coefficients. Hence, these models capture the correlation effect directly. Except for *Factored Simulation,* the other models treat uncertainty as having both favorable and adverse effects [31].

The models that have been developed for evaluating uncertainty in early cost estimates also utilize MCS in general. In this study, the general trend is to capture the correlation between the costs directly by correlation coefficients using subjective or previous data. However, they are not factor-based and indirect correlation elicitation has not been considered. Hence, the sensitivity of the estimated costs to particular risk-factors cannot be detected and in turn, uncertainty evaluation cannot be done competely [32].

CHAPTER 3

COMPUTERIZATION OF USER INTERFACE

3.1 Introduction

The success of construction projects is evaluated based on specific measures. Most of these measures are in relation with quality, safety, functionality and cost. Cost estimation can be considered as one of the most important tasks necessary for being successful in construction projects. Since various risk-factors affect the construction costs, the actual costs generally deviate from the estimated costs in favorable or adverse direction. Therefore, not only estimation of the costs but also the analysis of the uncertainty effect on the estimated costs is required. The widely used method of project cost estimation, i.e. predicting the construction costs and simply calculating the total, is deterministic and insufficient. This approach neglects the uncertainty and the correlation effects.

Project risks are the results of uncertainty in any effective factor such as weather conditions. These results may be a favorable or adverse variation in the affected project aspect. For example, uncertain weather conditions may create the risk of variation in item costs either in adverse or favorable direction, i.e. the actual cost may be more or less than the expected cost.

3.2. Short information about CCRAM

CCRAM is developed as a risk analysis tool for usage in early cost estimation phase of any construction project. It is a risk-factor based and simulation based model that indirectly incorporates the positive correlation effect between cost items and between risk-factors (two sided correlation) in both favorable and adverse direction [33].

The sensitivity of the estimated costs to particular risk-factors cannot be detected and in turn, the evaluation of uncertainty cannot be performed completely. In this regard, correlated cost risk analysis model (CCRAM) was developed by Ökmen to analyze construction costs under uncertainty when the costs and risk-factors are correlated. CCRAM is produced as a risk analysis tool for usage in early cost estimation phase of any construction project. It is a risk-factor based and simulation based model that indirectly incorporates the positive correlation effect between cost items and between risk-factors in both favorable and adverse direction. Formulations of CCRAM's algorithm is used in user interface of CCRAM. It is a stepwise procedure consisting of data input parts, computation parts, probability distribution parts and result part.

3.3 Strengths and Limitations of User Interface

User interface of CCRAM has some limitations. Prior to emphasizing these limitations of user interface can described as follows:

- Data entered to the program should be realistic although they are highly judgmental and independent of the similar project records completed in the past. Unrealistic or missing input data would produce unrealistic and wrong results.
- User interface can calculate up to 15 cost item and 15 risk factor with the current capacity of total cost estimate. Furthermore, the full risk analysis support systems can be developed with the most cost items and risk factors.
- Elicitation of correlation indirectly by utilizing qualitative data
- Subjectively and qualitatively determined simplified input data
- Independence on previous data belonging to past completed projects
- Consideration of adverse and favorable effects of risk-factors on item costs
- Simulation based algorithm is not capable in user interface.
- Useful in developing risk response strategies in advance and managing cost risks throughout a construction project.

3.4 Computerization of User Interface

CCRAM has been computerized by using Visual Basic and Excel program. The computerization of CCRAM is described under two sections. In section 3.4.1, input data properties of the user interface are introduced and afterwards, in section 3.4.2, computation properties are described. Visual Basic codes of the user interface on which the distinguishing input and computation parts are clarified with numbered headings is given in parts with the figures in Appendix A and in a compact disc attached to the thesis. Furthermore, the spreadsheet is filled up with the data of a hypotetical application, which is described in chapter 5 in detail.

3.4.1 Input Data parts of User Interface

Input data cells of user interface of CCRAM have been designed in green&yellow background color as shown in Figures A.1, A.2, A.3, A.4, A.5 and A.6 of Appendix A. The user is free to enter data into these yellow cells. However, computation parts of the model have been designed in grey background color as shown in Figures B.1, B.2, B.3, B.4, B.5 and B.6, and the user is prevented to enter data into these cells.

There are five input data parts in user interface spreadsheet as shown in Figures A.1, A.2, A.3, A.4, A.5 and A.6. Brief descriptions about these parts are introduced below:

Input Data 1 - *Project Information*: General identifying information about the project on which user interface is applied can be entered into this part. The user is free in recording whatever user desires regarding the project (Figure A.1). In these region, cost-item number and risk-factor number must be assigned for the other parts of user interace. Dates, project duration time and additional time period are not necessary, but these can be necessary about project general information. “OK” button have to be used to translate input data informations to the other regions. Each item’s cost is represented with a normal probability distribution in user interface of CCRAM. The entered minimum, maximum and most likely expected costs are used in the calculation of the means and variances of the representative normal distributions. Afterwards, the user has to enter the cost item ~ risk-factor influence degrees. This input data is entered in the form of “high, medium, low or no” qualitative terms and each of these qualifications show the uncertainty (i.e. variation) creation effect of each predetermined risk-factor on any cost item. This procedure is important for providing the correlation between the cost items. Further description will be given about the details of this correlation capturing process in the next section.

Input Data 2 - *Cost Information*: Descriptions of the cost items, and their minimum expected, maximum expected and most likely expected costs are entered into this part (Figure A.2). *Cost information*s are minimum, most likely and maximum expected item costs. Your project cost item description informations should write in the yellow background color regions. The information regarding the risk-factors, their effects on the costs and the three characteristic expected item costs (minimum, most likely and maximum) are extracted from the results of the previous risk management steps. User interface of CCRAM requires the cost items with their three characteristic expected values. Each item's cost is represented with a normal probability distribution. Mean, variance and standart deviation values are calculated to use the same name buttons which have process of mathematical calculation to evaluate minimum, most likely and maximum expected cost values and translate to the Computation part 1. OK button have to be used to translate input informations to the other regions.

Input Data 2 - *Risk Information*: Descriptions of the risk factors (Figure A.3). Your project risk item description informations should write in the grey background color region one by one. Names of risk-factors which create uncertainty on costs. This region is necessary to use project information of Excel part of CCRAM.

Input Data 3 - *Scale Quantities & Probability Boundaries*: Names, scale quantities and probability boundaries of the risk-factors are entered into this part (Figure A.4). Risk-Factor influence degrees of each project cost item is important to determine correlated calculation. The same probability boundary values should be entered to be used risk buttons according to risk factor degrees for the correlated risk-factors, in accordance with the logic. Firstly entering the “Risk-Factor Influence Scale Quantities” according to risk-factor degrees to use “1-10”, “10-50”, “20-100” buttons. Secondly applying the “Risk-Factor Situation Probability Boundaries” according to correlated risk situation to use “Risk ##” buttons. Thirdly calculate “Risk-Factor Situation Probability Values” to use the same name button. Finally “OK” button have to be used to translate informations to the other regions and to be other pages active of user interface.

Input Data 4 - *Influence Degrees*: Influence degrees of the risk- factors on the costs (high, medium, low or no) are entered by selecting from the list embedded in the cells of this part (Figure A.5). These datas are determined degrees of effected by the Cost Items according to the risk-factors. "Cost item ~ Risk-factor "influence degrees": risk-factors and their expected effects on cost items in terms of "high, medium, low or no" qualifications. These qualifications reflect the intensity of the uncertainty creation effect of predetermined risk-factors on cost items. They are required for eliciting the correlation between cost items. Yellow background color regions are assigned one by one, not to pass blanks in these cells. “OK” button have to be used to translate input informations to the Computation part 2.

Input Data 5 - ***Setting of Random Number Generator****:* There are a number of cells (as many as the risk-factors) in the random number generator column as shown in Figure A.6. The first row cells belongs to the first risk-factor, the second row cells belongs to the second risk-factor and so on. These cells are assigned with using “R.N.G” and “High-Medium-Low Limits”buttons randomly in Figure A.6.

The cells belonging to the correlated risk-factors are set equal to each other with equalization. Formula, so that the same random number is utilized for the correlated risk-factors and different random numbers are processed for the uncorrelated risk-factors at each simulation iteration, in accordance with the logic of user interface of CCRAM. To assign random number to risk factors between 0 and 1. User interface produces random numbers from the uniform probability distribution to determine the risk-factor situations.

A different random number is produced for every uncorrelated risk-factor situation from the uniform probability distribution in order to produce random cost values from the situation probability distributions. However, the same random number is used for the correlated ones.

The random numbers are compared with the "probability boundaries" for the determination of which situation occur for the iteration in question; i.e. better-than-expected, expected or worse-than-expected.

3.4.2 Computation parts of User Interface

There are five computation parts in the user interface as shown in Figures B.1, B.2, B.3 and B.4. Descriptions about these parts of user interface are given below:

Computation 1 - ***Probabilistic Representation of Costs****:* Three different calculations are performed under three columns of this part. Through these calculations, the mean, variance and standard deviation of item costs are calculated by using their minimum expected, maximum expected and most likely expected costs which are entered into the “INPUT DATA 1”. Equations 2.1 and 2.2 are used for the calculations. For instance, the first cells of the three columns as shown in Figure B.1 have been loaded with the following Visual Basic formulations compatible with Equations 2.2 and 2.3, and the definition of standard deviation.

Item costs are represented by normal probability distributions in CCRAM. The characteristic parameters of the normal distributions are determined by substituting minimum (o), maximum (p) and most likely (m) expected costs into the following approximated equations:

Mean column cells – mean: “Mi = (o + 4m + p)/6”

Variance column cells – variance: “VARi = ((p-o)/6)^2”

Standart Deviation column cells – standard deviation: “SDi = VARi ^ 0.5”

Where Mi and VARi denote the mean and variance of the normal probability distributions assigned to item cost i, respectively. So, the uncertainty of the item cost i can be shown as Ni (Mi, VARi); where Ni denotes the normal probability distribution of item cost i. “OK” button have to be used to translate informations to the other computation part.

Computation 2 – *Intermediate Regulation of Input Data (Quantification of Influence Degrees)*: This part has been designed for the purpose of regulating the data entered into “INPUT DATA 3” and “INPUT DATA 4”. The qualitative influence degrees entered in the fourth data input part are converted to quantitative values in this part and these values are used later in the next computation parts. Risk-factor situation probability values and the scale quantities corresponding to the influence degrees in question for each cost-risk pair are gathered cells at Input Data 3 - 4 parts as shown in Figure B.2.

The probability boundaries corresponding to the better-than-expected, expected and worse-than-expected situations of the risk-factor, respectively. The cells belonging to the other risk-factors have been loaded with the appropriate similar formulas following the same logic.

The scale quantities corresponding to the influence degrees in question for each cost-risk pair are found with three parts by using the visual basic formulas. Total influence of risk-factors over each item cost is computed in this part under the “Total Influence” column with the “Calc. Total Influence” button. Total influence values computed under the “Total Influence” column.

Computation 3 - ***Uncertainty Distribution to Risk-Factors (First Step Uncertainty Distribution)*:** In this computation part, the first step uncertainty distribution of CCRAM of which the logic has been described in *StepII (a)- Uncertainty distribution to risk-factors* is realized. The variance values of costs that are computed in the first computation part are distributed to risk-factors by using the data gathered up to this point as shown in Figure B.3.

The variance of the main cost distribution of the first cost item, total influence degree belonging to the first cost item computed under the Total Influence column of the second computation part and the influence degree belonging to the first risk-factor ~ first cost item pair found in the second computation part, respectively. The cells belonging to the other cost items in the “COMPUTATION 3” have been loaded with the appropriate similar formulas following the same logic through user interface of CCRAM.

Another feature of the third computation part is the “Total Variance” column. This column has been designed for the controlling purpose. The total variance computed for any cost item on this column must be equal to the variance values computed during the first computation part.

Computation 4 - ***Uncertainty Distribution to Risk-Factor Situations (Second Step Uncertainty Distribution) & Production of Correlated Item Costs for Simulation**:*

In this computation part consist of fifteen parts (RF1, RF2, RF3, RF4, RF5, RF6, RF7, RF8, RF9, RF10, RF11, RF12, RF13, RF14, RF15) which every each parts have shown every each risk-factor probability values (mean-variance-standart deviation) computations. The second step uncertainty distribution of CCRAM of which the logic has been described in *StepII (b)-Uncertanity Distribution to risk-factor situations (second step uncertanity distribution of CCRAM)* is realized. The variance values of costs that are computed in the third computation part (i.e. first step uncertainty distribution) are divided into mean, variance and standard deviation values for each risk-factor situation (i.e. better-than-expected, expected and worse-than-expected) of each risk-factor. The fourth computation part has been designed as shown in Figure B.4.

These data are determined to evaluate second step disintegrated cost distribution. Second Step Disintegrated Cost Distribution means that Uncertainty distribution to risk-factor situations. Decomposition of sub-distributions according to risk-factors' situation "probability boundaries.

The risk-factors are represented by three different situations in CCRAM: better-than-expected, expected and worse-than-expected. These are random events. However, they may not be uncorrelated. Randomness is provided by assigning "probability boundaries" to the risk-factors, which show the probability territories of the risk-factor situations. The correlation between risk-factors is supplied by assigning the same probability boundary values for the correlated risk-factors and by using the same random number.

Similarly, the cell designations should be followed on the user interface of CCRAM spreadsheet attached to the thesis in a compact disc so that they become understandable. The cells belonging to the other cost items in the part have been loaded with the appropriate similar formulas following the same logic.

3.4.3 Probability Distribution Parts of User Interface

The Probability distribution computation parts consist of fifteen parts (Risk1, Risk2, Risk3, Risk4, Risk5, Risk6, Risk7, Risk8, Risk9, Risk10, Risk11, Risk12, Risk13, Risk14, Risk15), which have been designed as shown in Figure B.5. Normal probability distributions are produced through a sign conversion operation and through Visual Basic codes to be used during CCRAM simulation in Excel part for the production of correlated item costs. Correlated risk formula of user interface used in the Input Data 3 parts produces random values from the normal probability distributions during MCS of CCRAM in Excel spreadsheet.

In case of the first distribution, the variances of the item costs that are calculated from the maximum and minimum expected item costs have been divided into a number (as many as the number of risk-factors) of sub-variances (variance of probability sub-distributions). The amount of a sub-variance shows the effect of the corresponding risk-factor's effect on the uncertainty of the relevant item cost. In other words, the uncertainty of costs has been distributed to the risk-factors in the first distribution. The problem now is how to distribute the uncertainty represented by the probability sub-distributions to the risk-factor situations.

3.4.4 Results Part of User Interface: In the last computation part, correlated item costs are produced, total project cost is calculated and all of the results translated to the Excel spreadsheet of CCRAM for saving and reporting functions of user interface.

There exist two columns in the fifth computation part having headings “Cost” and “Total Project Cost”. As an example, the cells belonging to the first cost item of these two columns as shown in Figure B.6 has been loaded with the user interface.

Finally, the results of user interface calculation are translated to the Excel spreadsheet of CCRAM. After that, calculated project simulated total cost by using @Risk program with same input data in user interface.

Once more, the cell designations used in user interface formulas should be followed on the CCRAM spreadsheet attached to the thesis in a compact disc so that they become understandable. The cells belonging to the other cost items in the "Simulated Cost" column have been loaded with the appropriate similar formulas following the same logic through CCRAM Excel spreadsheet. While different random cost values are produced in the cells of the "Simulated Cost" column at each simulation iteration, these random cost values are added up in the "Simulated Total Project Cost" cell and a different project cost is calculated in any iteration. "Simulated Total Project Cost" cell enables MS Excel to save all the produced data during the simulation regarding the total project cost and enables to conduct uncertainty and sensitivity analyses.

This two stepped procedure is repeated for each risk-factor and then all the results provided by the user interface are evaluated and enables MS Excel to save and compared for carrying out the risk-factor – project cost sensitivity analysis.

3.5 Summary

This chapter constitutes the description of the logic and features user interface of CCRAM. The chapter also includes the computerization of user interface. The tool is shaped into a computerized, easy-to-use and user-friendly form by using the Visual Basic codes and programming capabilities of MS Excel's spreadsheet. Of course, the computerization can also be realized by using different spreadsheet programs or programming languages. The next chapter presents the user interface design of CCRAM.

CHAPTER 4

USER INTERFACE DESIGN OF CCRAM

4.1 Introduction

This chapter is evaluated user interface design of CCRAM which consist of six functional areas: data entry, data display, sequence control, user guidance, data transmission and data protection. In addition, user interface presentation will be referred to as the CCRAM for developed user interface name is called CCRAM.

If you are a teacher, a student, a human factors practitioner or researcher, these regions can serve as a starting point for the development and application of expert knowledge. The design are proposed here as a potential tool for designers of user interface. That translation from general guidelines to specific rules will help focus attention on critical user interface design questions early in the design process [34-37].

The user interface design of CCRAM will often involve a considerable investment of time and effort. Design of user interface can help ensure the value of that investment. Computers today are used for a broad range of applications. User interface design are necessary in every case of program configurations. When there is no user interface, user can not manage effectively in every case of the program.

4.2 Significance of the User Interface

The design of user interface of CCRAM is not only expensive and time-consuming, but it is also critical for effective system performance. To be sure, users can sometimes compensate for poor design with extra effort. If probably no single user interface design flaw, in itself, will cause system failure. But there is a limit to how well users can adapt to a poorly designed interface. As one deficiency is added to another, the cumulative negative effects may eventually result in system failure, poor performance, and/or user complaints [38-40].

