UNIT COST MODELLING OF PUBLIC BUILDING PROJECT IN KEPULAUAN RIAU - INDONESIA

INDRASTUTI

DEPARTMENT OF CIVIL ENGINEERING
FACULTY OF ENGINEERING
UNIVERSITY OF MALAYA
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THESIS SUBMITTED IN FULFILMENT OF THE REQUIREMENT FOR THE DEGREE OF DOCTOR OF PHILOSOPHY

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ABSTRACT

This research analyzes the uncertainty of unit cost that influences the cost of the frame element of a building and how to model it using the simulation method for public building projects in Kepulauan Riau Province, Indonesia. The research is expected to be able to provide a great benefit to the stakeholders. Monte Carlo simulation technique is used as a tool in the analysis of the model; it encompasses the traditional building economics principle that a complex building cost-estimating problem should be broken down (analysed) into recognisable parts such as work unit rate, which can be cost, and which can be determined by tornado graph and spiderplots individually and then reassembled to the whole to provide the total estimate of the cost of the frame element of the building. Each of these unit costs of work is represented by a probability density function. The data collected were from the contract documents, which include the index of material usage, index of labour needed and index of tools used by the unit work of reinforcement, concrete, light formwork and heavy formwork. The study shows that the reinforcement unit has the most influence on the frame element, and the materials have the most influence on the reinforcement work. The probability density and cumulative probability functions curves produced as the result of this study allow a cost estimator to know the associated degree of risk of an estimate by interpreting directly from the curves. The estimate can be in total cost or subtotal of element group. The incorporation of time and location factors enable the formulated cost model to be used in cost prediction of price for future government building projects at various locations in Indonesia. A close assessment of the graph indicates that the pdf curves were all positively skewed – a pattern that was consistent with the prediction of the model. A positive skewed curve indicates that the most likely value (relates to the most frequently observed events of the past) falls towards the risky end of the range of likely outcomes.

The main reason why the most likely value is inherently optimistic and risky is the fact that individual costs almost always display more scope to overrun than they do opportunity to improve. The typical shape of cumulative probabilistic cost is the S-curve. It means that the chances for a work to be implemented at extremely low rates (optimistic) and high rates (pessimistic) are very unlikely, although it is possible theoretically.

ABSTRAK

Kajian ini menganalisa ketidaktentuan kos unit yang mempengaruhi kos rangka elemen sesebuah bangunan dan bagaimana untuk membentuknya dengan menggunakan kaedah simulasi untuk bangunan awam di Wilayah Kepulauan Riau, Indonesia. Kajian ini dijangka memberi manfaat yang besar kepada pihak berkepentingan. Teknik Simulasi Monte Carlo digunakan sebagai alat dalam menganalisis model; ia merangkumi prinsip ekonomik bangunan tradisional di mana masalah anggaran kos terhadap bangunan kompleks perlulah dihuraikan (dianalisa) kepada bahagian-bahagian yang dikenalipasti misalnya unit kadar kerja, iaitu kos, dan di mana ia boleh ditentukan dengan graf *tornado* dan *spider plot* secara individu dan digabungkan semula secara keseluruhan untuk memberikan jumlah anggaran kos rangka elemen sesebuah bangunan. Setiap unit kos kerja ini diwakili oleh kebarangkalian fungsi ketumpatan. Data yang dikumpulkan adalah daripada dokumen kontrak, di mana ia mengandungi indeks penggunaan bahan, indeks pekerja yang diperlukan, dan indeks peralatan yang digunakan oleh unit kerja untuk kerja-kerja pemasangan tetulang, konkrit, acuan ringan dan acuan berat. Kajian menunjukkan unit tetulang mempunyai pengaruh yang paling tinggi terhadap rangka sesebuah elemen, dan bahan-bahan pula banyak mempengaruhi kerja pemasangan tetulang. Kebarangkalian keluk ketumpatan dan keluk kebarangkalian fungsi kumulatif yang dihasilkan sebagai keputusan akhir kajian ini membolehkan penganggar kos mengetahui tahap anggaran risiko dengan menafsirkan secara terus dari keluk. Anggaran adalah dalam jumlah kos atau subtotal dari kumpulan elemen. Penggabungan antara faktor masa dan faktor lokasi membolehkan formula model kos digunakan dalam ramalan kos harga untuk projek bangunan kerajaan di pelbagai lokasi serata Indonesia pada masa hadapan. Pendekatan penilaian graf menunjukkan keluk pdf mencondong secara positif – corak yang konsisten dengan ramalan model. Keluk condong positif

menunjukkan bahawa nilai yang paling mungkin (berkaitan dengan peristiwa-peristiwa yang kerap diperhatikan pada masa lalu) jatuh ke arah yang berisiko daripada hasil kepelbagaian kemungkinan. Punca utama mengapa nilai yang paling mungkin sering optimistik dan berisiko adalah kerana hakikatnya kos individu hampir sering memaparkan lebih skop untuk dilaksanakan daripada untuk meningkatkan peluang. Bentuk tipikal kos kebarangkalian kumulatif adalah S-lengkung. Ini bermakna bahawa peluang untuk kerja-kerja yang akan dilaksanakan pada kadar yang terlampau rendah (optimistik) dan kadar yang tinggi (pesimis) sangat tidak mungkin walaupun ia adalah mungkin secara teori.

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CHAPTER 1

INTRODUCTION

1.1 Background

The preliminary step in realising a construction project is by understanding its nature, dynamics and complexity. The activity of project construction is only performed once and normally takes only a short period of time. The sequence of activities of the construction project constitutes activities which are related to each other. Mostly, it starts with the rise of a need, and continues with a feasibility study phase, planning/designing phase, procurement phase, execution phase, and completion phase. Each phase of the sequential activities takes a different range of time and is necessary to make an estimate of cost. The purpose of making a cost estimate is to predict/forecast the amount of budget required to carry out the project work in the future (Newton et al., 1990).

Estimate cost must be arranged in line with the stages of the project work, beginning with making a conceptual estimate until a detailed estimate is arrived at in the procurement and execution phase. Every phase has a different estimation method; for example, in arranging a detailed estimate, this is started by arranging/classifying the level of work activity or Work Breakdown Structure (WBS). The next step proceeds by illustrating the quantity of work (quantity takeoff) based on drawing and specification. Last but not least is designing an analysis of a unit price of work consisting of labour cost, equipment cost, material cost, subcontracting cost, and other costs required to support the execution of work (Tjaturono, 2003).

The main factors causing a decrease in numbers of developers in terms of managerial weaknesses (Kaming et al, 1998; Praboyo, 1999; Santoso, 1999) are, among others: not carefully planning their work, especially on cost estimate, coordination of communication shortage and lack of good project control. Managerial weakness is also a dominant factor in the cause of the time delays and cost overruns in construction development. As a result, during the economic recession, many developers were not able to compete and were forced to close down (Tjaturono, 2007).

According to Kaming (1998), developers currently should always be prepared in the face of unforeseen external factors in Indonesia. Competitive ability of the developer or contractor can be achieved primarily through the production cost efficiency and time management of the construction industry (Kerzner, 2009). Cost of production efficiency can be estimated especially from labour cost savings (Budiharto, 1992, Pangestu, 2004, Tjaturono, 2003); it has been found that share of labour costs generally covers 25-35% of total cost of construction (Suharto, 1995, Kaming et al, 1997). When one housing developer is able to perform labour cost efficiency, compared to other developers, then that developer can sell the house at a lower price for the same quality. Nowadays, in order to overcome the competition in the real estate industry and in the future developers need to behave and achieve more efficiently (Tjaturono, 2007).

The planning and estimating of construction costs in Indonesia are still calculated by standard numbers. This refers to labour productivity, which was researched some years ago namely in *Burgelijke Opernbare Werken* (BOW) in 1921. The BOW Standard is no longer appropriate when calculating the planning of labour costs on construction projects, for work methods, equipment, supervisors, and other factors are much more different now compared to the situation during 1921 when the *Burgelijke Opernbare Werken* or BOW was drafted (Suryanto, 1997).

Therefore, when planning labour costs some developers are no longer using the BOW 1921 to determine the productivity of labour. The developers revise unit labour productivity in terms of productivity on the previous project (Zainal et al., 1992;

Soedrajat, 1992). The Indonesia Department of Public Works Research and Development Center has conducted research in Bandung and Jakarta to illustrate the productivity of labour in the field of residential construction. Given the establishment of SNI (Indonesian National Standard) 2001 was much sourced by the 80% secondary data (Budiharto, 2004), without doubt the productivity of SNI 2001 is not reflected in actual labour productivity yet. Based on this situation it is necessary to conduct research that aims to compensate for shortcomings of SNI 2001 by focusing directly on some private developer. That process is to obtain the actual value of the unit price of construction especially in labour cost, which will be referred to as productivity. The information on the actual level of labour cost (what actually happened in the field) is required by the developers, as this is one of the key factors for achieving competitive value. Besides that, it is defined for cost efficiency for developing intermediate housing (Lowe, 1987; Ratnayanti, 2003; Trucker et al, 1999).

According to research that had been conducted by Sutikno (2000) into masonry for multi-storey buildings, some of the factors that determine labour productivity are the location of materials, weather, site, and experience, age, salary and education of the workers. Meanwhile, according to Rostiyanti (2001), a factor needing to be reviewed in determining labour cost for masonry on luxury housing in Jakarta is the methodology they used and their experience.

Ratnayanti (2003) considered that the factors affecting labour cost in the construction of multi-storey construction are: supervision, planning and coordination, sequence of work, the composition of the working group, field conditions and overtime. It is considered that this study focused on internal and external factors of labour, although their emphasis is different on several types of homes. Labour productivity was obtained from comparing the mentioned results with each other, so it cannot be used in calculating the benchmark regained labour productivity as expected by the developer.

The above description reveals that it is still not known for certain large labour productivity closer the field. The labour cost should be expressed in the form of quantitative empirical models to include factors influencing factors as independent variables of the model (Thomas et al, 1994). The form of empirical modelling requires consideration of many internal and external factors that affect labour productivity. In simple building construction, there are twenty types of jobs in order to create modelling productivity, the twenty-first kind of work is a series of interrelated activities in the construction of a simple building. So empirical modelling is to involve all the labour activities.

In addition, to be more convincing when calculating the actual labour productivity, a variety of conditions that may occur in the field need to be included. Modelling empirical labour cost is very useful to strengthen the studies aimed at construction, given that the pace of development continues to increase from year to year.

Research on labour productivity in the construction of multi-storey buildings has been conducted by Lamming et al. (2000). The results of this study concluded that the main factor affecting labour productivity is the provision of materials, weather, building quality, experience and tools. This research is more dominated by external factors. Research by Tjaturono in 2004 mentioned that the eight internal factors consisting of workforce motivation, discipline, skill, experience, education, age, ethnicity or origin, and health affect labour productivity in intermediate housing.

The use of standard labour productivity based on the BOW 1921 and SNI 2001 is estimated to be very detrimental to developers and consumers because the price of housing will be much more expensive than it should be. Similarly, the state would be harmed if the developer or contractor bid prices based on standard BOW 1921 and SNI

2001 for the projects subsidised by the state. In addition, the BOW 1921 and SNI 2001 do not demonstrate how to improve the productivity of the workforce due to unknown dominant factors.

Based on research conducted by Khalid in 2008, the unit price of concrete slab work based on the Field method is greater than those using other methods. It is about 30.64% compared to the SNI system and greater by about 58.31% compared to the BOW system, while the ratio of field data is greater than the BOW system by about 1.44 since based on field data it is 2.4 greater than the SNI system, and the BOW system is 1.66 greater than the SNI system. By comparison of the work unit price in the BOW method, SNI method and Field method, it can be seen that the dominant component is difference on labour wage of unit price.

Walker (1981) expressed that the major parameters that need to be evaluated when preparing estimates in a particular area are related to political, financial, law, social system, geography and industry.

Some examples of the factors that should be considered in order to determine the labour price per unit have been pointed out by Pratt (1995):

1. The number of workers that comprise the work crew and their trades;
2. The wage rates of the trades involved;
3. The probable productivity rate of the crew or the equipment they are operating;
4. The productivity time factor (per hour, per day or per week?

1.2 Research Gap

It is obvious from the above reason that for cost estimators to be able to perform estimating duties in Indonesia there is a need to develop unit price or cost models when it comes to factors and conditions prevailing in this country. However, this scope of cost modelling is very wide and it is impossible to cover all aspects in one thesis.

From the mentioned condition, research efforts are needed to eliminate disparities in the cost of construction with the actual productivity standards; it will be noted that there are a wide range of differences in productivity compared to the standard at the BOW 1921 and SNI 2001 index system.

In an effort to address the existing gaps, this thesis will concentrate on unit cost of work in the public service building used by government development in the location of Batam City and Tanjung Pinang. The unit cost of work model obtained will be useful for contractors who generally wish to get value from a competitive unit price. It is also proper for the public in determining the cost-efficient development regionally and nationally. Similarly, it will be useful for general contractors in the face of market competition to win tenders, both national and international tenders, located in Kepulauan Riau Province.

Each assumption of unknown factors involves a high degree of uncertainty and when combined can multiply into a total uncertainty of critical proportions. This is where the element of risk enters and it is the evaluation of risk that is most essential. Since building projects tend to involve longer term and substantial investment, the associated risk and uncertainty is likely to be significant.

Since the construction industry is inherent with risks and uncertainties, incorporation of these factors is a necessity for reliable production cost models. The cost information in the database in Indonesia is defined as public building project and is published twice a year (Public Works Department, 2002). This available information is an index of the material, labour and tools, location factors, average percentages of preliminary works, average cost of main building works in square metres, percentages of work carried out by specialist and percentages of external works. The outputs of the analysis are categorised in terms of building function, namely educational, public health office and others. The information provided is not adequate for the analysis of tender price especially in a municipal area such as Kepulauan Riau Province, which is a boundary area and a Free Trade Zone Area and the applications of these data are limited. First and primary, data collected were from historical records covering only public projects implemented by the department. Tender price indices computed also use prices from the similar group of projects. Secondly, the sample size was inadequate as many of the projects have only one or two samples. In addition, statistical analysis test was not carried out and as such inference cannot be made on the reliability of these data sets.

It is for this reason that the aim of this research is to formulate the building cost model using the simulation method for the public building in Kepulauan Riau Province, Indonesia. The model is intended for conceptual estimating as well as being a tool for cost planning, control and balancing.

1.3 Statement of Problems

The true large labour productivity costs in the field are still not known for certain. The Labour Cost should be expressed in the form of quantitative empirical models to include certain influencing factors. Influencing factors are known as independent variables of the model (Thomas et al 1994). Empirical modelling requires consideration of many internal and external factors that affect the unit cost of work. In housing construction, there are twenty types of jobs to create modelling productivity (Tjaturono et al, 2003). The twenty-first kind of work is a series of interrelated activities in the construction of a simple building which is similar to the intermediate house. So the empirical modelling is to involve a unit of work of construction activities.

Due to inflation, one of the most important issues is updating the unit cost of the composite element alternatives in databases.

The unit cost work model obtained will be suitable for contractors who generally wish to obtain the value of a competitive unit cost of work. The unit cost of work model is also useful for the public in order to illustrate cost-efficient development regionally and nationally. Similarly, it will be useful for the general contractor in the face of market competition to win tenders located in Kepulauan Riau Province.

The research efforts need to eliminate disparities in the cost of construction with the actual index standards. It can be noted that there are large differences in unit cost of work compared to the standard BOW 1921 and SNI 2001. In an effort to address the existing gaps, this thesis will focus its research on the unit cost of work in the service building construction carried out by government development in the location of Batam City and Tanjung Pinang City.

1.4 Research Objectives

1. To analyse the variability of work unit cost of work that is known as one of the impacts of the most influential uncertainty variable.
2. To model the unit cost of work that will form the cost of the frame element of the building construction process.
3. To demonstrate that probability distribution can be used to represent all unit costs of work.
4. To establish the probability density function (pdf) and cumulative density function of the frame element of the building.
5. To determine that the uncertainty regarding unit cost will affect the risk-based estimate.

1.5 Research Question

It has been found that the purpose of the model has a considerable influence upon the most appropriate approach to model formulation. It will prove useful to characterise models according to the purpose and classification used here to identify those under (1-4) as micro models and number 5 as a macro models.

More specifically, the research underlines the following questions:

1. What are the components that provide the differences and the similarities in preparation of the unit cost of work?
2. What is the probability distribution that can be used to represent the unit cost of work to be studied?

1.6 Significance of the Research

The research associated with the analysis of uncertainty variables influencing the construction project is expected to be able to contribute a great benefit to the stakeholders, as follows:

1. Contractor can calculate the cost of unit work and the cost of building more accurately.
2. Contractor can estimate how much savings can be when they apply to labour productivity in terms of results of the study when compared to BOW 1921 and SNI 2001.
3. Contractor can allocate a more optimum contingency cost in accordance with the most influential uncertainty variable; as a result a good quotation can be obtained.
4. Project owner, being understood as the most influential variable, is expected to be able to arrange the owner estimate more realistically, as a result approaching the price offered by the contractor.

1.7 The Scope of the Study

The entire cost-modelling process involves many stages and each of these stages may consist of many different options, alternatives and approaches. It is not possible to cover all these combinations in this research. The author will only be able to concentrate on the areas of current interest and reliable techniques. In this aspect, the research will be limited to the following scope of work:

1. The discussion focused on the public service building habitability.
2. The usage method in this work is the implementation of the standard method commonly used by contractors in Indonesia today for the public service building: the labourers do the job using simple devices and tools that do not include heavy equipment (Suharto, 1995).
3. Implementation of primary research conducted in the cities of Batam and Tanjung Pinang in Riau Islands with intermediate contractors.
4. Data fitting techniques are limited to parametric equation, empirical distribution and theoretical distribution.

1.8 Limitation of the Problem

The scope of the study concerning the uncertainty variables in estimating the work unit price of construction project is limited to the following:

1. Case study of this research is only conducted on construction projects in the province of Kepulauan Riau.
2. Data/information collection is only limited to the period of 2000-2009.
3. The influence of uncertainty variable is only limited to material unit cost, wage and equipment whereas the material quantity and equipment and productivity rate is assumed to be fixed.

4. Discussion of uncertainty variable is only limited to anticipate loss incurred from the execution of the construction project.

1.9 Definition of Terminology

Beta distribution: A simple distribution that, depending upon two shape factors, can assume many shapes within two bounds. It is used in the classic PERT project schedule calculations.

BOW (Burgelijke Opernbare Werken) 1921: The method of calculating the price index calculation unit for buildings through the materials application, labour usage, and use of equipment. Indonesia has used this system since 1921. But today some indexes are not appropriate and so Indonesia issued the Public Works Indonesia National Standard for the index in 2001.

Central Limit Theorem: The mean of the sum of a large number of independent distributions. It is approximately normal regardless of the shape of the component distributions. This requires that no component distribution contributes significantly to the sum.

Correlation Coefficient: A measure of the linear correlation between two variables, tolerances from -1 to +1.

Deterministic: A model that is fixed for all parameters or 'determinates'. It is a single-point solution.

Frequency Distribution: A graph or other characterisation of the observed values in a sample data set. That graph is known as a frequency histogram. Simulation trial results are often presented in the form of a frequency histogram (bar graph), whose shape approximates the true probability density function. It is called a relative frequency diagram when the frequencies are expressed as fractions.

Frequency Distribution: A graph of the probability density function; a histogram showing the frequency of occurrence of each value segment, approximating the probability density functions.

Histogram: A graph showing frequency of observations counted in segments of the value range, usually presented as a vertical bar chart.

Indonesian National Standard (SNI): SNI is the only standard that applies nationally in Indonesia. SNI was formulated by the Technical Committee and confirmed by the National Standardization Board. The SNI was formulated to meet the WTO Code of Good Practice.

Lognormal distribution: A frequently encountered positively skewed, continuous distribution. It arises when the value is the product of other distributions. The log values are normally distributed.

Mean: The arithmetic average of equally likely outcomes or a set of observations. This is usually the best estimator for a chance event. Synonymous is expected value when referring to the mean of a *probability distribution*. Symbols are μ for populations (pdfs) and x for data.

Median: The most central value of a population or simple set. Half of the other values lie above, and the other half below. With an even number of equally likely outcomes or observations, the median is the average of the two centremost.

Mode: The particular outcome that is most likely. This is the highest point on a probability density distribution curve. A curve with two localised maxima is called *bimodal.* With sample data having high resolution, there are seldom two identical values. Thus, with frequency *histogram* data, the mode is typically chosen as the midpoint of the bin having the most counts.

Model: A simplified representation of a system of interest. Models for decision purposes usually represent a business enterprise, project, or transaction and consist of variables and mathematical formulas.

Normal Distribution: The frequently encountered, bell-shaped distribution; also called *Gaussian distribution.*

Probability P (x): The likelihood of an event occurring expressed as a number from 0 to 1 (or equivalent percentages). Synonyms: chance, likelihood, odds. The sum of the probabilities of all possible outcomes equals one.

Probability density function (pdf): A mathematical or graphical representation that represents the likelihood of different outcomes from a chance event. The integral of a pdf equals one. Also, it is called *Probability distribution* and *Probability function.* 'Mass' instead of 'density' is often used when referring to a discrete distribution. Also, it is known as *Probability distribution* and *Probability function.* Common examples include binomial, normal, and triangle distributions.

Random Number: A number obtained from sampling, (usually) a 0-1 uniform distribution and used for *Sampling* in *Monte Carlo simulation.* A table of random digits serves the same purpose by placing a decimal point in front of the integers.

Random Variable: A symbol or measure of a chance event. Also it is called a *Statistic variable.*

Rank Correlation: The statistic used in popular Monte Carlo simulation software to express correlation. It is the Pearson rank correlation coefficient using the value *rank* rather than the actual values.

Regression: Determining the coefficient of an equation that best fits the sample data. The name of regression analyses refers to the form of the dependent variable equation: linear, multiple linear, and polynomial (curve fitting). The coefficient is usually chosen so as to minimise the square of the errors (least-squares fit).

Risk: The quality of a system that relates to the possibility of different outcomes. There are unknowns about conditions of nature and about how the system operates. Risk is approximately synonymous with *uncertainty*. Informally, 'risk' is used when there is a large, usually *unfavourable* potential outcome (typically a *discrete event).* For example, risk of failure. 'Uncertainty' is used when there is a range of possible outcomes. For example, price uncertainty.

Risk Analysis: The process of assessing a probability or the shape of a probability distribution. The term is sometimes used in place of *decision analysis*. Some people combine the two into the inclusive R&DA, *Risk and decision analysis*.

Sampling (for Monte Carlo simulation): A process of obtaining a trial value of a probability distribution. With conventional Monte Carlo sampling, a random number between 0 and 1 is used to enter the y-axis on a cumulative probability distribution; the corresponding x-axis value is extracted and becomes that variable's value in the simulation trial.

Sensitive analysis: An analysis to determine how variations in input values affect the outcome value. It is important to the evaluation team in understanding which variables are most important. It is usually done by examining the effect of changing one variable at a time from the base case assumptions.

Sensitivity Chart: A chart showing the prioritised importance of input variables based upon the *correlations* calculating between input variables and the outcome value measure. Variables can be ranked by *correlation coefficient*, rank correlation coefficient, or estimate contributions to total variance.

Simulation: An artificial representation, in the context of business analysis, representing the essential feature of a system in a model. The model is used to anticipate the behaviour and performance of the system under assumed conditions.

Simulation, Monte Carlo: A process for modelling the behaviour of a stochastic (probabilistic) system. A sampling technique is used to obtain trial values for key uncertain model input variables. By repeating the process for many trials, frequency distributions are built up, which approximate the true probability distribution for the system's output.

This random sampling process, averaged over many trials, is effectively the same as integrating what is usually a very difficult or impossible equation.

Skewness: A character of distributions when deviations about the mean are asymmetric. Positively skewed distributions appear to lean to the left and have a longer tail in the positive direction. The skewness statistic is the third moment about the mean divided by a3. A symmetric distribution has a skewness of zero.

Spider diagram: A graph of the sensitivity of value to several input values.

Standard deviation (SD, σ, or s): The square root of the variance. The standard deviation is more meaningful because it has the same units as the distribution measured.

Standard error of the mean (SEM or σ_x): A measure of the uncertainty of the sample mean, x, in representing the true population mean, μ. SEM is useful in determining whether a sufficient number of trials have been run in a Monte Carlo simulation.

Statistic: A number that describes some attribute of a population or event space. The most common statistics are mean, median, mode, standard deviation, and variance. A statistic provides information about a distribution. To distinguish between statistics from populations and statistics from samples, different letters are used.

Schohastic (pronounced stow-kastic): An adjective meaning probabilistic, statistical, chaotic, or random. The term is complementary to deterministic.

Stochastic dominance: A situation when one alternative is better than all others at all levels of cumulative probability. This is observed with cumulative probability curves when the curves do not overlap. When (1) the curves do cross and (2) the best *EV* alternative is more risky, then risk attitude is important to the decision.

Tornado diagram: A sensitivity graph showing the output value range produced by the range of each key uncertain input variable, arranged in decreasing magnitude of effect.

Triangle distribution: A continuous distribution uniquely specified by its range (low and high) and its mode. This is the most popular distribution in *Monte Carlo* simulation because of its simplicity and ease of sampling.

Uncertainty: An informal distinction in that uncertainty is used when the outcome is variable, such as a future product price. Some project management professionals classify uncertainty (i.e., a surprise or contingency) as the most general term; this is divided into events with good outcomes called opportunities and those with bad outcomes called risks or threats. An event having both good and bad outcomes thus is classified as both a risk and an uncertainty.

Uniform distribution: A continuous distribution with constant probability density between two bounds.

Unit Cost of Work: A cost that is formed by a cost of material used, cost of labour used and cost of equipment used in constructing a part of a building element such as the frame element.

Variance (σ2 **statistic):** A popular measure of uncertainty. The expected value is the sum of the squared deviations from the mean. Variance is the standard deviation squared. There is a difference between the forecast and actual outcome. Normally, it is calculated so that an unfavourable variance is negative.

Variance analysis: A post-evaluation for the purpose of reconciling the difference between the forecast and actual outcome, usually detailed by components. Variance in this context is the difference between forecast and actual.

1.10 Organization of the Thesis

This thesis has been divided into seven chapters.

Chapter 1 provides an introduction about why the research has been undertaken, and its aim, objective and scope

Chapter 2 addresses and reviews Construction industry in Kepulauan Riau Province, and Cost System in Indonesia

Chapter 3 provides an introduction of cost modelling, briefly touching on the definition, purpose and classification of cost models. A brief introduction of the adopted probabilistic approach in cost modelling for the research is given.

Chapter 4 covers the methodology and concept of the research: the concept, reasons and the approach taken to analyse the data, process the simulation and procedure in Monte Carlo simulation.

Chapter 5 explains the process of collecting data and points out the problems encountered. This chapter will present the collectd data and explanation why this kind of data were chosen

Chapter 6 presents the probability data modelling techniques that are used to identify the best form of input distribution to be used in Monte Carlo simulation. The results from the analysis of the collected data and curve fitting, which can be used for calibration and validation of cost model, also form part of this chapter. Analysis of simulation output and its relationship to the risk-based estimate as an application of the unit cost of work modelling are also included.

Chapter 7 provides the Conclusion and Recommendation, highlighting the limitations of this study and recommendations for further research.

CHAPTER 2

CONSTRUCTION COST SYSTEM IN INDONESIA

2.1 Cost Estimate

To prepare an accurate cost estimate, estimators must perform a careful and thorough analysis of the work. The analysis includes type and quantity of work, type and size of equipment to be used during construction, production rate of labour and equipment to install the work, and other job site conditions that are unique to the project that can impact the time and cost of construction (Bowen et al., 1987). To assemble a complete estimate for the development purposes, estimators must combine their knowledge of construction methods and technique into an orderly process of calculating and summarising the cost of projects (Priyanto, 2000). Workbook estimating involves performing a material quantity take off, obtaining unit costs from a nationally published cost manual, and multiplying the quantity of work times the unit cost of material and labour to determine the cost estimate. However, unit cost can vary widely, depending on the volume of work, weather condition, tender price, variations in the skill and productivity of workers, and numerous other factors. Costs of previously completed projects and cost quotes from supplier, vendors, and subcontractors must be gathered (Kaming et al., 1997).

The designer of a project must determine the cost of various design alternatives to obtain an economical design that meets the owner's budget. For many projects, a significant amount of work is performed by subcontractors who specialise in a particular type of work. For building type projects examples include land clearing, drywall laying, painting and flooring contractors. Profit value can vary considerably, depending on numerous factors, such as size, complexity of the project, amount of work in progress by contractor, accuracy and completeness of the bid document, competition for work, availability of money, and volume of construction activity in the project area (Budiharto, 1993).

In a detailed cost breakdown, there are two types of format that are usually used in Indonesia: consultant's format and contractor's format. The differences are found especially in the description of the material of concrete. Estimates of consultant's types of workers are differentiated according to the level of expertise and the units used. The parameter for the workers used are man days, while estimates from contractors use group of workers with m^3 or adjusted unit labour productivity in completing the unit m^3 concrete work, so that the units used are for volume. Similarly, there are differences between contractor and consultant in measuring the use of equipment. The consultant uses the lump sum while the contractor differentiates types of tools and productivity of tools for a single unit of volume.

The following points should be considered when considering cost breakdown:

(i) The collection of data should consider the use of the unit cost analysis needs distinguished between consultant's format and contractor's format.

(ii) For both consultants and contractors, the general cost index for the material has the same value for all work factors. But the cost index for wages and worker equipment has different values and formats for the analysis method and construction procedure used.

When the rupiah exchange rate depreciated up to 400% in the middle of 1997 and 1998 against 1996, it really influenced the selling cost of cement and concrete rebating in the market. The unit cost of cement increased up to 56% and the unit cost of concrete rebating increased significantly up to 125%. The rise of cement cost is less than the increase of concrete rebating because the government controlled the distribution of cement and determined its maximum selling cost; whereas the selling cost of concrete rebating depended on the market mechanism (Mukomoko, 2007).

It can be found that each type of work will have a different cost composition. Inaccuracy in estimating the cost component that has the biggest contribution will make a big variability of work unit cost. The variability is closely related to the risks made, either in the form of loss or in the form of failure to obtain the work (Rafttery, 1984).

2.2 Cost Components in Indonesia

2.2.1 Material Unit Cost

Material unit cost consists of material supply cost, transportation cost, unloading cost, warehousing cost and tax. The material supply cost contributes the biggest portion in forming the material unit cost compared to the other components of cost. So the variability of material unit cost is much influenced by the material supply cost. For that reason the contractor must get the best cost from the supplier in relation to the selling cost, method of payment, discount, and delivery time. The selling cost of material is much influenced by the economic condition and the supply demand of the material. The economic indicators considered the most influential factor toward the selling cost of material are exchange rate and interest rate.

The rupiah exchange rate will also influence the production cost of material especially for the material imported from overseas. Fluctuation of the exchange rate will cause the producer difficulties in obtaining the raw material; as a result production capacity will be limited, production process delayed, and cost of production will be increased. This incident makes the selling cost become higher and fluctuate and causes material shortage. Another impact faced by contractors is no fixed cost given by the supplier; as a result the contractor will find it difficult to determine the appropriate cost in making cost estimates (Budiman, 1999).

Additionally, the condition of the exchange rate also has an influence on the transportation cost of material where, if the exchange rate lowers, the selling cost of spare parts and the operational cost of vehicles will also rise. However, the contribution of transportation cost is too small in forming the material unit cost; the increase of transportation cost has no significant influence on the increase and the variability of material unit cost (Siswanto, 1997).

As for the concrete rebating work, estimation of material unit cost is very important, as material cost contributes the biggest percentage to work unit cost. The materials used for concrete work are mostly cement, concrete rebating, sand, gravel and concrete wire.

This cost demonstrates that within one year the selling cost of this material fluctuated in line with the development of an unstable exchange rate. This condition gives a negative impact to the contractors who are carrying out the project work; as a result many contractors experience losses and have to terminate their activity. The government policy to make costs escalate can only help the contractors to accomplish their work with small profit. For contractors who take part in work bidding, the above condition will make it complicated for them as they have to provide more detailed cost estimates of material cost (Hafid, 1995).

During the unstable economic conditions, like in 2001 to 2004, the variability of unit cost for cement and concrete rebating was around 1%-5%, where at that time the rupiah exchange rate and interest rate showed a stable development. The variability of unit cost of the two components showed a usual and common development of cost growth in the market and the producer was able to fulfil the public need.

Other materials like sand and gravel also have a high cost increase when the rupiah depreciates. But the increase in cost is not as high as for cement and concrete rebating. Therefore, it can be said that the decrease of the rupiah exchange rate does not have a significant influence on the increase of cost for natural material, but this is just a psychological impact of an economic condition and adapting to the market condition (Budiharto, 1995).

Generally speaking, within a stable economic condition, coefficient of variance of the five material unit costs is around 1%-5%; whereas, within uncertain economic conditions, the contractor is required to carefully pay attention to the economic development, especially the development of the rupiah exchange rate against the US dollar. The contractor can fix a safe exchange rate during the execution period of construction with a logical assumption. In determining an exchange rate, the contractor must previously perform an analysis of economic conditions, such as exchange rate targeted by the government in APBN (national budget), exchange rate for tax payment, development of global economy, and non-economic analysis like condition of social-political development in Indonesia. Determining a pessimistic exchange rate will make the cost of the quotation very high, whereas an optimistic exchange rate will create a big risk for work unit cost.