User interface has little use of automated capabilities. When a system warns in this tool at program, the result is disrupted operation and program give a message ‘CCRAM Message!’ as shown in Figure 4.1, so it assure wasted time, effort and failure to achieve the potential benefits of automated information handling.

Figure 4.1 CCRAM Message format at Visual Basic in Computation Parts 4

4.3 Data Protection

Data protection attempts to ensure the security of computer-processed data from unauthorized access, from destructive user actions, and from computer failure. User interface prevents wrong data entry (nonnumerical data e.g.) to the program processing of item descriptions in data input parts. So program give a message with name as "CCRAM Warning" to the user as shown in Figure 4.2, Figure 4.3 and Figure 4.4 when user imply necessities the parts of the program. After this warning show at the screen of the program which say to users about making necessity of the process. With increasing use of computer-based information systems, there has been increasing concern for the protection of computer-processed data. The design of data entry, data display, sequence control, user guidance, and data transmission functions can potentially affect the security of the data being processed. In many applications, however, questions of data protection require explicit consideration in their own right [41-45].

Figure 4.2 CCRAM Warning format at Visual Basic in Input Data parts 2

Data protection must deal with two general problems. First, data must be protected from unauthorized access and tampering. This is the problem of data security. If this is the problem of error prevention, program give a message again under name as

“CCRAM Question” to the user as shown Figure 4.3. When protection of displayed data is essential, maintain computer control over the display. It is not enough simply to instruct users not to make changes in displayed data. Users may attempt unwanted changes by mistake, or for curiosity, or perhaps even to subvert the system. As required for security, establish procedures to control access to printed data at Excel spreadsheet in CCRAM.

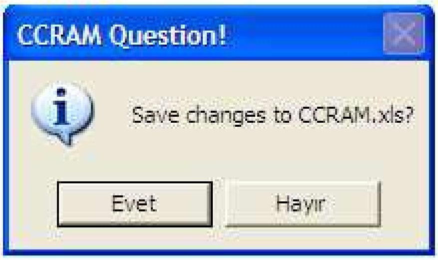


Figure 4.3 CCRAM Question format at Visual Basic at Exit buton in Toolbar menu

Figure 4.4 CCRAM Warning format at Visual Basic in final parts of program

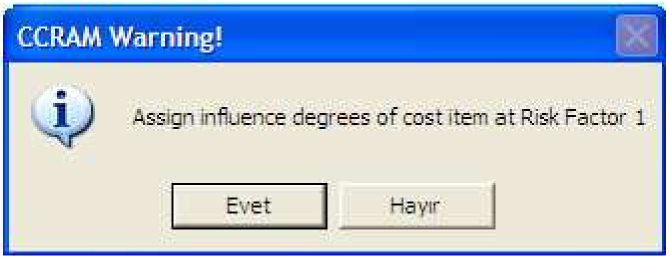


Figure 4.5 CCRAM Warning format at Visual Basic in Input Data 4

4.3.1 Data Access

Data access constraints established to exclude unauthorized users should not hinder legitimate use of data. Records of data use may help software designers improve file structure, reduce data access time, and manage multiple use of shared data files. Data access records may also be required for purposes of data protection/security.

When protection of displayed data is essential, maintain computer control over the display and do not permit a user to change such "read-only" data. It is not enough simply to instruct users not to make changes in displayed data. Users may attempt unwanted changes by mistake, or for curiosity, or perhaps even to subvert the system. Brief information is displayed about user interface of CCRAM as shown in Figure 4.6 which is given mail adress to contact us encounter problems of users.

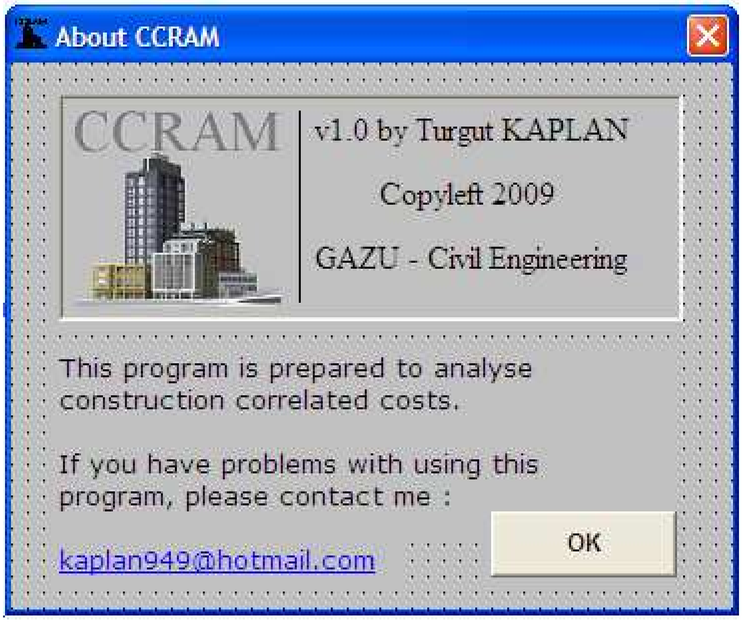


Figure 4.6 About CCRAM text in Program

As required for security, establish procedures to control access to printed data, rather than simply prohibiting the printing of sensitive data.

4.3.2 Data transmission

Data transmission refers to computer-mediated communication among system users, and also with other parts in user interface of CCRAM. Preceding sections of this report have dealt with the basic functions, entering data into a computer, displaying data from a computer, controlling the sequence of input-output transactions, with guidance for users throughout the process.

In considering data transmission functions, a broad perspective must be adopted. Data that are transmitted via computer may include words and pictures as well as numbers. And the procedures for data transmission may take somewhat different forms for different system applications (translate Excel result format).

Figure 4.7 CCRAM Warning format at Visual Basic in Input Data 1 parts

Data might be transmitted by transferring a data file from Visual Basic format to Excel spreadsheet format and between user interface phases, perhaps with an accompanying message to indicate that such a file transfer has been initiated. Data might be transmitted by directly linking two display terminals, so that whatever data one user keys onto a display will be displayed to another user as well. More commonly, however, data are transmitted "CCRAM Message" as shown in Figure 4.7, which involves creation of a specially-formatted file with a formal header to specify the sender, recipient, etc. In these guidelines, the word "message" is mostly used in this sense, to denote data transmitted with a formal header. But the phrase "message handling" sometimes refers more generally to user participation in data transmission.In a designed information system, data transmission by file transfer may be largely automatic, accomplished with little user involvement.

4.3.3 Data Entry

Data entry constraints may be needed to prevent unauthorized data change as well as data loss from user errors as shown in Figure 4.2. Establish user authorization for data entry/change at initial; do not require further authorization when a user attempts particular data entry/change transactions.

When data must not be changed, maintain computer control over the data, and do not permit users to change controlled items. It is not enough simply to instruct users not to make changes in displayed data. Users may attempt unwanted changes by mistake, or for curiosity, or perhaps even to subvert the system. In situations where unauthorized data changes may be possible, allow users (or a system administrator) to request a record of data entry/change transactions. Transaction records might be maintained for purposes of user guidance as well as for data protection, as recommended elsewhere.

Simple procedures will help ensure accuracy in data entry/change transactions.

Require users to take some explicit OK action to accomplish data entry/change transactions; data change should not occur as a possibly unrecognized side effect of other actions.

A user may choose to move the cursor back in order to correct earlier data items, and cannot be relied upon to move the cursor forward again. User interface allow users to correct keyed data entries (and control entries) before taking an explicit OK action.

4.3.4 Data Display

Data display refers to computer output of data to a user, and assimilation of information from such outputs of Figure B.7, Figure C.1 and Figure C.2 in user interface of CCRAM. Some kind of display output is needed for all information handling tasks. Data display is particularly critical in monitoring and control tasks. Data may be output on electronic displays, or other auxiliary displays, which may alert users to unusual conditions. Data are considered to be display elements related to a user's information handling task. Displayed data might consist of stock market quotations, or the current position of monitored aircraft, or a page of text, or a message from another user. Displayed data might provide guidance to a user in performing a maintenance task, or might provide instruction to a user who is trying to learn mathematics.

In general, somewhat less is known about data display, and information assimilation by the user, than about data entry. In current information system design, display formatting is an art.

4.4 Sequence Control

Sequence control refers to user actions and computer logic that initiate, interrupt, or terminate transactions. Sequence control governs the transition from one transaction to the next. General design objectives include consistency of control actions, minimized need for control actions, minimized memory load on the user, with flexibility of sequence control to adapt to different user needs. Methods of sequence control require explicit attention in interface design, and many published guidelines deal with this topic.

One of the critical determinants of user satisfaction and acceptance of a computer system is the extent to which the user feels in control of an interactive session. If users cannot control the direction and pace of the interaction sequence, they are likely to feel frustrated, intimidated, or threatened by the computer system. Their productivity may suffer, or they may avoid using the system at all.

4.5 User Guidance

User guidance refers to error messages, alarms, prompts, and labels, as well as to more formal instructional material provided to help guide a user's interaction with a computer. The fundamental objectives of user guidance are to promote efficient system use (i.e., quick and accurate use of full capabilities), with minimal memory load on the user and hence minimal time required to learn system use, and with flexibility for supporting users of different skill levels.

Design consistency implies predictability of system response to user inputs. A fundamental principle is that some response be received. For every action (input) by the user there should be a noticeable reaction (result) from the computer. In an interactive computing situation, immediate feedback by the system is important in establishing the user's confidence and satisfaction with the system. A message that indicates that the system is still working on the problem or a signal that appears as shown in Figure 4.8, Figure 4.9 and Figure 4.10 while the system is processing the user's input provides to user with the necessary assurance which is all right.

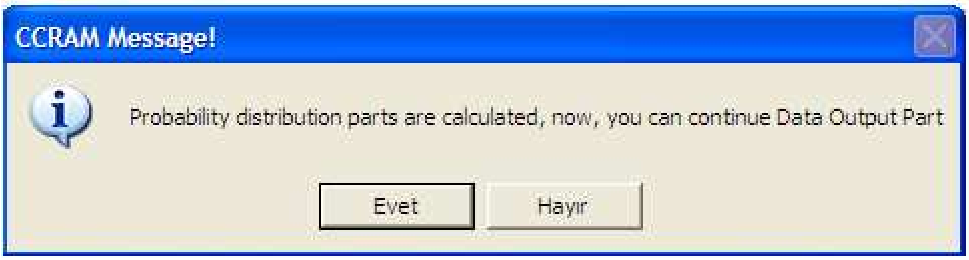


Figure 4.8 CCRAM Warning format at Visual Basic in Probability Distribution Parts

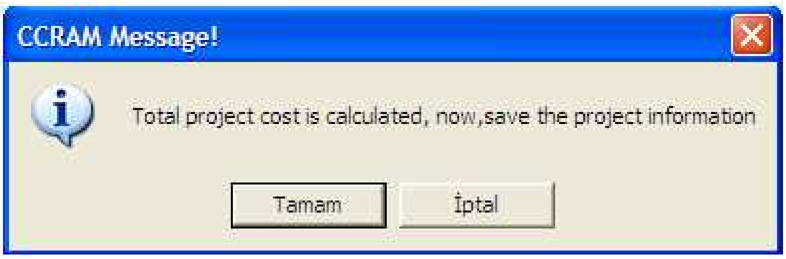


Figure 4.9 CCRAM Message format at Visual Basic in Results Part

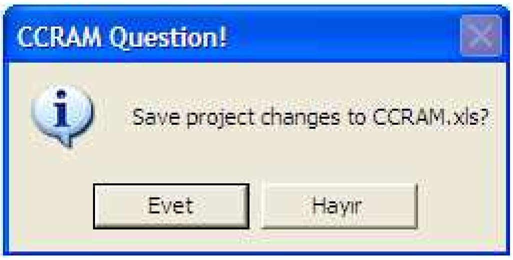


Figure 4.10 CCRAM Question format at Visual Basic in Toolbar save button

Predictability of computer response is related to system response time. Timely response can be critical in maintaining user orientation to the task. If a reponse is received only after a long delay, the user's attention may have wandered. Indeed, the user may forget just which action the machine is responding to. Frequent user actions, generally those involving simple inputs such as function key or menu selections, should be acknowledged immediately.

CHAPTER 5
HYPOTHETICAL CASE STUDY OF USER INTERFACE

5.1 Introduction

This chapter includes detailed evaluation of user interface for CCRAM. Indirect, two-sided and qualitative correlation capturing algorithm of the user interface is examined. The discussable default parameters and user-dependent variables are modified past experience of the user. The results of the application are compared between user interface and Excel spereadsheet of CCRAM. The study is a kind of sensitivity and scenario analysis in some aspects. The sensitivity of the user interface of CCRAM can be assured by different cost scenarios. Instead of arriving at general conclusions, risk analysis capability user interface of CCRAM is evaluated in a comparative manner without simulation. The evaluation is performed with scenarios which is three cost items and three risk factor evaluation [46-49].

5.2 Three cost items – three risk factors evaluation scenario

This scenario is constituted for the purpose of evaluating user interface of CCRAM's capability of indirectly capturing correlation between the costs. For achieving these purposes, the cost group worked on is composed of three cost items (A, B, C) and three effective risk-factors (Risk-factor 1, Risk-factor 2, Risk Factor 3), which are correlated between Risk-factor 2 and Risk-factor 3. The details of the user interface input data is given.

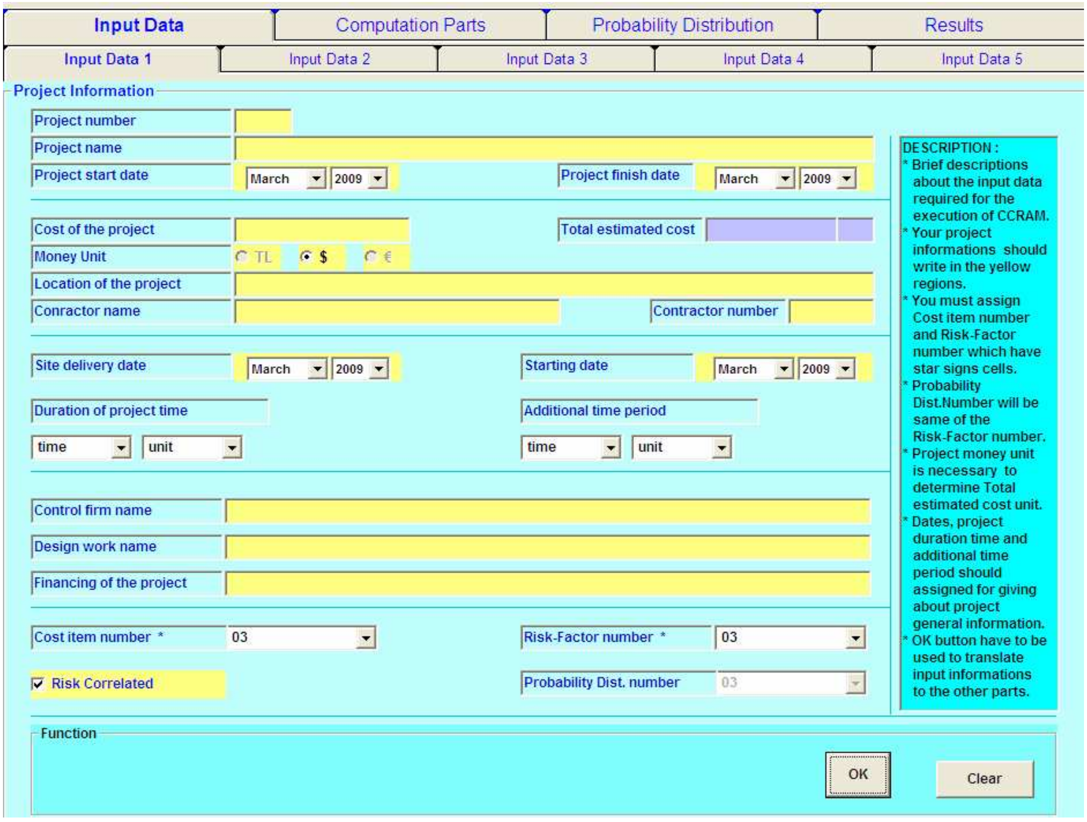


Figure 5.1 Project information of example

Assume that the minimum, most likely and maximum expected costs of cost item A, cost item B and cost item C are assigned as $19000, $21000, $24000 ; $22000, $25000, $29000 and $32000, $34500, $36000 respectively as shown in Figure 5.2. Calculation of item costs translated to the computation parts 1 as shown in Figure 5.3.

Step I - Probabilistic representation of item costs

This calculation is as follows for the example iteration:

<u>Cost item A :</u>

minimum expected cost: $19.000

maximum expected cost: $24.000

most likely expected cost: $21.000

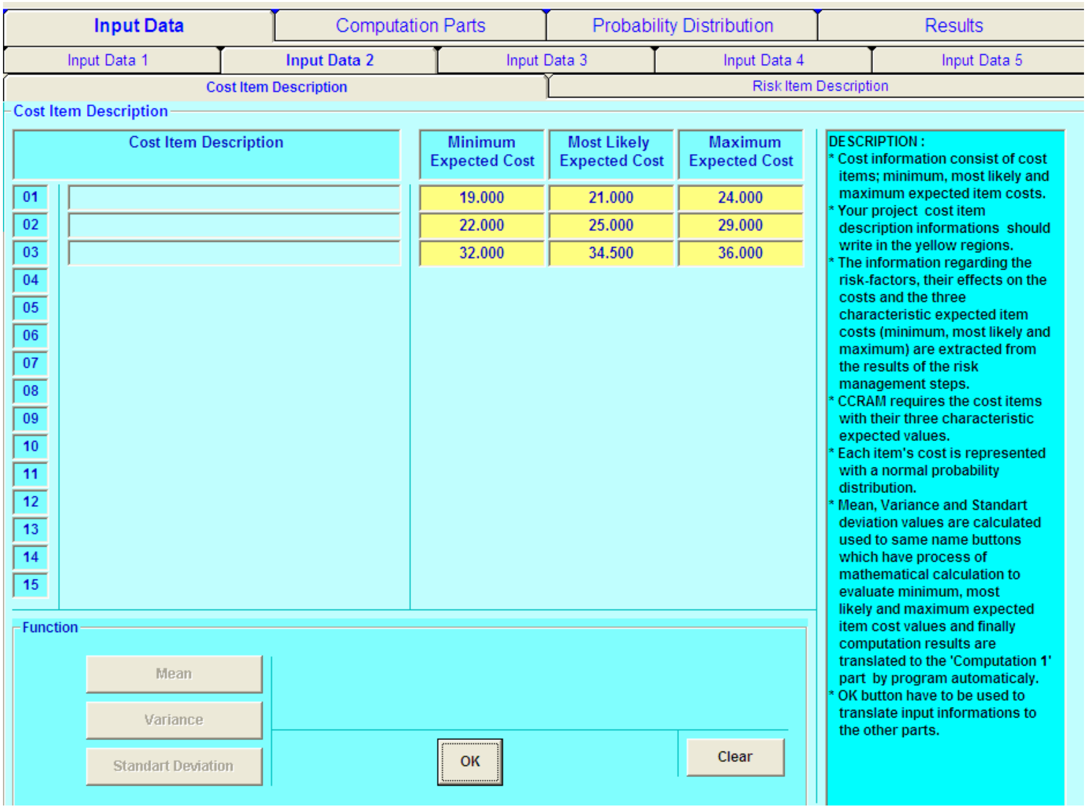


Figure 5.2 Cost item description of example

M_A = (min.cost + 4 x most likely cost + max.cost) / 6 (by Equation 2.1)

M_A = (19.000 + 4 x 21.000 + 24.000) / 6 = 21.167

VAR_A = [(max.cost - min.cost) / 6]^2 (by Equation 2.2)

VAR_A = [(24.000 – 19.000) / 6]^2 = 694.444

<u>Cost item B :</u>

minimum expected cost: $22.000

maximum expected cost: $29.000

most likely expected cost: $25.000

M_B = (min.cost + 4 x most likely cost + max.cost) / 6

M_B = (22.000 + 4 x 25.000 + 29.000) / 6 = 25.167

VAR_B = [(max.cost - min.cost) / 6]^2

VAR_B = [(29.000 – 22.000) / 6]^2 = 1.361.111

Cost item C :

minimum expected cost: \$32.000

maximum expected cost: \$36.000

most likely expected cost: \$34.500

M_C = (min.cost + 4 x most likely cost + max.cost) / 6

M_C = (32.000 + 4 x 34.500 + 36.000) / 6 = 34.333

VAR_C = [(max.cost - min.cost) / 6]^2

VAR_C = [(36.000 – 32.000) / 6]^2 = 444.444

So, the uncertainty of the item costs can be shown as N_A (21.166,67 ; 694.444,44), N_B (25.166,67 ; 1.361.111,11), N_C (343.33,33 ; 444.444,44) where N_i denotes the normal probability distribution and i denotes the cost items.

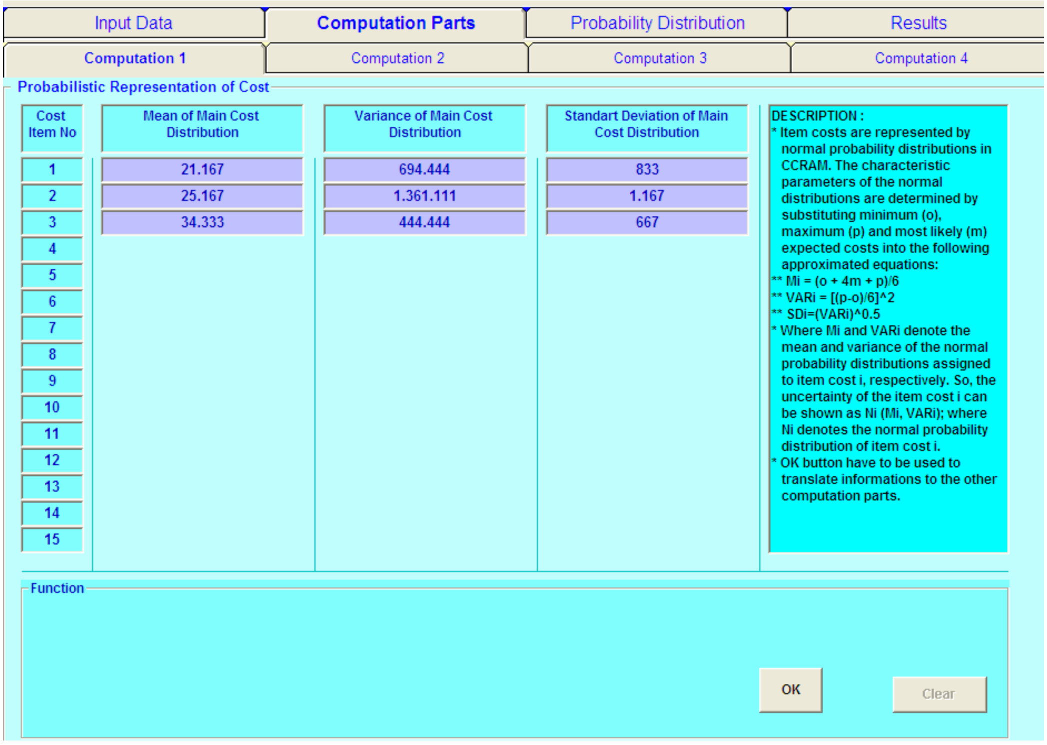


Figure 5.3 Probabilistic representation costs of example

Risk-Factor influence degrees of each project cost item is important to determine correlated calculation. The same probability boundary values should be entered to be used risk buttons according to risk factor degrees for the correlated risk-factors, in accordance with the model's logic. Firstly entering the "Risk-Factor Influence Scale Quantities" according to risk-factor degrees to use "1-10", "10-50", "20-100" buttons. Secondly applying the "Risk-Factor Situation Probability Boundaries" according to correlated risk situation to use "Risk ##" buttons as shown in Figure 5.4. Then, calculate Risk-factor situation probability values which used to "Calculate Risk-Factor Probability Values" button. If it is noticed that the "probability boundaries" of risk-factors are the same as shown in Figure 5.4, they are assumed as correlated. This is the way user interface of CCRAM follows in order to capture the correlation between the correlated risk-factors.

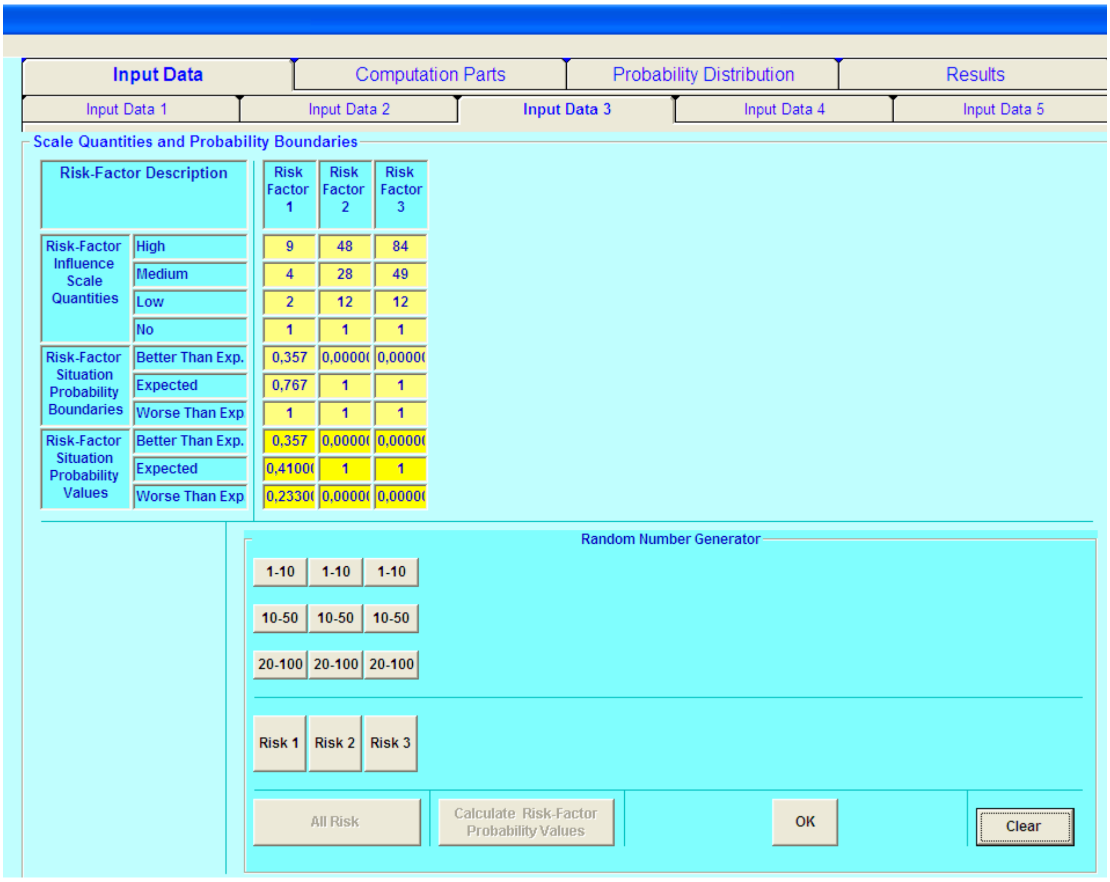


Figure 5.4 Scale Quantities and Probability Boundaries of example

Influence degrees of the risk- factors on the costs (high, medium, low or no) are entered by selecting from the list embedded in the cells of Figure 5.5. These data are determined degrees of effected by the Cost Items according to the risk-factors. "Cost item ~ Risk-factor "influence degrees": risk-factors and their expected effects on cost items in terms of "high, medium, low or no" qualifications.

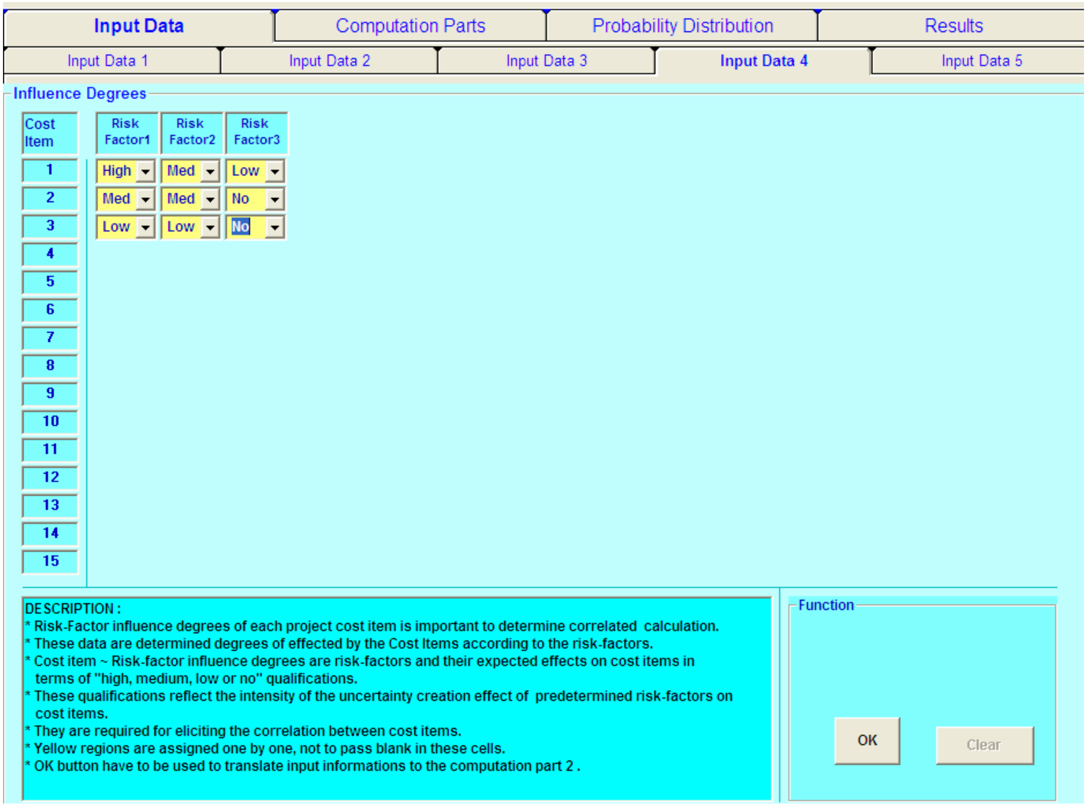


Figure 5.5 Influence Degrees of example

Setting of Random Number Generators are a number of cells (as many as the risk-factors) in the random number generator row as shown in Figure 5.6. The first column cells belongs to the first risk-factor, the second column cells belongs to the second risk-factor and so on. These columns are assigned with using “R.N.G” and “High-Medium-Low Limits”buttons randomly as shown in Figure 5.6. To assign random number to risk factors between 0 and 1. User interface produces random numbers from the uniform probability distribution to determine the risk-factor situations. However, the same random number is used for the correlated ones.

A different random number is produced for every uncorrelated risk-factor situation from the uniform probability distribution in order to produce random cost values from the situation probability distributions. However, the same random number is used for the correlated ones.

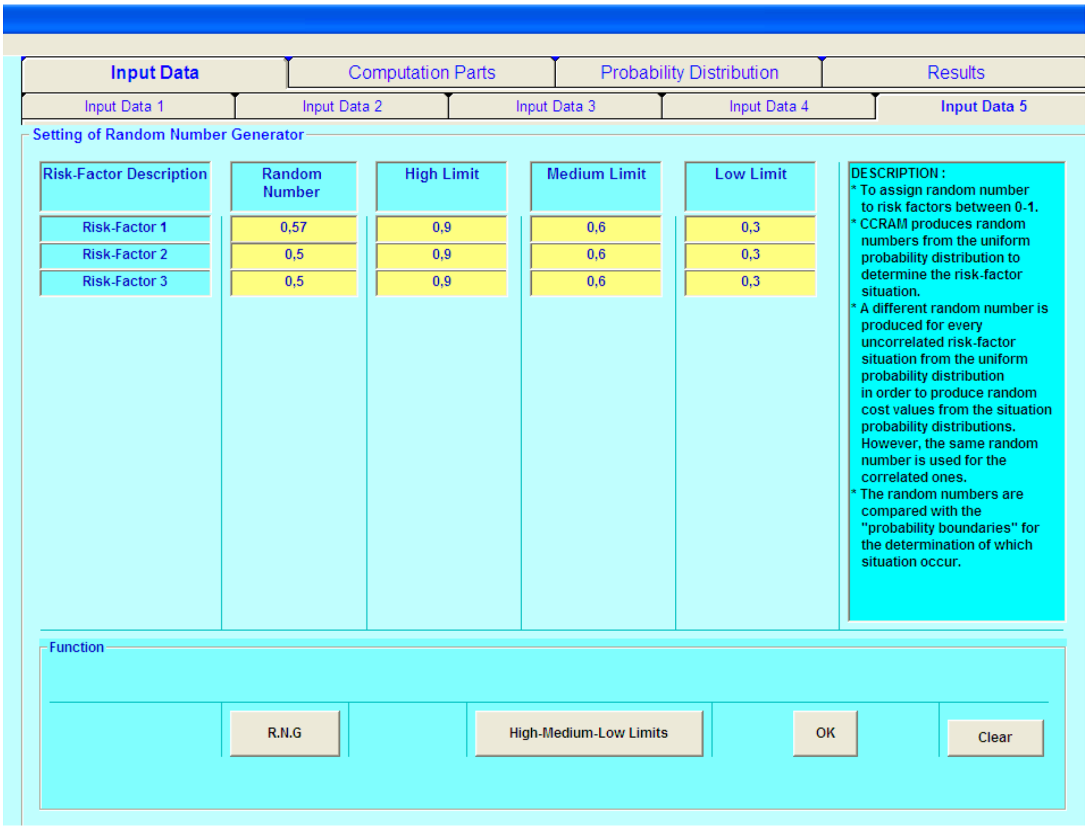


Figure 5.6 Setting of Random Number Generator of example

Step II (a) - Uncertainty distibution to risk-factors (first distribution)

The computation of the distribution of uncertainty in item costs to risk-factors for the example iteration is given below:

<u>Cost item A</u>

$K_A = VAR_A / \sum DA_{Aj}$ (by Equation 2a)

$K_A = 694.444{,}44 / (9 + 28 + 12)$

$K_A = 694.444{,}44 / 49 = 14.172{,}34$

$VAR_{A1} = K_A \text{ x } DA_{A1} = 14.172{,}34 \text{ x } 9 = 127.551{,}06$ (by Equation 2b)

$VAR_{A2} = 14.172{,}34 \text{ x } 28 = 396.825{,}52$

$VAR_{A3} = 14.172{,}34 \text{ x } 12 = 170.068{,}08$ can be calculated.