2.3 Construction Cost Estimation

Among the phases of construction project activity, types of estimation of most of the contractors in Indonesia can be divided into several categories, as follows (Eriyanto, 2007):

2.3.1 Order of Magnitude Method

This estimation is conducted to analyse the feasibility of a project to be carried out or to select several alternative designs already made. In this phase, the estimation is made with very limited data/information; as a result the accuracy level of value obtained shows too wide a range, namely around +50% or -30%. Order of magnitude method applies several criteria, such as width of building floor, volume of work and so forth.

2.3.2 Budget Estimates

A budget is aimed to identify the amount of funds to be prepared for executing the project, not for the budget to control the project in these estimates. This estimate is made more detailed compared to the previous estimates, so the accuracy range of this estimate is around +30% or -15%. The level of accuracy will merely depend on the quality of information available.

2.3.3 Detailed Estimates

A detailed estimate is made on the basis of two applications, that is to propose a quotation for a work and to be used as a basis for control of a project. Detailed estimates can be made after completing the data/information regarding the project, such as the availability of drawing document, technical specification and other supporting requirements. This estimate will give more accurate results because the data/information required is available completely. This estimate can also be made by the owner in order to obtain the amount of owner estimates to be used as a benchmark for the quotation proposed by the bar gainer party. The accuracy level of this estimate is around +15% or -5%.

The principal point in making detailed estimates is defining the scope of work, and classifying the work. Several steps in arranging detailed estimates are, as follows:

(a) Reviewing all documents and real condition of the project, such as explanation of the document including addendum, and the site condition and the risk level that will be faced.

(b) Outlining and classifying the work items.

(c) Calculating the quantity of work which is function of the measurement unit and the kind of work.

(d) Calculating the cost of material cost component, equipment cost and labour cost.

(e) Analysing the cost offered by the subcontractor and supplier.

(f) Calculating the overhead cost, tax, insurance, collateral required by the project.

(g) Calculating the contingency cost, risk of work to be done.

(h) Calculating the profit that will be obtained from the project.

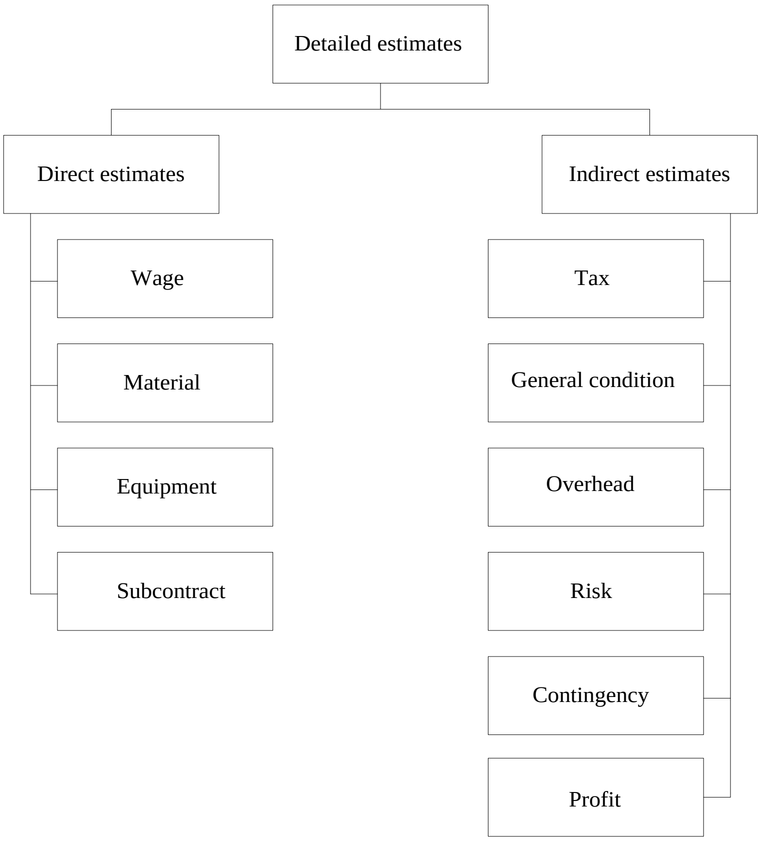


Figure 2.1: Components of Detailed Estimate (AACE, 1992)

Components of the detailed estimates can be divided into the two following sections:

1 Direct Cost/Estimates

2 Indirect Cost/Estimates

According to Ervianto (2007), there are two kind of cost:

(1) Direct Cost which is all costs that become permanent.

Direct costs are the costs required for the procurement of materials and labour costs (SNI, 2008). Direct costs are components that have an important role in preparing the budget. According to Gould (1997), direct costs are directly related to the construction process, which covers the entire cost of the activities carried out in the project and the cost to bring in all the resources required by the project. Direct costs consist of: material cost, labour cost, equipment cost, subcontractor cost, and others such as, field overhead costs, etc. Judging from the results of the activities, included in the direct costs are those costs for activities' preparatory work, work under the structure, the structure of the work, and finishing work. Under structure work, upper structure work and finishing, subcontractor and overhead cost (Budiharto & Lili, 1993).

(a) Material Cost

Material Cost can be calculated in unit cost or lump sum; this depends on the cost offered by the supplier. Besides material cost, the estimator must also consider other existing costs that are necessary to be calculated, such as transportation cost, warehousing cost, unloading cost, material testing cost, quantity of material availability, tax, method of payment, date of delivery/arrival, material directly supplied by the owner and so forth.

(b) Equipment cost

This cost is required to accommodate the equipment required, especially heavy equipment that will be used on the construction project. The calculation of equipment cost can be divided into three, as follows (SNI 2012):

(i) Supply cost

(ii) Project Overhead

(iii) Contingencies

This cost is allocated to compensate for the lack of information and mistakes in interpreting the information obtained causing an uncertainty. This can be a risk that must be anticipated in the execution of the project later. The allocation of contingency cost would be significantly minimised by making a reasonable estimate and completing the uncertainty and the inadequate information by directly asking the owner of the project or the related parties. This is aimed to obtain the precise value of the equation.

(c) Labour Cost

Labour cost is defined as the salary (straight time wages), overtime pay, labour insurance, work safety, general facilities for workers, and fringe benefits. Worker's Salary (fixed salary) must consider several factors, such as project location, and labour's skill. Labour's wage can be paid on the basis of: union wages, one shop wage, or prevailing wage. The wage value to be paid absolutely depends on the productivity of the labour, where it will be influenced by: attitude/personality of the labourers, type of project, climate condition, complexity and supervisory function.

(d) Subcontractor Cost

This cost is calculated for the need for a subcontractor supplied by the main contractor due to transferring a specific work expertise. Several matters that must be noticed by the main contractor in involving the subcontractor are: estimates system applied by subcontractor, capability of subcontractor, and analysis of the quotation proposed by the subcontractor.

(2) Indirect Cost

Indirect costs are expenditures for management, supervision and procurement services for parts of the project that will not be a permanent building but which are necessary in order to support the project development process. Indirect costs consist of:

(a) General Condition

General Condition are usually notable to immediately put into a type of work in the project, such as office rent, office equipment and stationery, water, electricity, telephone, insurance, taxes, interest money, notary fees, travel expenses and the purchase of various kinds of small items.

(b) Overhead Project

Overhead cost of the project is to be charged to the project but cannot be charged to the cost of materials, labour or equipment costs such as: insurance, telephone mounted on the project, purchase of additional employment contract documents, measurement (survey), the letter-licences and so forth. Total overhead can range from 12% to 30%.

(c) Profit

Profit usually expressed in percentage gain and total cost amounts to about 8% to 15% depending on the desire to engage a certain contractor for the project. This percentage also depends on the size of the risk of the work, the difficulties that will arise and local regulations for labourers' wages.

(d) Tax

There are various kinds of taxes such as VAT and income tax. Cost (budget) is the sum of each result estimating the volume of the corresponding unit cost work.

Indirect cost can also be the cost that supports the work but is not included as payment item of the work, such as: overhead cost. It is all cost spent on the operation of the company but cannot be distributed into a work package, such as: insurance, allowance, etc. The margin value may be added to the estimation value that is already arranged.

The following diagram, Figure 2.2, illustrates the factors to be considered in the formation of the unit cost. In estimating the work unit cost, the amount to be spent during the execution of construction cannot be known for certain. This is closely related to the variables that cannot be predicted correctly or having an uncertainty in the execution phase of construction; as a result this will cause:

(i) Variability of unit cost, such as fluctuation of material cost, equipment and wage.

(ii) Variability of work quantity, such as the difference between the work quantity carried out in the field and those listed in the Bill of Quantity.

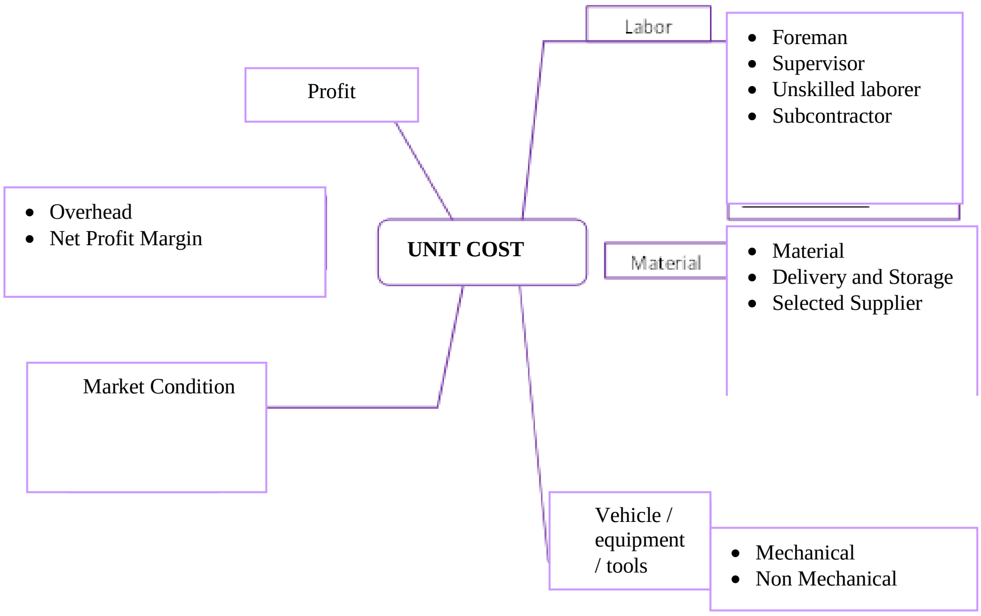


Figure 2.2: Representation of Unit Cost (SNI, 2008)

To anticipate the loss which will happen due to the impact of the existence of uncertain variables that cannot be forecasted for sure or having uncertainty at the time of making the estimation, it is necessary to allocate an amount of expenses posted in the indirect cost as risk cost (Figure 2.1), in this case called contingency cost.

In research written by Beeston (1973) uncertainty in a construction project is influenced by external factors and internal factors of the project. From the above factors, there are four main sources that cause uncertainties in arranging the cost estimation; they are as follows:

1 External factor: that is factors coming from outside of the project surrounding and contributing to influence the project work, such as policy made by the government related to the construction project, economic circumstances such as inflation, fluctuation of exchange rate, and technological changes.

2 Complexity of project, such as project scale, period of project, technical matters.

3 Project management handling, such as planning and controlling the internal resources.

4 Unrealistic estimates, where the estimates were made without considering/complying with the situation/condition occurring at that time.

The procedure for the calculation of the unit cost of this work is related to results of research at the Centre for Analysis of Common Construction Litbang Settlements 1988-1991 (Public Work Department of Republic of Indonesia). Research conducted by the Public Work Department was carried out in two stages. The first phase was the collection of secondary data obtained from the analysis of the cost of some state-owned contractors and the data derived from the analysis of existing previous BOW (Burgerlijke Openbare Werken). Secondary data were collected from the selected data with the highest mode. The second stage is the research field to obtain primary data as a crosscheck against secondary data selected in the first phase of the study. There are some fields of research in the form of labour productivity research field calculations on some construction projects and residential buildings as well as laboratory research building materials for the composition of the materials used in every type of job performance approach/performance of related jobs.

The calculation of unit cost of work used in the contractor's budget and planning is based on an index of construction materials and labour required for each unit of work which has been used as a reference basis for implementing a uniform calculation of housing construction and calculation of the unit cost for building work and housing by the Indonesian National Standard.

Unit cost according to Mukomoko (1987) is defined as the amount of work material costs and labour costs based on the calculation analysis. Material costs are obtained from the market and collected in a list called the List of Materials Unit Cost. Any substance or material has its own kind and quality, so material costs vary. For that reason the benchmark cost is usually based on the location of these materials that come from the specific area and according to the reference cost published by the government.

The cost labour available at the location is collected and recorded in a list called the List Unit Cost Wage. To determine the standard of salaries, the prevailing cost in the market or the area where the project is carried out can be taken in accordance with the specifications of the Public Works department. There are three methods used, which include work equipment or any worker should have her/his own working tools that support each skill.

To determine the total cost of building construction, use the standard prevailing cost in the market or the area where the project is carried out in accordance with the specifications of the local department of Public Works Unit Cost List of Materials.

To determine the unit cost of work, use a standard tool costs prevailing in the market or the area where the project is carried out in accordance with the specifications of the local service; this is called PU Unit Cost List of Equipment.

In general it can be concluded as the following equation:

Unit Cost of Work = Unit Cost of Material × Unit Cost of labour/ Wages + Unit Equipment cost …………………………………………………………..(2.1)

Based on Indonesia National Standard (SNI, 2001), one method of cost estimating often used is the method of analysing elements. In the method of elemental analysis estimating cost, the scope of the project is broken down into elements by function. A structure is obtained such that a gradual improvement can be made in accordance with the progress of the project, in terms of the input in the form of new data and information obtained; it can be accommodated in order to improve the quality of cost estimates. For example, residential poles can be made of wood, steel or concrete, but their function is the same. In order to use the approximate cost effect, the function selection should be based on (SNI 2008):

(a) Clearly indicate the relationship between the components of the project, and when it was given the costs, indicating the cost components of other similar projects;

(b) Can be compared to the components of similar projects' costs;

(c) Easily measure or calculate and assess the comparison (ratio) of the standard data.

Construction cost analysis is the method of calculating unit costs of construction works, which are translated into multiple salary indexes of construction materials and labour to the cost of building materials and labour wage standards, to complete per-unit construction. Analysis of the cost of construction is known as the analysis of BOW.

However, there are several types of building materials that are found in today's construction market but there is no analysis of the workload in the system analysis BOW 1921. Besides, the analysis can only be used for labour-intensive jobs that use simple tools. As for jobs which use modern equipment/heavy equipment, BOW analysis cannot be used.

Some BOW analyses are no longer relevant to the development needs, both for material and labour costs. However, analysis of BOW can still be used as a guide in preparing the budget for the building. From 1987 to 1991, the Research Center and Settlement Development of Indonesia Public Works conducted a study to develop BOW analysis. The research approach taken was through the collection of secondary data analysis of the costs used by some contractors in calculating the unit cost of the job. In addition, it also conducted primary data collection, through field research on housing development projects. Data obtained were primarily used as a comparison/to crosscheck the conclusions' secondary data. These activities have resulted in the construction cost analysis products that have been confirmed as Indonesia National Standard/IEC in 1991-1992 by the National Standardization Board/BSN.

In 2002 the Indonesian National Standard (SNI) was re-examined for enhancement with the broader goal of building and housing; in addition, the SNI analysis can be used by central and local governments to streamline development funds that are allocated.

In the current economic conditions the country is experiencing an economic crisis, directly or indirectly impacting on wage rates and costs of materials. The financial benefits a contractor derives depends on her/his ability to make cost estimates. If the bid cost submitted in the auction process is too high, the contractor will most likely lose. At this time, the contract is generally made based on bid cost analysis; it is not entirely based on the analysis of BOW and SNI analysis. The contractors are more likely to calculate the unit cost of the work in accordance with their own analysis based on previous experience in completing the construction work, although not independent of BOW analysis or analysis of SNI.

The principle of the method of calculation of unit costs in SNI is valid for all Indonesian occupations, based on the unit cost of materials, labour wage unit cost and the unit cost tools suited to local conditions. The specification of the material used and the way of working has been adapted to the standard technical specification work. Later on, the implementation of the calculation unit of work should be based on technical drawings and plans and the conditions that apply (RKS).

Calculation of the index material has an added tolerance of 15% - 20%, a category including shrinkage rate, the amount depending on the type of materials and composition. Effective working hours for workers account for 5 hours per day. The principle of the work unit cost calculation method is similar to ISO calculation method

BOW, but there are differences to the BOW method in the value of the coefficient of the material and labour costs (Santoso, 1999).

The procedure was developed to refer to the results of the assessment of some of the analysis work that has been applied by several contractors with comparative analysis of BOW in 1921 and construction cost analysis study conducted by the Center for Research and Development of Settlement in the Department of Public Works in 1998 to 1993.

Table 2.1: Component Differences and Similarities of BOW

No	BOW method	SNI Methods
1	In determining the index or the magnitude of the coefficient of the material, based on the amount of material used per unit of work, the difference occurs because there are differences in the capacity of the materials used in completing the work. The magnitude of the safety factor is not fixed and is not necessarily the magnitude.	In determining the index or magnitude of the coefficient of the material, based on the amount of material used per unit of work, the difference occurs because there are differences in the capacity of the materials used in completing the work.
2	Wage index based on the daily wages of labour, and labour productivity in the work done per unit of day. The comparison table above shows the percentage of wages is a very dominant force as a differentiator with the SNI method, wherein the BOW method has a larger percentage because the quality of the resources available at the time was still low when compared with the existing resources.	Wage index based on the need of time to work on each unit of work. Wage index calculation based on effective working hours, which is 5 hours per day.
3	The equipment index is calculated based on the average level of productivity of the equipment used.	The index is based on the calculation of the equipment acquired in accordance with the capacity of production equipment.

By comparison between the methods of BOW and SNI (Table 2.1), it can be seen that the dominant component of the difference between the two methods is wage unit cost.

2.3.3.1 Project Construction Cost

The factors that are closely related to the construction costs to be considered are as follows:

(1) Construction Workers

To organise the project, one of the resources that is a determining factor of success is the labour. The type and intensity of the project changes rapidly throughout the cycle, thereby necessitating the need to provide the workforce, types of skills and expertise to follow the changing demands of the ongoing activity. Starting from this fact, a workforce planning project must include a thorough and detailed estimate of when labour is needed and the type of labour required, such as experts from various disciplines in the engineering design and procurement phase, and supervisors and field workers for manufacturing and construction. With an estimate of the number and schedule needs, then information can start to be collected about the source of supply of both quantity and quality. Similarly, human resources is planning for equipment and materials for the project, especially for items with long delivery times, or those with limited availability in the market (Suharto, 1995).

(2) Construction Equipment

Definition of construction equipment is the tools/equipment required to perform construction work mechanically. This can be a crane, grader, scraper, truck, backhoe (back-hoe), air compressor, and others. By knowing the scope of work and schedule of the project implementation, the type and quantities of construction equipment required can be analysed. In estimating the cost of construction, one of the difficult tasks for the contractor is to choose between renting, buying or using one's own equipment but having to bring it from a distance. Various factors must be examined before arriving at such a decision: is there a local shop, is the equipment suitable to the specification as required, and are the spare parts and personnel available to handle the equipment? If not, the contractor should consider bringing their own spare parts and skilled mechanics for setting up facilities outside the project. This is especially true for swamps, muddy, dusty or rocky areas where heavy construction equipment must work – it requires intensive care so that it is always ready to operate at any time (Suharto, 1995).

According to Soedrajat, 1984, the budget plan divided into:

(a) Rough Budget Plan

An interim budget plan is defined as the work is calculated by square footage. Work experience greatly affects rough expense interpretation; the results of this estimate compared to planning a carefully calculated budget are slightly different.

(b) Detailed Budget Plan

This is conducted by calculating the volume and cost of each work carried out so that the work can be satisfactorily resolved. The first step is how to calculate the unit cost, in which all the unit costs and the volume of each type of work are calculated. The result of the first step is called by index of unit cost analysis. The second step is calculation of the total cost by multiplying the volume of work with the index of unit cost analysis, as can be seen in the following figure:

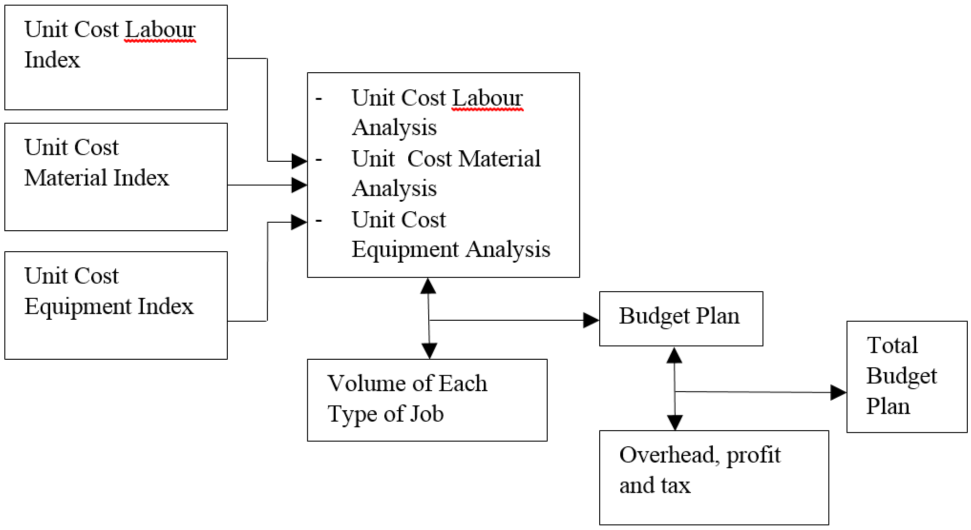


Figure 2.3: Unit Cost Analysis (Mukomoko, 1987)

Analysis of materials unit cost is the method to count the material used in the unit of work. Needed substance/material is the large amount of materials needed to complete the job in a single piece of work (Ibrahim, 1994 in Kurniawan, 2004).

Material requirements can be calculated by the following general equation:

The volume of material used = *index* × *volume of work* …………….. …….(2.2)

Quantum of materials index is an index that shows the required building materials for each unit of work. Analysis of materials from a unit of work is an activity to count the volume of material, as well as the cost of the required materials unit while the index shows the number of materials needed to produce 1 m3, 1 m2, the volume of work to be carried out (Ibrahim, 1993).

2.3.3.2 Wage Unit Cost Analysis

Analysis of the cost of a job is counting the amount of labour required, and the cost required for the job (Ibrahim, 1993) The need for labour is the large amount of energy required to complete the work in one unified piece of work; speed and completion of a job depends on the quality and quantity of their work (Kurniawan, 2004). In general, the amount of labour required for a particular job volume can be found using the equation:

$$\textit{Labour required} = \textit{index (SNI)} \times \textit{volume of work} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2.3)$$

Index of labour force is the large amount of labour needed to complete the job section in units of work (Ibrahim, 1993).

Employment levels and tasks of each method are as follows:

a. Workers: this is the type of labour workforce levels.
b. The mason is in charge of labour in terms of fitting stones in mortar or glue mixture on the construction work.
c. The foreman: in addition to serving as a bricklayer, this type of worker is also in charge of the other masons.
d. Head Foreman is the most powerful labouring role and the job is simply to oversee the work.

Before calculating the unit cost of the work, the contractor must be able to master how to use the analysis of BOW and SNI. In the analysis of BOW, the determined figure is the amount of labour and materials required for the job, while SNI is newer than the BOW analysis.

Principles contained in the BOW method include a list of the coefficients of wages and materials that have been set. There are two coefficients that will be obtained calculating the necessary materials and the calculation of waged work. The comparison and composition of materials and labour on the job has been set, which in turn is multiplied by the unit cost of the prevailing wage.

2.3.3.3 Uncertainty on a Construction Project

In making estimates of work unit cost for a construction project, there are several items that cannot be estimated precisely (unforeseeable), or cannot be stated clearly (intangible), or cannot be forecasted (unforeseen); all of them can be categorised as an uncertainty.

In encountering the uncertainty, it is necessary to allocate some amount of expenses for one of the components of the indirect cost, namely contingency. In allocating the contingency cost, assessment ability of the estimator is really required in order to avoid the cost overrun or cost under run that will cause loss.

Uncertainty estimating the work unit cost can be caused by two factors. They are external uncertainty factor and internal uncertainty factor (Skitmore, 1999).

(1) External Uncertainty Factor

External uncertainty factor is defined as uncertainty factors that are coming from the outside of the project. External uncertainty factors can be divided into several variables, such as economic variable, socio-cultural variable, geographical variable, and government policy variable on the construction sector.

(a) Economic Variable

Economic variable is one of the variables in the external uncertainty variable in making the estimate cost of the construction project; its nature, tendency and growth cannot be predicted precisely. The causes of this variable among others are: the growth and nature of this variable is closely related to the growth of the global economy and the prosperity of a country. The benchmark of the economic growth of a country/region among others can be seen from the growth of Gross Domestic Product (GDP) or Gross Regional Domestic Product (GRDP) and the growth of inflation.

The effect of economic uncertainty towards a construction project can be measured with several economic variable indicators, such as inflation growth indicator, interest rate, foreign exchange rate, regional minimum wage, and bank credit lending limit. The variable indicators above are closely related to the fulfilment of the resources required, such as material, equipment, capital, and human resources, and method of execution (Pemda, 2010).

(b) Inflation Growth

Inflation growth is defined as a value that shows a decrease of currency value to purchase goods at a certain period of time. The growth of inflation rate can be seen through the increase of goods cost that is caused by some factors, such as a high demand for goods (high demand), low production of goods (low supply), the increase of exchange rate against US dollar (imported inflation), etc. The growth of inflation rate shows the ability of society to fulfil their living needs.

The impact of inflation growth will also influence the construction sector, such as the increase of material cost, spare parts cost, and labour pay, and material shortage. Uncertainty in determining the growth of inflation rate in a period of execution causes the contractor difficulty in fixing the unit cost of material, equipment and wage.

(c) Interest Rate

In executing a construction project sometimes the contractor requires financial aid from the bank/non-banking sector; therefore the contractor will have loan interest (cost of fund) imposed on her/him. The interest rate will be determined by the Central Bank, Bank of Indonesia.

The interest rate applied absolutely depends on the growth of inflation rate and the exchange rate of the rupiah. The above factors often cause the interest rate to be changed in accordance with the current situation/condition of economic development. Interest rate very much influences the economic cycle, because a high interest rate will influence the rate of return on investment (ROI), and will make it difficult for a debtor to settle the credit loan and will then cause economic stagnation.

Credit loan for construction projects can be classified as short-term transactional credit or being adjusted to the period of project execution. Interest rate applied to credit is effective interest rate. On effective interest rate, the interest rate applied will be reviewed at least once in three months or adjusted to the current economic condition; that means the interest rates always fluctuate.

The above explanation shows that the interest rate of transactional credit will cause an uncertainty for the debtors to make precise interest rate estimates. Therefore, the debtor must be thoroughly observant in order to avoid the loss due to fluctuation of interest rate (cost fund) to be paid.

(d) Rupiah Exchange Rate

Rupiah exchange rate against US dollar is a conversion of rupiah currency against US dollar currency. In any trade transaction related to imported product/goods, generally the currency used is in accordance with the currency agreed, such as US dollar, Yen, and so forth.

In the last couple of years, the rupiah exchange rate against the US dollar has been depreciated by up to 400% compared with the exchange rate in 1996. As a result the cost of imported goods/material has significantly risen. And until now, the rupiah exchange rate against the US dollar is still fluctuating depending on the condition of the global economy, Indonesian social/political circumstances, and so forth (BI, 2009)

The impact of the depreciation and the fluctuation of the rupiah exchange rate against the US dollar will greatly influence the construction project because a lot of resources used (material and spare parts) are imported from foreign countries. Suppliers/manufacturers will adjust the selling cost of the goods/items, complying with the exchange rate applied upon the transaction made. As a result, in making the cost estimates contractors find it difficult to determine/predict the appropriate exchange rate that will be used in the future. So this matter makes rupiah exchange one of the uncertainty indicators necessary to be considered in arranging the cost estimates.

(e) Regional Minimum Wage (UMR)

Regional Minimum Wage shows a minimum income rate of labour/employee. The rate of Regional Minimum Wage is appointed by the government in terms of the region and type of work. The government decree on Regional Minimum Wage rate does not explicitly stipulate any consideration of scale of business, productivity and standard/certification of skill that must be possessed by labour/employee. This will make difficulty or uncertainty for the employer for illustrating the rate of Regional Minimum Wage associated with the situation/condition of the job site; as a result, this often causes a conflict between employer and labour/employee.

Regional Minimum Wage policy issued by the government does not clearly stipulate more detailed rate of pay on construction projects in accordance with the position, skill and experiences possessed by labour/employee. As a result, the rate of wage paid varies and is estimated in accordance with the judgement of the contractor or depending on the rate of wage publicly applied.

(f) Credit Lending Limit

Those contractors who have limited capital in developing their business will require financial aid or credit from a financial institution like a bank or /non-banking institution. Especially during 2010-2013 economic crisis has attacked Indonesia, causing the Bank of Indonesia (BI) to issue a policy to limit credit lending and credit dispensing. This policy really disturbs debtors who wish to extend their business.

When it comes to contractors, the credit provided is working capital credit (KMK), categorised as transactional credit. Credit in the construction sector is a kind of credit that has a wide risk. Credit risk is caused by two factors: incidents that can be controlled by management and/or incidents that cannot be controlled by management. The risks among others are: failure in execution of development, delay, rise of wage, abuse of fund usage, natural factors and difficulty in collection of receivables.

For contractors, the policy changes will make an uncertainty to obtain a credit loan as proposed within the period of time already planned. As a result upon making cost estimates, contractors will find it very difficult to ensure the sources and the amount of credit loan that will be obtained later.

(2) Socio-cultural Variable

Social/cultural life of a community group in Indonesia is very much influenced by tribe and custom. Custom and tradition of society will deliver a culture that will form and influence the character of the community. Indonesia, which consists of various tribes and customs, will deliver different social/cultural manners.

For contractors who do not very well understand the social/cultural manner of society around the project, this will deliver a value of uncertainty. The social/cultural uncertainty variable can be classified into three parts, namely: socio-cultural condition, attitude/order of society, and labour's attitude.

(a) Socio-cultural Condition

Various tribes in Indonesia deliver a variety of culture and social life of the community. Every tribe has a typical socio-cultural attitude. For example, the Melayu tribe in Kepulauan Riau: the society has an interesting socio-cultural condition among others, having a strong custom, family spirit and high cooperation and being famous for their trading skill and going overseas. This socio-cultural condition will influence the pattern of its society living. From Central Bureau for Statistics (BPS) data, it is obtained that most parts of society are merchants, farmers, and going overseas; the rest of them are working in the formal sector. Therefore, the impact on a construction project in Kepulauan Riau as a result of the above condition will be fewer people working on the construction project.

This result will cause an uncertainty towards productivity and quality of work performed by the labour.

(b) Attitude/Order of the Society

The Attitude/Order of Melayu society has a typical characteristic that has an impact/influence on the construction project, which is a sense of belonging to region or village; for example, where the community of a village possesses a high responsibility for their own village. However, this is often misused, such as forcing the contractor to involve the local society (workers) to work on the construction project without considering the skills and experience they have. Besides that, a community group still often collects illegal tax on behalf of village interests. Another impact felt is in the land-clearing case, where mostly the status of land in Kepulauan Riau is as communal land; as a result clearing the land often causes conflict.

The impact/effect above will cause an uncertainty for the contractor in making cost estimates because many conflicts with local society take place during the execution of a construction project; as a result it can cause delay in executing the project and increase the cost to complete the project.

(c) Labour Attitude

Labour attitude of the region is very much influenced by the socio-cultural condition. For example, in the Melayu society, people mainly work as merchants or farmers, resulting in fewer people working in the construction sector and difficulties in recruiting labour that has strong motivation and good skill/trade in the construction sector. Besides that, mostly the people who work in the construction sector still have farms/plantations in their village so when harvesting time comes they leave their work on the construction project. This will give the contractor difficulties in finding substitutes; as a result the contractor must recruit labour from outside of Kepulauan Riau Batam, and Pulau Jawa. The mixing of two groups from different societies often creates conflict and dispute in the field.

The above condition will influence the labour's productivity and quality of work. For that reason, in making cost estimates the contractor needs to take labour attitude into consideration as an uncertainty.

(3) Geographical Variable

Condition and geographical location of a region is closely related to natural resources contained in that region. Those regions that have overwhelming natural resources will very possibly be explored. Well-performed exploration will support the economy and the prosperity of local society. The province of Kepulauan Riau has one main natural resource, which is the fishery sector, whereas natural resources for the construction sector such as raw material for cement, wood, ceramics and coal are very limited. To fulfil the resource need of the construction industry sector in Kepulauan Riau province it is necessary to send in the resources needed, such as from Pulau Jawa, Medan, or imported from other countries.

Condition and geographical location of a region will influence the availability of resources, their accessibility and the physical condition of the project location.

(a) Geographical Location

Condition and geographical location is closely related to the available resources in one region. Kepulauan Riau, which is geographically surrounded by sea, possesses great resources in the fishery sector whereas its resources in the construction industry sector are very limited.