Note that $VAR_A = \sum VAR_{Aj}$ (by Equation 2c)

$VAR_A = VAR_{A1} + VAR_{A2} + VAR_{A3}$

$VAR_A = 127.551{,}06 + 396.825{,}32 + 170.068{,}06 = 694.444{,}44$

<u>Cost item B</u>

$K_B = VAR_B / \sum DA_{Bj}$ (by Equation 2a)

$K_B = 1.361.111,11 / (4 + 28 + 1)$

$K_B = 1.361.111,11 / 33 = 41.245,79$

$VAR_{B1} = K_B \times DA_{B1} = 41.245,79 \times 4 = 164.983,16$ (by Equation 2b)

$VAR_{B2} = 41.245,79 \times 28 = 1.154.882,12$

$VAR_{B3} = 41.245,79 \times 1 = 41.245,79$ can be calculated.

Note that $VAR_B = \sum VAR_{Bj}$ (by Equation 2c)

$VAR_B = VAR_{B1} + VAR_{B2} + VAR_{B3} + VAR_{B4}$

$VAR_B = 164.983,16 + 1.154.882,12 + 41.245,79 = 1.361.111,11$

<u>Cost item C</u>

$K_C = VAR_C / \sum DA_{Aj}$ (by Equation 2a)

$K_C = 444.444,44 / (2 + 12 + 1)$

$K_C = 444.444,44 / 15 = 29.629,63$

$VAR_{C1} = K_C \times DA_{C1} = 29.629,63 \times 2 = 59.259,26$ (by Equation 2b)

$VAR_{C2} = 29.629,63 \times 12 = 355.555,56$

$VAR_{C3} = 29.629,63 \times 1 = 29.629,63$ can be calculated.

Note that $VAR_C = \sum VAR_{Cj}$ $(j = 1,2,3)$ (by Equation 2c)

$VAR_C = VAR_{C1} + VAR_{C2} + VAR_{C3}$

$VAR_C = 59.259,26 + 355.555,56 + 29.629,63 = 444.444,44$

Once more, it should be mentioned that the distributed variances calculated above are the variances of the normal probability sub-distributions corresponding to the risk-factors.

Qualification of Influence degrees part filled one by one before first step uncertainity distribution passed. This part has been designed for the purpose of regulating the data entered into "Input data 3" and "Input data 4". The qualitative influence degrees entered in the fourth data input part are converted to quantitative values in this part and these values are used later in the next computation parts. Risk-factor situation probability values and the scale quantities corresponding to the influence degrees in question for each cost-risk pair are gathered cells at Input Data 3- 4 parts as shown in Figure 5.7.

The probability boundaries, corresponding to the better-than-expected, expected and worse-than-expected situations of the risk-factor, respectively will be converted to the probability values that show the probabilities of occurrences of the risk-factor situations.

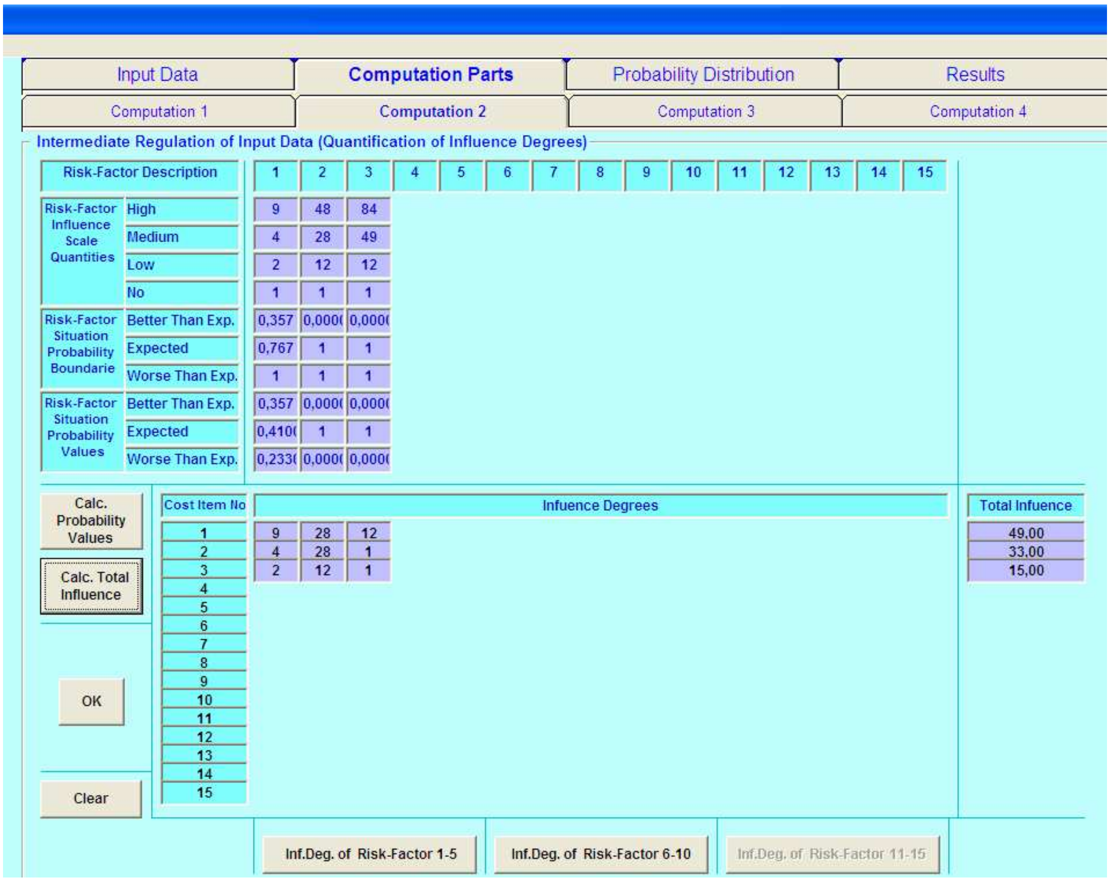


Figure 5.7 Setting of Random Number Generator of example

The variance of the main cost distribution of the first cost item, total influence degree belonging to the first cost item computed under the Total Influence column and the influence degree belonging to the first risk-factor ~ first cost item pair found in the second computation part as shown in Figure 5.8.

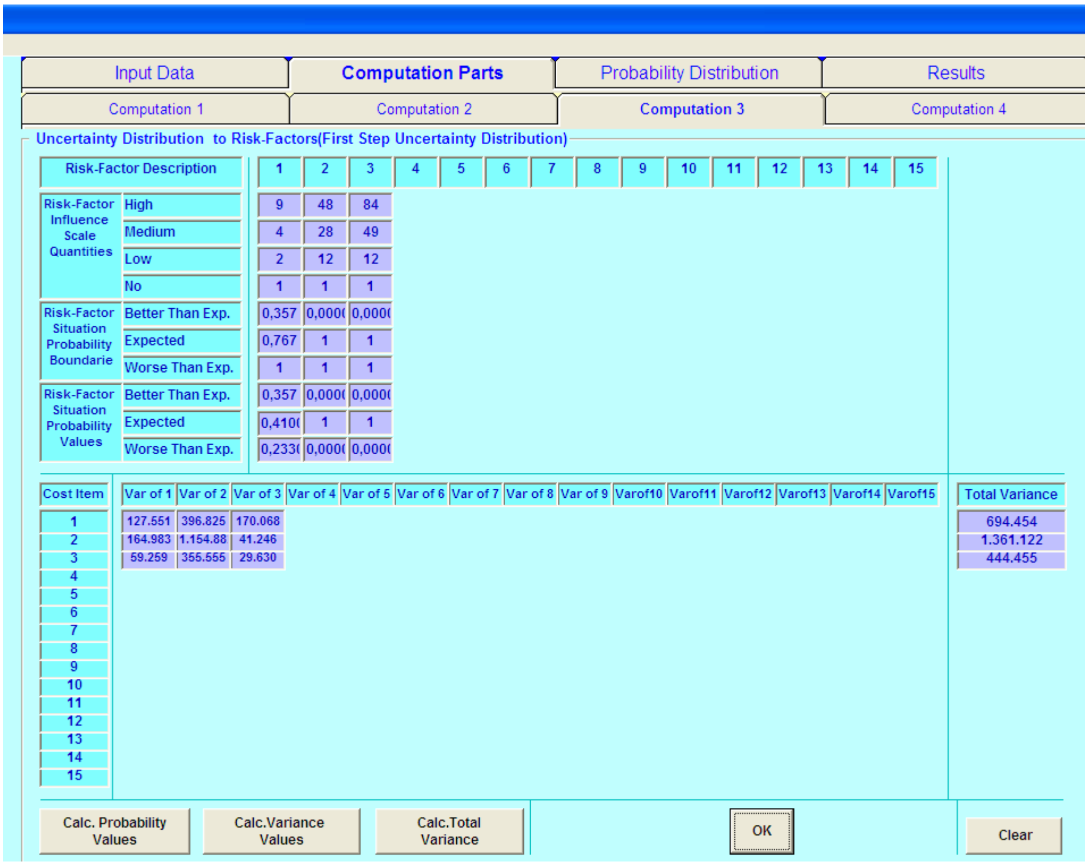


Figure 5.8 Uncertainity Distribution to Risk-Factors(First Step) of example

Step II (b) - Uncertainty distribution to risk-factor situations (second distribution)

First of all, let's show the conversion process of risk-factor situation "probability boundaries" to the situation probability values (p_{jk}) for our example iteration as shown in Figure 5.9. The conversion process is a simple subtraction operation:

Risk-factor-1 / better-than-expected : 0 ~ 0.357; p_{11} = 0.357-0.00 = 0.357

/ expected : 0.357 ~ 0.767; p_{12} = 0.767-0.357 = 0.410

/ worse-than-expected : 0.767 ~ 1.00; p_{13} = 1.00-0.767 = 0.233

Risk-factor-2 / better-than-expected : 0 ~ 0.10; p_{21} = 0.10-0.00 = 0.10

/ expected : 0.10 ~ 1.00; p_{22} = 1.00-0.10 = 0.90

/ worse-than-expected : 1.00 ~ 1.10; p_{23} = 1.10-1.00 = 0.10

Risk-factor-3 / better-than-expected : 0 ~ 0.10; p_{31} = 0.10-0.00 = 0.10

/ expected : 0.10 ~ 1.00; p_{32} = 1.00-0.10 = 0.90

/ worse-than-expected : 1.00 ~ 1.10; p_{33} = 1.10-1.00 = 0.10

In this calculation, p denotes the occurrence probability of the risk-factor situation. The rest of the calculation is as follows:

Cost item A

Risk-factor-1

$x_{limit\text{-}ij} = \sqrt{[VAR_{ij} / (p_{ij1} p_{ij3}^2 + p_{ij3} p_{ij1}^2)]}$ (by Equation 3.10a)

$x_{limit\text{-}A1} = \sqrt{[VAR_{A1} / (p_{A11} p_{A13}^2 + p_{A13} p_{A11}^2)]}$

$= \sqrt{[127.551,06 \ / \ (0.357 * 0.233^2 + 0.233 * 0.357^2)]}$

$x_{limit\text{-}A1} = 1.612,14$

$DA_1 = \text{high} \Longrightarrow x_{A1} = 0.9 \ x_{limit\text{-}A1} = 0.9 * 1612,14 = 1450,93$

$m_{A11} = p_{A13} \ x_{A1} = 0.233 * 1450,93 = 339,07$

$m_{A13} = p_{A11} \ x_{A1} = 0.357 * 1450,93 = 518,98$

$m_{A12} = 0$

$var_{A11} = var_{A12} = var_{A13} = [VAR_{A1} – (p_{A11} p_{A13}^2 + p_{A13} p_{A11}^2) * (m_{A11} / p_{A13})^2]$

$= [127.551,06 – (0.357 * 0.233^2 + 0.233 * 0.357^2) * (339,07/0,233)^2]$

$= 21.423,95$

Risk-factor-2

$x_{limit\text{-}ij} = \sqrt{[VAR_{ij} / (p_{ij1} p_{ij3}^2 + p_{ij3} p_{ij1}^2)]}$ (by Equation 3.10a)

$x_{limit\text{-}A1} = \sqrt{[VAR_{A2} / (p_{A21} p_{A23}^2 + p_{A23} p_{A21}^2)]}$

$= \sqrt{[396.825,52 / (0.1 * 0.1^2 + 0.1 * 0.1^2)]}$

$x_{limit\text{-}A1} = 14.085,9$

$DA_1 = \text{med} \Longrightarrow x_{A1} = 0.6 \ x_{limit\text{-}A1} = 0.6 * 14.085,9 = 8451,54$

$m_{A21} = p_{A23} \ x_{A1} = 0.1 * 8451,54 = 845,15$

$m_{A23} = p_{A21} \ x_{A1} = 0.1 * 8451,54 = 845,15$

$m_{A22} = 0$

$var_{A21} = var_{A22} = var_{A23} = [VAR_{A2} – (p_{A21} p_{A23}^2 + p_{A23} p_{A21}^2)) * (m_{A21} / p_{A23})^2]$

$= [396.825,52 – (0.1 * 0.1^2 + 0.1 * 0.1^2) * (845,15/0,1)^2]$

$= 254.020,81$

Risk-factor-3

$x_{limit-ij} = \sqrt{} [VAR_{ij} /(p_{ij1}p_{ij3}^2 + p_{ij3}p_{ij1}^2)]$ (by Equation 3.10a)

$x_{limit-A1} = \sqrt{} [VAR_{A3} /(p_{A31}p_{A33}^2 + p_{A33}p_{A31}^2)]$

$= \sqrt{} [170.068,08 / (0.1 * 0.1^2 + 0.1 * 0.1^2)]$

$x_{limit-A1} = 9.221,39$

$DA_1 = \text{low} \Longrightarrow x_{A1} = 0.3\, x_{limit-A1} = 0.3 * 9.221,39 = 2.766,42$

$m_{A31} = p_{A33}\, x_{A1} = 0.1 * 2766,42 = 276,64$

$m_{A33} = p_{A31}\, x_{A1} = 0.1 * 2766,42 = 276,64$

$m_{A32} = 0$

$var_{A31} = var_{A32} = var_{A33} = [VAR_{A3} - (p_{A31}p_{A33}^2 + p_{A33}p_{A31}^2))* (m_{A31} / p_{A33})^2]$

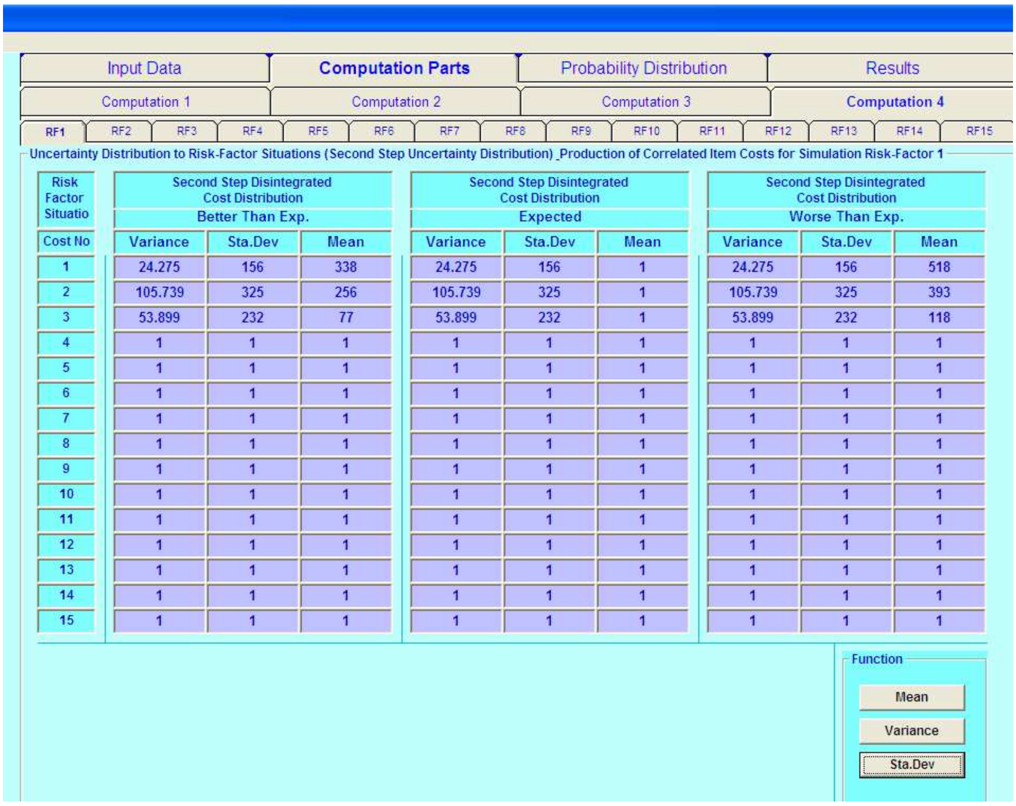
$= [170.068,08 - (0.1 * 0.1^2 + 0.1 * 0.1^2)*(276,64/0,1)^2]$

$= 154.722,14$

Cost item B and cost item C are calculated with using the same formulations and results produced through the second distribution of uncertainty are given in Figure 5.9a, Figure 5.9b, Figure 5.9c. This figure constitutes the means and variances of the situation probability distributions belonging to the cost items A, B and C.