Fulfilling the resource needs in the construction industry requires support from infrastructure and adequate transportation; as a result resources can be made easily accessible. Disturbance of accessibility will influence the cost of transportation and schedule of resources' arrival such as delay and damage. Inaccuracy in determining transportation cost and schedule of resources' arrival will create an uncertainty on unit cost of material/equipment that will be offered and work execution time. For that reason, in making cost estimates the contractor must be able to predict the impact of uncertainty of the resources' accessibility on the execution of work.

(b) Resource Shortages in the Construction Industry

Resource shortages in the construction industry sector may result in material/equipment shortage. Material/equipment shortage will occur because the accessibility of resources is disturbed, consumer's demand for goods is very high or suppliers can rarely meet the need for a particular item if a large amount is required.

The resources shortage will result in several bad impacts for the contractor, such as delay in work execution, providing an opportunity for producer/supplier to increase the selling cost. For that reason, in making cost estimates the contractor is required to consider the uncertainty cost and the supply schedule of material/equipment that will be used upon the execution of work.

(c) Physical Condition

The physical condition of a project is closely related to the natural condition around it, such as climate, and land condition. Physical condition is very much influenced by geographical location of a region, such as a mountainous area will have a high level of rainfall and the soil is unstable compared to a low plain area. Kepulauan Riau province, which is in a coastal area, has a high level of rainfall and unstable soil; as a result landslides and floods often occur.

The above conditions will influence the accessibility and arrival schedule of resources; as a result this will result in an uncertainty towards the execution schedule of project and the cost to be spent. Therefore, before making cost estimates, the contractor is required to identify the physical condition of the project surroundings, such as by collecting and analysing the data/information.

(4) Government Policy Variable in the Construction Sector

In order to regulate the implementation of a construction project, it is necessary for the government of Indonesia to issue some policies, such as Government Regulation (PP), Presidential Decree, Law, and Local Regulation. In the policies issued, the government regulates the classification of contractor based on the type/subtype of work and contract value. Additionally, in general the policies made include the order of work bidding, right and responsibility of the parties involved, system/procedure of payment, settlement of dispute, and so forth. Having these policies, it is expected that contractors can perform the construction project complying with the resources and experiences they have.

The policy issued by the government is often changed in a short period of time and without consulting without consulting the interested parties. This condition often confuses and causes difficulties for contractors to understand and implement a policy (Tjaturono, 2007).

Therefore, the role of the government and the construction association is very much expected to introduce the policy made to the parties involved through training, workshop, or seminar. As a result the policy made will not create a new problem in the execution of construction projects. Otherwise, inadequate understanding or interpretation among the involved parties will create uncertainty towards a problem; as a result a conflict or dispute will appear in the execution of the project.

(a) Internal Uncertainty Factor

Internal uncertainty factor is defined as uncertainty factors that derive from the inside of project surroundings. Internal uncertainty factors can be divided into two variables, construction project complexity variable and project management handling variable.

(5) Construction Project Complexity Variable

Construction project complexity variable constitutes one of the internal uncertainty variables, bearing in mind the nature of a project is dynamic and there are different characteristics between one project and another project and of course there are different problems between one project and another project.

Complexity of a construction project can be seen from the scale/scope of the project that will be carried out, project location, period of project execution, and completeness/clarity of bidding documents.

(6) Project management handling variable, related to the managerial ability of the team involved, such as owner, consultant, contractor, supplier, appropriateness of the resources involved, and relationship between contractor and supplier.

(a) Scale/Scope of Project

Scale/scope of a project can be identified through project value and kind of work that will be performed. The bigger the scale/scope of a project, the bigger the risk it will create. Therefore, the contractor who will perform a project must be able to consider and believe that, with the resources possessed, s/he will be able to anticipate all incidents in accordance with the scale/scope of the project.

The bigger the scale/scope of a project, the greater possibility that upon making a cost estimate the contractor cannot identify and comprehend in detail the incidents that will occur in relation to the project to be carried out. Those restrictions will create an uncertainty value that will necessitate more money/funds to be reserved/allocated.

(b) Project Location

Understanding the nature of a project, which is dynamic and unique, can be obtained from the learning about the project location. Each project site will create some characteristics, such as accessibility to project location, resources' availability, society manner around the project, soil condition, weather, material/debris disposal, security of project surroundings, and so forth. The above characteristics will create an uncertainty value, especially regarding a location that has never been developed before.

For that reason, in making cost estimates the contractor is required to consider the things that will contain uncertainty value due to location of the project. The contractor can perform a site visit to the location of the project and interview either the people living around the project or the contractors that have ever done any work in the project location in order to obtain data/information required. The data/information is very useful for minimising the uncertainty value occurring due to project location.

(c) Period of Execution

Execution period of a project will depend on the quantity of work, type of work, productivity of equipment, and labour. For the quantity of work and type of work, cost estimates can be made with a high accuracy; whereas, in calculating the productivity of equipment and labour, there are many influencing factors, such as amount of wage, labour attitude, surrounding conditions, type of work, physical condition of project and so forth. Those factors mean that the period of execution of a construction project cannot be estimated precisely.

In making estimates for a quotation, it is necessary to consider things that will create uncertainty towards the execution of the schedule of work because, in encountering the uncertainty, some fund is required in order to meet the execution schedule already planned. For that reason, in arranging the execution schedule it is necessary to consider the ability and the availability of resources owned along with considering other influential factors.

(d) Clarity/Completeness of Bidding Document

Contractors will receive the bidding document when they have already passed the pre-qualifying round and are interested in proposing a quotation. The bidding document contains drawing, format of quotation letter, explanation and technical requirement, explanation and administrative requirement, and bill of quantity. In relation to content and comprehension of the bidding document, contractors are provided with several days to learn the bidding document, and then an explanatory meeting will be held together with a site visit to the project location. At the meeting the contractor can ask any question in relation to the content of the bidding document and site visit to the project location.

As the time provided by the bidding committee is very short, it is difficult for the contractor to be able to comprehend the drawing and technical/administrative explanation, which often causes misinterpretation and misunderstanding about the content of the bidding document. When the contractor wins the bidding, then the content of the bidding document along with its amendments made in the explanatory meeting will become a part of the contract. Therefore, any mistakes made will become the responsibility of the contractor.

The contractor is expected to be able to identify and comprehend the content of the bidding document thoroughly in order to minimise things that create problems or risk upon the execution of the project later; whereas, according to the research conducted by Cretu et al. (2011), uncertainty/risk that will be faced by the contractor is more caused by the internal condition of the project, such as complexity and managerial ability. So, the uncertainty/risk found can be divided into 3 (three), as follows:

(i) Uncertainty caused by the project itself, such as project scale, location of project and so forth.

(ii) Uncertainty caused by team involved, such as performance and owner credibility, experiences and skill possessed by either planning consultant or supervisory consultant, and government party.

(iii) Uncertainty caused by estimate processes performed by the contractor, such as ability and experiences owned by estimator, and the truth of the information obtained.

From the two above opinions, further study about the uncertainty that occurs in construction projects in Indonesia can be conducted. The uncertainty in construction projects in Indonesia will be more complex, bearing in mind the condition of our country having a variety of social-cultures, geographical condition, low education level, unbalanced economic living of the society, social political unrest, and unrecovered economic crisis. The above circumstances will have a big impact on the completion of a good project.

Having understood the above matters, uncertainty in construction projects in Indonesia can be classified into two factors namely, external uncertainty factor and internal uncertainty factor:

a. External uncertainty factor is an uncertainty factor coming from the outside of the project surroundings, and can be divided into several variables:

   (i) Economic variable, related to the economic condition, such as inflation rate, interest rate, exchange rate to US dollar, regional minimum wage, and credit limit provided by banking/non-banking.

   (ii) Social culture variable, related to behaviour/order of the society at the project location, and labour behaviour.

   (iii) Geographical variable, related to the project location which influences the accessibility to resources.

   (iv) Government policy variable, related to the policy made by the government concerning the construction sector.

b. Internal uncertainty factor, which is uncertainty factors that derive from the inside of the project surroundings, can be divided into two variables, as follows:

(i) Project complexity variable, influenced by scale/scope of project, project location, period of project, and administration/technical factors.

(ii) Project management handling variable, related to the managerial ability of the team involved, such as owner, consultant, contractor, supplier, appropriateness of the resources involved, and relationship between contractor and supplier.

CHAPTER 3

COST MODELLING

3.1 Introduction

According to the Fontana Dictionary of Modern Though (Bullock and Stalybrass, 1977), a model is “A representation of something else, designed for a special purposes”. The ‘something else’ here is what is known about the prototype (Aris, 1978). The ‘purpose’ can be either to remind, discover or explain.

Symbolic models are the most common type of technical model and are the most convenient ones for analysis. These models represent the elements of the prototype and their relationships in the form of symbols. They can be used to test the robustness of a solution by sensitivity analysis through ‘what if’ type experiments. These specific models are also useful for extrapolation and experimentation generally. In many ways symbolic models are like theories in that the model should therefore determine what data are needed and should be collected.

According to Gilchrist (1984), the modelling activity itself involves an iterative process of model identification and fitting. Identification is the process of finding or choosing an appropriate model containing the set of useful elements and their functional relations for the required purpose. The two basic approaches to identification are the conceptual approach and the empirical approach. At the extreme, conceptual identification seeks a model on the basis of rational argument from some knowledge of the domain, but without reference to any actual data. Empirical identification considers only the data and their properties without reference to the meaning of the data or the situation in which they arose. Model fitting is the process of moving from the general form to the specific numerical form by assigning value to the functional relations in the model.

The model should be used with care and not pushed beyond the limits of its validity. Two broad approaches to model validation are the black box approach and the white box approach. Under the black box approach the model's internal structure is assumed to be obscure but its performance can be observed. The idea is thus to compare the output of the prototype itself under the same stimuli. In contrast, the white box approach involves the detained comparison of the model and prototype structure. Which of the approaches is used depends largely on the purposes of the model – the performance approach often being used to test discovery models and the structural validation approach for explanatory models (Skitmore and Marston, 1999).

3.2 Estimating Construction Cost

One of the most important concerns in any construction project is its cost. In order to control the cost within an acceptable level, appropriate and accurate measurement of various project-related determinants and understanding of the magnitude of their effects are required. According to previous studies which have been conducted by Songer and Molenaar (1997) and Konchar and Sanvido (1998), a list of metrics to measure and compare the performance of constructions project has been identified. Other empirical studies (Akintoye, 2000 and Chan et al., 2001) have identified the determining factors and assessed their impact on project cost.

A common finding of such studies is that cost is affected by a large number of factors. This can be explained by the fact that construction is a multidisciplinary industry and its work involves many parties such as owners, professionals, contractors and suppliers. Therefore, integrated efforts of the various parties and their decisions regarding the design, technology and implementation of a project can have a significant effect on the overall project cost.

Studies carried out by Trost (2003) and Ling (2004) to establish the relationship between determining factors and cost applied the ordinary least square regression approach and, based on the coefficient of multiple determination of the R2 value, then chose the best model. However, this approach tends to produce regression coefficient estimators that will perform poorly in the presence of multicollinearity, which is likely to surface due to high correlation among a large group of variable. In addition, the variance of the ordinary least square estimator becomes inflated, which results in the low possibility of the estimator being close to the true value of the regression coefficient.

3.3 Cost Modelling

According to Ferry and Brandon (1994), cost modelling is defined as the "the symbolic representation of a system, expressing the content of that system in terms of the factors which influence its cost". The 'system' is determined through extensive analysis of cost data of a building which influences its cost and after being satisfied with the ability of the system to give acceptable output for an established series of input data. Cost modelling, as a term, is used when referring to estimate construction costs for clients, designers and contractors. As Asworth and Skitmore (1983) represent, reliability and acceptability of a model is largely dependent on estimating the accuracy of the model's output. Typically, the cost estimate is least accurate at the conceptual stage but increases in accuracy as the design stage approaches finalisation (detail estimating), particularly culminating in the tender period. Based on Ashworth and Skitmore (1983) review of the literature, there is a wide variety of opinion on accuracy in the early design stages, which seems to be on the order of 15 to 20%, improving to approximately from 13 to 18% at the detailed design stage. Moselhi (1997) set of figures differs slightly and contains additional probable accuracy levels at both the conceptual and preliminary stage. The levels, which are from ±50% to ±30% at the conceptual stage, reduce to ±28% to ±15% at the preliminary stage, ±15% to ±10% at the early design stages and finally ±10% to ±5% at the detailed design stage.

Skitmore (1998) research points to a typical relationship between the percentages of estimating error and project stages in the graphical format. Also, another research by Barnes (1979) indicates that forecasting accuracy is improved by increasing the number of items in the forecast.

Generally speaking, a good model should incorporate the following criteria:

(1) The input data for the model should be freely available in the appropriate form and adequate to fulfil the minimum requirements.

(2) The reliability of the model will suffer if there is inadequacy of data.

(3) The model should have the flexibility of continuous updating of data as new data become available.

(4) The model should be able to react to the changed circumstances and to maintain accuracy as a result of the evolutionary nature of the construction industry.

(5) The model should be simple enough for manipulation and easy to understand.

(6) The accuracy of the model output should be adequate to present what it is attempting to predict.

According to Helyar (1978), there are two factors that always affect the cost of construction. First, external factors: material costs, labour costs, equipment costs and the cost which is affected by the national economic policy (inflation, market and interest rate). Second, the internal factors: factors such as types of building, location, the site's shape, size, height, exterior cladding planning efficiency, materials, and the type of contract.

The attractiveness of models lies in attempting to provide simple and straightforward answers to very difficult and complex problems. They tend to be rules of thumb which unfortunately sometimes become more important than the solution itself. The situation is probably even more complex than this because the estimators' own method of pricing may have little resemblance to the manner in which costs are incurred on site. There is a touch of unreality about these models, and what the participants in this forecasting process appear to be doing is trying to match one simplified model with another model that is slightly more complex. Modelling the reality, i.e. the way costs are incurred on site, does not enter into the process until operational costs are considered, usually at the post-contract stage.

Cost modelling may be defined as the symbolic representation of a system, expressing the content of that system in terms of the factors which influence its cost. In other words, the model attempts to represent the significant cost items of a cash flow, building or component in a form that will allow analysis and prediction of cost to be undertaken. Such a model must allow for the evaluation of changes in such factors as the design variable construction method as timing used in the models for estimating and planning cost evolve gradually. Their adoption by the profession at large has led to the establishment of what might be called a traditional technique (Beston, 1978).

3.4 Descriptive Model

Based on Beeston (1987) definition, descriptive models are formulae in which the variable describes the design and its environment by measurements of such factors as size, shape, type of construction and location. The coefficient of the factor represents the best combination for estimating the way in which cost depends on the factor. The effect of a particular choice in a feature of a design can obviously only be measured by a regression model if the factor which describes the feature is present. But even if the appropriate factor is present its effect is likely to have been contaminated by its having to stand as proxy for other factors which are not selected during the analysis and which are, even to a small extent, correlated with it. In any case, the mechanism producing variability is much more complex than could be represented by the comparatively few variables for which it is practicable to obtain data and which quality for inclusion in the regression formula (Beeston, 1987). If there is much variance caused by factors outside the model domain then we must examine why we need to use models.

A descriptive model can be defined as refinements of the crude $/m2 approach to costing which is applied at some stage, at least informally, to every design. If there had not already been well-tried quantity-based methods, the next logical step in development from unsatisfactory descriptive models would have been to link costs to parts of a building by calculating the costs of per unit quantity including the cost of putting the materials in place (Beeston, 1987).

3.5 Realistic Model

A proper representation of the effect of a design change can be obtained only by calculating its effect on the whole construction process. This can be done by calculating costs in the way in which they arise, or as closely as possible to this ideal. The models can be described as realistic. The limitations are the ability to describe and collect data for construction methods, the ability to handle complexity and the extent to which all contractors can be represented by the same model. These are soft limitations in that there is continual movement towards perfect representation with no definite point at which it must stop. Techniques are rapidly improving to extend the first two limitations and although there are still some differences between contractors their methods are already quite similar and further industrialisation, whereby the site process becomes little more than the assembly of large components, should make them still more similar. The production of realistic models can be tackled in several ways. Three attractive approaches can be described as follows (Beeston, 1987):

(1) The simulation of construction in detail;

(2) Attaching costs to activity networks;

(3) Representing the decision process of a planner when calculating the plant and labour requirement of a design.

A problem associated with the new wave of cost models, particularly those involving statistical analysis, such as regression, is that they are by their nature black box technique (Beeston, 1973).

The realistic methods place much greater reliance on numerical information of site performance. Simulation offers the chance for greater analysis and experimentation because it can retrace the steps and investigate the point where the cost is incurred. Human performance is a variable and the interaction of human performance on site has a major impact on cost. With simulation, it can investigate the results of this interaction repetitively and provide probability ranges. Unlike the unit cost, element, bill of quantities, and operation cost procedure there is not a changing model structure as information is refined.

3.6 Model Structure

The model structure is the overall representation of the prototype in its model form. It contains appropriate elements and functional relationship. Cost models are those where the construction production process is modelled.

For many years contractors had different ideas of how much to allow for rapid inflation. This made accurate estimating impossible and the existence of high inflation provided a ready excuse for poor estimating. The demand for a better technique was small, but with the recent comparative stability of prices the need for improved methods is easier to perceive and the low accuracy of methods based on approximate quantities and elements is less acceptable. Based on Besston (1987), all estimating methods can be described as models. A cost model's task may be to estimate the cost of a whole design or of an element of it or to calculate the cost effect of a design change. It can be classified as in place quantity-based, descriptive or realistic. Although it is possible to use different types of model for different purposes it is sensible to aim to find a common basic method for all applications. Then cost advice at various stages can lead smoothly to the final estimate and cost control by the contractor.

Two types of cost model structures are identified in several studies and both are symbolic. The first type models the cost C as a function of a useful set of product elements:

$$C = f(p_1, p_2, \ldots) \quad \ldots\ldots (3.1)$$

Whilst the second type models the cost as a function of a useful set of production process elements, r1, r2... etc., required for design realisation:

$$C = f(r_1, r_2, \ldots) \quad \ldots\ldots (3.2)$$

Process-based resources measure such factors as the number of men and machine hours and quantity of materials.

This is particularly true for the process elements, which are themselves a rather poorly understood function of the building design and those true value are seldom (if ever) known by the cost modeller. The nature of cost modelling is such that the element and function value cannot be derived in the absence of a target project and therefore their derivation is necessarily a part of the project cost estimation, or implementation, phase of the project.

For specific projects, implementation often takes the known functional values extracted from a selection of similar completed projects, with suitable subjective adjustment for dissimilarities, such as market condition, with the perceived target project characteristic. In this case the size and selection of the sample taken is a decision problem in its own right, with the degree of similarity between the sample project and the target project characteristic (principle of homogeneity) being the key issues regression (Kouskoulas and Koehn (1998), and fuzzy set type models of course generate functional value estimates automatically through the analytical procedures embodied in the approach.

The validity of a cost model effectively depends on three factors:

(1) The purpose of the tasks supported by the model and hence the purpose of the model itself.
(2) The usefulness of the elements in the model.
(3) The accuracy with which its values and functional relationships are estimated.

According to Pratt (1995), structural validation in cost modelling or white box is a method of testing how good a model is by comparing the structure of the model with its prototype. White box validation is only possible with production process models.

The role of estimating in the construction industry estimates serves six main functions:

1. An estimate of the probable cost of construction work is required in the early stage of a building programme in order to determine whether or not a project is

financially feasible. As they are required at a time when the project is often little more than a vague idea, cost estimates should be produced from the most minimal detail, as the design process will not begin until the owner is satisfied that the cost of proceeding with it is justified.

2. Estimates at this stage of the project are known as conceptual estimates, which we consider only briefly in this text as their preparation is very different from that of contractor's estimate.
3. Estimates are also required in cost control programmes to facilitate the control of the expenditure of funds on a project.
4. Cost management during the design stage of a project includes the consideration of alternative design and components, which requires a series of preliminary estimates to be prepared so that informed decision may be made on what to include in the design.
5. Later, when the construction work is underway, estimates are again utilised, this time by the contractor, to provide a budgetary control system that enables her/him to identify production deficiencies so that timely action may be taken to correct problem and maintain profit margin.
6. Most contracts that transpire in the construction industry result from competing bids from contractors to supply goods and services to meet certain specifications for a stipulated sum of money. The sum of money contained in such a bid represents the total amount that the contractor will receive for performing the work described in the contract. An accurate forecast of the cost of this work is necessary if the contractor is to profit from her/his endeavour and be competitive. Providing this cost forecast is the prime function of the contractor's cost estimate prepared from the drawings and specification supplied by the owner to denote the extent of the contract work.

3.7 Purpose of Cost Modelling

Cost Model, which is based on a conceptual model, is an estimating model prepared using engineering concepts and avoiding the counting of individual pieces. Modelling and implementation involve a considerable degree of judgement on the part of the modeller and implementer, due to the inherent uncertainty and complexity of the prototype.

According to Wilson (1984), the purpose of cost models generally is to support at least one of the following tasks:

1. Forecasting the total price that the client will have to pay for the building, at any stage in the design evolution.
2. Comparing a range of actual design alternatives, at any stage in the design evolution.
3. Comparing a range of possible design alternatives, at any stage in the design evolution.
4. Forecasting the economic effects upon society of changes in design codes and regulations.

3.8 Classification of Cost Models

All such cost models have been collected by Ashworth and Skitmore (1983), Skitmore and Patchell (1999), Newton (1991), and Fortune and Lees (1996) and set out classification of the techniques currently in use. Although the terms that they use to describe the classification may be different, the characteristic of each classified group is quite similar. It is felt that the grouping of cost models as used by Fortune and Lees (1996) is sufficient to represent most of the cost models.

3.9 Design Aspect

Architecture is concerned with the creation of space. A good building design will capture and articulate space to satisfy both quantitatively and qualitatively the demands of the process to be accommodated. The total number of design decisions that must be taken is enormous. They vary, for example, from the choice of structural frame type to the position of light switches, from the number of storeys to the type of window fastening. It is convenient to regard the decisions as design variables which simply take different values in different buildings. Since these decisions can determine the nature of the building, they cause increments to the cost of building. Thus:

Cost, $C = f_1(v_1, v_2, v_3, \dots, v_{24})$……………………………………………… (3.3)

Where v_1, v_2, etc. are design variables.

However, the cost of the building work actually incurred and price is usually expressed, not in terms of design variable, but in terms of the resources of all kinds which the design decisions commit. Thus:

$C = f_2(\sum R_j)$……………………………………………………………… (3.4)

Where R_j are the resources committed.

The central task of cost modelling is the reconciliation of equations (3.3) and (3.4). It is possible to recognise differences between these two, although not mutually exclusive, approaches to the construction of cost models.

3.10 Deductive Approach

Deductive methods involve the analysis of cost data over whichever design variables are being considered, with the objective of deriving formal mathematic expressions which succinctly relate a wide range of design variables' value to cost. This approach draws heavily upon statistical techniques – correlation and least squares regression in particular. Disadvantages of this approach arise from the not inconsiderable limitations of these statistical techniques, and from the total dependence upon the suitability of the cost data used.

3.11 Inductive Approach

Inductive methods, on the other hand, involve not analysis of a set of given cost data but rather the synthesis of cost of individual discrete design solutions from the constituent components of the design. Whilst deductive methods are, perhaps, more important in the early stages of design, inductive methods are more important in the later stages. Deductive methods arise largely from equation (3.3) and inductive methods arise largely from equation (3.4). Inductive methods require the summation of cost over some suitably defined set of subsystems appropriate to the design. The most detailed level of subsystem definition would be the individual resources themselves, but several other levels of aggregation are in common use, e.g. operational activities and constructional elements.

3.12 Exploration of Cost Modelling

Below are the types of cost modelling development in the UK since late 1950 (Raftery, 1987).

3.12.1 Unit Method

This method assumes that there is a close relationship between the number of functional units it contains.

Total Cost = Unit price of a function × *Number of function units* ………… (3.5)

3.12.2 Cube Method

This method is based on the volume of space.

Cost = Rate per cubic volume × *volume of building* ……………………….. (3.6)

3.12.3 Storey Enclosure Method

The storey enclosure method was introduced by James (1954) as a result of many defects of the cubing and unit rate methods.

3.12.4 Artificial Neural Networks (ANNs)

If the data are structured into elemental format, then the output of the techniques can be used for cost planning, cost balancing and cost comparison. When combined with probabilistic techniques, the method can be further extended to handle risk and uncertainly that are inherent in the construction industry. It is one of the most promising techniques and is further proven by the large number of papers presented in both the United Kingdom and United States.

The newer generation of cost modelling techniques tends to capitalise on the computational power of computers. The theory of some of the techniques is complex and may be difficult to understand. Although the problem can be overcome by creating a customised computer program to handle all complex and tedious tasks, it would not be good for the general acceptance of the models if users do not have clear understanding of the techniques. Many of these techniques capitalise on the human intelligence processing system but there are still many obstacles that need to be overcome especially on the capture and transformation of experts' knowledge into the database.

Table 3.1: Cost Modelling (Skitmore 1999)

No.	Estimate Techniques	Model	Relevant Contract Type	General Accuracy (cv)	Det/ Prob	Type	Det/ Prob	Derivation Data Base	Current	Det/ Prob
1	**UNIT**	$P = f,(q)$	All	25-30%	Det	any comparable unit, e.g. tonne steelwork metre pipeline	Det	Averaged price-cost unit	Direct	Det
2	**GRAPHICAL**	$P = qr$	Process Plant	15-30%	Det	ditto	Det	Trended price-cost unit	Interpolated	Det
3	**FUNCTIONAL UNIT**	$P = qr$	Buildings	25-30%	Det	ditto e.g. number of beds, number of pupils	Det	Averaged/ rule price-cost unit	Direct	Det
4	**PARAMETRIC**	$P = f(q_1 q_2 q_3 \dots)$	Process	15-30%	Det	process parameters e.g. capacity pressure, temperature, materials, cost index	Det	Averaged/ rule price-cost parameter	Direct	Det
5	**EXPONENT**	$P_2 = {p_2}^{\frac{q_2}{q_2}}$ $P = \sum f_{act1} \sum q\, r_1$	Process Plant	15-30%	Det	size of plant or equipment e.g. capacity	Det	Averaged/ rule price-cost exponent	Direct/ Interpolated	Det

Table 3.1, Continued’

No.	Estimate Techniques	Model	Relevant Contract Type	General Accuracy (cv)	Det/ Prob	Type	Det/ Prob	Derivation Data Base	Current	Det/ prob
6	**FACTOR**	a)m=1(lang method) b)m>fact1=$fact_2$ etc.(hand method) c)$fact_1$=u(a_1,b_1)Chiltern method	Process pl#ant	10-15%	Det	any	Det	Averaged/ rule price-cost	Factored	Det
7	**COMPARATIVE**	$P_2 = P_1 + \sum(P_1 + P_2)$	All	25%-30%	Det	depends on differences	Det	Price-cost items	Adjusted	Det
8	**INTERPOLATION**	$P = qr$ $P = f(P_1, P_2, \ldots)$	Buildings	25%-30%	Det	gross floor area	Det	$price/m^2$	Interpolated	Det
9	**CONFERENCE**	$P = qr$	Process Plant	1	Det	any	Det		Negotiated	Det
10	**FLOOR AREA**	$P = qr$	Buildings	20-30%	Det	gross floor area	Det	averaged $price/m^2$	Direct	Det
11	**CUBE**	$P = qr$	Buildings	20-45% (based on 86 cases)	Det	volume	Det	averaged $price/m^2$	Direct	Det

Table 3.1, Continued'

No.	Estimate Techniques	Model	Relevant Contract Type	General Accuracy (cv)	Det/ Prob	Type	Det/ Prob	Derivation Data Base	Current	Det/ prob
12	**STOREY ENCLOSURE**	$P = \sum q_1 r_1$	Buildings	15-30%	Det	floor/wall area/ basement/ roof	Det	averaged price/SE unit	direct	Det
13	**BQ PRICING**	$P = \sum q_1 r_1$				SMM	Det	averaged BQs	direct	
	a) conventional	$P = \sum q_1 r_1$	construction	10-20% (5-8% for builder)	Det					Det
	b) B fine	$P = \sum q_1 r_1$	Buildings	15-20%	Prob					Prob
14	**SIG. ITEMS**		PSA Buidings	10-20%	Det	SMM	Det	averaged BQs/rule	direct	DET
15	**ELEMENTAL**	$P = \sum q_1 r_1$	Buildings	20-25%	Det	BCIS/CI afb entities	Det	averaged BQs/ BCIS/	composited/ direct	Det
16	**CPU**	$P = \sum q_1 r_1$	Buildings	20-25%	Det	similar	Det	averaged BQ	composited	Det

Table 3.1, Continued'

No.	Estimate Techniques	Model	Relevant Contract Type	General Accuracy (cv)	Det/ Prob	Type	Det/ Prob	Derivation Data Base	Current	Det/ prob
17	**APPROXIMATE QUANTITIES**	$P = \sum q_1 r_1$				SMM combined few				
	a)(Conventional)	$P = \sum q_1 r_1$	construction	15-25%	Det		Det	a)averaged BQ/price book	composited	Det
	b)(Gleeds)	$P = \sum q_1 r_1$	buildings	15-25%	Det		Det	b)averaged BQ/price	composited	Det
	c)(Gilmore)	$P = \sum q_1 r_1$	buildings	15-25%	Det		Det	c)averaged BQ/price book	composited	Det
	d)(Ross 1)		buildings	25% (based on 17 cases)	Det/ Prob		Det	d)50 BQ's averaged	direct	Det
	e)(Ross 2)		buildings	50% (based on 17 cases)	Det/ Prob		Det	e)50 BQ's averaged	mathematically	Prob

Table 3.1, Continued'

No.	Estimate Techniques	Model	Relevant Contract Type	General Accuracy (cv)	Det/ Prob	Type	Det/ Prob	Derivation Data Base	Current	Det/ prob
	f)(Ross 3)	$P = \sum q_1 r_1$ $P_1 = a + bq_1 + e$ $e = N(o, o^2)$	Buildings	30%(based on 17 cases)			Det	f)50 BQs	mathematically	Prob
18	**ELSIE**	$P = \sum q_1 r_1$	Offices		Det	DBE	Det	averaged BQ/rule	direct	Det
19	**NORMS** (Schedule)	$P = \sum q_1 r_1$	Buildings	10-20%	Det	SMM type eg PSA schedule	Det	cost-based rules	direct	Det
20	**REGRESSION**	$P = a + \sum a_1 b_1 + e$ $e = N(o, o^2)$	All	15-25%	Det/ Prob	usually contract characteristics e.g. floor area, number of storeys	Det	any	mathematically	Prob
21	**LU QIAN**	$P = \sum q_1 r_1$	buildings	1	Det	usually contract characteristics e.g. floor area, number of storeys	Det	any	mathematically	Det

Table 3.1, Continued'

No.	Estimate Techniques	Model	Relevant Contract Type	General Accuracy (cv)	Det/ Prob	Type	Det/ Prob	Derivation Data Base	Current	Det/ prob
22	**RESOURCE** (Activity, operational, scheduling)	$P = \sum q_1 r_1$	All	5-8% builders	Det	resource e.g. man hours, materials, plant	Det	average cost	direct/ analytical	Det
23	**PERT-COST**	$P = \sum q_1 r_1$	All	N/A		usually time resources e.g. man hours	Prob (time)	–	–	–
24	**CPS**	$P = \sum t_1 r_1 + \sum n_1 r_1$ $t = f(o^1, o^2)$	Buildings	6.5% (based on 4 cases)	Prob	resource e.g. man hours, materials, plant	Prob (time)	average cost	direct	Det
25	**RISK ESTIMATING**	$P = \sum q_1 r_1$	construction	N/A	Prob	any	Det	theoretical frequency distribution of cost	random selection	Prob
26	**HOMOGENISED ESTIMATING**	$P = \sum q_1 r_1$	Buildings	N/A	Det	any	Det	average BQ	direct	Det

3.13 Variability of Price and Cost Data

Cost planning and estimating rely heavily on historic price data. The reliability of these data can be measured by the consistency that they exhibit when many prices are obtained relating to the same item description. The item may be as small as an entry in a bill of quantity or as large as the value of the whole building.

Even if repeat prices are not obtainable, this concept of variability is still useful. Any price should be looked upon as a member of a huge imaginary family of prices for, as near as we can define it, the same item. The prices in the family have different values, any of which could by chance have occurred instead. The one that did occur is no more correct that any of the others. If there is a right price it is some sort of average of all the possible prices in the family, but if we have only one price we do not know where it stands in relation to the average.

Contractors have to bear the majority of the risks pertinent to a project, as specified in the contract documents. In a highly competitive international market, marginal cost overruns can easily erase contractors' profits and may lead to major financial problems (Gorgan, 1995). Hence, project managers involved in international construction need to identify major country risk sources causing cost overruns in advance, and the price to be proactive in managing them. The major concern for the project manager, when project progress is affected by a risk situation, is to assess and select the most effective response to forecast the effect of country risk, and to apply mitigating strategies before actual project performance suffers. If factors leading to a country risk can be identified in advance, then techniques for managing the risk can be an integral part of project design and implementation. To minimise the effects of country risk, a systematic approach to the management and assessment of project risks and uncertainties in the planning phase is required. International firms usually allocate contingency allowances in the budget to provide for unforeseen circumstances based on country and economic factors. The project baseline budget is modified according to the magnitude of country risk expected for the project in the form of a contingency added to budget cost. The provision of risk allocation should ensure that the budget set aside for project execution is realistic and sufficient to contain the unforeseen cost increases due to this risk; the cost effect of each significant risk factor should be analysed to determine realistic cost estimates for projects. A realistic estimate that quantifies an appropriate allowance for all those risks and uncertainties is usually anticipated from experience and foresight (Perry, 1986).