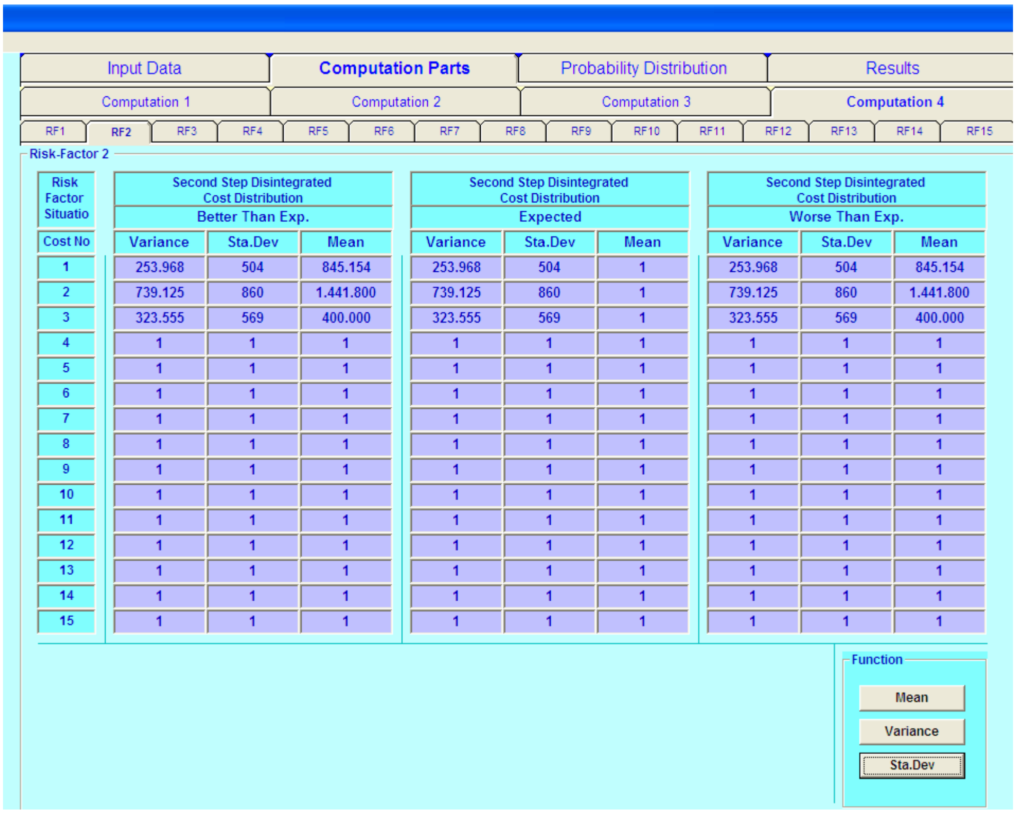
The variance values of costs that are computed in the third computation part (i.e. first step uncertainty distribution) are divided into mean, variance and standard deviation values for each risk-factor situation (i.e. better-than-expected, expected and worse-than-expected) of each risk-factor. The fourth computation part has been designed as shown in Figure B.4.

These data are determined to evaluate second step disintegrated cost distribution. Second Step Disintegrated Cost Distribution means that Uncertainty distribution to risk-factor situations. Decomposition of sub-distributions according to risk-factors' situation "probability boundaries”.



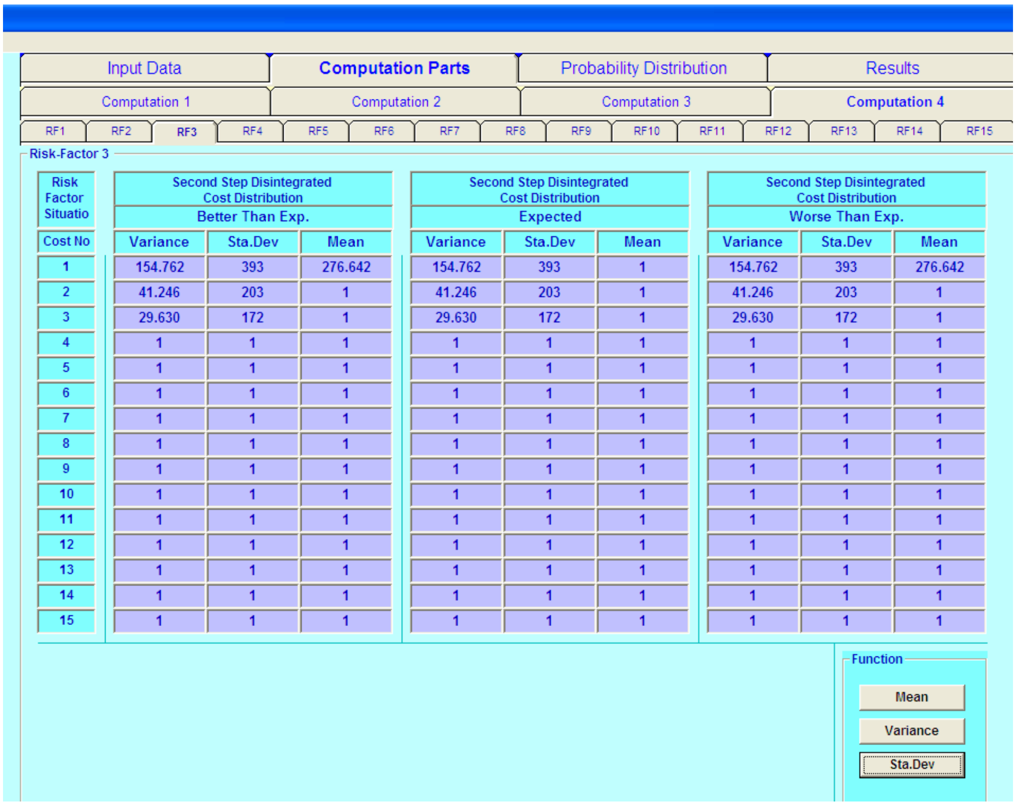
Risk Factor Situatio	Second Step Disintegrated Cost Distribution Better Than Exp.			Second Step Disintegrated Cost Distribution Expected			Second Step Disintegrated Cost Distribution Worse Than Exp.		
Cost No	Variance	Sta.Dev	Mean	Variance	Sta.Dev	Mean	Variance	Sta.Dev	Mean
1	24.275	156	338	24.275	156	1	24.275	156	518
2	105.739	325	256	105.739	325	1	105.739	325	393
3	53.899	232	77	53.899	232	1	53.899	232	118
4	1	1	1	1	1	1	1	1	1
5	1	1	1	1	1	1	1	1	1
6	1	1	1	1	1	1	1	1	1
7	1	1	1	1	1	1	1	1	1
8	1	1	1	1	1	1	1	1	1
9	1	1	1	1	1	1	1	1	1
10	1	1	1	1	1	1	1	1	1
11	1	1	1	1	1	1	1	1	1
12	1	1	1	1	1	1	1	1	1
13	1	1	1	1	1	1	1	1	1
14	1	1	1	1	1	1	1	1	1
15	1	1	1	1	1	1	1	1	1

Figure 5.9a Uncertainity Distribution to Risk-Factors-1 (Second Step) of example



Risk Factor Situatio	Second Step Disintegrated Cost Distribution Better Than Exp.			Second Step Disintegrated Cost Distribution Expected			Second Step Disintegrated Cost Distribution Worse Than Exp.		
Cost No	Variance	Sta.Dev	Mean	Variance	Sta.Dev	Mean	Variance	Sta.Dev	Mean
1	253.968	504	845.154	253.968	504	1	253.968	504	845.154
2	739.125	860	1.441.800	739.125	860	1	739.125	860	1.441.800
3	323.555	569	400.000	323.555	569	1	323.555	569	400.000
4	1	1	1	1	1	1	1	1	1
5	1	1	1	1	1	1	1	1	1
6	1	1	1	1	1	1	1	1	1
7	1	1	1	1	1	1	1	1	1
8	1	1	1	1	1	1	1	1	1
9	1	1	1	1	1	1	1	1	1
10	1	1	1	1	1	1	1	1	1
11	1	1	1	1	1	1	1	1	1
12	1	1	1	1	1	1	1	1	1
13	1	1	1	1	1	1	1	1	1
14	1	1	1	1	1	1	1	1	1
15	1	1	1	1	1	1	1	1	1

Figure 5.9b Uncertainity Distribution to Risk-Factors-2 (Second Step) of example

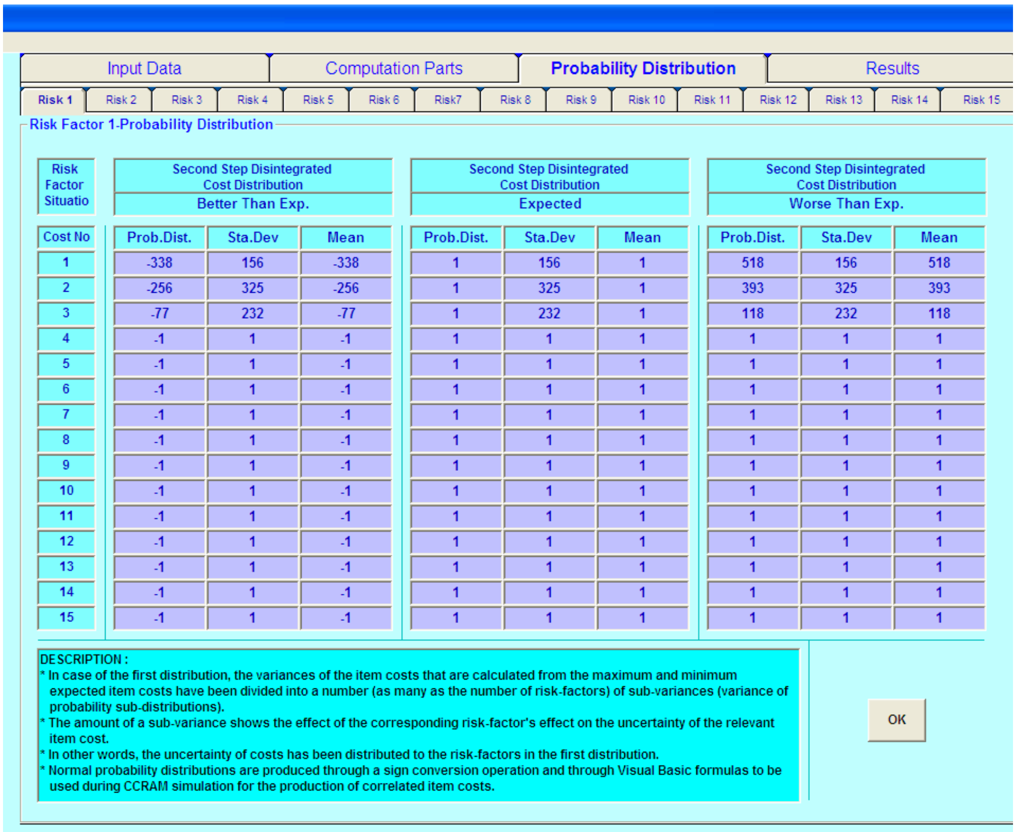


Risk Factor Situatio	Second Step Disintegrated Cost Distribution Better Than Exp.			Second Step Disintegrated Cost Distribution Expected			Second Step Disintegrated Cost Distribution Worse Than Exp.		
Cost No	Variance	Sta.Dev	Mean	Variance	Sta.Dev	Mean	Variance	Sta.Dev	Mean
1	154.762	393	276.642	154.762	393	1	154.762	393	276.642
2	41.246	203	1	41.246	203	1	41.246	203	1
3	29.630	172	1	29.630	172	1	29.630	172	1
4	1	1	1	1	1	1	1	1	1
5	1	1	1	1	1	1	1	1	1
6	1	1	1	1	1	1	1	1	1
7	1	1	1	1	1	1	1	1	1
8	1	1	1	1	1	1	1	1	1
9	1	1	1	1	1	1	1	1	1
10	1	1	1	1	1	1	1	1	1
11	1	1	1	1	1	1	1	1	1
12	1	1	1	1	1	1	1	1	1
13	1	1	1	1	1	1	1	1	1
14	1	1	1	1	1	1	1	1	1
15	1	1	1	1	1	1	1	1	1

Figure 5.9c Uncertainity Distribution to Risk-Factors-3 (Second Step) of example

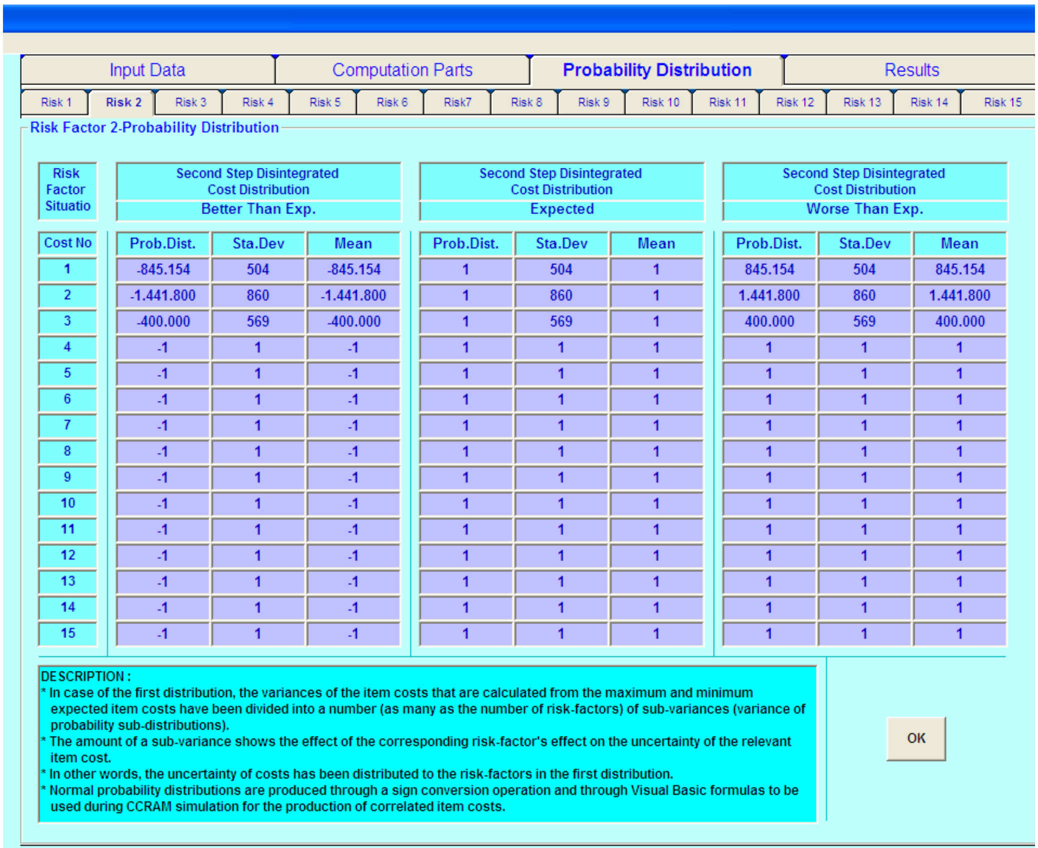
The Probability distribution computation parts consist of three parts (Risk1, Risk2, Risk3) in example which have been designed as shown in Figure 5.10a, Figure 5.10b, Figure 5.10c. Normal probability distributions are produced through a sign conversion operation and through user interface codes to be used for the production of correlated item costs. Correlated risk formulations of user interface used in the Input Data 3 part produces random values from the normal probability distributions.

In case of the first distribution, the variances of the item costs that are calculated from the maximum and minimum expected item costs have been divided into a number (as many as the number of risk-factors) of sub-variances (variance of probability sub-distributions). The amount of a sub-variance shows the effect of the corresponding risk-factor's effect on the uncertainty of the relevant item cost. In other words, the uncertainty of costs has been distributed to the risk-factors in the first distribution.