Risk identification is a difficult task because it is often highly subjective, and there are no unerring procedures that may be used to identify construction risks other than relying heavily on the experience and insight of the key project personnel (Bajaj et al., 1997). Nevertheless, it is still possible to approach country risk in a systematic way. Risk involved in a project can be identified by subdividing a project into its major elements, and analysing in detail the risk and uncertainty associated with each. Each work centre can be treated as a risk centre. The amount of contingency allowance to be allocated for each will be different. The reasoning used by the project manager in predicting the expected risk performance requires an understanding of the characteristics of the project work and the environmental attributes surrounding the work that contribute to a particular performance.

Risk evaluation of construction projects requires the analysis of various construction processes in order to account for the involved and perceived risk associated with these processes. It can be observed that the cognitive process of the project manager leads to a conceptual representation of the circumstances surrounding a project performance at a given time, in order to forecast the expected risk effects. This representation includes functional relationships among various factors causing risk and the cost performance of the project. Any prediction of the effect of country risk requires a clear understanding of the key country risk variables that impact the performance of the project.

Risk does not completely follow historical data; rather, it also depends on environmental factors. Most projects contain a number of reasonably standard and recognisable country risk situations (Bajaj et al., 1997). In such situations, the judgement of the project manager plays an important role in forecasting country risk, rather than basing the estimate on historical frequencies.

Once the risk variables that affect the cost are identified and the cost's status is determined, an expert in country risk can make intuitive judgements about the expected influence of these variables on the risk parameters, based on analogy and without the necessity of deep reasoning. A project manager uses her/his expert knowledge, gained through education and experience in the construction environment, to identify the magnitude of variation in cost from the reference project cost. This knowledge includes technical skills; economic, country, and financial knowledge; and social, communication, and legal skills, as well as country knowledge. A systematic pattern of these judgements can be coded and represented in a neural network. The list of country risk source variables will act as the input variables for the network, while the expected variance rating due to the perceived risk, represented in a suitable form, will be the corresponding output variables.

Construction risks are frequently project-specific. These are sometimes accounted for by estimators by adding a risk premium to the tender cost estimate. Consider the tender summarised in Table 3.1, this was prepared by an estimating group in a workshop on estimating technique. The estimate is for an office building in Daman; costs are given in Finnish marks.

Estimators have long been aware of construction risks but traditional methods of including them in the calculations have tended to obscure the issues. The approaches described here attempt to capture the estimator's perception of risk in a realistic way by eliminating the need for the estimator to make one best estimate for each variable. Instead s/he may enter into the calculation a description of her/his complete judgement made in the form of probability distribution. The method consists of combining these probabilities and calculating the resultant outcome. This is done in a non-mathematical way by generating a large number of projects with the general characteristic of the one in hand and observing the pattern of the result. In fact, a statistical analysis is made of the results just as if they were a sample of actual projects. This method of analysing risks for large capital investments has been described in detail by Hertz (1979).

Various factors have been identified by Skitmore (1988), Rapier (1990), Pearl (1994), Eschenbach (1996), and Moselhi (1997). Some of the more prominent ones are:

(a) Design criteria

(b) Product specification

(c) Item not originally included in the drawing or not thought of

(d) Changes of design that occur during detailed engineering and construction

(e) Quality and thoroughness of detailed design

(f) Contracting strategy

(g) Type and conditions of contract and condition

(h) Geographical and environmental decision

(i) Project management skill

(j) Procurement policy and country decision

(k) Degree of cost control and schedule control

(l) Regulatory requirement, environmental, legal and operational constraints, pending legislations

(m) Personal fluctuations and labour relations

(n) Market and economic conditions

(o) Interest rate and inflation

(p) Financial capability

These factors are largely unknown and unpredictable and are ultimately translated into the cost estimates. Each assumption of an unknown factor involves a high degree of uncertainty and when combined can multiply into a total uncertainty of critical proportions. This is where the element of risk enters and it is the evaluation of risk that is most essential. Since building projects tend to involve longer-term and substantial investment, the associated risk and uncertainty are likely to be significant.

A sound management in this sector will have great impact on the economy of the country as it involves a huge workforce, suppliers of building material, manufacturers and other professionals. The most important component of sound management is none other than cost efficiency. Since the construction industry is inherent with risk and uncertainties, incorporation of these factors is a necessity for producing reliable cost models.

3.14 Cost Indices

When constructing an index for a complete building, the task becomes more complex although the same principle applies. A typical procedure can be summarised as follows:

1. A typical building is selected for analysis into its constituent proportions of labour, plant and material.

2. Analysis takes place and the building resources are allocated under various headings to suit the representative cost factors for which information is available.
3. The different types of labour are identified and the basis for evaluation of a unit of labour cost identified; usually this would include the following:
    (a) Changes in the hourly or weekly wage rate as determined by agreement of the parties to the wage-fixing body
    (b) Change in productivity
    (c) Change in location
    (d) It may be necessary to assume a particular geographical position for the typical building in order that regional differentials can be ignored.

By bringing together all the variable information relating to a project such as fees, land purchase, holding cost etc., the client is able to obtain information important in the decision-making process. The largest variable in the equation is usually the building cost; most other factors are established by market forces, such as land cost and rent. It is at this stage therefore that the budget figure for the building cost will be established, despite the normal lack of substantial definition as to form, function and quality.

3.15 Risk Assessment

Assessing risk and assigning contingency to the base estimate is one of the most important tasks in preparing early estimates. Risk assessment is not the sole responsibility of the estimators. Key members of the project management's team must provide input on critical issues that should be addressed by the estimators in assessing risk. Risk assessment requires a participatory approach with involvement of all project stakeholders including the business unit, engineering, construction and the estimating team.

The owners are responsible for overall project funding and for defining the purpose and intended use of the project. The design organisation is responsible for producing the contract document, and the plans and specifications to construct the project. The estimating team is responsible for preparing an estimate of the probable final cost to construct the project, including direct and indirect costs and assessing risk and assigning contingency

Typically, risk analysis is a prerequisite to assigning contingency. Based on the acceptable risks and the expected confidence level, a contingency is established for a given estimate. Risk analysis and the resultant amount of contingency help management to determine the level of economic risk involved in pursuing a project. The purpose of risk analysis is to improve the accuracy of the estimate and to instil management's confidence in the estimate.

A formal risk analysis for determining contingency is usually based on simulation. A simulation of probabilistic assessment of critical risk elements can be performed to match the desired confidence level. Monte Carlo simulation software is a useful tool for performing simulation.

Range estimating is a powerful tool that employs Monte Carlo simulation to establish contingency. Critical elements are identified that have a significant impact on the base estimate. For many estimates, fewer than 20 critical elements are used to form the basis for simulation. Using this method, no critical elements can be combined into one or a few meaningful elements. Range estimating is probably the most widely used and accepted method of formal risk analysis. In range estimating the first step requires identification of the critical items in the estimate.

3.16 Developing Cost Model (Proposed for this Research)

Based on the explanation in Chapter 2 and this chapter, 3, in order for cost estimators to be able to perform estimating duties in Indonesia there is a need to develop cost models based on the factors and conditions prevailing in this country. However, the scope of cost modelling is very wide and it is not possible to cover all aspects. For the purpose of this research, the author decided to concentrate on the areas that are greatly needed and have the potential for significant improvement in terms of cost efficiency in the building construction industry. These are none other than conceptual cost modelling using cost planning data structure that can also be used for cost planning and cost balancing. For a model to address this dual function, the author has decided to combine the resource-based model (based on cost planning structure data), probabilistic estimating techniques and simulation approach, which is called probabilistic unit price modelling**.** The unit price-based model can be analysed through simulation and the simulation approach is chosen because of its reliability and well-proven technique. Since probabilistic modelling focuses on the attention of estimators on ranges (probability distribution) of possible values of various risk variables, it therefore helps to model project variables vigorously and systematically and provides estimators with a more robust and reliable decision-making tool (Raftery, 1993). The term unit has the same meaning as cost component, input variable and cost item in the context of this research.

Data will be collected from published tender reports and the quantity surveying section of a local authority and a nationalised industry to establish the achieved precision of current practice. Precision will be achieved using automatic selection of statistical models based on criteria.

No one particular modelling method was appropriate for use in all cases. The automatic selection of statistical models proved to be the most consistent in that the coefficient of variation of the ratios forecast to tender in a group of predictions was the smallest.

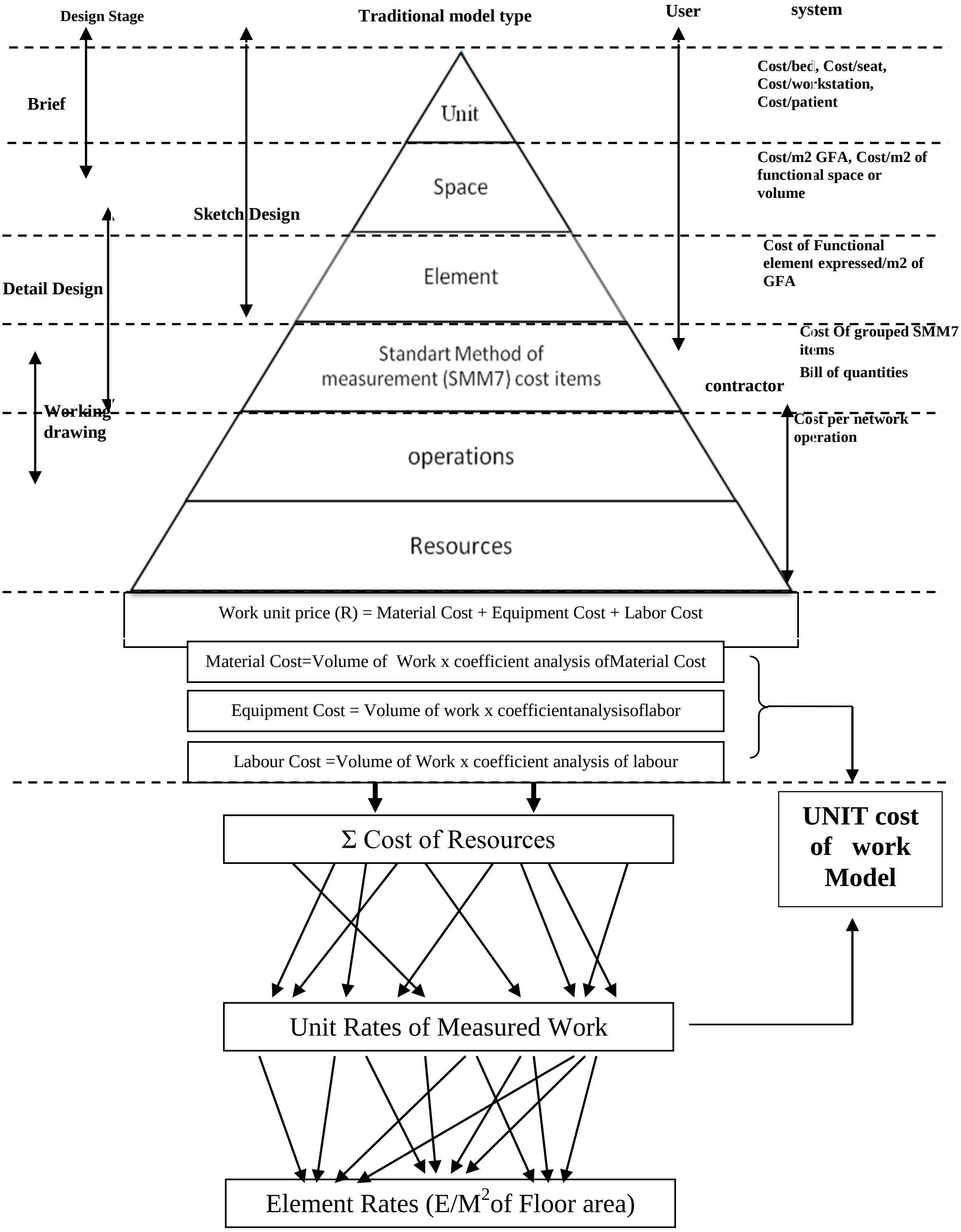


Figure 3.1: The Diagram of the Proposed Model

The test using the system was conducted by including all the available data for a given building type prior to the date of the test estimate. No selection of the base data was exercised and no attempt was made to exclude from the test items such as external works that are inadequately represented by element data.

Models for estimating and planning costs have evolved gradually. Their adoption by the profession at large has led to the establishment of what might be called 'traditional' techniques (Brandon, 1999). The differences that occur between traditional estimating methods are usually in the number and type of item and the derivation and degree of detail involved in estimating their respective quantity and rate value (Beeston, 1987).

A cost model's task may be to estimate the cost of a whole design or of an element of it or to calculate the cost effect of a design change. It can be classified as in-place quantity-based, descriptive or realistic; although it is possible to use different types of model for different purposes it is a sensible aim to find a common basic method for all applications. Then cost advice at various stages can lead smoothly to the final estimate and cost control by the contractor (Beeston, 1987).

The purpose of the proposed model has a considerable influence upon the most appropriate approach to model formulation. This study is essentially concerned with micro models. Increasing the detail and complexity of quantity-based methods seems to produce greater overall accuracy.

The cost of the building work actually incurred and price is usually expressed, not in terms of design variable, but in terms of the resources of all kinds which the design decisions committed. Whilst the uncertainties implicit in any industrial cost estimating have long been recognised at least qualitatively, it is only in the fairly recent past, with the stimulus of computer-based cost modelling that there has been real movement towards attempting to quantity them.

Measured in-place quantity-based costing methods would possess the required property if, whatever the rest of the design was like, each work item had its own fairly constant material used, labour and time requirement which changed proportionately when the quantity of the item changed. Unfortunately, this is not so. Construction costs arise from the use of material and labour on a series of tasks and it is not sensible to try to allocate all their time to them individually. Data produced from such a procedure would not be applicable to the circumstances of another project: yet of course the application of most techniques depends on doing just that.

The production of these proposed models can be tackled by simulation of cost unit produced, which will consist of material, labour and equipment to be used in a unit of work.

CHAPTER 4

METHODOLOGY RESEARCH

4.1 General

The method that is employed to form a cost model in an uncertain environment is simulation. Simulation is also referred to as the Monte Carlo technique – or a stochastic technique – due to the presence of random processes (Bennett, 1984). Stochastic simulation typically generates costs for each activity in a plan by randomly calculating a feasible value for each from a statistical probability frequency distribution which represents the range and pattern of possible outcomes for a unit cost.

To ensure that the chosen values are representative of the pattern of possible outcomes, a large number of repetitive deterministic calculations – known as iterations – are designed. The result is typically introduced as a cumulative distribution plot and a frequency histogram.

Due to the repetitiveness of the process and the handling of large numerical information values, it has only been feasible to implement this technique since the advent of computers. The current practices of industry, in usage of single-value, deterministic methods are a legacy from the era before computing liberated people from laborious calculations. Also, it permits a deeper investigation of problems – such as construction – that have neither a single-value solution that can be represented by a formula nor operate in a totally random environment. It can be represented by statistics, but as a variable with a random component it is called stochastic, which can be investigated most effectively through simulation.

It has been found that the introduction of simulation methods for construction management is likely to have as great an impact on the construction industry as did the introduction of network planning and scheduling methods some two decades ago (Berends, 2011). Some of the advantages for the technique are listed as follows:

1. The major advantage is related to results of such simulation, given the validity of input assumptions; they provide an unbiased estimate of the project completion distribution. This is particularly important in the light of evidence of inherent bias in deterministic cost analysis.
2. Simulations provide an almost unlimited capacity to model construction operations. Also, they permit the construction manager to quickly evaluate many different combinations of equipment and methods under varying conditions of operation at modern cost.
3. Simulation can give the manager an insight into which factors are important – and hence where to concentrate her/his effort – and how they interact.
4. Simulation permits the user to experiment with different strategies without the risk of disturbing the real project and incurring costs. Also, simulation enables one to study dynamic systems in much less time than is needed to study the actual system.
5. The four most common distributions that are used by simulation, namely, uniform, triangular, normal and β, are permanently available. Users can also create skewed distributions or the triangular, normal and β to model pessimistic or optimistic production rates. Bimodal distributions can also be created in a wide variety of shapes, and actual histograms of real data can be entered and saved as the histogram or as a 'best lit curve'. Some typical distributions are illustrated in the next section.
6. The distributions created in the program (this study will apply program @Risk) are contained in a library or database which will rarely require updating once compiled.

Distributions should be regarded as a library to aid the student in applying the simulation processes in this database.

For the estimation of the total cost, the technique that can be applied is regression models, given an expression as the following equation:

$y = ax\ bx$ …………..…………………………………………………….. (4.1)

Where y is rate of x and is quantity, and a and b are given by the analysis.

For an assumed quantity, the value y can be calculated and is taken to be the estimate of the rate for that element and the mean of a normal distribution whose standard deviation is set equal to the standard deviation of the residuals from the regression model. This normal distribution is subsequently used in the simulation of the whole building cost. When the quantity of the element being estimated is outside the range of the data being analysed, the regression model can break down. For instance, a negative rate is yielded following this matter. In these circumstances, the system defaults to an appropriate univariate analysis to calculate the rate.

The least-squares technique can also be used to estimate total cost from unit price of work. This technique is related to assumption of normality. However, there are rarely sufficient data for a true estimation of the form of the distribution of the data set. The mean is very sensitive to deviations from normality due to outliers, long tails, etc., which usually appear in the data. To overcome these problems, a robust method is required that yields similar estimates to the least-squares estimates when data are normally distributed but yield estimates little changed when the data contains outliers.

For data with the normal distribution, simple least-squares regression is appropriate. The transformation of log cost was introduced because rate versus quantity-scatter diagrams showed that, for many elements, rates tended to change exponentially and not linearly with quantity.

In this research, the cost modelling process will use Monte Carlo simulation to understand the properties of different statistics computed from sample data. The sample data distribution will find out how different parameters perform under different circumstances. In each case it will set up an artificial figure – a random – in which the values of important parameters and the nature of the chance process are specified; the computer will be used to run the chance with the iteration to form the distribution to be analysed and, because Monte Carlo simulation is based on repeatedly sampling from a chance process, it stands to reason that random numbers are a crucial part of the procedure.

4.2 Theoretical Random Number Generation

These sorts of number are used by all versions of MS Excel software. The method used is called a Linear Congruential Generator (LCG). Starting from an initial value called seed, the LCG simply puts a number through the equation:

$$\text{Next Number} = (B.\ \text{Previous Number} + A)\ \text{Mod}\ m \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ (4.2)$$

The mentioned equation is applied to generate the next number. In the formula above Mod means Modulus. The expression x Mod y yields the remainder when a number x is divided by another number y.

Excel's RAND function simulates a uniform distribution on the interval from 0 to 1 (known as the Uniform (0, 1) distribution). It can be said that it will be drawing random numbers from the interval 0 to 1 with every number equally likely to be chosen.

4.3 Simulation Process

The first step in Monte Carlo simulation, also referred to as simulation by random sampling, is to formulate an analytical model consisting of all input (cost) variables that have an impact on its output. The second step, called Data Collection, involves data collection, while the third step (Random Number Sampling), fourth (Model Output) and Simulation steps are to analyse the estimate with a simulation.

The model is run repeatedly to determinate the range and the probabilities of all possible outcomes by combining the input variables factor. On such run, a value from each variable is selected randomly based upon its specified probability distribution. When values for all variables have been determined, total cost for this particular run is calculated. The model is then cycled around again until a reasonable sample size is achieved. Results can be converted into a histogram-type probability density function from the model, which in turn can be presented as a cumulative probability curve.

It is basically a technique that combines the probability theory and simulation to handle risk and uncertainty that are inherent in the real world. The keywords in this technique are probability and simulation. A probability is a way of measuring uncertainty and can be estimated from past results, statistical record of previous events or by subjective judgement. Simulation assumes that the values of the different variables may be combined as in the following figure:

Process of Simulation:

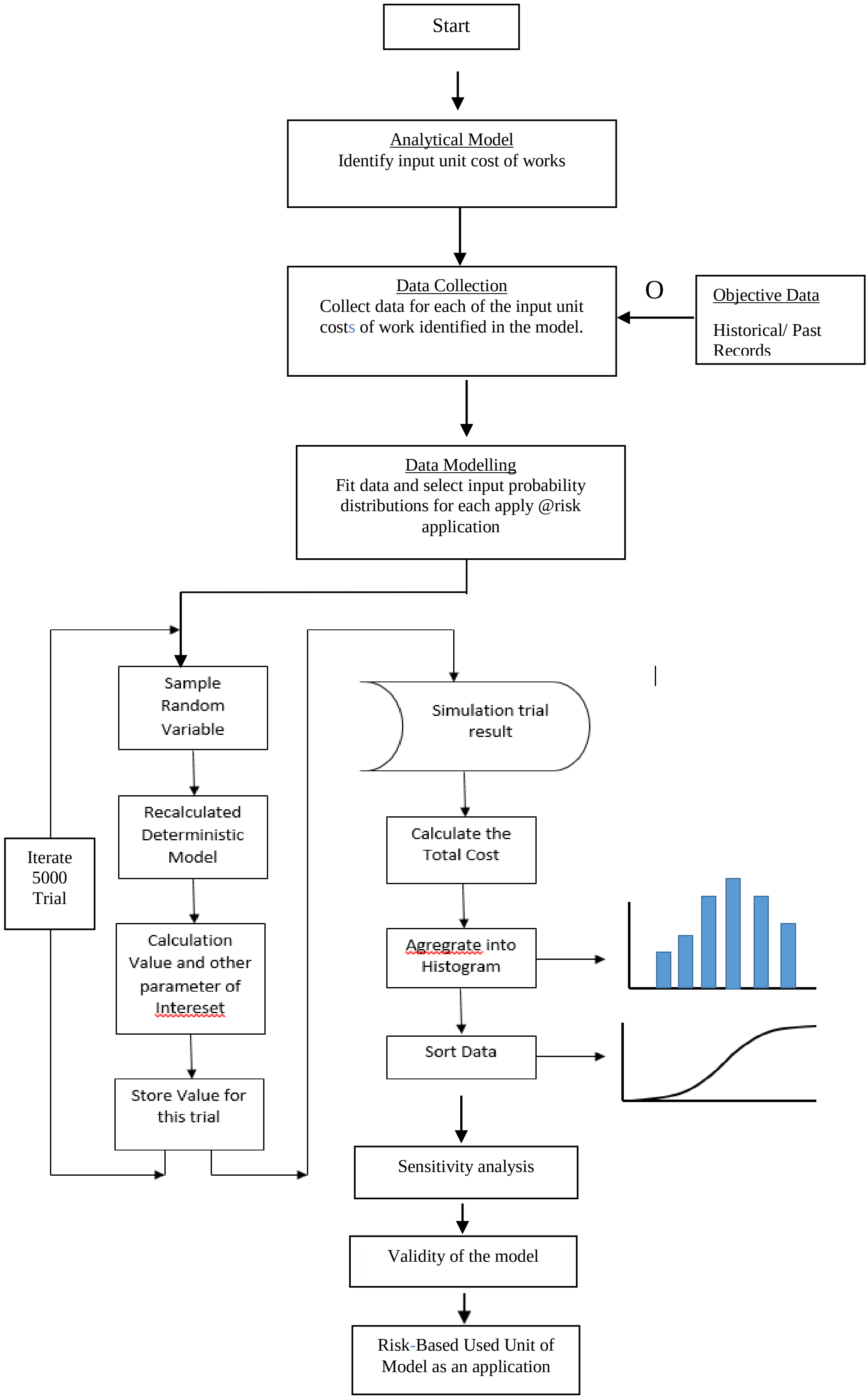


Figure 4.1: Unit Cost Modelling Flow Chart

Analytical Model

An Analytical Model by pure definition and in terms of being applied the construction cost system is a set of equations describing the performance of a cost system. In practical terms, it describes a collection of measured and calculated behaviours of different unit cost of works over a finite period of time within the construction cost system – material, labour cost, equipment cost – and can even include the actions (Caliri, 1999).

In most instances, the capacity planner constructs the model using activity measurement information generated and collected during one or more time intervals. It is critical that an interval or series of intervals be used that contain significant construction process activity. Then units of work are characterised by type and grouped into workloads.

4.4.1 Purposes for Building Analytical Models

In general the reason for building an analytical model is to gain understanding of the current activity of the system and to measure performance and analyse behaviour of the cost within it. In the construction system, it will be used as a basis for prediction of behaviour of certain unit cost of works within a system by inputting changes to different elements of the system; one might include labour, material and equipment changes. These unit costs of work will be applied for an analytical model. Beyond entering changes to the overall system of the building construction used, is an input to the model so as to measure the total cost of the building as a result of this unit cost of work. Establishing the purpose for the modelling study will affect the total approach that is taken to model construction, characterisation of workloads, and series of analytical iterations to be performed with the model.

4.4.2 Data Collection Model Construction

A data collection method will be designed and arranged, and the data collected must be robust enough so that appropriate records are available to identify elements constructed and all pertinent items of building unit of work activity.

A reflection on the nature of the unit of work activities reveals the generality of the cost estimation function and suggests ideas regarding the measurement of the variables. The function is applicable in as many types of building projects as may be assigned to the domain of type variables, at any moment in time and for any place. At this point, it might be defined as a global pre-design cost-estimation function.

The quality and technology variables are not subjective but seem to be highly correlated with the cost. In principle, the system is aimed at achieving better results by narrowing the range of unit rates, according to building type and specification and compiled from historical cost data, to be applied to the areas of floors, roofs and enclosing walls multiplied by certain factors.

Whilst it has been sufficient to test the system and to demonstrate that it is an improvement on the ‘cube’ and ‘floor area’ methods, it is insufficient to provide the same extensive historical data available with them. Also, the multiplication factors adopted, being related to experience in use and not upon proven data, are open to question as to their reliability for universal application. Even so, this system has resulted in unit rates being less variable within buildings of similar type than with the ‘cube’ and ‘floor area’ systems.

Like the ‘cube’ and ‘floor area’ systems, when it comes to the ‘storey enclosure’ system, it depends upon a cost rate selected by judgement and little direct evidence is given as to ways in which economy of design might be achieved or the measure of possible economies (Skitmore, 1999).

In this research, the analytical model will represent a set of instructions describing how the cost components fit together to produce system outputs. It will be manipulated and varied to functions. It provides a particular conceptualisation of the problem that we wanted to solve. A basic knowledge of the system is required when setting up the model. The system is very much a function of the objective of the model. In the case of capital investment in building a factory to produce certain products, the model might contain variables such as cost of construction, market size, selling costs, market growth rate, demand and supply, economic conditions, labour market, residual value of investment and fixed cost.

In building construction, the analytical model is commonly based on unit cost components. Unit cost of work modelling encompasses the traditional building economics principle that a complex building cost estimating problem should be broken down (analysed) into recognisable unit cost of works which can be individually cost and then reassembled to the whole to provide the total estimate of the cost of the building. A unit cost of work is defined by Ferry and Brandon (1994) as “major parts of the building which always perform the same functions irrespective of their location or specification”. Estimating the total building cost of a proposed new building using the element method involves summing the costs of each unit cost of works. Each of these unit cost of works is calculated as the product of an estimated element cost and an estimated gross floor area (GFA) of the building to be built.

In Indonesia’s construction system the element of building will be divided into eight elements such as shown in the following table (PU, 2007):

$$C_{GFA}=C_1+C_2+C_3+C_4+C_5+C_6+C_7+C_8 \quad \ldots\ldots (4.3)$$

Table 4.1: Building Element Based on Indonesia Public Work no 45/ 2007

Building Element		**Average**
Foundation	C_1	10%
Structure	C_2	30%
Floor	C_3	15%
Wall	C_4	15%
Ceiling	C_5	5%
Roof	C_6	10%
Utility	C_7	5%
Finishing	C_8	10%

Based on the mentioned equation, each of the C_i needs to be adjusted for various factors as mentioned in equation 1. If the proposed new building has a Gross Floor Area (A), it can be estimated as the Total Cost, which shall be determined as the following equation:

$$C_T=C_{GFA}*A \quad \text{.... (4.4)}$$

Estimators are all different in their experience, perception, belief and construction environment that they have encountered. Decision on the selection of critical unit cost of works for a model will be associated with the in-depth knowledge of a project location/country and should not be generalised.

The content of an analytical model is largely dependent on the availability of data. It can be related to functions and design and even process-determined based on methods, materials, equipment and plant requirements (resource-based model). If data are readily available in various formats, then the emphasis will be given to select only the significant subsystems/unit cost of work of the system theoretically. One way of doing this is to run a sensitivity analysis based on the historical data. However, for the case of unit cost modelling, number of unit cost of works in a building is quite standardised and is not large. The effort to sieve out significant unit cost of works might not be worthwhile, since all computations nowadays take place using a computer, which has over the years become very powerful and affordable besides the availability of sophisticated software. Placing non-cost significant items in a model does not invalidate that model. It does not reduce or raise the accuracy of the model, except that it may take a slightly longer time to process and produce the outcomes. The impact of leaving out non-significant items that might actually be significant could be much worse than the longer evaluation time.

4.5 Model Development

4.7.4 Parametric Equation

The best-fit curve is initially chosen by the program using an automated feature; that is, by letting the program compare source data to each model to choose the best curve. The best curve is decided by the correlation coefficient value.

4.7.5 Theoretical Distribution

The goodness-of-fit tests are: chi-square, Kolmogorov-Smirnov and Anderson-Darling. The chi-square is the most common, but the others may supply more detailed information about distribution. As has been highlighted, the main weakness of the chi-square test is that there is no clear guideline for selecting intervals. In some situations, the researcher can reach different conclusions from the same data depending on how the intervals (number of classes) were specified.

There is no specific goodness-of-fit test that will give the ‘best’ result. Each test has its strengths and weaknesses. The chi-square and K-S tests have been used in previous related simulation research. It was found in 1978 (Clemens and Willenbrock, 1978) and they used only the chi-square test in their study. More recent research (Daellenbach, 1994) used the K-S test. The A-D test has not been used extensively in construction-related research. It is interesting, however, that many researchers have failed to identify exactly why a particular distribution was selected. It is with this background that the author has carried out a study by using all the three tests in the simulation run in order to know the effect.

4.6 Probability Distribution

The second step of probabilistic modelling using Monte Carlo simulation technique is to assign each cost variable a probability distribution. Probability distribution is a curve that shows all of the possible values of a random variable and their corresponding probabilities. Not only does it tell us the possible values of the random variable, but also how likely they are. There are three approaches that are commonly used in constructing probability distribution. The first approach elicits data subjectively, based on the present state of knowledge, while the second approach elicits data objectively, by obtaining quantifiable data from the past or on-going projects. The third approach is the combination of both subjective and objective method. Townley (1991) stated that objective data are preferred because of their consistency and perceived accuracy.

The best approach to developing a cost risk analysis is to have objective data elicited from the historical database. The subjective data approach as mentioned above is only the second alternative to this method and should only be used in the absence of objective data. It is based on the assumption that the past trends or behaviours of a system to a certain extent can be made to represent future events having considered the influencing factors over the time period. In short, the future trend is the repetition of past trends. The accuracy of this presentation has its limits as, over time, the reliability and accuracy will diminish, due to technological advancement, innovative creations, application of information technology, change in labour market and many other reasons. It may also vary from one country to another. The author has not come across publication of research on the subject of validity of historical data sets in terms of time span. Moreover, the effects of accuracy on estimates using a small recent data set as compared to a large set of data dated many years back have not been established either. Hence, with these unknown, it is advisable to select data sets from as recently as possible and ones that are adequate to meet the research aims, and researchers should not be overly ambitions by using enormous data sets.

Unlike the subjective method, which uses two- or three-point judgmental estimates, the process of determining the probability distributions of the uncertain unit cost of works using historical data needs to be conducted in a rigorous and systematic manner. The process is to select and accurately fit sample data to flexible families of probability distribution. It involves complex numerical procedures based on a number of statistical estimation methods. This approach is quite similar to the objectivity elicited data method. It is most useful for cases where only a small sample of data is available from previous buildings. The probability distribution, in this case, is defined by selecting this small sample of data from previous buildings similar to the proposed buildings and using the sample data to calculate the parameters of the distribution. Selection of a small sample of data is the subjective part while parameterisation is the objective part.

Bledsoe (1998) introduced a variation to this approach. Instead of just using historical data to fit into histogram distribution, he also used it to fit into a uniform and triangular distribution. A comparison was then made between simulating from the triangular distribution using judgmental data and triangular and uniform distribution based on historical data. The output results from his research confirmed that the simulation from distributions obtained using historical data yielded better results.

4.7 Correlation among Unit Cost of Works

Correlation is present if the costs of two (or more) unit cost of works move together. It is defined between pairs of cost unit cost of works, although an individual cost unit cost of work may be correlated with many others. Correlation varies between -1.0 and +1.0. The + and – signs are used to indicate positive correlation and negative correlation respectively. A negative correlation indicates that the two costs unit cost of works move in opposite directions while the positive correlation is vice versa. Perfect correlation is ±1.0 and represents two unit costs of works that are always expected to occur in lock step, perhaps reflecting an accounting formula. A value of 0 indicates that there is no correlation (independence) between the two variables.

One of the most common sources of error in Monte Carlo simulation is that cost unit cost of works are assumed to be independent, so changes in one cost unit cost of work do not affect any other unit cost of work. Such an assumption would have little impact on construction costs if the correlations between the variables were small and insignificant. However, in cases where the cost unit cost of works are truly interrelated but not recognised, the consequences are serious and eventually lead to completely wrong interpretation of analysis. Generally, disregarding the correlation among variables in a Monte Carlo simulation will result in an underestimation of total cost variance (narrow spread of total cost distribution). Unfortunately, the cost correlations are usually neglected due to the difficulty of modelling dependence, i.e. to detect, measure and quantify the dependency.

Pouliquen (1970) highlighted the importance of incorporating correlations in decision-making. In one of the projects he encountered, he found that the probability of The Port of Mogadishu project earning less than 10% was only 15% if correlations are neglected. Furthermore, he noted that, although the treatment of correlation between variables remained a major problem (theoretically), the real danger was that there was apparently a systematic tendency to overlook correlation, which could lead to the wrong decision. In his comparison with various different probability distributions, he emphasised that the importance of correlations outweighed the choice of probability distribution.

The findings by Touran and Wiser (1992) confirmed further that correlation was important in cost estimating of buildings. They show that neglecting correlation resulted in severe underestimation of total cost variance. However, the effect of cost mean was not significant. Further research by Touran (1993) using a different set of data concurred with the earlier findings that ignoring correlation between variables resulted in the underestimating of variance but not mean. The conclusion made by Chau (1995), "… dependence incorporated in the simulation model gives a reasonable approximation to reality", reaffirms the danger of ignoring dependency in simulation.

The conclusions made by Touran and Wiser (1992) were based on US data. A similar study was carried out in the UK by Wall (1997) using unit cost of work cost data extracted from the Building Cost Information Service (BCIS). Although the outcomes were not similar in some other aspects of the objectives of the study, its conclusion on the need of incorporating correlation among variables was similar. The following concluding statement summed up his important findings: "Although the mean without-correlation simulations are insignificantly different from with-correlation there is a significant and substantial different in standard deviation". There are several approaches that can be used to incorporate correlations among variables in Monte Carlo simulation. They are by grouping method, exact method and rank correlation.

4.7.1 Rank Correlation

As with all estimating activities, estimating bias and consistency are important validation issues and are directly affected by the heuristic employed and various debiasing technique are now becoming available.

Pouliquen (1970) used the Monte Carlo simulation technique in appraising projects for the International Bank for Reconstruction and Development and concluded that:

1 Risk analysis was a powerful technique to handle uncertainty and viability of projects.
2 Framework of risk analysis provides a highly efficient medium of communication, evaluation and discussion among the members, and
3 Risk analysis replaces skilled judgement.

Diekmann (1983) identified that the Monte Carlo method is the most promising approach to probabilistic estimating. This technique has also been applied to cost modelling (Wilson, 1982), cost plans (Mathur, 1982), resource modelling (Baxendale, 1984), network planning (Bennet and Ormerod, 1984 and Finley and Fisher, 1994) and bid analysis (Raftery, 1985).

Curran (1989a) gave a hypothetical example of using this approach to measure and to manage uncertainty in evaluating the feasibility of a planned expansion project. Perry and Hayes (1985), Shafer (1991), and Morgan (1991) have agreed that the traditional single-value cost method has failed to adequately deal with risk and uncertainty. The output profiles obtained from probabilistic estimating, namely the recommendations to be made, are not possible under the single cost estimating approach.

The concept and methodology employed in developing a cost model for this study are divided into five separate sections, namely data modelling, Monte Carlo simulation, correlation analysis, sensitivity analysis, and verification and validation of model.

4.7.2 Sensitivity Analysis

Sensitivity analysis of the input to a simulation allows the identification of the degree of impact of input variables (cost units) towards the total project cost. The two methods used to display the results in this study are tornado graph and spiderplot. The input data that are required for the construction of these graphs will be based on the assumption that input variables cost can range from 5% to 95% (equivalent to area under the pdf curve) due to many uncertainties in project implementation. The base case value for each variable is mean. A base case value is a value that would have been used if no sensitivity analysis were to be done. At each of these intervals (5%), the corresponding value (cost) is read from the cumulative curve and the difference between this value and the base case value in percentage is recorded in the table.

In this study, sensitivity analysis will use a tornado graph in which only the limits of output uncertainty are specified. The other graph used to analyse the sensitivity is the spiderplot. There are two directions to measure uncertainty on spiderplots. On the x-axis the potential uncertainty in the input variable is measured. On the y-axis the impact of that input uncertainty on the project total cost is measured. Thus, spiderplots measure the (i) ability of each input variable to change, (ii) limits of uncertainty of each variable and (iii) impact of each on the output variable (total cost). The centre of the 'spider' is the base case. Measurement of uncertainty for both input and output can be deduced from the spiderplots.

4.7.3 Verification and Validation of Model

The approaches that have been adopted in ensuring the validity and credibility of formulated cost model are discussed in the following sections.

4.7.4 Verification

As has been defined before, verification is concerned with determining whether the simulation model has been correctly translated into a computer program. Simulations in this study were carried out using @Risk. In addition, the sample mean and other statistical descriptions were also computed and compared with the desired values to ensure that the program correctly generated the values. @Risk simulation program is a well-established commercial simulation package and has been used by many institutions of higher learning and corporations for some time. In view of such extensive usage, errors would have been discovered much earlier and corrected. As such, verification is deemed not necessary for this software.

4.7.5 Validation

Validation is simply the test of the cost model to establish that its output data closely resemble the output data that would be expected from the actual system. The first technique uses statistical procedures to validate the degree of fitness between collected data and the selected input distribution. Meanwhile the second technique, which is inspection approach, compares the computed statistics of collected data with model output data. Graphical comparison is also part of this technique.

In statistical procedures, two-sample Chi-Square, two-sample Kolgomorov-Smirnov and two-sample Anderson-Darling were used to determine whether the underlying distributions of the simulated and collected data sets can be regarded as being ‘similar’ in data fitting. These two-sample statistical tests have resulted in a number of probability distributions that can be considered ‘similar’, i.e. the acceptance of null hypothesis in the hypothesis test. The accepted distributions were then ranked according to their degree of fitness, with those having the closest fit being call first-ranked. The use of only first-ranked distribution in the analysis carried out in this study, described in sections 8.4 and 8.5, has lent itself to the credibility and validity of the model. In inspection approach, the model output data that were closest to the collected data sets, in terms of mean, standard deviation, probability density function and cumulative density function curve were chosen as the most valid and credible model.

The model output data from the following cases were compared:

1. Simulation using empirical distribution as input distribution
2. Simulation based on first-ranked distribution selected using Chi-Square Goodness-of-fit test but with different number of class intervals.
3. Simulation based on first-ranked distribution selected using different Goodness-of-fit tests.
4. Ditto, with correlation relation between cost units taken into consideration.
5. Simulation based on single-family of distribution chosen using statistical test.
6. Ditto, with correlation relation between cost units taken into consideration.

4.7.6 Summary

In the beginning part of this chapter, two pre-simulation tests were carried out with the intention of knowing that the random-number generators were not biased and the number of iterations were adequate to produce stable and accurate results. Simulation output based on empirical and collected distribution was then compared to determine the applicability of empirical distribution, as an input distribution in simulation modelling. The effects of using first-ranked distribution chosen using different goodness-of-fit tests and class intervals of Chi-Square test as an input model were also presented and discussed. The results of the in-depth analysis and findings on the suitability of using just one single-family of distribution to represent all unit costs have also been presented in this chapter. A method of generating correlated random numbers was then suggested and incorporated into the cost model.

This was followed by presentation of techniques employed in building a credible and valid model. The procedures for verification and validation were also described.

Sensitivity analysis forms the ending part of this chapter. Based on this analysis, the degree of impact of the input variables (cost units) towards total project cost can be accessed and arranged in ascending order. Results of the analysis were presented in the form of tornado graphs and spiderplots. An assessment of the validity and credibility of the formulated simulation model was also given.

The complete process of probabilistic simulation modelling has been reviewed in this chapter. The research direction together with it advantages and drawbacks of various alternatives and options were identified, discussed, reviewed and compared at all stages of the process. The simulation process begins with the formulation of an analytical model that fits together all the input variables in the modelling system. The review then moved on to the approaches used in assigning probability distribution to the input variables. Theoretical distribution appeared to be the most promising method for input modelling based on the current trend and recent research. In this respect, it is treated in much more detail than the other approaches. The applicability and usefulness of many probability distributions in representing construction processes were also highlighted, as well as the discussion of the recent findings. Current techniques for estimating the parameters of distributions and testing of goodness of fit using hypothetical tests were included. The importance of correlation and recent developments in estimating correlating structure for Monte Carlo simulation have also been discussed and brought up to date.

Although the Monte Carlo approach provides a straightforward means of probabilistic estimating, there are two major limitations in its application. First, one needs to establish statistical distributions for various cost components. Second, if the random numbers are not independent, their correlation should be accounted for in the simulation.

CHAPTER 5

DATA COLLECTION

5.1 Data Source

Data that will be used in this analysis are known as data from the bills of quantities of past projects, especially public service building in Kepulauan Riau Province, Indonesia. All the data used in this thesis have been collected via this method since it is established that historical data sets are able to provide sufficient information for the achievement of the objectives of this research. All the data were collected from the successful bidder tender documents.

Information to be abstracted from each of the contract documents is project location, building details and bill of quantity of all elements. Data will only be collected from government building projects. Arithmetic errors in bills of quantities will be adjusted and discount given will not be considered in order to avoid inconsistency as the discount may vary from one project to another.

In this research the time value of money will not affect the actual cost in the mind of cost estimators at the time of tendering. Cost information gathered about the building has been categorised under five element groups.

Data collection constitutes a systematic procedure to obtain the data required after having closely related it to the research problem that will be solved. Data collection in this research is conducted by literature study and from the contractors in Kepulauan Riau.

5.1.1 Data from Literature Study

Data collected is limited to the period of 2000-2009 with a consideration that the data are considered to have represented the problem condition and limited time of the research. Data collected are related to the condition, geographical location, socio-cultural condition, economic condition like distribution and growth of Gross Regional Domestic Product (PDRB), inflation rate, interest rate of working capital, rupiah exchange rate against US dollar, regional minimum wage (UMR), number of population with over 10 years of working in the industrial sector and the data related to the construction project. When looking at the construction projects, information considered includes: allocation of development fund, number and value of construction projects in Kepulauan Riau, qualification growth of the construction company, and also the data regarding regulation/policy issued by the government in relation to the construction industry. Data are obtained through the Central Bureau of Statistics (BPS), Regional Office of Public Work, Association of Construction Companies (Gapensi), Manpower Office and so forth.

5.2 Data of Kepulauan Riau

5.2.1 Geographical Data

Geographically located in the Kepulauan Riau Province 04°15' north latitude, 0°45' south latitude and 103 011'-109°10' east longitude, Kepulauan Riau Province is an archipelago consisting of both large and small islands, about 2408 in total, of which as many as 366 islands are inhabited and 2042 are uninhabited. The total area of the province of Kepulauan Riau is comprised of 253,420 km^2: sea area 242,825 km^2 (96%) and land area 10,595.41 km^2 (4%).

The province has two cities: Batam and Tanjungpinang. Kepulauan Riau Province also consists of five districts namely Bintan, Karimun, Natuna, Lingga and one new district, Anambas Islands District, formed on July 21, 2008 (Act No 33 of 2008), which is a division of the Natuna regency. Six districts which were previously located in the Natuna regency are now included in this new district: Siantan Anambas Islands, East Siantan, South Siantan, Palmatak, Jemajak, and Jemaja East.

Administratively, Riau Islands Province Local Government oversees the seven (7) regional administrative districts/cities. The areas are:

1 Batam City
2 Tanjungpinang
3 Bintan
4 Karimun District
5 Anambas Islands District
6 Natuna regency
7 Lingga District

5.2.2 Socio-Cultural Data

The socio-cultural conditions of a region will influence the productivity of its human resources. For example, Kepulauan Riau province: as has been explained previously, most of the people work in the sectors of agriculture, trading, and fishery. Only a small part of Kepulauan Riau society works in the construction sector. There are several socio-cultural attitudes of Kepulauan Riau society that influence the productivity of human resources in the construction sector. They are as follows:

1. Familial relationship: the majority of Kepulauan Riau society consists of the Melayu tribe, which has strong familial relationship; as a result when doing work

or a project they will involve their family/relative or people from the same village. In a construction project it can be proven that we can find a site manager or chief foreman involving their relatives or the people from their village without considering the skill, experience, and manner or attitudes of these people. Moreover, because of having strong relationships with each other, there is a tendency that the site manager or foreman is very unwilling to address their subordinates who make mistakes in performing their work. The above condition will very much influence the productivity and quality of work performed.

2. Most members of Melayu society still have a legacy, such as farming and fishing. For men, they have responsibility to cultivate their legacy. As a result when the harvesting time is approaching, the workers often leave their work in the construction sector to cultivate their farm or go fishing. This condition will complicate the project management as the manager will need to find substitute labour to continue the abandoned works.

3. Because most members of the society work as farmers and merchants, the project management team has to employ people coming from outside of Kepulauan Riau, such as from west Sumatera, Java Island, and North Sumatera. This will make it difficult for the management team to facilitate worker socialisation during the project; as a result this often creates conflict or dispute.

   Through observation and interview conducted, the tribal composition of construction workers was obtained; that is Melayu tribe of ±85%, Nias tribe of ±10%, Javanish tribe and others tribes of 5% in an average project.

5.2.3 Economic Data

1. Gross Regional Domestic Product (PDRB)

The economic growth and per capita income of a region can be reflected in the growth of Gross Regional Domestic Product (PDRB) which is classified into 9 (nine) business lines.

Table 5.1: Gross Regional Domestic Products – Kepulauan Riau*

Business Sector	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Agriculture	31.92	31.14	29.69	22.30	21.41	20.78	20.98	20.22	21.45	23.22
Mining	1.46	1.36	1.50	5.30	5.87	6.25	6.35	6.83	4.71	3.67
Process Industry	12.12	12.33	13.11	14.72	14.55	15.28	15.37	15.00	13.58	12.71
Electricity, Gas, Drinking Water Industry	1.26	1.22	1.16	0.91	0.97	1.09	1.20	1.42	1.09	1.15
Construction	3.92	3.89	3.76	6.15	6.21	6.50	7.15	7.41	4.84	4.24
Trading, Hotel, Restaurant	23.99	24.06	24.17	17.06	16.17	16.99	16.21	16.15	18.80	18.02
Transportation, Communication	9.23	9.70	10.04	10.84	11.13	11.45	11.76	11.82	12.00	12.30
Financial, Leasing, Company Services	4.95	4.92	4.74	6.14	5.86	5.53	5.17	5.05	5.61	5.40
Services	11.16	11.38	11.83	16.58	16.46	16.13	15.82	16.09	16.91	18.25
Total of PDRB (10* rupiah)	**3.302**	**3.733**	**4.273**	**6.027**	**7.218**	**8.267**	**9.519**	**10.76**	**17.84**	**20.79**

* Source: BPS – Kepulauan Riau (2010)

As it can be seen by Table 5.1, the economic growth of Kepulauan Riau shows a significant increase, reflected on the increase of Gross Regional Domestic Product from year to year. The business sectors that provide the biggest contribution are the agriculture and trade sectors, even though they contributed less in 2010 than in 2009. This is in line with the livelihood of Melayu society: agricultural living and trade living.

During the last ten years, the construction business sector was only able to contribute from 4% up to 7.5% of total Gross Regional Domestic Product (PDRB). Moreover, the growth of the construction business sector in Kepulauan Riau has fluctuated over the period, where in 2003-2004 there was an increase more than 2% but during the years 2009 and 2010 a negative growth of about 3% occurred. The decrease of the construction sector occurred during the monetary crisis, reaching up to -35.44%, but by 2009 the construction business sector had recovered with the growth of -4.27%. It is expected that the recovery will continue to improve, reaching a positive growth.

2. Inflation Growth

The decline of economic growth momentum in Kepulauan Riau has been estimated from earlier period after experiencing very high growth rates in the period beginning in 2010. The economy in the third quarter of 2010 was estimated to rise by 6.16%, while in the previous quarter it grew by 7.43% (yoy). Official figures from the Central Bureau of Statistics (BPS) are relatively lower than Bank Indonesia's Batam projections that predict growth will remain at the level of 6.8 ± 1%. Regional economic growth in this quarter was still above the national record, which grew 5.8%, and Sumatra is estimated to grow 5.39%.

Unlike the national growth trend which has improved in all sectors, economic conditions marked by slowing in Kepulauan Riau in nearly every economic sector except for the infrastructure sector. For the region of Sumatra, the Kepulauan Riau economic growth patterns also have different characteristics due to the large dependence on exports of the manufacturing sector. This makes the province quite sensitive to the dynamics of the global economy, which indirectly affect the demand for the order processing industrial sector in the region.

Meanwhile, in Kepulauan Riau the rate of inflation remained at a relatively restrained level below the national inflation level. Annual inflation in Kepulauan Riau by the end of the third quarter of 2010 had increased to reach levels of 5.16% (yoy) after the previous quarter's level of 5.06% (yoy). Increasing inflation is more due to an increase in prices on core inflation components, especially of food, beverages, cigarettes and tobacco, and clothing.

In general, the development of bank lending in general illustrates an improvement over the previous quarter. This condition is seen from the level of commercial bank credit growth in Kepulauan Riau in the third quarter of 2010 which amounted to 13.92% (yoy) higher compared with the previous quarter by 11.97% (yoy). Regarding the ratio of non-current loans for credit in Kepulauan Riau in 2009, the average was still below 3% but, starting in 2010, increased to the range of 3%.

Economic developments that occurred in several countries during the first half of 2010 still showed a positive trend. The International Monetary Fund (IMF) still believes that the global recovery is going well, although with an increased risk in the European financial sector in mid-2010. The cycle entered the stage of slow recovery, which has occurred in almost all areas, both developed and developing countries.

At the regional level, the magnitude of economic recovery for Kepulauan Riau was projected to fizzle out in the fourth quarter of 2010. Economic growth was projected in the range 4:58 ± 1%, again slower than the estimated growth in the third quarter of 6.16% (y-on-y). Overall, the rate of economic growth in Kepulauan Riau during 2010 was estimated to reach 6.8 ± 1%, while the rate of inflation in the town of Batam during the months of October to December 2010 was estimated to reach 0.80 ±

1%, down compared to the rate of inflation in the third quarter of 2010, which was recorded at 1.76% (cumulative monthly inflation rate). Thus, the rate of inflation until the end of the year was projected to be in the range of 5.93 ± 1% (yoy). Similarly, in the city Tanjungpinang, inflationary pressures during the fourth quarter of 2010 also had the potential to decrease to 0.84%, with the inflation rate throughout 2010 estimated at 5.41 ± 1%.

Table 5.2: Inflation Growth of Kepulauan Riau*

INDICATOR	**Q.II 2009**	**Q.III 2009**	**Q.IV 2009**	**Q.I 2010**	**Q.II 2010**	**Q.III 2010**
PDRB-Constan Cost (Billion Rp.)	9,463	9,694	9,954	10,064	10,165	10,165
PDRB Growth (yoy %)	2.26 %	3.50%	7.74%	9.24%	7.43%	6.16%
Yearly Inflation Rate of Kota Batam (yoy %)	2.52%	2.57%	1.88%	2.97%	5.14%	5.15%

*Source: BI (Bank Indonesia) - Republic of Indonesia's central bank (2010)

This condition beats the national economic condition very much, where most prices increased steadily, especially those for products or goods imported from overseas. The occurrence of high inflation growth is caused by, among others, imported inflation due to high exchange rate of the rupiah against the US dollar, the Bank of Indonesia printing new notes, and a high gap in supply and demand of products. The decrease of supply is caused by the decline of production due to a difficulty in importing the raw material, breakdown of distribution chain caused by social unrest and vandalism, liquidity problem of business sector (interest rate, termination of credit dispensing), high production cost and the increase of spreading money (Econit, 1998).

High inflation growth (hyperinflation) gives a strong hit to the construction industry, such as high increase of price for equipment and material, especially those that are imported like concrete iron, steel, ceramic and other finishing materials. As a result by the time the monetary crisis occurred, many construction projects were delayed/stopped and many contractors went bankrupt.

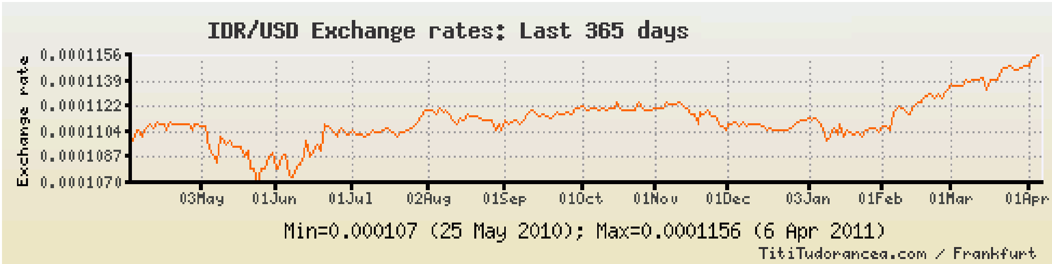
One of the government measures to overcome the above incidents is to apply a price escalation policy or price adjustment/price alteration policy due to inflation.

3. Rupiah Exchange Rate against US Dollar

Rupiah exchange rate is one of the indicators in the economic sector, where the currency of the US dollar has a significant influence on the global economy. In Figure 4.3, it can be seen that the rupiah exchange rate against the US dollar from 2004 up to 2010 depreciated around 32%, and in 2008 the rupiah continuously depreciated up to 400%, reaching Rp. 8,025 per US dollar.

Depreciation of the rupiah exchange rate is one of the causes of the monetary crisis that occurred in this country; this shows that the trust of the domestic market and foreign markets towards rupiah currency is very low.

Construction projects have a close relation to the rupiah exchange rate against the US dollar because almost all transactions for purchasing the material/equipment that contains imported components are carried out in foreign currency. High fluctuation of exchange rate will make it difficult for the contractor to determine the appropriate exchange rate in order to supply the material/equipment needed.



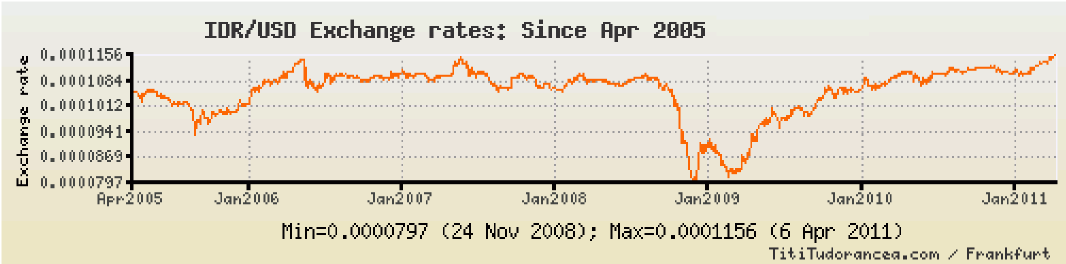


Figure 5.1: Rupiah Exchange Rate Against US Dollar
(Source: BI - Republic of Indonesia's central bank (2010))

Another impact felt by contractors due to the fluctuation and depreciation of rupiah currency within 2008 – 2010 is a change of scheme/procedure of payment to the supplier. The scheme applied by the supplier is by advance payment and paid in cash and the selling prices are subject to change at any time.

4. Interest Rate

A working capital loan is used to finance a process/cycle of production. The interest rate of working capital credit will differ from other banking credit; this complies with the banking policy regarding the risk to be borne. In Figure 4.4, the difference of interest rate between Bank Mandiri (state owned bank) and Bank Pembangunan Daerah (local bank) can be seen, in accordance with the target and the strategy of each bank. Bank Persero can give lower interest rates with a strict procedure and detailed requirements, such as having collateral, completeness of administration, and period of return. Bank Pembangunan Daerah can give higher interest rates with looser requirements and procedures.

In general, the interest rate that has been appointed and can support the Indonesian economy within the last 10 years (2000 – 2010) is around 15%-20% per annum. But when Indonesia had an economic crisis, the Bank of Indonesia applied a policy to increase the interest rate of credit, reaching to more than 26% per annum. This policy made it very difficult for the contractors to compete and to get the maximum profit; as a result in the end the creditor cannot settle the credit and may become bankrupt.

The high interest rate of credit is one of the impacts of the monetary policy issued by the Bank of Indonesia increasing its interest rates in order to strengthen the rupiah exchange rate against the US dollar. The high interest rate policy complicates credit dispensing and restricts the development of industry, especially in the real sector.

5. People Who Work by Main Industry

From the data collected, most people in Kepulauan Riau work in the agriculture sector, trade sector and industry sectors. Looking at the main working population in August 2009, almost all sectors experience an increase if compared with the situation in February 2009, except in the Agriculture Sector, which decreased by 1.42 million people (3.30%). Sectors that experienced the biggest increase in a row: the Construction Sector rose by 0.88 million people, the Community Services Sector rose by 0.39 million people and the Industrial Sector rose by 0.22 million people. When compared to the same period a year before, all sectors increased except the Transport Sector, which dropped by 60 thousand persons (0.97%).

Table 5.3: People's Main Job*

Sector	2007		2008		2009	
	Feb	**Aug**	**Feb**	**Aug**	**Feb**	**Aug**
Agriculture	42,61	41,21	42,69	41,33	43,03	41,61
Industry	12,09	12,37	12,44	12,55	12,62	12,84
Construction	4,4	5,25	4,73	5,44	4,61	5,49
Trade	19,43	20,55	20,68	21,22	21,84	21,95
Transportation	5,56	5,96	6,01	6,18	5,95	6,12
Finance	1,26	1,4	1,44	1,46	1,48	1,49
Social Service	10,96	12,02	12,78	13,10	13,61	14,00
Other	1,27	1,17	1,27	1,27	1,35	1,39

* Source: BPS – National Labour Force Survey of 2007-2009 (Prepared by Pusdatinaker)

6. Regional Minimum Wage (UMR)

From the data collected, there is no clear explanation about the minimum wage for the construction sector in Padang, Kepulauan Riau. As the benchmark Regional Minimum Wage (UMR) is applied, a change in the Regional Minimum Wage (UMR) will affect the minimum wage of the construction sector.

Table 5.4: outlines the condition of the regional minimum wage between 2005 and 2010. It can be clearly seen that in 2010 the regional minimum wage was still lower than the national minimum wage; as a result it can be categorised that labour prosperity of Kepulauan Riau is still low. Then the government increased the regional minimum wage to keep up with the economic developments, like the growth of inflation. On the other side, the increase of the regional minimum wage will enhance the public buying power.

Table 5.4: Increase of Regional Minimum Wage of Kepulauan Riau*

REGIONAL MINIMUM WAGE	YEAR (RUPIAH)					
	2010	2009	2008	2007	2006	2005
	1073.264	892.000	833.000	805.000	760.000	557.000

* Source: BKPM – Indonesia Investment Coordinating Board (2010)

Table 5.5: Increase of Regional Minimum Wage in Kepulauan Riau*

REGIONAL MINIMUM WAGE	YEAR (RUPIAH)					
	2010	2009	2008	2007	2006	2005
Provinsi Kepulauan Riau	1073.264	892.000	833.000	805.000	760.000	557.000
Kabupaten Karimun	-	-	839.000	-	-	-
Kabupaten Lingga	-	-	-	805.000	-	-
Kabupaten Natuna	-	-	-	817.000	-	-
Kota Batam	-	-	960.000	860.000	-	-
Kota Tanjung Pinang	-	-	835.000	805.000	-	-

* Source: BKPM – Indonesia Investment Coordinating Board (2010)

5.2.4 Construction Project Data

5.2.4.1. Construction Project Allocation in Kepulauan Riau

Construction projects in Kepulauan Riau consist of government projects and non-government project, with a composition of 75%: 25%. The contractors generally rely on the government projects. The projects owned by the government sector are those such as offices, housing, rubber industries, fishing, and so on. From the data collected, several dominant factors were obtained regarding executing development in Kepulauan Riau; they are as per the following points:

1. The land that can be cultivated in Kepulauan Riau is very limited, that is ±20%, and the rest is a line of hills with an unstable condition. The cultivated land has potential to be irrigated land of ±10% and the rest used for fishing. Another effort related to the land limitations is preventing the seashore abrading.
2. Given the realisation of being self-supporting in food requirements since 1984, Kepulauan Riau is also required to fulfil the food need of neighbouring provinces (Pekanbaru, Palembang, Medan); as a result acceleration of construction projects is required, such as:
   (a) Acceleration of PSD-PU irrigation development
   (b) Optimising the function of inter-province roads

3 Given that the Indonesia, Malaysia and Singapore Growth Triangle (IMS-GT) cooperation agreement insisted that the province of Kepulauan Riau should be involved in industrial cooperation and foreign investment, such as developing Padang Industrial Estate, Kepulauan Riau province must be able to:
   (a) Benefit from the excellence of resources, among others tourism sector, mining sector, and industrial sector as main capital.
   (b) Benefit from the development of the eastern province of Sumatera Island, like North Sumatera, Riau, Jambi, as support for accelerating the economic growth of Kepulauan Riau by improving the roads heading for the eastern part.

4 High urbanisation growth in relation to the increase of strategic sector transformation like industry and services; as a result it requires the city to have a double function; that is besides becoming the centre of settlement, government, trading, and other economic activities, it is also required to be able to push the economic growth of its vicinity. The increase of the city services requires the

availability of adequate infrastructure for the water supply, roads/bridges, clean water and settlements with better surroundings.

From the dominant factors above, development project planning is focused on the irrigation sector and road infrastructure sector. In Figure 4.6 it can be seen that within the last ten years the fund allocation for the irrigation sector and the sub-sector of road infrastructure is around 30%-66% of the total budget provided; whereas for the building sector and settlement sector this is around 10% to 20%, and the rest is for the state apparatus sector and supervision along with the knowledge and technology sector.

5.2.4.2. The Growth of Construction Project Companies

Qualification and membership of the contractor company in Indonesia shall comply with the regulations issued by the government, such as Presidential Decrees (Keppres), Government Regulation (PP) or Constitution. Within 2005 – 2010 membership qualification for contractor companies has changed several times, such as in 2001-2004 the qualification of contractor company B consisted of B1 and B2, and since 2004 up to the present the qualification of B1 and B2 has been combined into qualification B. And also qualification C, which consisted of C1, C2, and C3, changed to qualification C1 and C2 from 2004 to 2010. This alteration can be seen in the table below.

Table 5.6: The Growth of Qualifications Required for the Contractor Companies in Kepulauan Riau*

No	Period of Budget	Qualification							Number of companies
		A	B	B1	B2	C1	C2	C3	
1	2001/2002	17	-	64	176	116	128	894	1,395
2	2002/2003	23	-	79	299	123	153	900	1,577
3	2003/2004	23	-	80	146	158	191	567	1,165
4	2004/2005	27	-	121	301	203	314	1,068	2,034
5	2005/2006	27	-	137	391	242	364	1,406	2,567
6	2006/2007	34	-	128	415	204	379	1,109	2,269
7	2007/2008	34	79	-	-	263	1,439	-	1,815
8	2008/2009	38	89	-	-	270	1,492	-	1,889
9	2009/2010	40	88	-	-	281	1,529	-	1,938
10	2010/2011	36	87	-	-	324	1,286	-	1,733

* Source: Regional Office of Ministry of Public Works – Kepulauan Riau Province, Gapensi (2011)

The growth of contractor qualifications A and B has increased from year to year. Not all contractors with qualifications A and B are able to get a project every year because the number of projects available is not in line with the growth of the contractor companies, so it is found that many contractors had no activity but they are listed in the Association of Construction Employers (Gapensi). Therefore, the Association of Construction Employers (Gapensi) tries to accommodate them by performing tenders in turn or arranging a quotation in order that the distribution of work packages can be divided among the sub-contractors.

5.2.5 Government Policy on the Construction Sector

The policy issued by the government regarding the construction sector in Indonesia is aimed to create the principle of equality, professionalism, proportionality and efficiency. The policy is stipulated in Presidential Decrees (Keppres), Government

Regulation and Law. From 1984 to 2000, the government issued several policies, as seen in the table below:

Table 5.7: Government Policy in the Construction Sector*

No.	Policy
1.	Decree No. 29/84 on the Implementation of State Budget
2.	Decree No. 16/94 on the Implementation of State Budget
3.	Decree No. 24/95 on the Implementation of State Budget
4.	Decree No. 17/2000 on the Implementation of State Budget
5.	Decree No. 18/2000 on the Implementation of State Budget
6.	Government Regulation No. 28 year 2000 on Business and Society of Construction Role
7.	Government Regulation No. 29 year 2000 on Organization of Construction Services.
8.	Government Regulation No. 30 year 2000 on Management of Construction Services.
9.	Law No. 18 year 1999 on Construction Services.

* Source: Gapensi Regional Office – Kepulauan Riau Province

5.2.6 Data from Industry

The previous section describes the currently available best sources of data on variability of building work, but the search for relevant data was extended to organisations with links to industry and to commercial contracting companies.

Many organisations were approached but none within Indonesia were able to supply data in a relevant format. However, in order to use the raw data in a deterministic commercial environment, the variability of the data has been reduced by the use of work studying such things as the condition of work, and the physical effort expended.

As mentioned earlier, government policy is frequently issued, causing a difficulty in socialising (to make public aware) and implementing the policy.

The collected data used in this study were the actual construction costs of 25 projects of government service buildings that were built by general contractors between 2001 and 2009 in Batam and Tanjung Pinang, Indonesia. These costs data were the direct costs of Government Service buildings without mark-up.