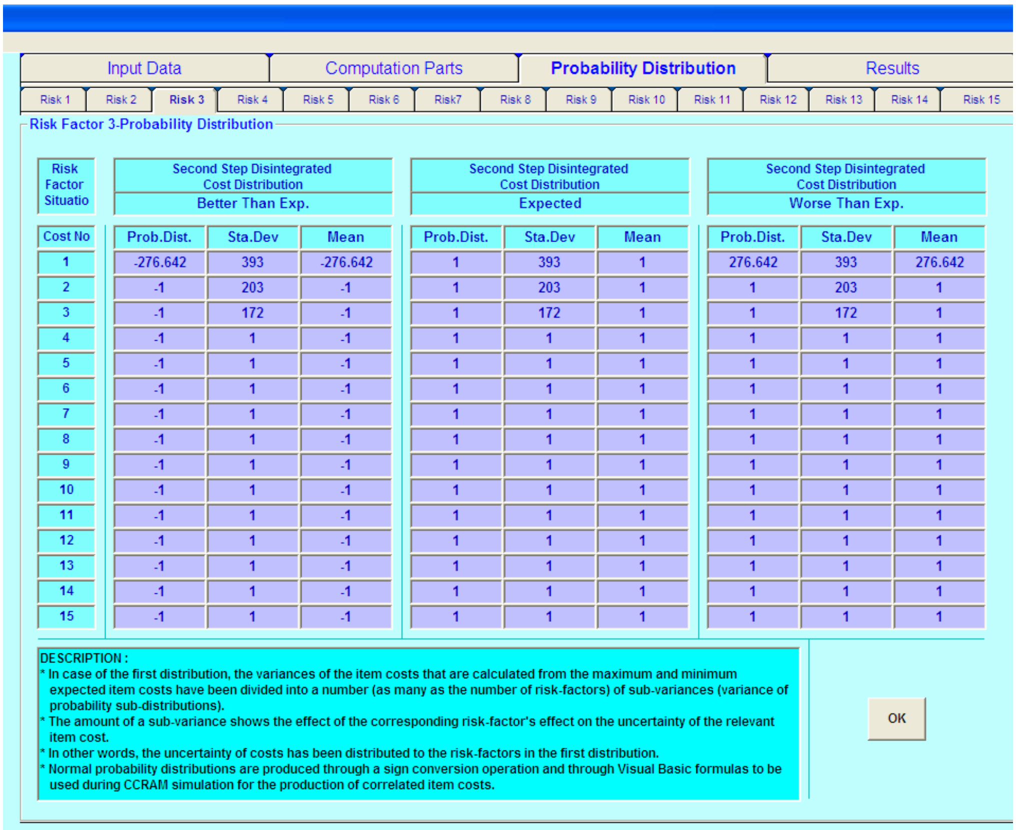
Risk Factor Situatio	Second Step Disintegrated Cost Distribution Better Than Exp.			Second Step Disintegrated Cost Distribution Expected			Second Step Disintegrated Cost Distribution Worse Than Exp.		
Cost No	Prob.Dist.	Sta.Dev	Mean	Prob.Dist.	Sta.Dev	Mean	Prob.Dist.	Sta.Dev	Mean
1	-338	156	-338	1	156	1	518	156	518
2	-256	325	-256	1	325	1	393	325	393
3	-77	232	-77	1	232	1	118	232	118
4	-1	1	-1	1	1	1	1	1	1
5	-1	1	-1	1	1	1	1	1	1
6	-1	1	-1	1	1	1	1	1	1
7	-1	1	-1	1	1	1	1	1	1
8	-1	1	-1	1	1	1	1	1	1
9	-1	1	-1	1	1	1	1	1	1
10	-1	1	-1	1	1	1	1	1	1
11	-1	1	-1	1	1	1	1	1	1
12	-1	1	-1	1	1	1	1	1	1
13	-1	1	-1	1	1	1	1	1	1
14	-1	1	-1	1	1	1	1	1	1
15	-1	1	-1	1	1	1	1	1	1

Figure 5.10a Uncertainity Distribution to Risk1 (Second Step) of example



Risk Factor Situatio	Second Step Disintegrated Cost Distribution Better Than Exp.			Second Step Disintegrated Cost Distribution Expected			Second Step Disintegrated Cost Distribution Worse Than Exp.		
Cost No	Prob.Dist.	Sta.Dev	Mean	Prob.Dist.	Sta.Dev	Mean	Prob.Dist.	Sta.Dev	Mean
1	-845.154	504	-845.154	1	504	1	845.154	504	845.154
2	-1.441.800	860	-1.441.800	1	860	1	1.441.800	860	1.441.800
3	-400.000	569	-400.000	1	569	1	400.000	569	400.000
4	-1	1	-1	1	1	1	1	1	1
5	-1	1	-1	1	1	1	1	1	1
6	-1	1	-1	1	1	1	1	1	1
7	-1	1	-1	1	1	1	1	1	1
8	-1	1	-1	1	1	1	1	1	1
9	-1	1	-1	1	1	1	1	1	1
10	-1	1	-1	1	1	1	1	1	1
11	-1	1	-1	1	1	1	1	1	1
12	-1	1	-1	1	1	1	1	1	1
13	-1	1	-1	1	1	1	1	1	1
14	-1	1	-1	1	1	1	1	1	1
15	-1	1	-1	1	1	1	1	1	1

Figure 5.10b Uncertainity Distribution to Risk2 (Second Step) of example



Risk Factor Situatio	Second Step Disintegrated Cost Distribution Better Than Exp.			Second Step Disintegrated Cost Distribution Expected			Second Step Disintegrated Cost Distribution Worse Than Exp.		
Cost No	Prob.Dist.	Sta.Dev	Mean	Prob.Dist.	Sta.Dev	Mean	Prob.Dist.	Sta.Dev	Mean
1	-276.642	393	-276.642	1	393	1	276.642	393	276.642
2	-1	203	-1	1	203	1	1	203	1
3	-1	172	-1	1	172	1	1	172	1
4	-1	1	-1	1	1	1	1	1	1
5	-1	1	-1	1	1	1	1	1	1
6	-1	1	-1	1	1	1	1	1	1
7	-1	1	-1	1	1	1	1	1	1
8	-1	1	-1	1	1	1	1	1	1
9	-1	1	-1	1	1	1	1	1	1
10	-1	1	-1	1	1	1	1	1	1
11	-1	1	-1	1	1	1	1	1	1
12	-1	1	-1	1	1	1	1	1	1
13	-1	1	-1	1	1	1	1	1	1
14	-1	1	-1	1	1	1	1	1	1
15	-1	1	-1	1	1	1	1	1	1

DESCRIPTION :
* In case of the first distribution, the variances of the item costs that are calculated from the maximum and minimum expected item costs have been divided into a number (as many as the number of risk-factors) of sub-variances (variance of probability sub-distributions).
* The amount of a sub-variance shows the effect of the corresponding risk-factor's effect on the uncertainty of the relevant item cost.
* In other words, the uncertainty of costs has been distributed to the risk-factors in the first distribution.
* Normal probability distributions are produced through a sign conversion operation and through Visual Basic formulas to be used during CCRAM simulation for the production of correlated item costs.

OK

Figure 5.10c Uncertainity Distribution to Risk3 (Second Step) of example

Step III - Production of correlated item costs for simulation and calculation of total cost; Let's assume that the random numbers produced for our example iteration to be used random number generator in Input Data 5 as shown in Figure 5.6. Notice that risk-factor-2 and risk-factor-3 are the same which assumed as correlated. Using the risk-factor situation probability boundary values and these random numbers in Input Data 5 parts (Random Number, High-Medium-Low Limits), the situations of risk-factors for the example iteration occurs as follows (see Figure 5.6):

In the direction of these randomly determined risk-factor situations, the characteristic parameters of the "situation probability distributions" that will be used in the current iteration example.

The mean and variance values given above constitute the characteristic parameters of the normal distributions representing the corresponding risk-factor situation. Now, random numbers (i.e. random cost values) can be produced from these normal probability distributions. Later, these random cost values will be used to produce the item costs that will be used in the example iteration. User interface produces different random numbers for each risk-factor situation by using uniform probability distribution in order to produce random cost values from the situation probability distributions.

By using these random numbers and User Interface Random Number Generator function (the function that calculates the inverse of normal cumulative probability function if the mean and variance are provided), random cost values are generated for the current example as follows:

Total cost is calculated as;

$TC_1 = C_{A1} + C_{B1} + C_{C1}$ (by Equation 13)

$= 21.168,2 + 25.168,2 + 34.334,2$

$= \$\ 80.682,00$

This example user interface of CCRAM shows that the total cost of the three cost items (\$80.679,00) deviate from the expected total cost (\$21.167,00 + \$25.167,00 + \$34.333,00 = \$80.679,00). As previously mentioned, total costs are calculated at the end of the user interface execution.

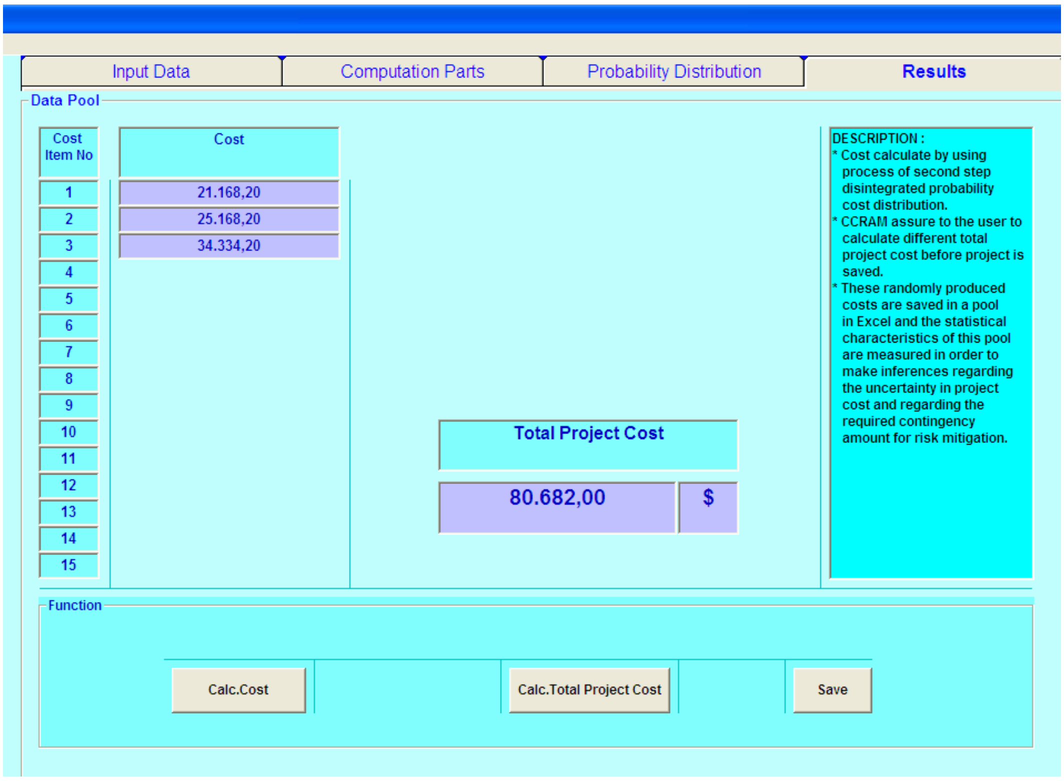


Figure 5.11 Data Pool of example

5.3 Application of User Interface

In order to perform cost estimation, the item costs were represented by triangular probability distributions. According to the previous data at hand, other type of distributions like normal, lognormal or beta may be more appropriate. However, it is sufficient to use triangular distribution due to its simplicity for above example application. The item cost probability distributions were the input and the total project cost probability distribution was the result of the user interface of CCRAM.

User interface of CCRAM the correlation effect between the item costs and the risk-factors indirectly and qualitatively in a more reliable and logical way.

Sensitivity analysis can also be performed by CCRAM in order to find out the most effective risk-factors on the total cost. Being aware of this information, it would be possible for the manager to control and prevent large cost fluctuations by taking the necessary precautions around the most effecting risk-factors in advance. Based cost estimation and user interface of CCRAM were evaluated in Visual Basic spreadsheets, first through designing the input cells, and second through setting up the user interface algorithms with Visual Basic codes. This procedure is clarified for user interface of CCRAM.

CHAPTER 6

CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

The risk analysis programs which are based on Monte Carlo simulation such as @Risk provide an easy and effective environment for data entrance and worksheet in Excel spreadsheet. Correlated cost risk analysis model (CCRAM) is one of the risk analysis technics under uncertainty when the costs and risk-factors are correlated. But, this model is not user-friendly and user interfaces are needed to develop. Use of the CCRAM are very complicated and the program format is not user friendly in terms of data input and calculations. In addition, guiding the user does not have an auxiliary grid, so the absence of user guides, is disadvantage of CCRAM. Data entry, data control, data transmission and data protection are necessary for a control analysis and model configuration.

For filling this deficiency, user interface for Correlated Cost Risk Analysis Model (CCRAM) is developed in this thesis. This user interface assure data entry to the CCRAM in Excel spreadsheet and evaluate the uncertainty effect on construction project estimated costs without simulation for contractor or decision makers. The developed user interface is combined with CCRAM in Excel spreadsheet through various software tools in order to provide integrated user-friendly usage environments. In addition, this user interface facilitate data entry to the CCRAM in Excel spreadsheet and estimate early construction cost. The user interface can be easily used and correlation between the item costs is captured indirectly through Visual Basic codes in a short time. CCRAM model that performs both correlated cost risk analysis has been developed in user interface in Visual Basic and Excel spreadsheet environments.

The sensitivity of uncertain total project cost and item costs in a project to risk-factors can also be analyzed by user interface of CCRAM. The information obtained through sensitivity analysis become useful in managing the project budget. Taking the necessary actions in light of the sensitivity analysis results would prevent budget overruns and constitute a powerful uncertainty control.

The developed user interface for correlated cost risk analysis model is a good starting development. When the produced results of different risk analysis programs in market compared user interface results, they are close to one another results. This approach demonstrate the functionality of the program.

As a last future work, user interface of CCRAM can be integrated into a full risk analysis system by adding a cash flow risk analysis model with simulation and a project progress control method working under uncertainty. Furthermore, this integrated risk analysis system can be converted into a full computer package program to be presented to the usage of the construction sector in practice as a professional device of project management.

6.2 Recommendations

User interface of CCRAM have some limitations, because they are only models produced for animating the situations of real life. Therefore, recommendations for the future work can be proposed around these limitations. The discussion regarding this issue is given below:

- Data entered to the program should be realistic although they are highly judgmental and independent of the similar project records completed in the past. Unrealistic or missing input data would produce unrealistic and wrong results.
- Program can calculate up to 15 cost item and 15 risk factor with the current capacity of total estimate.
- First of all, cost item breakdown structure should cover the cost analysis requirements. Next, minimum-most likely-maximum expected item costs should be determined realistically by taking the project conditions, resources and economic effects into consideration.
- In this study, a new user interface of CCRAM has been introduced. User interface of CCRAM is developed for the purpose of facilitating data entry and computation and to evaluate the uncertainty effect on construction project estimated costs without simulation when item costs and risk-factors are correlated. The description of the user interface is introduced and a hypothetical application is carried out within this thesis. The results of this application show that user interface operates well and produces realistic results regarding the uncertainty extent inherent in the project cost. However,

this conclusion cannot be generalized. User interface of CCRAM should be tested on several projects for full evaluation. Case studies are being carried out for this purpose; this application comprises only the development of the user interface.

- All of the "risk-factors", "activity ~ risk-factor influence degrees", "risk-factor situation scale quantities" and "risk-factor situation probability boundaries" should be determined properly by using appropriate risk identification techniques.
- Furthermore, database of the decision support systems can be constituted by expert knowledge and actual data of similar projects completed in the past