In particular, the construction year was not used as an input variable because the extracted variables from cost data were converted using the Indonesian standard (SNI).

Information containing the building cost in unit price format suitable for analysis is not available in published form. Therefore, a method of collecting the required information has to be devised. Direct extraction of data from the priced bills of quantities of past projects has been adopted as the method of data collection for this research since it is established that historical data sets are able to provide sufficient information for the achievement of the objectives of this research. As a result, it is necessary to collect as many successful bidder tender documents as possible.

Implementers tend to appoint the services of quantity surveyors only when the project is substantially large. Small projects are normally handled by in-house staff, who may not be competent enough to put up bills of quantities in accordance with the SNI standard form of cost analysis format. For this research, only established quantity surveyors' firms and developers are considered. Even then, the data for the projects were closely scrutinised before being accepted. Among the main criteria for acceptance are procurement method, compliance with standard form of cost analysis (SNI) and transparency in awarding. Those contracts that deviated slightly from the SNI format would be exempted if such deviations can be adjusted and corrected manually, even if it may be time consuming. Only those contracts that were awarded between 2001 and early 2009 are considered. The information to be abstracted from each of the contract documents is project location, gross floor area, and unit price cost of frame elements. The data have been categorised into three elements to allow for concise cost modelling. Data will only be collected from government building projects. Arithmetic errors in bills of quantities will be adjusted and discount given at pre-award negotiation stage will not considered, thus avoiding inconsistency as the discount may vary from one project to another. In addition, the discounted sum also does not reflect the actual cost in the mind of cost estimators at the time of tendering. Data from public building projects will not be considered due to the doubtfulness of transparency in awarding tenders. Owing to the commercially sensitive nature of the data, the name of the clients, location and the exact title of projects will not be released.

5.2.7 Project Location

Building materials have been imported into Batam and Bintan Island for a very long time: bricks were brought from other islands in Sumatra and timber from Java. Reinforcement came from Singapore and hardwoods came from other countries.

Improvement in packaging and transport, and the lowering of protective tariff have opened up the materials market to international competition on a very large scale. To some extent this is bound to put limits on the degree to which monopolistic or oligopolistic producers in Batam can raise their prices.

Each construction site has its own characteristics which have an important influence on its suitability for development. The size of the site required will generally be determined by the type of project to be constructed. The cost of the project will be affected by its location. It may be situated on a congested city site with all the problems of access, material deliveries, close proximity of adjacent structure, etc. Alternatively, it may be located in the heart of the countryside with its own peculiar problems, particularly transport costs. The availability of main services or the cost of their provision will be an important consideration. Construction cost will also vary between different parts of the country, with cost in Jakarta currently being in the order of 13% higher than the average in the provinces (REI, 2011). The location of the building on site will also affect the overall cost of the scheme. Some projects may necessitate long road journeys with the consequent cost necessity for provision and contract maintenance.

The constructional details, material used and method of construction will have important cost implications for the project. These items are therefore of direct relevance to the resource input of the project in terms of labour, materials, equipment and organisation. Although it may be necessary to examine the economic consequences of each element of operation in turn, the cost influence of individual unit cost of work must also be considered. Cost studies of the choices available should be undertaken in circumstances where the cost differences between alternatives may make a substantial difference to the overall cost of the scheme. Some of the methods have been discarded, while one of the methods described remains in its development stage. Although methods have evolved over a period of time, changes are slow to take effect owing to the conservatism within the industry. Often surveyors will prefer to continue to use an inferior method for their approximate estimate, rather than attempt to use an unknown method where the results obtained cannot be easily verified. The attractiveness, therefore, of each of these methods includes its ease of application, familiarity and speed, together with a tolerable level of accuracy.

This study will focus of the unit cost of work. The collected data from the Public Works and Local Government were extracted into a modelling format. The analytical modelling of the data is explained in detail in Chapter 6.

Table 5.8: Unit Cost Work Public Service Buildings in Kepulauan Riau

Name of building	Puskesmas		PUSTU		SMK		SD Negeri		Lab SMK		Gedung Pendidikan		PUSTU 2	
	Total	Per Square Meter	Total	Per Square Meter	Total	Per Square Meter	Total	Per Square Meter	Total	Per Square Meter	Total	Per Square Meter	Total	Per Square Meter
Total cost	2,430,310,000	3,654,548	1,872,273,673	2,815,408	2,141,918,912	4,743,796	4,029,668,468	4,743,796	2,401,070,870	3,610,580	4,773,254,388	3,654,547	2,113,166,128	3,177,647
Building Area	665		512		452		850		657		1,306		578	
Structure Cost	997,785,476	1,500,407	748,909,469	1,461,819	879,383,939	1,947,608	1,654,416,380	3,229,306	985,781,090	1,482,356	1,959,702,219	3,825,202	867,579,227	1,304,611
Readymix	346,781,520	521,468	260,284,370	508,057	305,630,926	676,893	411,853,315	803,909	342,609,381	515,195	461,683,675	901,174	301,528,184	453,419
Iron	354,461,710	533,017	266,048,903	519,309	312,399,751	691,885	423,379,268	826,407	350,197,171	526,605	474,604,160	926,394	308,206,146	463,461
Light Formwork	53,695,098	80,743	40,302,017	78,667	47,323,406	104,809	49,870,080	97,3433	53,049,091	79,772	55,903,888	109,120	46,688,144	70,207
Heavy Formwork	346,916,525	521,671	260,385,701	508,255	305,749,910	677,157	412,055,022	804,303	342,742,762	515,395	461,909,787	901,615	301,645,571	453,596

Table 5.8, Continued'

Name of building	Puskesmas 2		SMP Negeri		SMK 2		Kecamatan		SD Negeri 4		Dinas Pendidikan	
	Total	Per Square Meter	Total	Per Square Meter	Total	Per Square Meter	Total	Per Square Meter	Total	Per Square Meter	Total	Per Square Meter
Total cost	1,434,494,584	3,654,548	1,434,494,584	3,654,548	2,281,207,436	3,654,548	2,037,021,961	3,063,146	3,744,400,226	3,654,548	1,746,137,833	2,625,733
Building Area	393		393		624		557		1,025		477	
Structure Cost	588,944,563	885,618	588,944,563	885,618	936,570,087	1,828,120	836,317,559	1,257,602	1,537,296,955	3,000,697	716,892,482	1,078,018
Readymix	204,688,378	307,798	204,688,378	307,798	275,828,065	538,397	290,663,155	437,081	391,683,477	764,539	249,156,828	374,666
Iron	209,221,623	314,614	209,221,623	314,614	283,547,273	553,465	297,100,488	446,761	402,644,966	785,935	254,674,919	382,964
Light Formwork	31,693,622	47,659	31,693,622	47,659	33,399,192	65,193	45,005,820	67,677	47,427,775	92,576	38,579,046	58,013
Heavy Formwork	204,768,065	307,917	204,768,065	307,917	275,963,153	538,661	290,776,312	437,251	391,875,306	764,913	249,253,827	374,812

Table 5.8, Continued'

Name of building	Dharma Wanita		Kecamatan 2		SD Pulau Abang		Klinik		Gedung Adat		SMP Negeri 2	
	Total	Per Square Meter	Total	Per Square Meter	Total	Per Square Meter	Total	Per Square Meter	Total	Per Square Meter	Total	Per Square Meter
Total cost	3,000,709,196	3,654,548	2,143,577,319	3,223,377	4,034,251,235	3,654,548	1,859,911,121	2,796,818	3,283,297,182	3,654,548	1,710,642,639	2,572,357
Building Area	821		587		1,104		509		898		468	
Structure Cost	1,231,967,960	2,404,716	880,064,813	1,323,386	1,656,297,875	3,232,978	763,603,122	1,148,259	1,347,986,982	2,631,177	702,319,614	1,056,104
Readymix	335,751,578	655,364	305,867,564	459,944	412,172,198	804,532	265,391,166	399,079	357,628,179	698,065	244,092,010	367,050
Iron	345,147,780	673,704	312,641,631	470,131	423,707,075	827,047	271,268,799	407,917	367,636,611	717,601	249,497,930	375,179
Light Formwork	40,655,150	79,356	47,360,046	71,217	49,908,693	97,419	41,092,745	61,793	43,304,122	84,527	37,794,818	56,833
Heavy Formwork	335,916,014	655,685	305,986,641	460,124	412,374,061	804,926	265,494,485	399,234	357,803,329	698,407	244,187,038	367,193

Table 5.8, Continued’

Name of building	SD Pulau Abang Tambahan		SMK Negeri 4		PUSTU 3		Kelurahan		Kecamatan Pulau		Balai Pertemuan	
	Total	Per Square Meter	Total	Per Square Meter	Total	Per Square Meter	Total	Per Square Meter	Total	Per Square Meter	Total	Per Square Meter
Total cost	2,914,726,991	3,654,548	1,620,276,533	2,436,470	2,700,507,468	3,654,548	1,124,441,954	1,690,865	1,644,692,337	3,654,548	1,730,485,407	2,602,196
Building Area	798		443		739		308		450		474	
Structure Cost	1,196,667,198	2,335,811	665,219,002	1,000,315	1,108,717,460	2,164,139	461,649,687	694,200	663,418,153	1,294,946	710,466,239	1,068,355
Readymix	328,926,477	642,042	231,197,649	347,661	311,550,665	608,125	160,446,893	241,270	216,210,400	422,028	246,923,380	371,308
Iron	338,131,675	660,010	236,317,997	355,360	320,269,591	625,144	164,000,320	246,613	222,261,174	433,838	252,392,006	379,531
Light Formwork	39,828,719	77,743	35,798,276	53,831	37,724,734	73,636	24,843,341	37,358	26,180,268	51,102	38,233,223	57,493
Heavy Formwork	329,087,570	642,356	231,287,656	347,796	311,703,248	608,423	160,509,357	241,364	216,316,291	422,234	247,019,509	371,452

5.2.8 Data Format

The data format was adopted from the standard form of cost analysis (SNI) introduced by the Public Works Ministry, Indonesia.

Under the SNI format, the ‘Frame’ element group has four units of work, namely concrete work, light form work, heavy form work and reinforcement. As such, there are several different ways of dividing up a building into its separate elements and obviously it is possible to go into more or less detail.

Construction is in fact a process of resource conversion: materials are changed through the application of labour activity and other forms of energy into parts of the final building. Sometimes that conversion process goes through many stages, the earliest of which takes place well before materials get to the building site; some arrive at the site in virtually their raw state and are converted as part of the building process.

5.3 Data Adjustment

SNI has two additional adjustment factors, namely quality and quantity, in addition to the location and time factor. Unfortunately, in Indonesia there has been no research conducted in this area and hence the extent of their influence cannot be established. It is also not within the scope of this study to identify the coefficients of these factors. One way to overcome these limitations is to make the factors as ‘constant’ as possible so as to minimise the cost price differentials.

CHAPTER 6

DATA ANALYSIS AND DISCUSSION

6.1 Introduction

The main aim of this chapter is to form the analytical model, analyse and describe the output of simulation modelling, sensitivity analysis, validation of the model and analyse the unit cost of work model into the risk-based estimate as an application of the model.

In this simulation all the data are processed using the software as listed below:

Table 6.1: Software List

SOFTWARE NAME	PRODUCED BY	APPLICATION
Microsoft Excel	Microsoft Corporation	Data analysis (Analytical Model)
ExpertFit	Averill M. Law & Associates	Comparing goodness-of-fit list and distribution fitting
@Risk	Palisade Corporation	Monte Carlo Simulation and Data Distribution Fitting
MCSim.xla (Excel Add-in)	Introductory Econometrics by Humberto Barreto and Frank M. Howland, published by Cambridge University Press	Monte Carlo Simulation
Oracle© Crystall Ball	Oracle Company	Data Distribution Fitting
Curve Expert	Copyright 1995-2010 Daniel Hyams	Curve Fitting
IBM SPSS Statistics	IBM Corporation 1994, 2013	Data Analysis

As described in Chapter 4, the first process in this simulation is constructing the analytical modelling. In general, the purpose of building an analytical model is to gain understanding of the current activity in the system and to measure performance and analyse behaviour of the cost within it.

In a construction system, it will be used as a basis for prediction of behaviour of certain unit cost of works within a system by inputting changes to different elements of the system; one might include labour, material and equipment changes. The cost per unit of work will be useful in the analytical model as an input in the cost modeling in order to calculate the total cost of the building.

Establishing the purpose for the modelling study will affect the total approach that is taken to model construction, characterisation of workloads, and series of analytical iterations to be performed with the model. In this research, the analytical model can be described as below (the scheme of the analytical model can be seen in the appendices):

The unit cost of work is formed by material cost, labour cost and equipment. As the unit cost of work on one building construction will be more than a hundred variables, this study will concentrate on the frame element of building only. This is because a study by Baso (2000) found that the most influential building element on the total cost is a structural element which is formed by foundation (substructure), frame (upperstructure) and roof. And the largest part of the superstructure is the frame element (30% and more).

The unit cost of work to form the frame element is comprised of four unit costs; these are:

1. Unit cost of reinforcement
2. Unit cost of concrete

3. Unit cost of light formwork
4. Unit cost of heavy formwork

And the unit cost of reinforcement will be comprised of:

1. Cost of material
2. Cost of labour
3. Cost of equipment

As described in Chapter 2, the system follows the construction cost of the Indonesian National Standard, or a system that has often been used by contractors – that is the BOW system – but others decide for themselves based on experience on previous projects. The index used by the contractor at the time of construction of state-owned buildings usually follows the index released by SNI or PU based on the highest price average. Indices are:

Table 6.2: The Index for psqm of Building (Public Work 2007)

Light formwork	**1,000**	**m2**
plywood 9 mm	0,470	ply
Timber	0,018	ton
nail 2 1/2"	0,600	Kg
Foreman	0,220	md
Assistant Foreman	0,370	md
Head Foreman	0,010	md
Heavy formwork	**1,000**	**m2**
plywood 9 mm	0,470	Ply
Timber	0,060	Ton
scaffolding	0,700	Set
nail 2 1/2"	0,750	Kg
Foreman	0,220	Md
Assistant Foreman	0,370	Md
Head Foreman	0,010	Oh
READYMIX K225	**1,000**	**m3**
Readymix concrete K 225	1,050	m3
Foreman	0,350	Md
Assistant Foreman	1,200	Md
Head Foreman	0,010	Md
tool	0,045	Lmp
Reinforcement 10-19	**1,000**	**Kg**
Reinforcement 19 mm	1,050	Kg
Wire of Concrete	0,010	Kg
Foreman	0,003	Md
Assistant Foreman	0,015	Md
Head Foreman	0,001	Md
tool	1,000	Lsm

Table 6.3: Index (PU, 2007)

Resources	Intermediate Building (2nd class)	Heavy Building (1st class)
Crushing Stone	0,1276	0,1767
Cement 50 kg	0,3285	2,9988
Steel Bar dia 10	11,648	10,0361
Steel Bar dia 16	13,458	19,8851
Concrete wire	1,2712	2,7362
Nail 3 cm	0,2476	0,2576
Second class wood	0,1557	0,166
Plywood 4 mm	0,1349	0,1728
Plywood 12 mm		0,0025
Head Foreman	0,2976	0,2697
Foreman	0,2015	0,2617
Stone foreman	0,5053	0,3662
Helper of stone foreman	0,4043	0,2946
Steel foreman	0,4763	1,0618
Helper of steel foreman	0,3402	0,991
Wood foreman	1,5298	1,8229
Helper of wood foreman	0,3718	0,3183

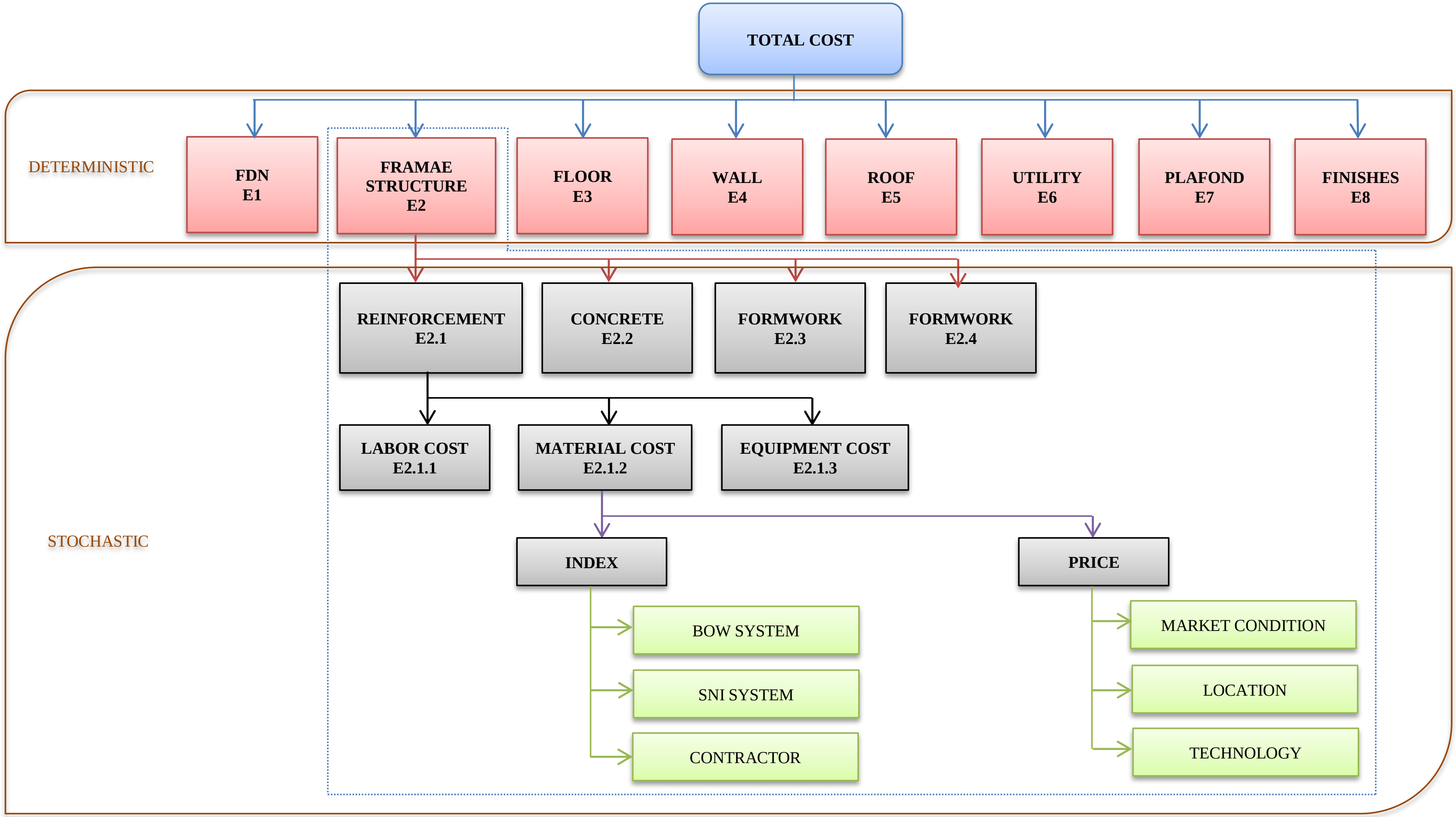
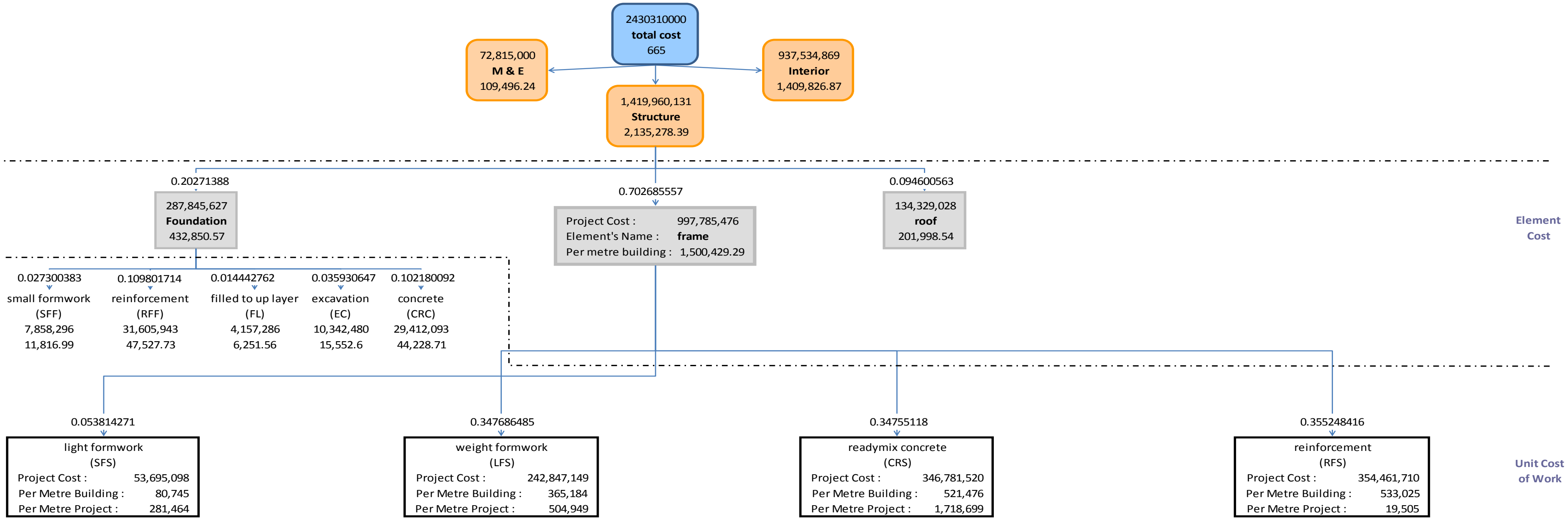


Figure 6.1: Explaining of The Analytical Model

ANALYTICAL MODEL



Plywood 9 mm	0.4696	230,000.00	108,004.17
Timber	0.0176	5,100,000.00	89,760.00
Nail 2 1/2"	0.6000	14,000.00	8,400.00
Foreman	0.2200	150,000.00	33,000.00
Asistant of foreman	0.3700	110,000.00	40,700.00
Foreman Head	0.0100	160,000.00	1,600.00
			281,464.17

Plywood 9 mm	0.4696	230,000.00	108,004.17
Timber	0.0600	5,100,000.00	306,000.00
Scaffolding	0.7000	7,350.00	5,145.00
Nail 2 1/2"	0.7500	14,000.00	10,500.00
Foreman	0.2200	150,000.00	33,000.00
Assistant of foreman	0.3700	110,000.00	40,700.00
Foreman Head	0.1000	160,000.00	1,600.00
			504,949.17

Readymix Concrete K 225	1.0500	1,456,000.00	1,528,800.00
Foreman	0.3500	150,000.00	52,500.00
Assistant of foreman	1.2000	110,000.00	132,000.00
Foreman Head	0.0100	160,000.00	1,600.00
Tools	0.0450	84,420.00	3,798.90
			1,718,698.90

Rebar 19 mm	1.0500	16,100.00	16,905.00
Concrete Wire	0.0100	24,000.00	240.00
Foreman	0.0030	150,000.00	450.00
Assistant of foreman	0.0150	110,000.00	1650.00
Foreman Head	0.0010	160,000.00	160.00
Tools	1.0000	100.00	100.00
			19,505.00

BOW Index	Contractor Index	SNI Index
0.5342	0.4696	0.4935
0.0186	0.0176	0.0123
0.6500	0.6000	0.5846
0.2584	0.2200	0.2479
0.5650	0.3700	0.3740
0.0100	0.0100	0.0097

Resource Based

Figure 6.1: Continued'

420,913,054.37

frame (COE)

0.053814271

(SFS)

psqm	80,745	735,330
m2 of work	281,464	488,994,450

material	206,164.17
labour	75,300.00
tools	0.00
	281,464.17

cost item	SNI indeks	variable	price	cost
nail 3 cm	0.2576	PK	16,500	4,250
2nd class wood	0.166	KY	3,000,000	498,000
plywood 4 mm	0.1728	KL4	55,000	9,504
plywood 12 m	0		-	-
			MSFS	511,754
wood foreman	1.8229	KK	70,000	127,603
helper of wood foreman	0.3183	LTK	55,000	17,507
foreman head	0.2697	MN	80,000	21,576
site foreman	0.2617	KT	75,000	19,628
			LSFS	186,313.00
tools	20%			37,262.60
				735,330

0.34755118

(CRS)

psqm	521,476	725,648
m3 of work	1,718,699	482,555,987

material	1,528,800.00
labour	186,100.00
tools	3,798.90
	1,718,698.90

cost item	SNI indeks	variable	price	cost
gravel sand	0.1767	PSB	245,000	43,292
gravel	1.3524	KRB	320,000	432,768
cement 50 kg	2.9988	SMN	50,000	149,940
				626,000
foreman head	0.2697	MNDR	80,000	21,576
site foreman	0.2617	KPTR	75,000	19,628
stone foreman	0.3662	TB	70,000	25,634
helper for stone foreman	0.2946	LTRB	55,000	16,203
				83,041
equipment			20%	16,608
				725,648

Price list		
gravel sand	0.1276	0.1767
gravel	0.2028	1.3524
cement 50 kg	0.3285	2.9988
rebar 10	11.648	10.0361
threaded rebar 16	13.458	19.8851
concrete wire	1.2712	2.7362
nail 3 cm	0.2476	0.2576
2nd class wood	0.1557	0.166
plywood 4 mm	0.1349	0.1728
plywood 12 m		0.0025
foreman head	0.2976	0.2697
site foreman	0.2015	0.2617
stone foreman	0.5053	0.3662
helper for stone foreman	0.4043	0.2946
steel foreman	0.4763	1.0618
helper for stone foreman	0.3402	0.991
wood foreman	1.5298	1.8229
helper for wood foreman	0.3718	0.3183

0.243386133

(LFS)

psqm	365,184	726,201
m2 of work	504,949	482,923,665

material	424,504.17
labour	75,300.00
tools	5,145.00
	504,949.17

cost item	SNI indeks	variable	price	cost
nail 3 cm	0.2576	PK1	16,500	4,250
2nd class wood	0.166	KB2	3,000,000	498,000
plywood 4 mm	0		-	-
plywood 12 m	0.0025	KL12	150,000	375
				502,625
wood foreman	1.8229	Tky	70,000	127,603
helper of wood foreman	0.3183	LTY	55,000	17,507
foreman head	0.2697	MND	80,000	21,576
site foreman	0.2617	KTR	75,000	19,628
				186,313
tools			20%	37,263
				726,201

0.34755118

(RFS)

psqm	533,025	462,869
kg of work	19,505	307,808,124

material	17,145.00
labour	2,260.00
tools	100.00
	19,505.00

cost item	SNI indeks	variable	price	cost
rebar 10	10.0361	BSBTP	7,050	70,755
threaded rebar 16	19.8851	BU	7,050	140,190
concrete wire	2.7362	KB	17,500	47,884
				258,828
steel foreman	1.0618	TBS	70,000	74,326
helper for steel foreman	0.991	LTB	55,000	54,505
site foreman	0.2617	KPB	75,000	19,628
foreman head	0.2697	MND	80,000	21,576
				170,035
tools			20%	34,007
			psqm	462,869

Figure 6.1: Continued’

The second step of simulation to form the model is finding the best fitted/first-ranked distribution called input data modelling. When it comes to the analytical model, input data modelling is combined with several variables like random sampling model. As far as uncertain value number or random sample model are considered, they include some several functions like cost of work in order to reinforce work form, concrete work, light framework and heavy framework. The next step is related to illustration of cost after clarifying uncertain variable factors. It can be found that cost factor will be used as random pattern and input model for this purpose; for instance, installation cost in the field of concrete reinforcement formation, light formwork and finally costly heavy framework. When it comes to statistical approach, data modelling has been designed by three different parameters: parametric, empirical and theoretical. Then, the result is analysed and compared versus intention to assess the suitability.

As far as theoretical distribution is considered, Chi-square, Kolmogorov Smirnov and Anderson Darling will be used for goodness of fit. For this purpose, first-ranked distributions are recognised in terms of initial identification. Whole unit costs are represented by one group of distribution usage. Based on a statistically accepted hypothesis known as a null hypothesis, three goodness-of-fit tests are recorded.

The presentation of input data modelling results is divided into three sections, namely parametric equation modelling, empirical and theoretical distribution approaches.

6.2 Analysing Data Modelling

Parametric equation input data modelling was carried out using the software and the results are presented in Table 6.4.

Table 6.4: Parameters of Input Distribution

Name	COE	PK	PK1	PSB	RFS
Description	Output	RiskBetaGeneral(2,026;2,0163;14840,5;18152,4;RiskName("PK"))	RiskBetaGeneral(2;2;14850;18150;RiskStatic(16500))	RiskNormal(245000;50000;RiskStatic(245000);RiskName("PSB"))	RiskBetaGeneral(2;2;-10;10)
Cell	analytical!X34	analytical!O48	analytical!V48	analytical!AA48	analytical!AD48
Minimum	289.658.500,00	14.863	14.865	59.769	-9,901894
Maximum	543.405.400,00	18.151	18.131	425.028	9,891012
Mean	420.883.100,00	16.500	16.500	245.001	-6,61149E-06
Std Deviation	35.551.400,00	738	738	49.989	4,472509
Skewness	0,0	0,0	0,0	0,0	0,0
Kurtosis	2,9	2,1	2,1	3,0	2,1
Mode	430.102.700,00	16.600	16.577	240.608	0,7346575

Table 6.4: Continued'

Name	BSBTP	KY	KB2	KRB
Description	RiskBetaGeneral(2;2;6345;7755;RiskStatic(7050))	RiskBetaGeneral(2;2;2700000;3300000;RiskStatic(3000000);RiskName("KY "))	RiskBetaGeneral(2;2;2700000;3300000;RiskStatic(3000000))	RiskNormal(320000;80000;RiskStatic(320000);RiskName("KRB "))
Cell	analytical!AF48	analytical!O49	analytical!V49	analytical!AA49
Minimum	6.350	2.702.976	2.700.159	7.541
Maximum	7.746	3.295.744	3.297.182	630.358
Mean	7.050	3.000.000	2.999.999	319.997
Std Deviation	315	134.177	134.179	80.019
Skewness	0,0	0,0	0,0	0,0
Kurtosis	2,1	2,1	2,1	3,0
Mode	7.055	2.993.997	2.981.978	314.982

Table 6.4: Continued’

Name	RFS	BU	KL4	SMN
Description	RiskBetaGeneral(2;2;-10;10)	RiskBetaGeneral(2;2;6345;7755;RiskStatic(7050))	RiskBetaGeneral(2;2;49500;60500;RiskStatic(55000);RiskName("KL4 "))	RiskNormal(50000;12000;RiskStatic(50000);RiskName("SMN"))
Cell	analytical!AD49	analytical!AF49	analytical!O50	analytical!AA50
Minimum	-9,8633	6.356	49.585	4.218
Maximum	9,9000	7.745	60.440	96.484
Mean	0,0000	7.050	55.000	50.000
Std Deviation	4,4727	315	2.460	12.001
Skewness	0,0	0,0	0,0	0,0
Kurtosis	2,1	2,1	2,1	3,0
Mode	-0,6006	6.998	54.963	50.752

Table 6.4: Continued'

Name	KB	KL12	Tky	MNDR
Description	RiskNormal(17500;4000;RiskStatic(17500))	RiskBetaGeneral(2;2;135000;165000;RiskStatic(150000))	RiskNormal(70000;16000;RiskStatic(70000))	RiskNormal(80000;16000;RiskStatic(80000);RiskName("MNDR"))
Cell	analytical!AF50	analytical!V51	analytical!V54	analytical!AA54
Minimum	2.392	135.111	10.873	23.302
Maximum	31.921	164.941	128.668	143.456
Mean	17.500	150.000	70.000	80.001
Std Deviation	4.000	6.709	15.998	16.000
Skewness	0,0	0,0	0,0	0,0
Kurtosis	3,0	2,1	3,0	3,0
Mode	17.450	149.900	68.996	78.594

Table 6.4: Continued'

Name	TBS	LTY	KPTR	LTB
Description	RiskBetaGeneral(2;2;63000;77000;RiskStatic(70000))	RiskNormal(55000;14000;RiskStatic(55000))	RiskNormal(75000;18000;RiskStatic(75000);RiskName("KPTR "))	RiskBetaGeneral(2;2;49500;60500;RiskStatic(55000))
Cell	analytical!AF54	analytical!V55	analytical!AA55	analytical!AF55
Minimum	63.090	4.076	3.040	49.528
Maximum	76.914	107.846	138.944	60.423
Mean	70.000	55.001	74.998	55.000
Std Deviation	3.131	13.999	18.002	2.460
Skewness	0,0	0,0	0,0	0,0
Kurtosis	2,1	3,0	3,0	2,1
Mode	69.860	56.936	74.323	54.890

Table 6.4: Continued’

Name	MND	TB	KPB	KTR
Description	RiskNormal(80000;16000;RiskStatic(80000))	RiskNormal(70000;16000;RiskStatic(70000);RiskName("TB "))	RiskBetaGeneral(2;2;67500;82500;RiskStatic(75000))	RiskNormal(75000;18000;RiskStatic(75000))
Cell	analytical!V56	analytical!AA56	analytical!AF56	analytical!V57
Minimum	21.527	11.419	67.596	10.027
Maximum	136.917	146.947	82.439	142.001
Mean	80.000	70.004	75.000	75.000
Std Deviation	15.995	16.013	3.354	17.998
Skewness	0,0	0,0	0,0	0,0
Kurtosis	3,0	3,0	2,1	3,0
Mode	78.595	70.601	74.850	74.323

Table 6.4: Continued’

Name	LTRB	MND
Description	RiskBetaGeneral(2;2;49500;60500;RiskStatic(55000))	RiskBetaGeneral(2;2;72000;88000;RiskStatic(80000))
Cell	analytical!AA57	analytical!AF57
Minimum	49.562	72.064
Maximum	60.449	87.958
Mean	55.000	80.000
Std Deviation	2.460	3.578
Skewness	0,0	0,0
Kurtosis	2,1	2,1
Mode	55.037	80.374

It is interesting to note that all unit costs can be represented by one type of model or equation, like for labour cost of head foreman (MDR): the characteristic of the β curve is S-shaped and is well suited for typical construction data, which has a constraint of decreasing probability of occurrence when approaching the upper and lower limits. It is a triangle shape, Unimodal, and has the desired properties as it can be accepted as the probability-density functions for simulation, as highlighted by Back et al. (2000). The high degree of fit can be further confirmed by the very low values of standard error, thus indicating that the data points are spreading very closely around the non-linear regression curve.

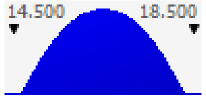
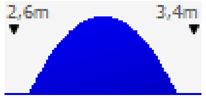
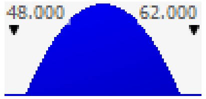
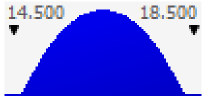
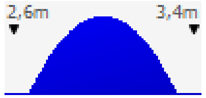
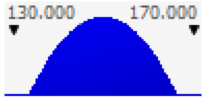
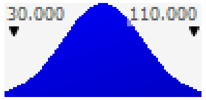
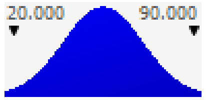
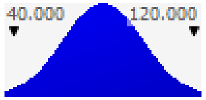
Name	Graph	Function	Min	Mean	Max
PK		RiskBetaGeneral(2,026;2,0163;14840,5;18152,4;RiskName("PK"))	14.841	16.500	18.152
KY		RiskBetaGeneral(2;2;2700000;3300000;RiskStatic(3000000);Risk Name("KY "))	2.700.000	3.000.000	3.300.000
KL4		RiskBetaGeneral(2;2;49500;60500;RiskStatic(55000);RiskName(" KL4 "))	49.500	55.000	60.500
PK1		RiskBetaGeneral(2;2;14850;18150;RiskStatic(16500))	14.850	16.500	18.150
KB2		RiskBetaGeneral(2;2;2700000;3300000;RiskStatic(3000000))	2.700.000	3.000.000	3.300.000
KL12		RiskBetaGeneral(2;2;135000;165000;RiskStatic(150000))	135.000	150.000	165.000
Tky		RiskNormal(70000;16000;RiskStatic(70000))	-∞	70.000	+∞
LTY		RiskNormal(55000;14000;RiskStatic(55000))	-∞	55.000	+∞
MND		RiskNormal(80000;16000;RiskStatic(80000))	-∞	80.000	+∞

Figure 6.2: Triangular Distribution of Reinforcement Cost

For the purpose of validation, the fitted curves for all cost units were compared with the collected data curves shown in the appendices. The cumulative percentages of collected data were derived using empirical distribution approach. The graph visually confirmed the high degree of fitness between model and collected data. The occurrences of these events were largely attributed to the inadequate sample data at the tail ends, which can be seen clearly from the graph. Random sampling of data during simulation at these portions of curve would be instable and may lead to large unrealistic cost values or infinity values. For instance, any random number generated between 0.9 and 1.0, when read from the graph, would have infinity cost for cost unit Reinforcement. Similarly, the left tail end also faced similar problems.

Although the curve fitting performs very well technically, it suffers a major setback in simulation applications. In this respect, it is the researcher's opinion that the parametric equation approach of data modelling has its problems and shall not be accepted for Monte Carlo simulation in the context of this research, which uses small data sets. In view of this, no further analysis of this technique will be carried out from this point onwards.

6.3 Empirical Distribution

The graph also displays the cumulative empirical distribution for all four cost units of work. The left-most dots represent the lowest value while the right most indicate the largest value in the data sets. The distributions were specified using collected data. The reliability of using empirical distribution as an input model to Monte Carlo simulation can only be accessed through the simulation output results.

6.4 Theoretical Distribution

Table 6.5: Results of Simulation Using First-Ranked Distribution

Cost Hierarchy			Collected Data		Simulated Data	
			Mean	**SD**	**Mean**	**SD**
Total Cost	**Element Cost**	**Unit Cost of Work**				
Total Cost			3,654,547.89	556,354.57	3,391,530.80	556,183.18
	Frame (element)		1,482,355.83	300,597.20	1,597,037.78	299,334.68
		Concrete	521,468.32	89,836.38	544,487.20	89,732.17
		Reinforcement	533,017.31	92,095.83	550,328.30	91,979.07
		Formwork	80,743.32	12,183.52	74,004.90	12,261.91
		Formwork 1	521,671.33	89,847.32	536,729.90	90,164.29

For example, taking the ‘Normal’ column and ‘Concrete’ row in Table 6.5, the ‘2’ means that cost data of ‘Concrete’ can be fitted into ‘Normal’ distribution and is second-ranked in the order of goodness-of-fit using Chi-Square test. The numbers shown at the bottom of the table indicate the number of times a particular distribution is able to fit the unit cost data.

Data tables at the bottom of Table 6.6 show the total number of times a distribution can be statistically fitted using different goodness-of-fit tests. Logistic distribution has been found to be able to fit all cost units irrespective of the type of goodness-of-fit test.

The characteristics of these distributions and their density functions formula are shown in Table 6.6 Out of these four distributions, only one will be selected and adopted for cost modelling. The approach to achieve this aim is by analysing the simulation output of each of these distributions.

Table 6.6: Results of Simulation

Element	Collected Data		Logistic		Normal		Ext Value	
Total/Sub Total	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Frame	1,852,866.65	889,618.17	1,756,891.40	929,403.67	1,852,866.60	889,618.20	1,826,678.76	829,948.90
Concrete	544,487.24	180,537.70	535,491.00	192,433.41	544,487.20	180,537.70	546,068.55	192,885.75
Reinforcement	550,328.25	187,128.27	546,760.70	198,508.91	550,328.30	187,128.30	560,304.66	225,057.74
Formwork	74,004.86	18,752.64	73,712.10	19,673.74	74,004.90	18,752.60	74,731.85	21,806.43
Formwork 1	536,729.88	181,524.26	533,581.60	192,383.89	536,729.90	181,524.30	546,840.18	219,613.32

Another reason for rejection is the existence of an almost flat shape at the upper and lower ends of the curve. Generating random values from these portions of the distribution would yield extreme high/low corresponding costs, which is not reflective of the actual system being modelled.

True to the expectation, the selected first-ranked distribution of cost unit of work was quite often not similar in Chi-square test. Likewise, the selected first-ranked distributions using different goodness-of-fit test were also often not similar. This shows that selection of input distribution is sensitive to class intervals and goodness-of-fit tests.

Among the distributions that have been found to have the potential to be used as the sole representation for all cost units were Normal, Lognormal, and Ex-value distribution. This is based on the criteria that these distributions have the highest and second-highest number of acceptance under the statistical hypothesis test of data fitting. All these distributions will be tested out to see which one of them produces results that are closest to the collected data.

Figure 6.2 also illustrates a sample of simulation run to generate total cost using first-ranked distributions selected from Chi-Square, K-S and A-D. Both the relative and cumulative frequency curves were very close to each other, thus indicating the closeness of output results irrespective of whether the first-ranked distribution is selected by Chi-Square, K-S or A-D test. Thus, the conclusion that can be drawn from these analyses is that first-ranked distributions selected using any of the three goodness-of-fit hypotheses tests have little impact on the simulation outcomes.

6.5 Empirical versus Collected Data Distribution

The simulation outputs are based on the input distributions established in Table 6.1 comparing the value of mean and standard deviation of the collected data with the simulation outputs using empirical distribution as the input model. For ease of comparison, a curve fitting was carried out to fit both the collected and simulated data into a theoretical distribution. The @Risk program has ranked Triangle and Normal distribution as the first-ranked distribution for collected and simulated data respectively. The ranking is based on K-S goodness-of-fit test. From Table 6.6, it can be observed that the mean values of the simulated outputs, using empirical distribution as an input model, are quite close to the collected data.

However, the SD is lower than the collected data of Rp. 187,128.27 for the reinforcement cost. When translated into graphical format, the difference in standard deviation can be clearly seen. The spread for Normal distribution is much narrower than lognormal distribution. The consequences of this are that underestimation of total cost will occur at the lower confidence limit, in this case 0%-60%, The occurrences are attributed to the limitation of this approach whereby the random sampling values cannot exceed the largest and the smallest values of the collected data. Another possible reason is the failure to take correlation among the cost units into consideration.

The result of the simulation using first ranked distribution (based on Chi-Square test) is shown in Figure 6.2.

The differences in mean and standard deviation between different numbers of class intervals were small and can be considered to be negligible. The outputs were almost identical both in shape and spread for all numbers of class intervals.

However, when compared to collected data, there was a marked difference in standard deviation. On average, the differences were as much as 30% for the total cost, 22% for the element frame cost and 40% for the reinforcement cost. Unlike the empirical approaches, which have a limitation that the generated values must be within the maximum and minimum cost, this approach was free from such limitation but still faced the similar problem that underestimating of standard deviation is most likely caused by the assumption of independence (no co-relational effects) among the cost units of work.

The above conclusion is only true when comparing results among the different goodness-of-fit tests. However, when these results are compared to the collected data, a different scenario surfaces. Although the means are quite similar, differences in standard deviation are too large to ignore.

The underestimation of standard deviation is as much as 18% for total cost component and definitely warrants further investigation. Again the assumption of independence between cost units is suspected to be the culprit. However, a further analysis to ascertain such discrepancies will be carried out and presented in the later part of this chapter.

6.6 Single Family Distribution

The distributions that have been identified are Normal, Lognormal and Ex-value; the input distributions used for simulation in this section are shown in Table 6.2.

6.7 Simulation with Correlated Random Numbers

Two conclusions can be deduced from the analysis of the values of mean. Firstly, the means of the simulated data based on the three separate goodness-of-fit tests were very close to each other, thus reaffirming earlier findings that the type of goodness of fit tests was not critical to the simulation model. Secondly, when comparing the means without correlation, the means were also very close, thus indicating that incorporation of correlation relationship has no significant impact on the mean. The most critical finding of this analysis was the standard deviation shown on the right side of the table. Standard deviation values increased by approximately 12% when the correlation incorporated into the simulation for all three tests, although the increase and the difference is still significant for each test. Hence, this analysis has thus confirmed the importance of correlation effects among cost units which shall be taken into consideration at all cost.

However, when standard deviation of collected cost data is compared with the simulated data, the generated results are significantly lower, especially for the top three cost unit groups. The average underestimation of total cost standard deviation was 18%. Even though the margin of error is on the high side, it is still within the limit of cost modelling at both the conceptual and preliminary stage of estimation (Skitmore, 1988).

The simulation outputs shown in Figure 6.4 were based on the incorporation of Spearman's coefficient correlation into the simulation system using a similar family of distribution for all cost units as the input model. The mean of collected cost data was also included. The two important pieces of information which can be observed from this analysis are: (1) the values of mean between different families of distribution for total cost and cost unit groups are generally similar; (2) there is no change in mean even though correlation effect is taken into consideration. A numerical computation was carried out and shows that the differences in mean between the cases of with and without correlation effects were less than 1%.

Thus it can be concluded that correlation has no significant impact on cost models using Monte Carlo simulation technique. These findings are in agreement with all other analysis conducted thus far. The same format for the table and histogram, as used above, was also utilised to compare the standard deviation. The corresponding table and histograms are close although the standard deviation (without correlation effect) of Normal was higher than the other family of distributions but, when compared to standard deviation of collected data, the differences were still large. When correlation effect was integrated into the modelling system, there was a drastic increase in standard deviation.

The difference in SD between the collected data and simulation outputs has narrowed. However, for the total cost and the superstructure cost unit group, which are most sensitive to simulation due to larger number of cost units, the differences varied significantly from one family of distribution to another. Excessive overestimation of SD in the Frame group has raised some concern in accepting LogNormal. To break this deadlock, a further graphical analysis was carried out. It is concluded here that LogNormal distribution is the most representative distribution for building cost units in the context of using Monte Carlo simulation technique.

The search for the most suitable probability distributions to model behaviour of building cost data ended with the selection of LogNormal distribution to represent all building cost units as described above. The functions, parameters and statistical description of each of these cost units represented using LogNormal distribution are shown in the appendices Besides Table 6.2, there is also the display of the probability density and cumulative density curves. The shapes of the density curves were all positively skewed, thus meeting the expectation of the nature of construction cost data that has many unfavourable events that might affect costs.

6.8 PDF and CDF of Total Cost and Cost Unit

The pdf and cdf in the appendices are the simulation outputs for building total cost and cost unit of work using LogNormal 5 as an input distribution for all cost units. The accompanying table at the left of the graph presents the summary statistics of the results of 5000 iterations. The mean, standard deviation, variance, kurtosis and skewness have the same meaning as for any large sample, and the definition and implication of each of this information has already been described. The standard error of the estimate quantifies the spread of the data points around the mean value. As the spread of the data decreases, the standard error approaches zero.

The minimum is the lowest value and the maximum is the highest value over all 5000 points. The range is the difference between the maximum and minimum values. A close assessment of the graph indicates that the pdf curves were all positively skewed – a pattern that was consistent with the prediction of the model. A positive skewed curve indicates that the most likely value (relates to the most frequently observed events of the past) falls towards the risky end of the range of likely outcomes. The main reason why the most likely values are inherently optimistic and risky is the fact that individual costs almost always display more scope to overrun than they do opportunity to improve.

The typical shape of cumulative probabilistic cost is the S-curve. It means that the chances for a work to be implemented at extremely low rates (optimistic) and high rates (pessimistic) are very unlikely although it is possible theoretically.

With the availability of these graphs, it is possible to specify a given degree of risk and read off an appropriate output (deterministic estimate). For example, a client could say "I want a total cost estimate with all possible risks taken into consideration that has only a 10% change of being exceeded (or 90% confidence that is will not be overrun)". In this respect, the estimator can refer to the graph for an answer. Using the secondary y-axis on the right and by projecting a straight line at 70% towards the cdf curve, one can read the corresponding value on the x-axis.

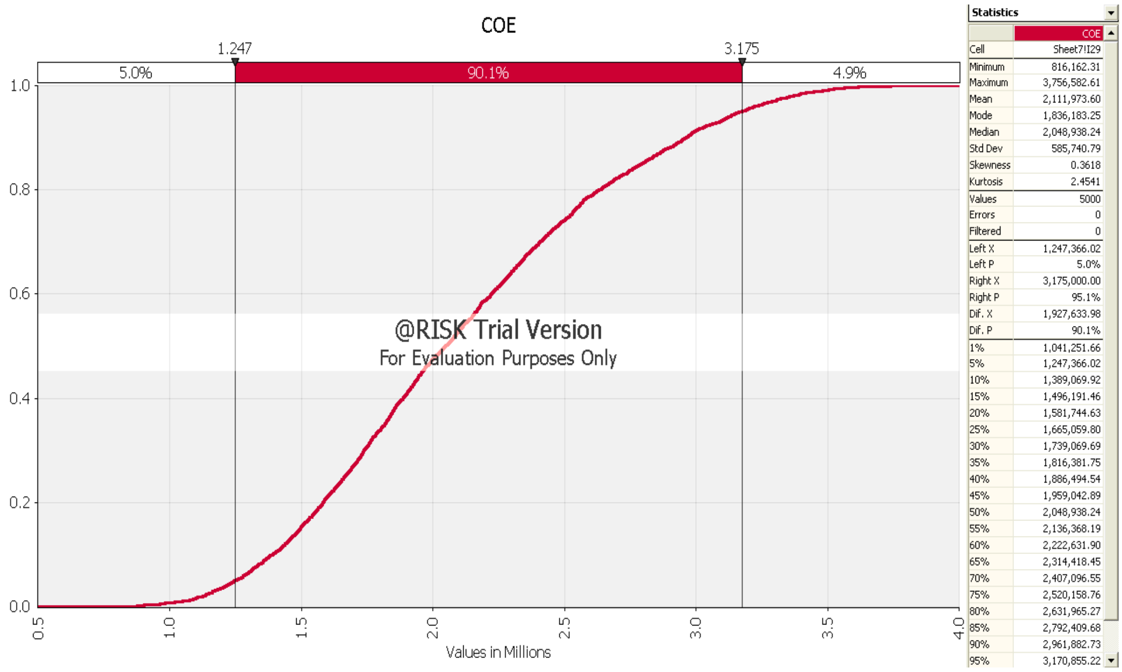


Figure 6.3: CDF of Framework

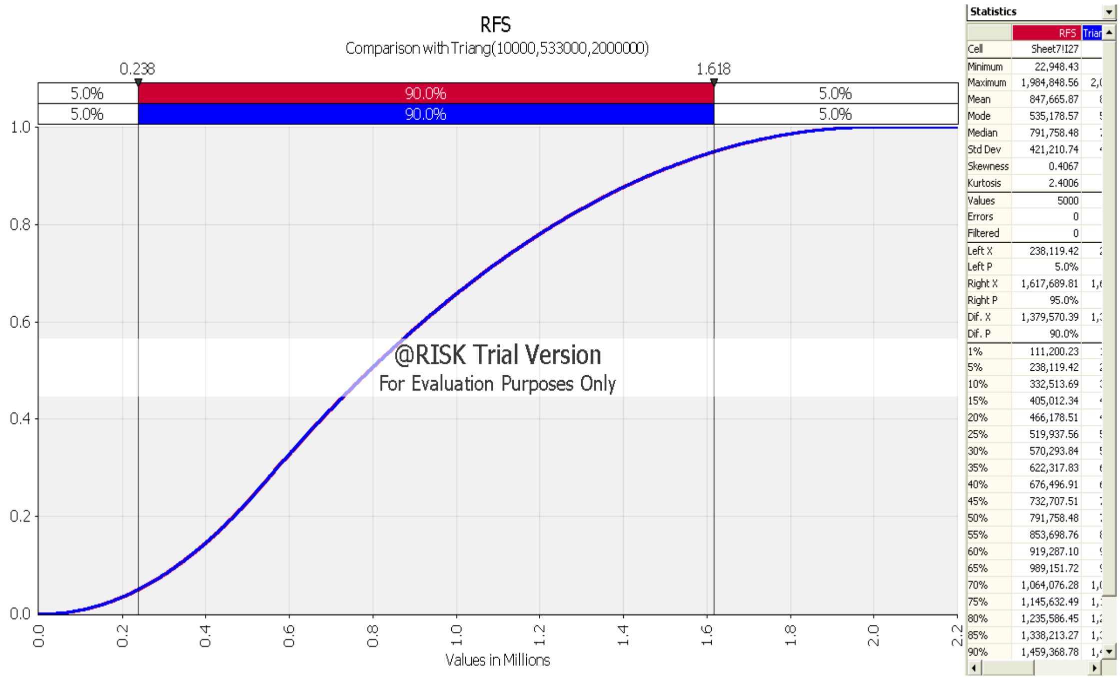


Figure 6.4: CDF of Reinforcement

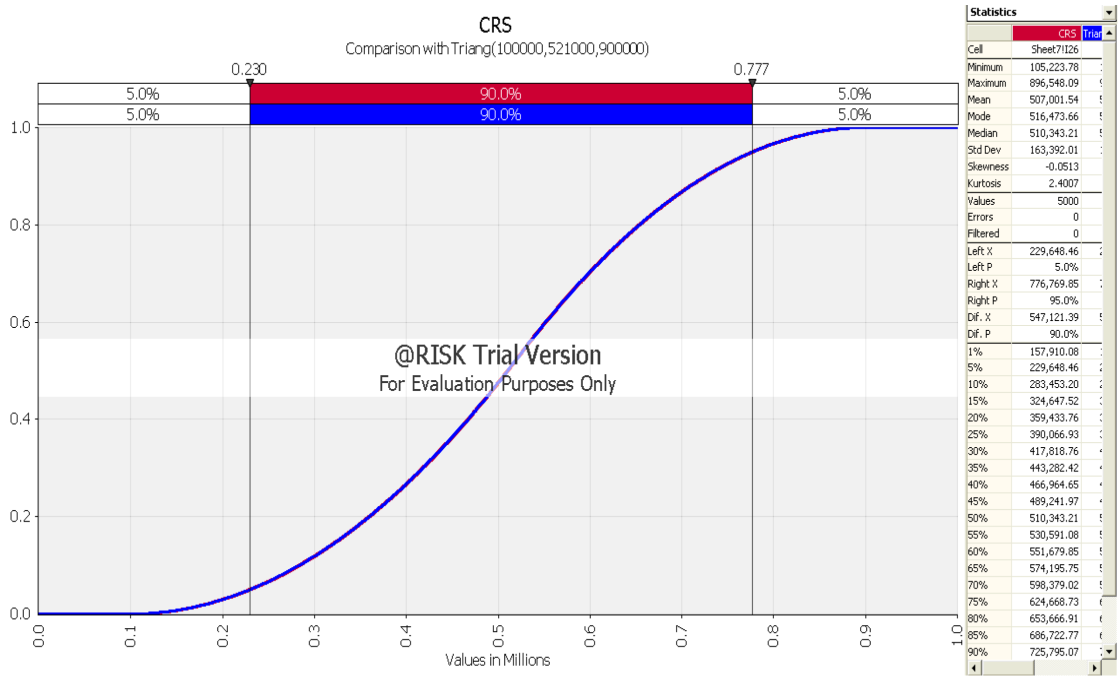


Figure 6.5: CDF of Concrete Cost

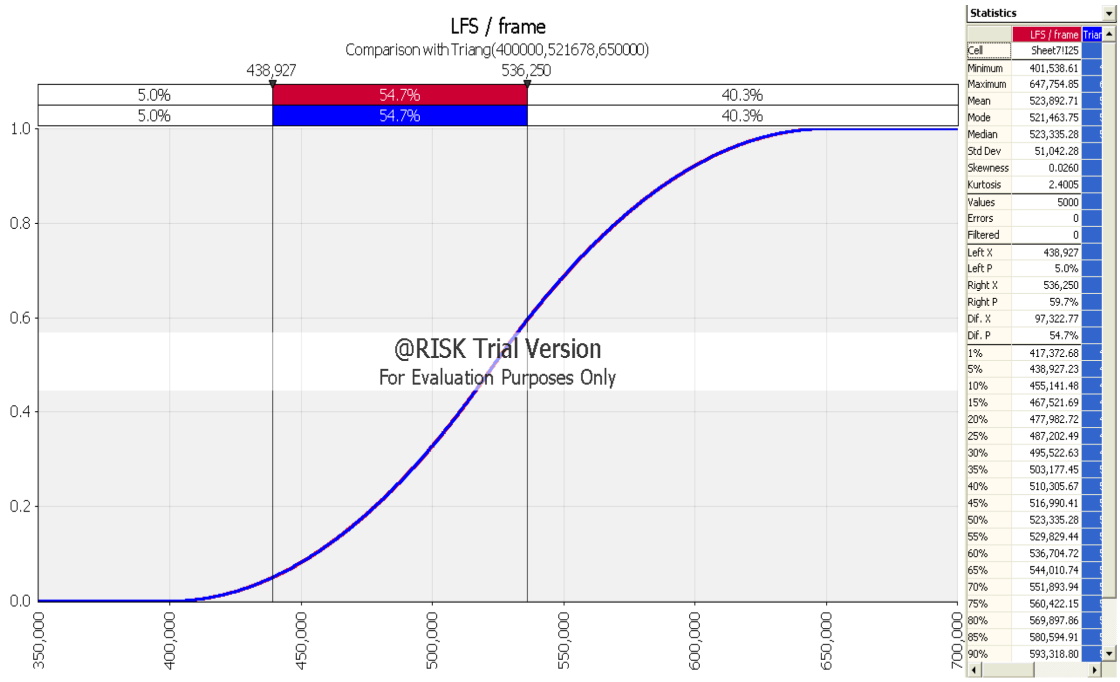


Figure 6.6: Formwork

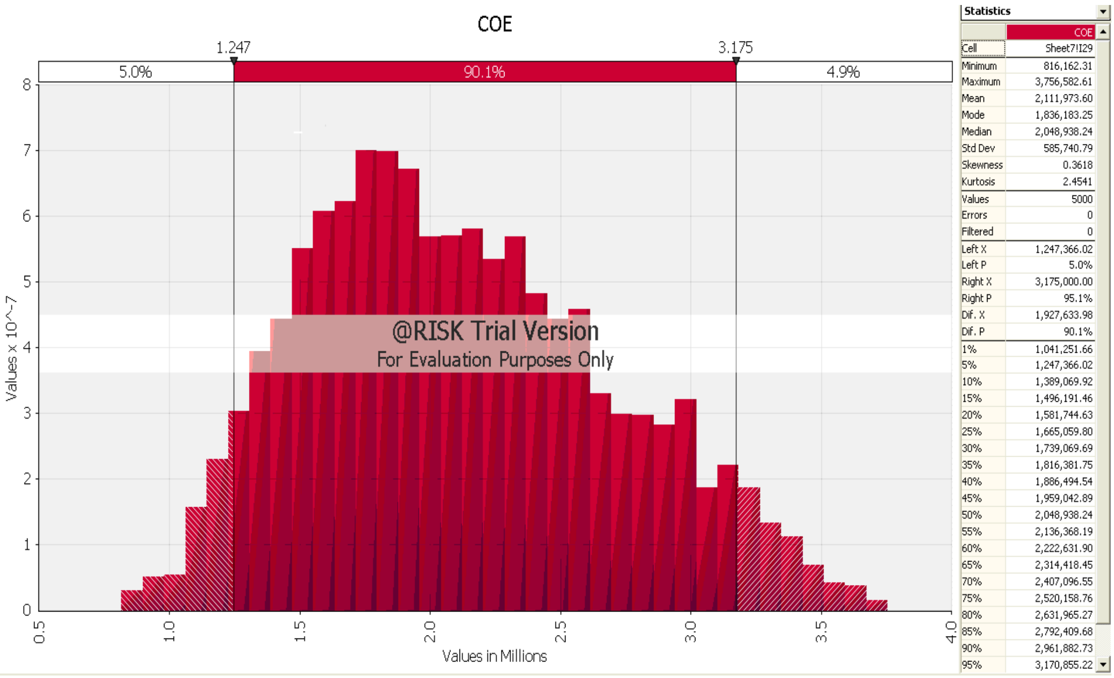


Figure 6.7: Cost of Element Frame (Output Simulation)

6.9 Sensitivity Analysis Results

In the model, some variables are more important than others. Sensitivity analysis is the process of analysing the relative importance of elements in the model. It usually focuses attention on the input variable assumptions and not on the model structure (Berends, 2011).

Monte Carlo simulation and decision-free analysis are ways to recognise uncertainty in input variables. These represent judgements about risk and uncertainties.

Sensitivity analysis of the input to a simulation allows the identification of the degree of impact of input variables (cost units) towards the total project cost. The two methods used to display the results in this study are tornado graph and spiderplot. The input data that were required for the construction of these graphs are shown in the appendices and were based on the assumption that input variables cost can range from

5% to 95% (equivalent to area under the pdf curve) due to many uncertainties in project implementation. Each of these variables has a Pearson 5 distribution.

Sometimes when performing sensitivity analysis it simultaneously changes two or more variables to determine the joint, or combined, effect. The joint variance (change) is usually different than the sum of the component variances. Analysis of joint effects is cumbersome with conventional sensitivity analysis utilising the deterministic model.

A sensitivity chart illustrates the relative importance of each input variable, according to variable rank correlation. (This graph was generated with Crystal Ball. @RISK produces a similar chart.)

As with a tornado chart, we prioritise input variables by the width of the bar. We can obtain a similar sensitivity chart, with the same ranking of variables, by approximating each input variable's contribution to the variance of the outcome variable.

6.10 Interpretation of Tornado Graph

In the tornado diagram featured in Figure 6.8, two effects determine the importance of a variable to the analysis outcome value:

(a) The sensitivity of the model to changes in the variable's value (i.e., the. slope of the line in a spider diagram).

(b) The uncertainty, or range, of the variable.

Using the 5% and 95% as the lower and upper limit respectively, shown in appendices and sorted in descending order, the sensitivity analysis result can be translated into a tornado graph for easier interpretation.

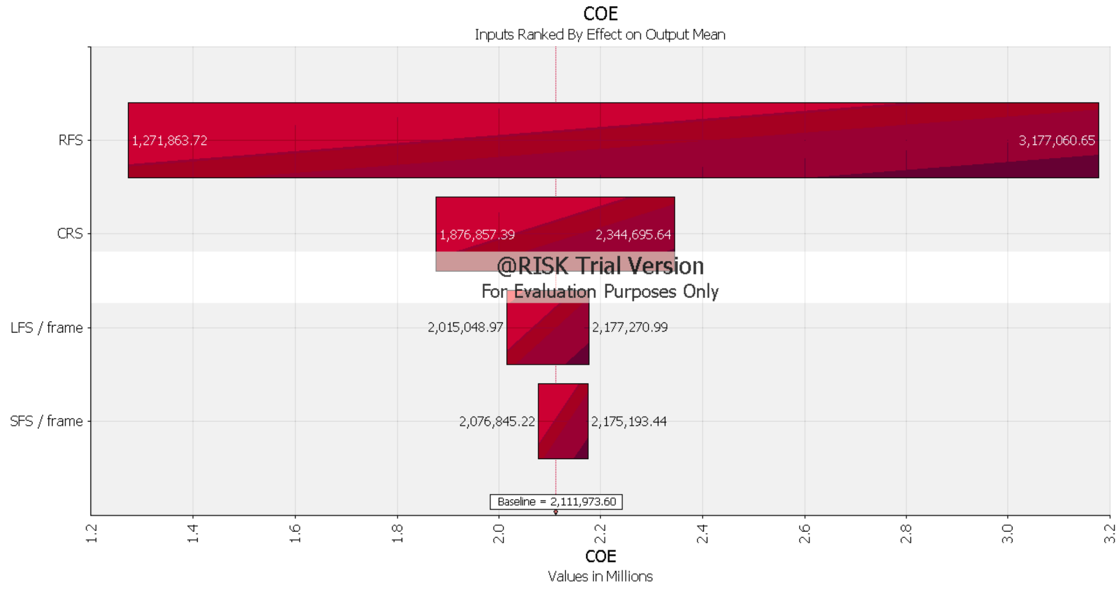


Figure 6.8: Tornado Graph

6.11 Interpretation of Spiderplots

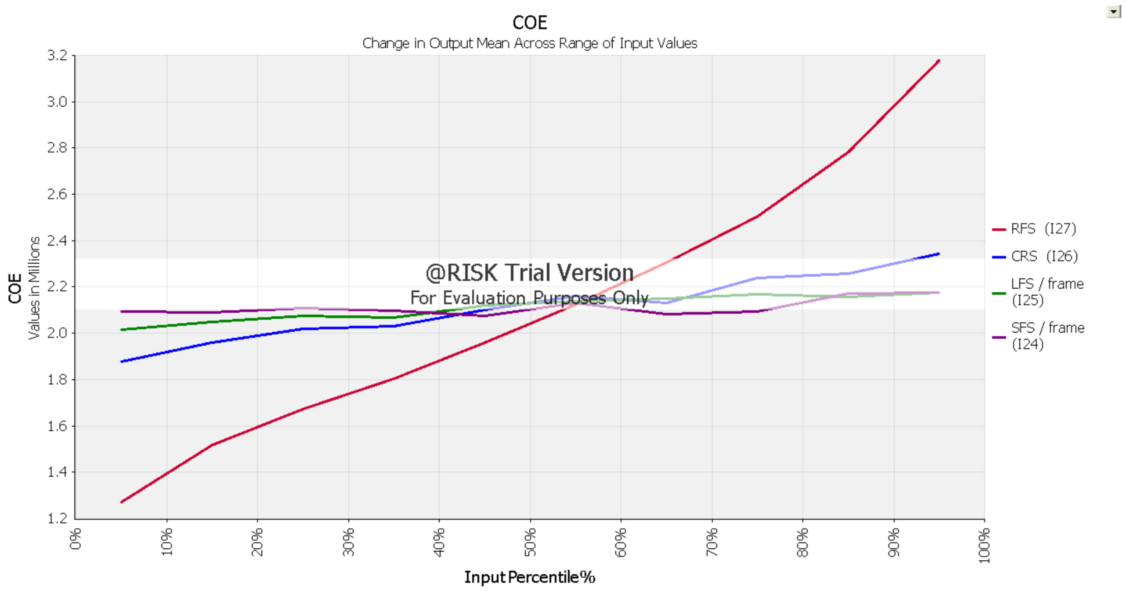


Figure 6.9: Spiderplot

6.12 Cost Allocation

Figure 6.8 shows the composition of total cost by cost units. The figure also shows the reinforcement cost unit group contributed almost half of the total cost unit of

Frame Element. The values indicate the percentage contribution of cost component to that particular cost unit group. Frame and roof were the biggest contributors to the superstructure cost unit group

6.13 Verification

One of the vital steps that have been carried out in verifying the computer program codes was comparing the simulation results to each other which is another useful method of verification, was also employed. In this technique, the contents of the variables, counters, event list, etc. were displayed just after each event occurred and compared with hand calculations to see if the software was as intended.