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APPENDIX

FIGURES OF VISUAL BASIC SPREADSHEET OF CCRAM

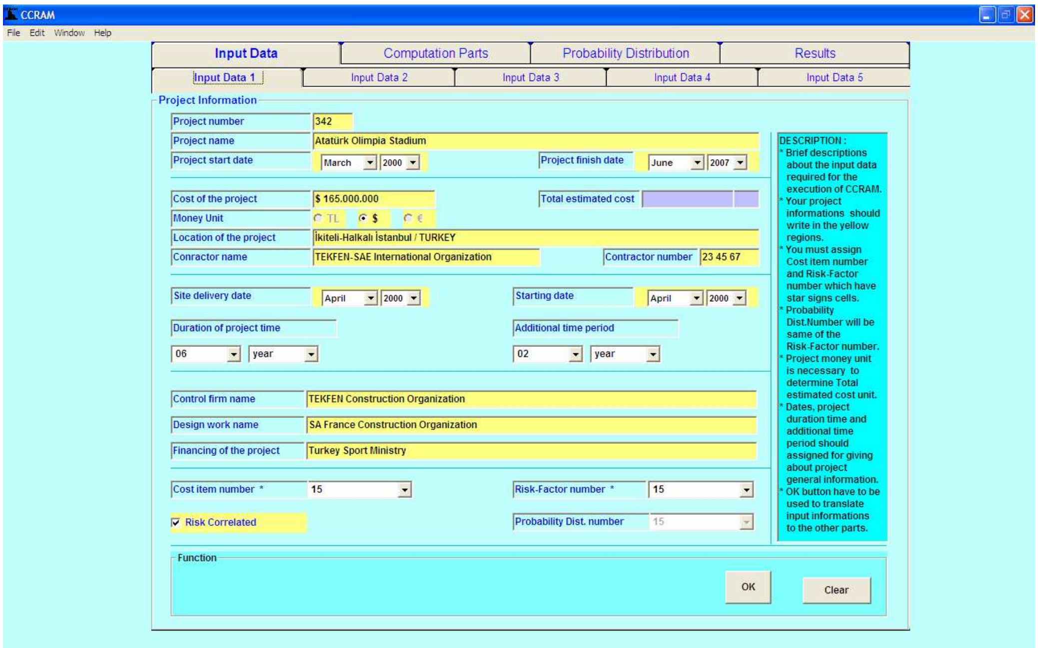


Figure A.1 Input Data 1 - Project Information

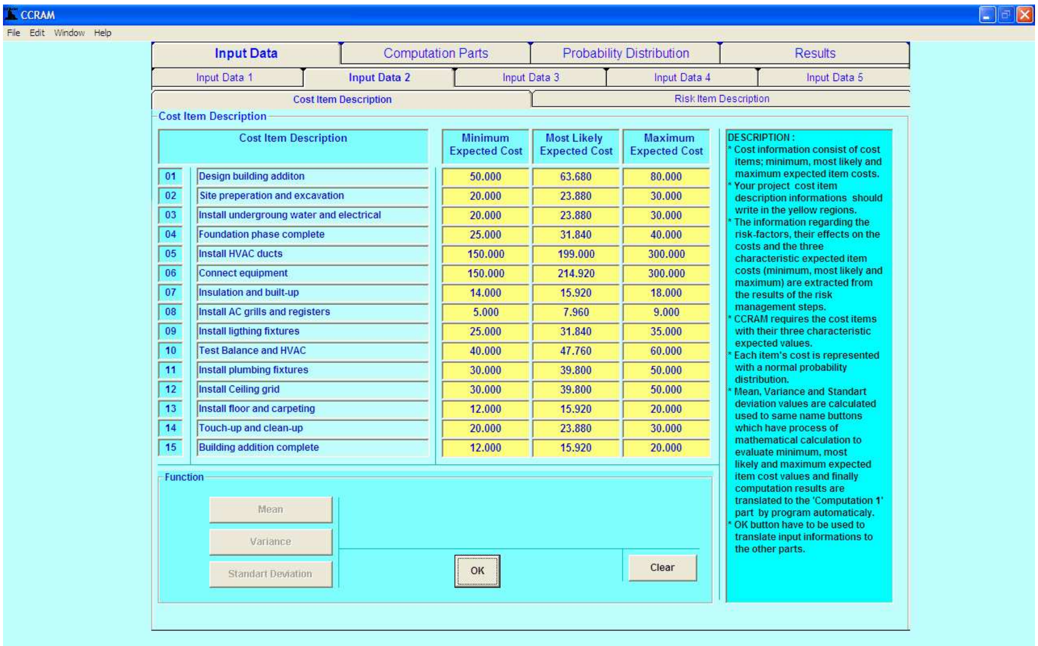


Figure A.2 Input Data 2 (1st region) – Cost Item Description

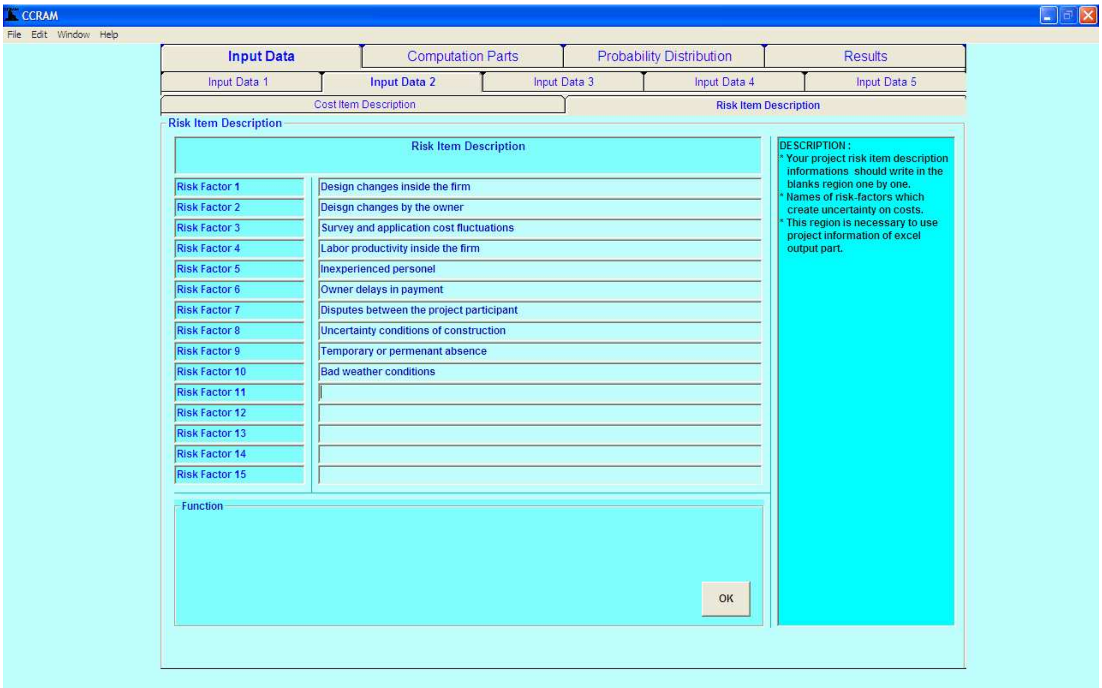


Figure A.3 Input Data 2 (2nd region) – Risk Item Description

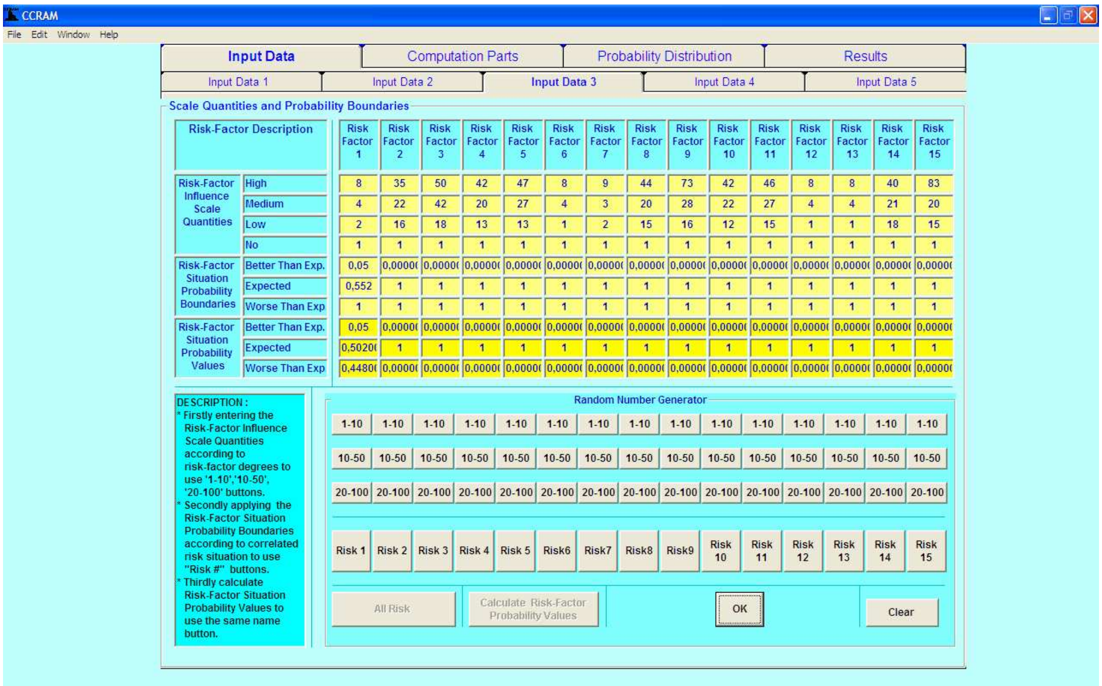


Figure A.4 Input Data 3 – Scale Quantities and Probability Boundaries

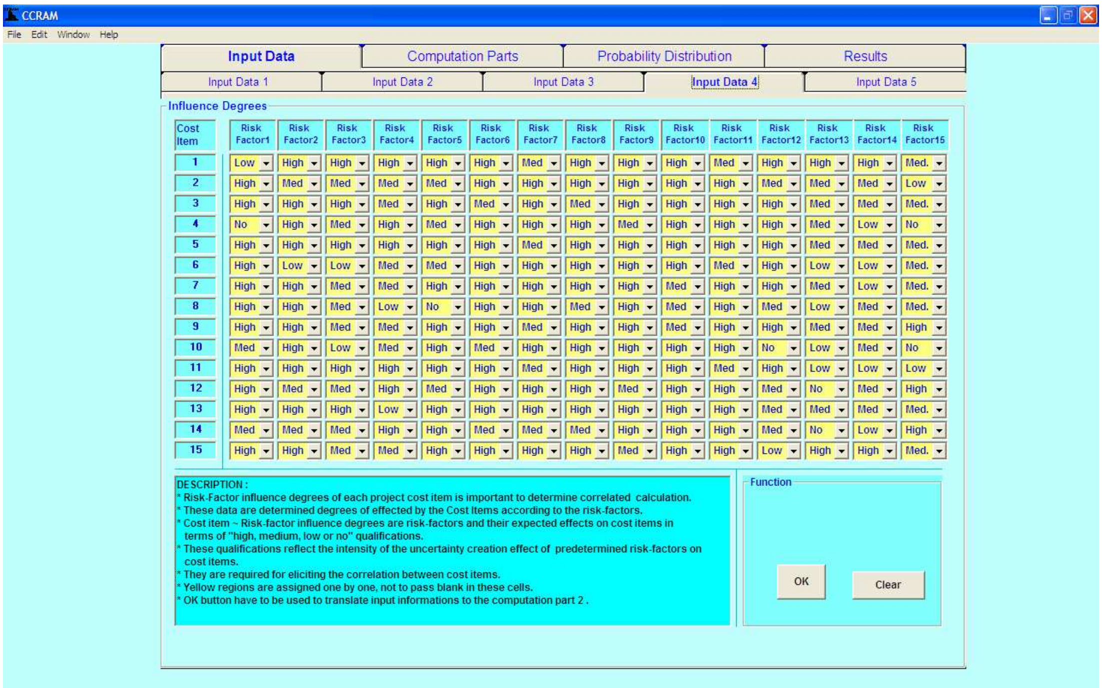


Figure A.5 Input Data 4 – Influence Degrees

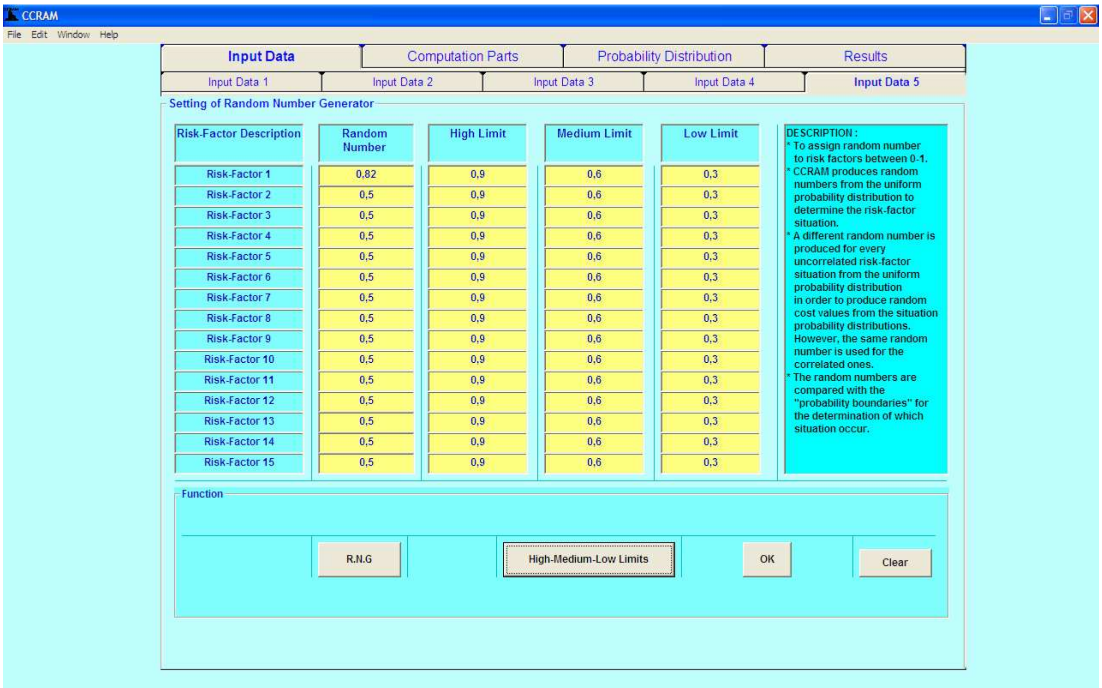


Figure A.6 Input Data 5 – Setting of Random Number Generator

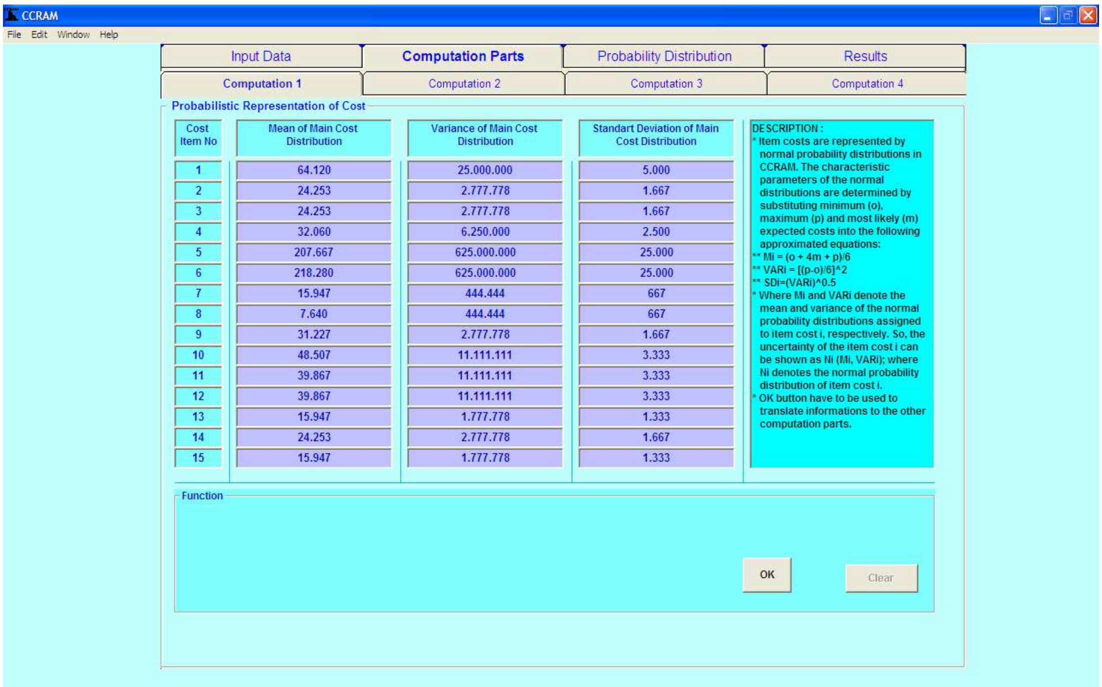


Figure B.1 Computation 1 – Probabilistic Representation of Cost

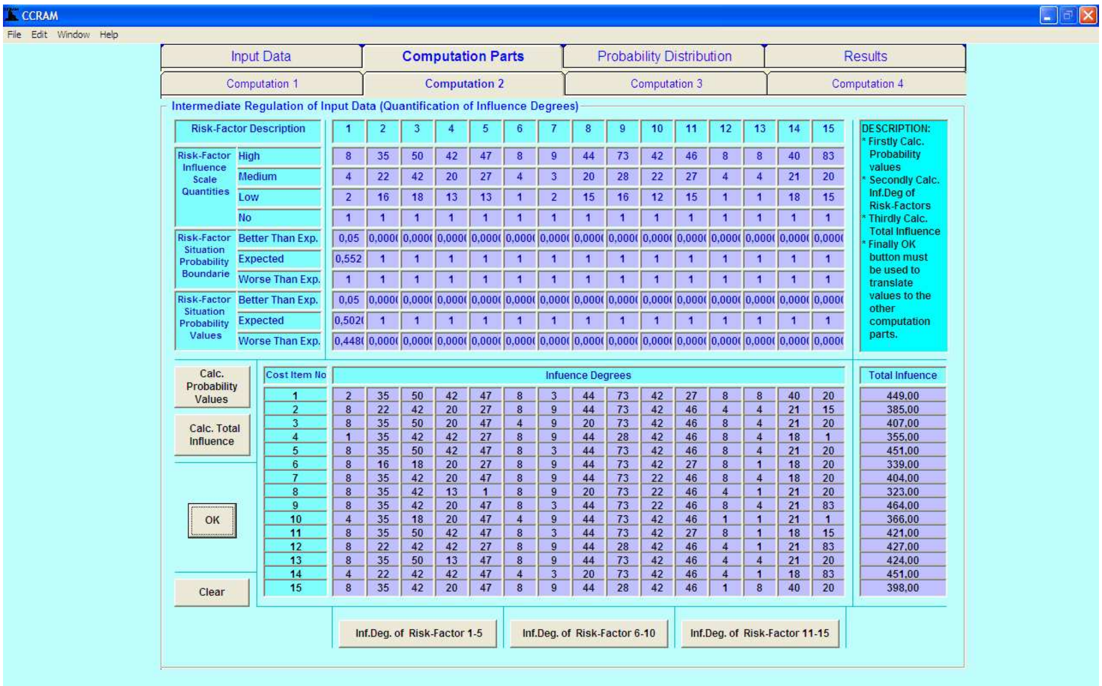


Figure B.2 Computation 2 – Intermediate Regulation of Input Data (Qualification of Influence Degrees)

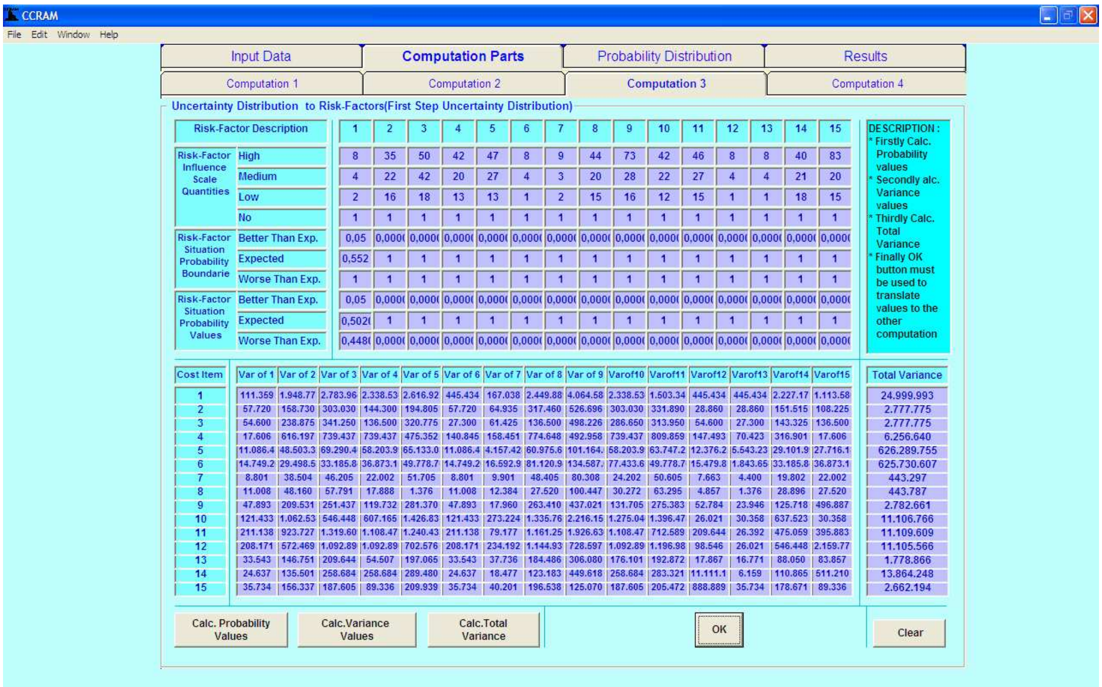


Figure B.3 Computation 3 – Uncertainity Distribution to Risk Factor (First Step Uncertainity Distribution)

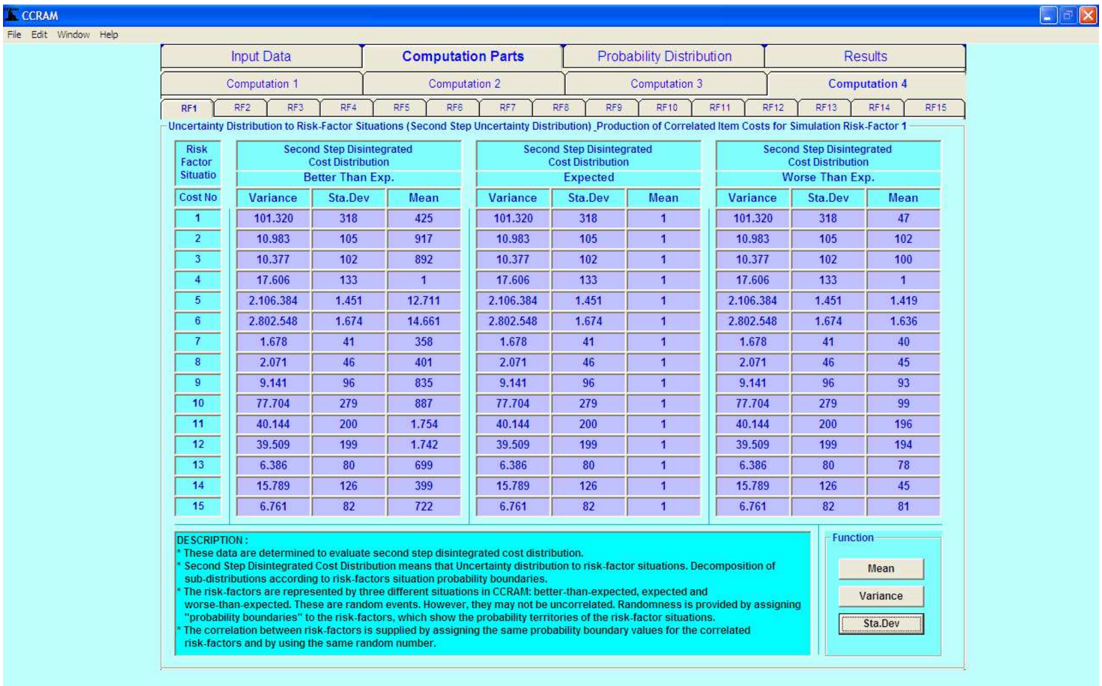
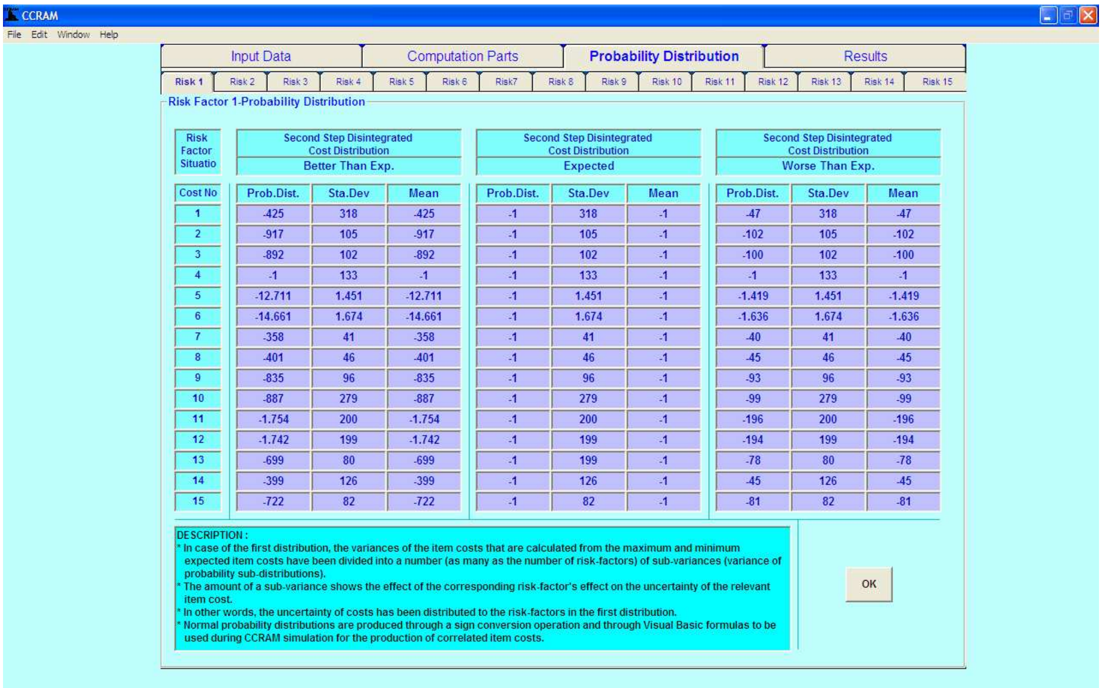
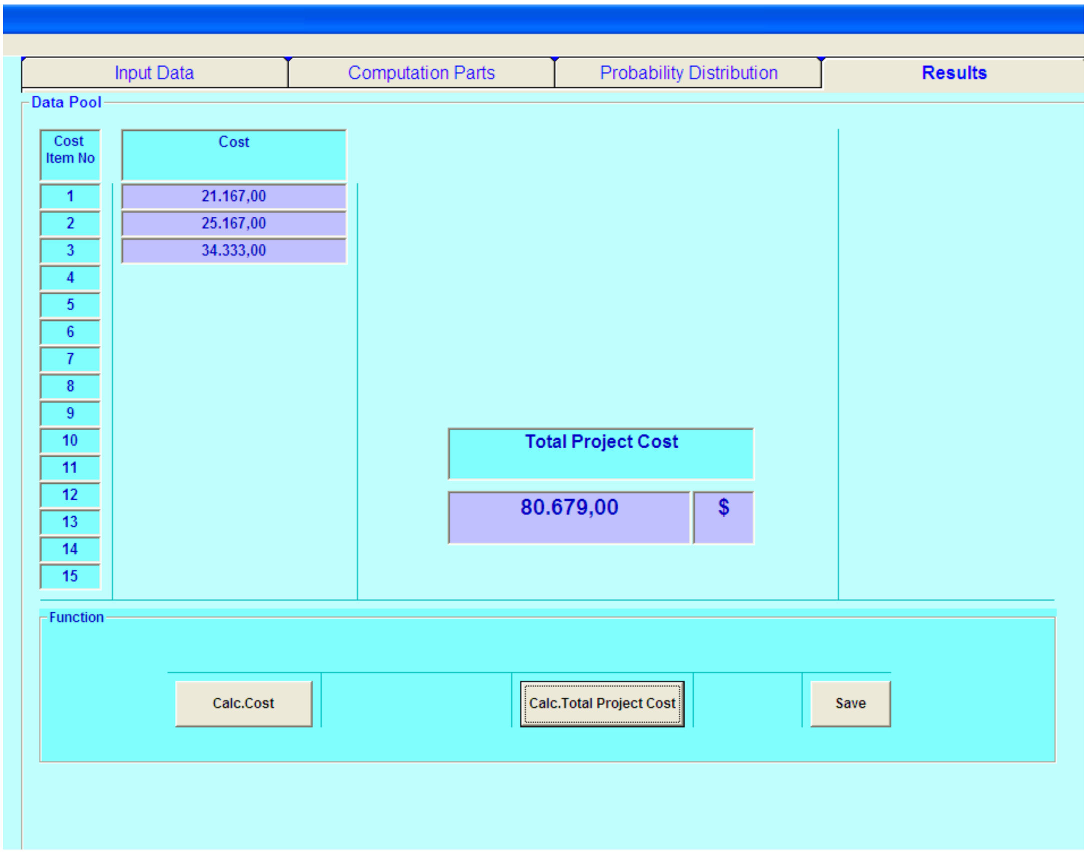


Figure B.4 Computation 4 – Uncertainity Distribution to Risk-Factor Situations



Risk Factor Situatio	Second Step Disintegrated Cost Distribution Better Than Exp.			Second Step Disintegrated Cost Distribution Expected			Second Step Disintegrated Cost Distribution Worse Than Exp.		
Cost No	Prob.Dist.	Sta.Dev	Mean	Prob.Dist.	Sta.Dev	Mean	Prob.Dist.	Sta.Dev	Mean
1	-425	318	-425	-1	318	-1	-47	318	-47
2	-917	105	-917	-1	105	-1	-102	105	-102
3	-892	102	-892	-1	102	-1	-100	102	-100
4	-1	133	-1	-1	133	-1	-1	133	-1
5	-12.711	1.451	-12.711	-1	1.451	-1	-1.419	1.451	-1.419
6	-14.661	1.674	-14.661	-1	1.674	-1	-1.636	1.674	-1.636
7	-358	41	-358	-1	41	-1	-40	41	-40
8	-401	46	-401	-1	46	-1	-45	46	-45
9	-835	96	-835	-1	96	-1	-93	96	-93
10	-887	279	-887	-1	279	-1	-99	279	-99
11	-1.754	200	-1.754	-1	200	-1	-196	200	-196
12	-1.742	199	-1.742	-1	199	-1	-194	199	-194
13	-699	80	-699	-1	199	-1	-78	80	-78
14	-399	126	-399	-1	126	-1	-45	126	-45
15	-722	82	-722	-1	82	-1	-81	82	-81

Figure B.5 Probability Distribution – Second Step Uncertainity Distribution, Production of Correlated Item Costs for Situation Risk-Factor 1



Cost Item No	Cost
1	21.167,00
2	25.167,00
3	34.333,00
4	
5	
6	
7	
8	
9	
10	
11	
12	
13	
14	
15	

Figure B.6 Results part – Cost and Total Project Cost

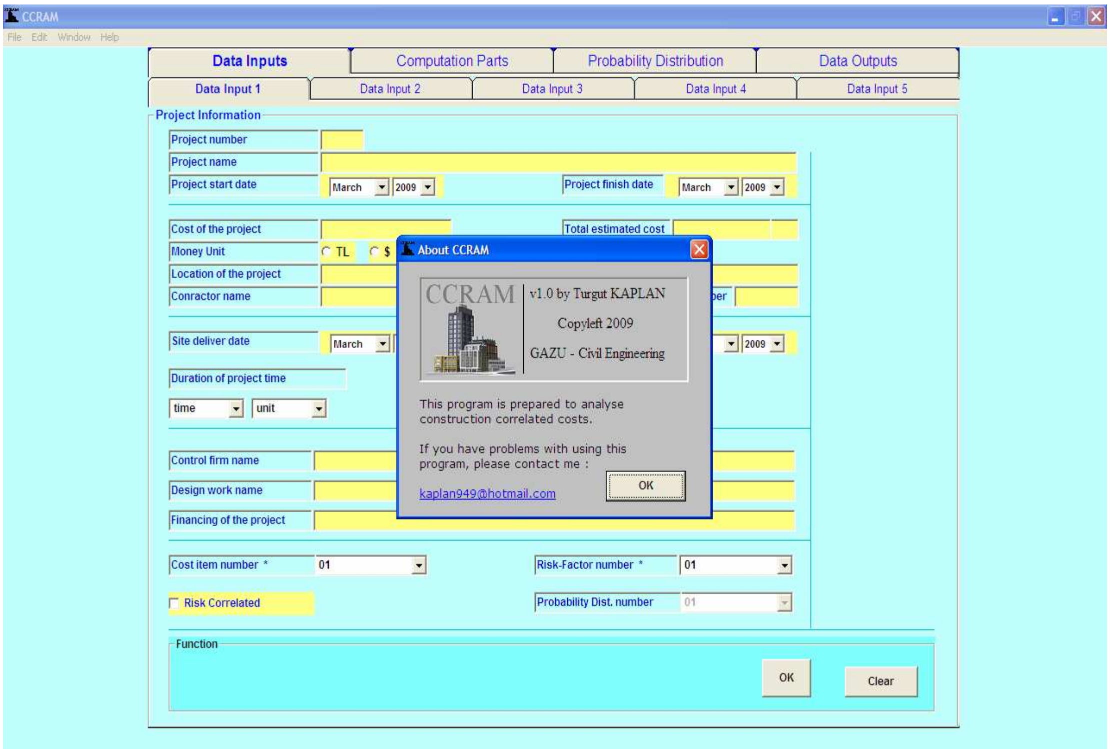


Figure B.7 Abut CCRAM at Visual Basic Software Program

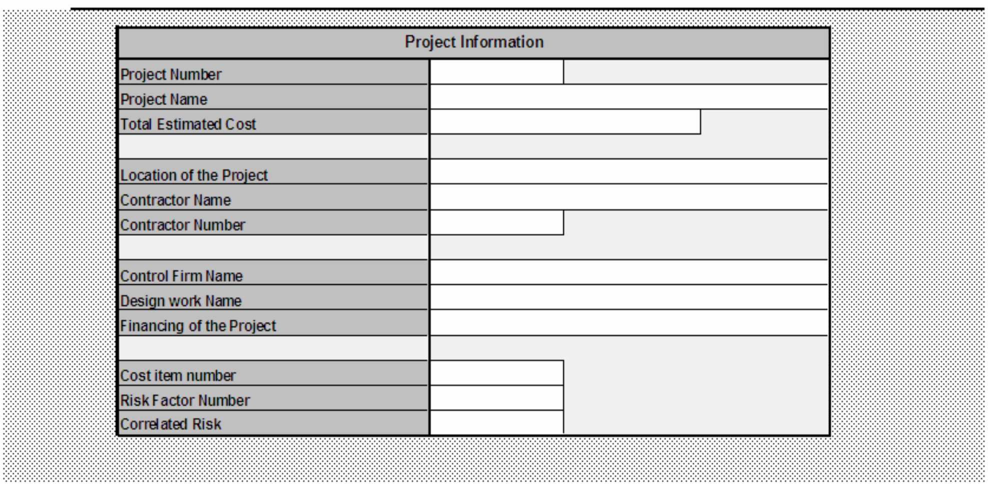


Figure C.1 Results of project information at Microsoft Excel in CCRAM

Risk Factor Description	
Risk Factor 1	
Risk Factor 2	
Risk Factor 3	
Risk Factor 4	
Risk Factor 5	
Risk Factor 6	
Risk Factor 7	
Risk Factor 8	
Risk Factor 9	
Risk Factor 10	
Risk Factor 11	
Risk Factor 12	
Risk Factor 13	
Risk Factor 14	
Risk Factor 15	

Figure C.2 Results of risk factor description at Microsoft Excel in CCRAM

Cost Information					Simulation Data
Cost Item No.	Cost Item Description	Minimum Expected Cost	Most Likely Expected Cost	Maximum Expected Cost	Simulated Cost (SC)
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					

Simulated Total Project Cost

Figure C.3 Results of Cost information and Simulated Cost at Microsoft Excel