6.14 Validation

In the validation analysis, the comparison of simulated output data and collected data. The mean and standard deviation for this model output (Frame Element Cost) were Rp. 1,756,891.40 and Rp. 929.403.67; the computed values of mean and standard deviation of collected data were Rp.1, 842,866.65 and Rp.889,618.17; the mean was underestimated by 1.6% while the standard deviation was underestimated by 4.9%. For cost unit group Frame, the mean was overestimated by 1.5% as compared to standard deviation of 12%. The differences in mean and standard deviation were much smaller than the range of general acceptance highlighted by Ashworth and Skitmore (1983) and Moselhi (1997) and hence the formulated model can be regarded as both credible and valid.

6.15 Application of Unit Cost of Work Model

The unit cost of work model will be used as a risk-based estimate cost in the construction cost estimate. It can be seen in the diagram below.

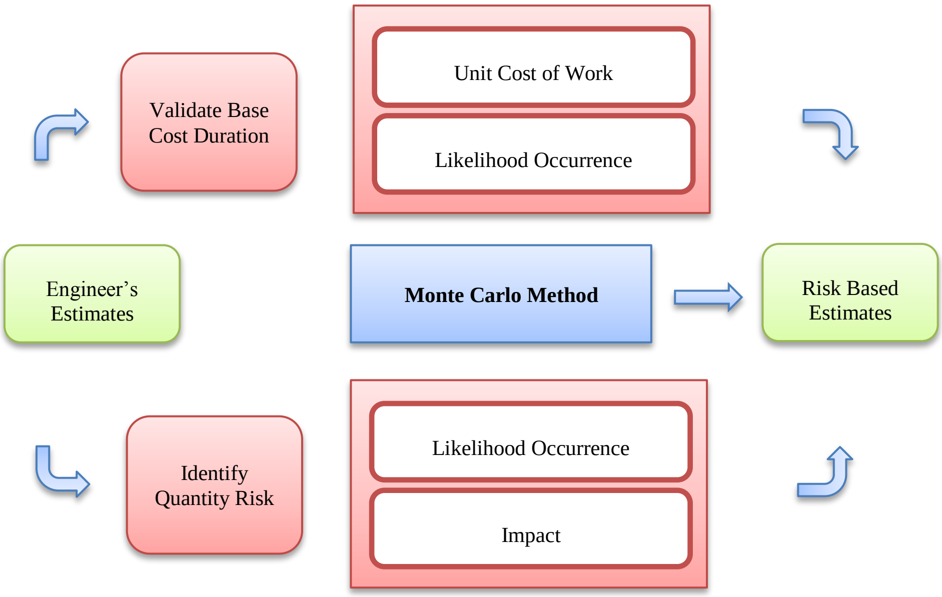


Figure 6.10: Risk-Based Estimates – the Process (Berends, 2011)

In Table 6.7 the uncertainty and risks use two distinct columns. It indicates the percentage of not exceeding an estimated value. The table may be read such as there is a 10% probability of the base cost uncertainty or there is a 90% probability of the base cost uncertainty exceeding Rp. 244,000,000.

The general expectation is that risks push the ends of the tails of the cost distribution farther away from the median for the subject project; despite the fact that the project had significant threats and opportunities, the model did not predict a noticeable expansion of its risk. One of the reasons is the fact that all risks were treated independently and the effect of opportunities was neutralised by the risks' impact (Benerd, 2011).

It is hard to accept that a contractor who is saving approximately Rp. 500,000 (approximately 20% of the contract value) is going to default at a rate of 1 out of 10. Perhaps a better risk assessment may reveal that the threat is mutually exclusive with the opportunities. This correction alone may push the ends of the tails farther away from the median value. Risk analysis is about examining the tails.

The cost data indicate that the low value represents the 20% probability of occurring and the high value represents the 80% probability of occurring; that means the risk definition allows 40% of values used during simulation to lie outside of the range defined by the LOW and HIGH. This approach helps in increasing the final range.

Table 6.7: Base Cost Uncertainty Only Vs. Base Cost Uncertainty Plus Risks

Probability	**Base cost uncertainty (Frame Cost)**	**Delta Base Cost Uncertainty**	**Total Base Cost Uncertainty + Escalation + Even Risks**	**Delta Total**
5%	1.183.612,00		1.479.515,00	
10%	1.206.612,00	-6,27%	1.423.802,16	-7,83%
20%	1.235.664,00		1.482.796,80	
30%	1.254.257,00		1.517.650,97	
40%	1.272.200,00		1.526.640,00	
50%	1.287.337,00		1.544.804,40	
60%	1.303.974,00		1.564.768,80	
70%	1.321.269,00		1.585.522,80	
80%	1.343.113,00		1.611.735,60	
90%	1.371.662,00	7%	1.714.577,50	9,902%
95%	1.395.699,00		1.674.838,80	

Table 6.8: Statistical Parameters

Statistical Parameters	Median Guess = 1.287.337,00		Delta
	Using the Median as the Most Likely Value	Using the True Most Likely Value	
Minimum	1.052.683,00	1.000.315	5%
Maximum	1.527.713,00	3.825.202	-150%
Mean	1.288.811,00	1.932.867	-50%
Std Deviation	64.161,44	814.426	
Skewness	0,0	1	
Kurtosis	3,0	0.4	
Mode	1.282.423,00	1.694.200	-32%

The table above provides information about how the model uses a risk defined in the study by its impact: Low Rp. 1.052.683,00. Most likely = Rp. 1.287.337,00. And High = Rp. 1.527.713,00. The software changes the meaning of LOW and HIGH from 20 and 80% to 7.5 and 80.5, respectively. It means that the function employed by the model allows 23% of values used during simulation to lie outside of the range defined by the model.

Furthermore, the most disturbing consequence of 20 and 80% margins is the fact that the model picks up values between Rp. 0 and Rp. 1.288.811,00, which clearly indicates that 23.3% of the analysis uses values greater than Rp. 1.288.811,00 for this risk.

In terms of the probability distribution shape it is recommended to use the symmetrical form of either a Pert or triangular distribution, which better captures the meaning of variability. This presents a base cost of Rp. 1.288.811,00 with a ±10% variability. The variability presented shows the absolute limits of the distribution range. It means that the base cost through its variability cannot be lower than Rp. 1.052.683,00 and cannot be higher than Rp. 1.527.713,00.

Assuming that the LOW value represents the 10% probability of occurring and the HIGH value represents the 90% probability of occurring allows that 20% of the values used during simulation are outside the range defined by the LOW and HIGH values.

The base cost of previous scenario is Rp. 1.288.811,00 with variability of ±20% and a threat with 50% probability of occurrence an impact of minimum Rp. 1.052.683,00. Figure 6.11 displays the cumulative distribution functions of asymmetrical large base uncertainty versus base variability complemented by risks.

The cumulative distribution function shows a clear increase of the base cost at the higher confidence level. At a high level of confidence this increase may reach 10% or higher. For example, at 70% confidence level, which many organisations often choose for establishing budget numbers, the asymmetrical distribution produces an increase of 5% on top of the increase provided by symmetrical distribution. Overall, at 70% confidence level, the asymmetrical distribution provides a 7.5% increase in the base cost values related to its deterministic value.

Furthermore, at a 90% confidence level the cost added by asymmetrical distribution is increased by 10% on top of the 5% increase given by the symmetrical distribution. So at 90% confidence level the base cost will have a value of about 11.5% of its deterministic value.

Moreover, the mean and median values increase by an average of 3%. The increase of the mean and median values suggests a hidden shift of the base cost towards the higher numbers and this shift generates the most troublesome effect that relates to having undocumented and unjustified change of the base values. In this study we are not aware of the real implication that the asymmetry in the base produces.

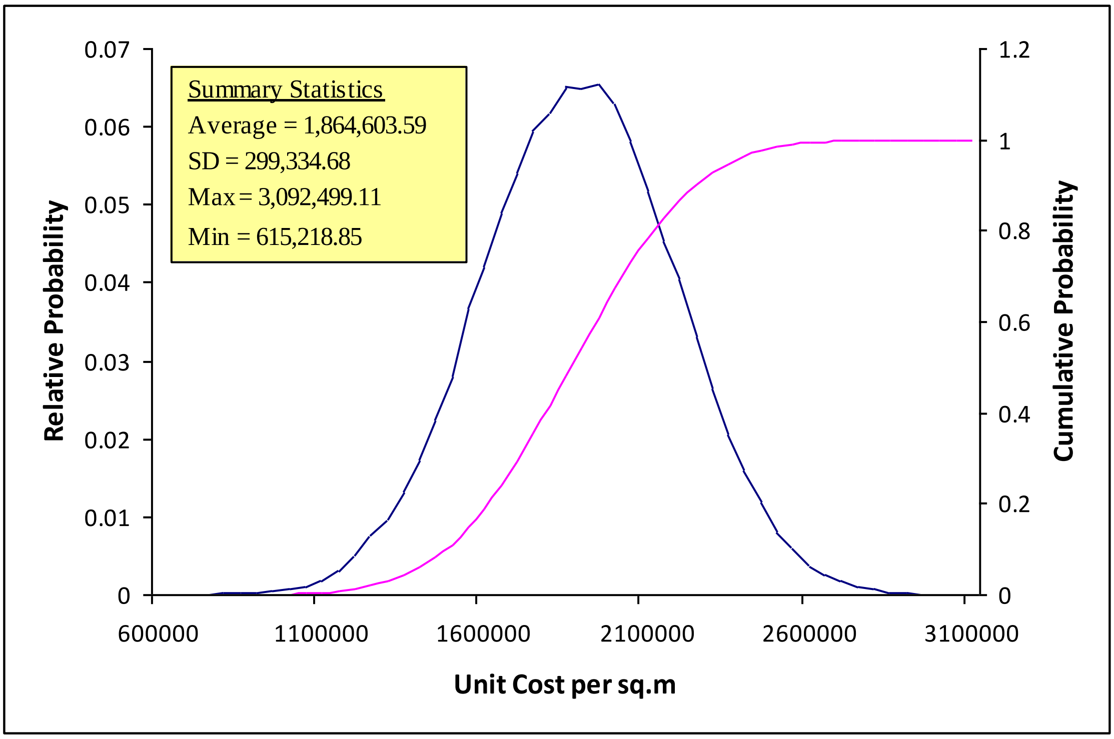


Figure 6.11: CDF Cost of Element Frame

At 70% confidence level, which many organisations often choose for establishing budget numbers, the asymmetrical distribution produces an increase of 5% on top of the increase provided by symmetrical distribution. Overall, at 70% confidence level, the asymmetrical distribution provides 7.5% increase in the base cost values related to its deterministic value.

Furthermore, at a 90% confidence level the cost added by asymmetrical distribution is increased by 10% on top of the 5% increase given by the symmetrical distribution. So at 90% confidence level the base cost will have a value of about 11.5% of its deterministic value.

Moreover, the mean and median values increase by an average of 3%. The increase of the mean and median values suggests a hidden shift of the base cost towards the higher numbers and this shift generates the most troublesome effect that relates to having undocumented and unjustified change of the base values. Perhaps the majority of users (project team members, project managers, subject matter experts, base cost lead, and sometimes the risk leads) are not aware of the real implication that the asymmetry in the base produces. Further discussion about the implication of using asymmetrical distribution to reflect variability in base values follows.

This trend of change in base values is more significant if the distribution has a triangular or uniform shape; as shown, it clearly shows that the asymmetry of the triangular distribution has a significant impact on overall distribution values The cumulative distribution functions (cdfs) of the triangular distribution do not intersect while the cdfs of the Pert distributions do intersect. On the other hand, the asymmetry on triangular distribution decreases the density values at the lower end and increases the density values at the higher end. The overall effect is a more dramatic shift of the base values towards the high end of its range.

In the case of triangular distribution, the increase of the mean and median values doubles if it is compared with similar values given by a Pert distribution. At the same time, the increase of base cost value at a higher confidence level is larger. For example, at a 70% confidence level, the asymmetrical distribution adds 9% on top of the increase provided by a symmetrical distribution. Overall, at 70% confidence level the asymmetrical distribution provides a 12% increase in the base cost values

The most important finding of the analysis presented above is the fact that the use of an asymmetrical distribution to express variability in the base cost or duration will change the meaning of the definition of base cost estimate.

The majority estimate has developed a bias towards seeing costs represented by an asymmetrical distribution, and that includes risks in the form of a standard, flat contingency factor. The base cost, by its definition, must be free of any significant risk-related events that would skew its distribution.

The variability in the base is designed to capture the uncertainty in the cost of material, equipment, and labour in conditions when no events will disturb the project delivery.

6.16 Relating to Market Conditions as an Example

Market conditions are of special interest in the analysis of cost and schedule estimates since they may produce a significant impact on their outcome. Market conditions may be viewed as the ‘random uncertainty’ component of the base estimate's uncertainty. Market conditions are generally uncontrollable; however, project costs might be managed considering market conditions in order to optimise them.

While market conditions may not be controllable by ordinary means, sometimes a good project manager may reduce their impact. When the project schedule allows for a wider window of the project's start date, market conditions may be addressed to some degree by controlling the indexes of the unit cost

In this case consider a project that is estimated to Rp. 10 B, and for this exercise we have assumed the project base cost is represented by a Pert distribution with a minimum value of Rp. 8 B, a maximum value of Rp. 12 B; and a most likely value of Rp. 10 B. This distribution represents the epistemic part of uncertainty in the base cost and can occur at ‘any time’ during the simulations. The random uncertainty is created by market conditions, which may change the most likely value of the base estimate. The base uncertainty components are in a non-realistic mode since, by its nature, the base cost could not have more than one value at a time; however, it shows that the shapes of distribution are identical. Better- or worse-than-planned market conditions use the same shape distribution. The absolute range value of each distribution is identical; the only change is in the most likely value. The most likely value of better-than-planned market conditions is Rp. 100 B less than planned conditions. The most likely value of worse-than-planned market conditions is Rp. 100 B more than the as-planned condition.

In order to bring this p-box to reality, a true representation of base cost uncertainty, it is necessary to calibrate it by applying the probability of occurrence. It is necessary to assign to the better-than-planned market conditions a percentage that will represent the probability of this condition happening and another percentage for worse-than-planned market conditions.

P-box = {10% Pert (7.9.11). 70% Pert (8.10.12). 20% Pert (9.11.13)} …… (6.1)

That represents:

1. A 10% chance that the entire distribution of the base variability is downward 10% from the most likely value of the as-planned distribution – better than planned
2. A 20% chance that the entire distribution of the base variability slides upward 10% from the most likely value of the as-planned distribution – worse than planned
3. A 70% chance that the base variability distribution will not move at all

The vertex of each distribution shown on the left axis is at half of the probability of the occurrence for the respective distribution; the maximum value of each cumulative distribution function indicates the probability of occurrence of that distribution, as is shown on the right axis. The right axes may be useful in maintaining quality control of how the p-box is defined because the sum of the maximum values of each function will be equal to one.

Figure 6.7 Represents the p-box components of the base cost uncertainty defined by the p-box = (10% Pert (7. 71.11). 70% Pert (8. 10.12). 20% Pert (9. 129.13)). This represents a situation when market conditions push the estimated cost towards the distribution's tails and at the same time extends the distribution's boundaries.

Figure 6.9 shows the results provided by running the p-box = (10% Pert (7. 71.11). 70% Perl (8, 10.12). 20% Pert (9, 12.9.13)) through 5000 iterations. There are significant changes in the p-box distribution where, as forecasted, the lower end and higher end of the distribution are quite relevant there is a dominant effect of the better-than-planned market condition and of the worse-than-planned market condition. The distribution tails extend and the probability increases substantially at both tails. The fact that the worse-than-planned market conditions have a higher probability of occurrence moves the graph toward the right and breaks the symmetry of the base cost uncertainty.

Normal inflation will push the cost higher according to the planned conditions; the graph shows that the magnitude of the ‘better-than-planned’ scenario is less than the magnitude of the ‘worse-than-planned’. At the same time, Figure 6.22 shows that the uncertainty in the base may not cover all possible market conditions (where the continuous line intersects the uncertainty's boundaries). The issue of concern here is how large base variability (±X percent) should be. Since the base estimate is a relatively new concept, there are no data to relate to. As a reminder to the reader: base estimate assumes no events during project delivery and as far as we know there are no such projects.

When increasing the base variability from ±20% to ±30%, the results of the project base cost lose its resolution and only an experienced viewer may see the effect of market conditions. It is hard to understand what is going on in the tails and only after reviewing the risk structure might someone associate the tails’ shape with market conditions. The histogram resolution becomes worse when the shift in market conditions is equal to or less than the base variability.

For the situation where the market conditions' probability of occurrence are kept the same as the first three cases presented before but the shift of market is about 20% lower or higher than the normal conditions and the variability is ±30%, the histogram loses its resolution and the viewer has no idea of what is going on in the analysis.

The same phenomenon essentially occurs when statistical data is displayed. If the shape of the data presented does not say much, it is because of the lack of resolution.

The issue of noise becomes more critical when the variability is defined by terms like 'LOW' and 'HIGH', where these terms represent symmetrical percentage values such as 10 and 90%. This happens when there is a 20% probability that the numbers used to represent the base cost will be between 80 to 90 and 110 to 120. This means that there is a one in five chance that the numbers selected by the model when it is running its 'plausible case' will be outside of the range; in other words, that the LOW boundary allows 10% of the numbers used during the calculation of the base cost to be below its value and the HIGH boundary allows 10% of the numbers used during the simulation to be above its value. This approach may lead to an analysis that will end with results presented in a form close to a normal distribution. The noise will dominate the analysis and the events that the analysis was supposed to focus on will become invisible in terms of the shape of the data.

As has been discussed the Pert symmetrical distribution it should be reminded about base variability distribution. The most likely value represents the distribution value with the highest chance of occurring. In the case of symmetrical distributions, the most likely value coincides with the distribution's median and mean values. The symmetrical distribution is used when an expert is considering that the values of a risk's impact are as likely to be above as below the most likely value

If the impact has a higher density on the lower or higher side of the most likely value, then a Pert asymmetrical distribution can be employed.

It is easy to see that the graph does not display values beyond Rp. 9 B. A rigorous calculation shows that only 0.3% of total possible cases will have a value greater than Rp. 8 Billion. In plain language, only 3 out of 1,000 iterations will have a value higher than Rp. 8 Billion. So far, however it means that deciding on Rp. 10 million for the maximum value may need further attention.

As presented earlier, the shape of a Pert distribution is given by the position of the third point relative to the range's ends. The third point is called the most likely value and represents the j distribution's mode (the value with highest frequency).

For the situation when the median value was used as the most likely value, if the best likely value superimposed the risk impact when the median value is used as a most likely value versus when the calculated most likely values are used, there is a significant change in the distribution’s shape and this change is further accentuated if the distribution has a higher degree of asymmetry.

If the elicited impact median values are used as the distribution's most likely value, all statistical parameters of the elicited impact distributions will change in the model. Table 6.9 shows how the statistical parameters change during this process.

While it is obvious how the change of the mean, mode, and median affect the distribution, it is less obvious how the change in skewness and kurtosis affects the results.

Skewness is a measure of the distribution's symmetry, or, more precisely, it is a measure of the distribution's lack of symmetry. A distribution is symmetrical if it looks the same to the left and right of the centre point. A higher skewness factor means that there is a higher asymmetry for the distribution and for the risk's impact, and represents a higher frequency at one of the extremes. In many cases, experts want this kind of distribution when they evaluate the value of the third point. So having the most likely value replaced by an elicited median value will thwart the expert's intentions and alter the results.

Kurtosis is a measure of whether the distribution has a peak or is flat relative to a normal distribution. High kurtosis tends to have a distinct peak near the mean, decline rather rapidly, and have heavy tails. Low kurtosis tends to have a flat top near the mean rather than a sharp peak. A uniform distribution would constitute an extreme case of low kurtosis. The kurtosis declines when the most likely value is replaced by the elicited median value. That means that the distribution in conclusion, the distribution's most likely value, is the value that the expert is most comfortable giving as the third point in the estimate and it is the value that needs to be entered into the model. Eliciting the median values and presenting them as the distribution's most likely values is bad practice; the elicitor may ask for the median value and make sure that this value is converted properly to the distribution's most likely value.

Pert distributions and triangular distributions have similar characteristics: (1) both are defined by three points – LOW, HIGH, and MOST LIKELY – and (2) both are intuitive. Besides their similarity they are different and a specific risk impact may prefer one distribution to the other. Figures 6 shows a significant difference between pert distributions and triangular distributions when the distributions have high skewness.

The triad's elements are interdependent and consequential to the project's cost estimate. In other words, a change of one element, say Reinforcement, will affect the cost.

The uncertainty zone presented within the deterministic concept is, essentially, a blank cheque to deal with anything that may happen; the value of the cheque is subjective to the estimator's experience.

Risk-based estimates are not without checks, but the process of risk analysis clarifies the purpose of the check. Further, risk analysis enables the management to thereby influence the number of zeros on the cheques.

Table 6.9 shows how the Monte Carlo method is applied to estimation. The model extracts a random value for the base cost of the reinforcement, concrete and formwork unit cost according to their cost distribution.

Table 6.9 shows a project that has all four activities presented; the estimate is performed only for current year rupiah so it does not; the project is an example of non-integrated cost risk analysis, and element frame costs are defined by their range (formwork: LOW = 307 and HIGH = 804; concrete: LOW = 367 and HIGH = 804; and reinforcement: LOW = 413 and HIGH = 827)

Table 6.9: Base Cost vs. Risk Cost

Total Cost	Max Value	3.517.30
Total Cost	Min Value	1.690.865
Total Cost	Median Value	2.811.275

Table 6.10: Unit Cost Activities

Phase	Reinforcement	Concrete	Formwork	Total Cost of element
Range	413 to 827	367 to 804	307 to 804	
Percentage	100%	100%	100%	
Iteration #	Base cost			
1	463.461	793.117	677.157	2.825.732
2	314.614	374.666	801.616	2.413.094
3	815.313	538.397	453.596	3.063.145
4	382.964	437.081	307.917	3.376.583
5	553.465	764.539	793.506	2.246.310
6	446.761	655.364	374.812	3.223.377
7	785.935	459.944	538.661	3.303.838
8	673.704	804.531	437.251	2.572.357
9	470.131	367.050	764.913	2.796.817
10	827.047	399.079	655.685	2.477.408
11	375.179	698.065	460.124	3.517.305
12	826.394	642.042	804.925	1.690.865

The 100% probability of occurrence means that during the simulation a value from the respective range will always be extracted and used in the calculations; the base estimate will always be represented in each plausible case.

Formwork Unit Cost is affected by a risk that has a 50% chance of occurring. The Concrete activity is affected by a risk with a lower probability of occurrence (30%); finally, Reinforcement is affected by the most significant risk that may occur.

The micro-project has a total simulated cost (TSC) that is 5% lower than the sum of its components (SUM) at a 90% confidence level.

6.17 Summary

The weaknesses, drawback, advantages and justification for each of the approaches or techniques in cost modelling are among the matters discussed in this chapter. Unless otherwise specified, the sensitivity analysis can determine how much total cost changes due to changes in the cost per unit. Simulation outputs shown in this chapter are all based on the average of ten simulation runs with each simulation iterated 5000 times.

In risk relating, the unit cost model can be applied as a base variability estimate on the total project whilst considering the risk impact.

CHAPTER 7

CONCLUSION AND RECOMMENDATIONS

7.1. The Research Conclusions

1) The cost modelling in this study is to measure uncertainty including the sensitivity analysis among the unit cost of work in the Frame Element of public service buildings. The sensitivity analysis represented by the tornado diagrams and spiderplots techniques found that the cost of reinforcement work has been identified as the most sensitive cost unit among other costs to form frame element cost. This research also found that the material cost in the reinforcement work is the most sensitive rather than the labour cost and equipment cost.

2) In the Frame Element cost, which is formed by the unit cost of work – reinforcement, light formwork, heavy formwork and concrete – the difference in mean is insignificant but the standard deviation and the range width of the simulation results have both increased considerably. The implication of this finding is that a simulation-based unit cost model should address explicitly the correlation among cost units in order to be credible. It is more important than the choice of distribution. The mean and standard deviation of frame element cost derived from using Beta distribution as an input distribution and with correlation relationship taken into consideration were Rp. 2.111.973 and Rp. 583.273 respectively.

3) The Reinforcement cost unit has been identified as the highest contributor. It should be pointed out that probabilistic estimating does not diminish the risks, remove the risks or control the risks. It is merely an attempt to evaluate them in

some reasonably consistent numeric fashion by attaching numbers to subjective perceptions of risk in estimation of future events. It is a valuable decision tool.

4) A close assessment of the graph indicates that the pdf curves were all positively skewed – a pattern that was consistent with the prediction of the model. A positively skewed reinforcement cost curve indicates that the most likely value (relates to the most frequently observed events of the past) falls towards the risky end of the range of likely outcomes. The main reason why the most likely values are inherently optimistic and risky is the fact that individual costs almost always display more scope to overrun than they do opportunity to improve. The typical shape of cumulative probabilistic cost is the S-curve. It means that the chances for a work to be implemented at extremely low rates (optimistic) and high rates (pessimistic) are very unlikely although it is possible theoretically. The outcomes of study have been properly tabulated in a table and shown in graphical format.

5) The cumulative distribution function shows a clear increase of the base cost at the higher confidence level. At a high level of confidence this increase may reach 10% or higher. At 70% confidence level, which many organisations often choose for establishing budget numbers, the asymmetrical distribution produces an increase of 5% on top of the increase provided by symmetrical distribution. Overall, at 70% confidence level, the asymmetrical distribution provides a 7.5% increase in the base cost values related to its deterministic value. Furthermore, at a 90% confidence level the cost added by asymmetrical distribution is increased by 10% on top of the 5% increase given by the symmetrical distribution. So at 90% confidence level the base cost will have a value of about 11.5% of its deterministic value. Moreover, the mean and median values increase by an

average of 3%. The increase of the mean and median values suggests a hidden shift of the base cost towards the higher numbers and this shift generates the most troublesome effect that relates to having undocumented and unjustified change of the base values.

7.2. Limitations

A fair question has been raised about the level of accuracy of the model. The concern is derived from the fact that the modelling process uses random numbers generated by Excel. Other specialised software programs use more sophisticated random number generators and more advanced sampling methods. Specialised software programs offer the option of selection between Monte Carlo simulation sampling and Latin-Hypercube sampling.

In the analysis of risk relating to the unit cost of work model, this research assumed that the project schedules are fixed. A real project has both cost and schedule that may change at the same time. In this case the cost and schedule should be integrated into a comprehensive risk-based estimate.

7.3. Applications

The unit cost in this study is an uncertainty component of the base cost estimate named as variability in the base cost estimate. Variability in the base estimate shrinks as the design evolves and more data about the project become available. During the design phase after the project has acquired a definite definition, the project base cost uncertainty depends on the quality of data related to things such as the cost of material, equipment and labour.

The probability density and cumulative probability functions curves produced as a result of this study allow a cost estimator to know the associated degree of risk of an estimate by interpreting directly from the curves. In this study the estimator can estimate the cost of the frame element of the building.

Sensitivity analysis results presented in spiderplots and tornado graph allow construction practitioners to know not only cost units that contributed largely to the total building cost but also recognise which cost unit is most responsive to the uncertainty in the building construction industry.

7.4. Recommendations

The followed are suggestions for further works that are required to enhance the accuracy of cost models and potential future areas of research:

1) Concern is derived from the fact that the modelling process uses random numbers generated by Excel. Other specialised software programs use more sophisticated random number generators and more advanced sampling methods such as Latin-Hypercube. Specialised software programs offer the option of selection between Monte Carlo simulation sampling and Latin-Hypercube sampling. For the next research it is recommended to use this Latin-Hypercube sampling and make some result comparison between these two sampling methods.

2) In the analysis of risk relating to the unit cost of work model, this research assumed that the project schedules are fixed. A real project has both cost and schedule that change at the same time. In this case the cost and schedule should be integrated into a comprehensive risk-based estimate.

3) To represent the real condition of the cost system, it is suggested that the data to be collected should be a broad set of the unit cost of work in terms of resources

such as material cost and labour cost in forming the unit work. Data from a wider range of locations have to be compared to determine the possible differences in labour, material, equipment cost, work practices and localised problems.

4) The fast growth in technological advancement and development, many work practices, methodology of construction, materials usage, equipment types and many others could become obsolete after a certain number of years. It is important to establish a guideline on the ‘life span’ of historical data through research.

5) It is also crucial to carry out research to identify with certainty the effect of other factors in cost modelling. Among the factors are quality adjustment – to measure quality of workmanship and materials; technological changes – to take account of extra/savings resulting from the use of new techniques; and quantity index – to factor in economy and diseconomy of scale.

6) Defining a methodology for including and excluding outliers in data sets. Outliers may occur as a result of wrong interpretation of drawings or misunderstanding in specification and errors in computation. An accurate cost model should be free from outliers otherwise bias may creep in.

7) Although the suitability of empirical distribution as input probability density curve has been ruled out in this research, because of its simplistic approach, it warrants further investigations. Since the main weakness is the limitation of simulated values to the minimum and maximum values of the collected data, incorporation of some form of adjustments may be able overcome this drawback.

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APPENDIX 1

COLLECTED DATA

MATERIALS AND TOOLS

NO	DESCRIPTION	UNITS	UNIT PRICE (Rp)	FACTS
	AGGREGATE RUDE AND MATERIAL ADHESIVE			
1	Black Soil	m^3	300,000.00	
2	Sand Urug	m^3	490,000.00	
3	Sand Post	m^3	490,000.00	1 Dump = 4 m3
4	Sand Cast	m^3	490,000.00	1 Dump = 4 m3
5	coral Concrete	m^3	546,000.00	1 Dump = 4 m3
6	Red brick	bh	800.00	
7	Red Brick Press	bh	6,000.00	
8	Cement	Zak	96,000.00	@ 50 kg
9	Cement White	Zak	92,000.00	@ 50 kg
10	Readymix Concrete K 300	m^3	1,484,000.00	
11	Readymix Concrete K 225	m^3	1,456,000.00	
12	Readymix Concrete K 175	m^3	1,400,000.00	
13	Readymix B0	m^3	1,358,000.00	
14	Cement Colors	Kg	12,000.00	
15	Plastic sheet	m2	10,000.00	
B	**FINISHING MATERIALS:**			
	Laburan, Fill and tools			
18	Plamur	kg	56,000.00	28000
19	The exterior paint	ltr	100,000.00	
20	Interior paint	ltr	90,000.00	
21	Foreign sealer	ltr	73,500.00	
22	sealer In	ltr	70,000.00	
23	Coating of natural stone	klg	120,000.00	
24	Sikatop 107	set	700,000.00	@ 25 kg
25	Paint rollers	bh	50,000.00	
26	spatula wall	bh	16,000.00	
27	Wood putty knife	bh	15,000.00	
28	Brush	bh	30,000.00	
29	Putty Fine / Imfra (Wood Filler)	Kg	36,000.00	
30	A thinner	Ltr	45,000.00	
31	tiner B	Ltr	40,000.00	
32	Melamik	Kg	46,000.00	
33	Plastic putty	Kg	33,000.00	
34	Duco putty	Kg	38,000.00	
35	Sandpaper	lbr	9,000.00	
36	Meni Wood / Iron	Kg	16,000.00	
37	Zinkromat	Kg	40,000.00	

MATERIALS AND TOOLS (CONTINUED)

NO	DESCRIPTION	UNITS	UNIT PRICE (Rp)	FACTS
C	**WOOD MATERIALS AND WOOD PROCESSED GOODS**			
37	Formwork Wood	ton	5,100,000.00	
38	3 mm plywood	lbr	90,000.00	
39	4 mm plywood	lbr	130,000.00	
40	6 mm plywood	lbr	180,000.00	
41	9 mm multiplex	lbr	230,000.00	
42	Multiplex 12 mm	lbr	260,000.00	
43	Multiplex 18 mm	lbr	300,000.00	
44	Tacon (fireproof)	m^2	160,000.00	
45	supercon	m^2	130,000.00	
46	6mm plain glass	m^2	140,000.00	
47	Rayban 6mm glass	m^2	160,000.00	
48	asahi 6mm glass colo	m^2	190,000.00	
F	**FLOOR AND WALL COATING MATERIALS**			
46	Tiles 40x40 Plain	m^2	300,000.00	
47	40x40 Tiles Anti Slip	m^2	320,000.00	
48	Homogenous Tiles 60x60 Plain	m^2	340,000.00	
49	Homogenous Tiles 60x60 Anti Slip	m^2	360,000.00	
50	Homogenous Tiles 30X60 Plain	m^2	189,000.00	
51	Homogenous Tiles 30X60 Anti Slip	m^2	189,000.00	
51	Natural stone Stacked	m^2	360,000.00	
51	Natural stone andesite	m^2	300,000.00	
G	**DIRTY WATER LINE MATERIALS / CLEAN**			
52	Buis Concrete 30 cm	bh	63,000.00	@ 60 cm
53	Injuk	Kg	6,000.00	

MATERIALS AND TOOLS (CONTINUED)

NO	DESCRIPTION	UNITS	UNIT PRICE (Rp)	FACTS
H	**METAL MATERIALS AND METAL PROCESSED GOODS**			
54	Iron 6 mm	Kg	16,100.00	
55	Iron 8 mm	Kg	16,100.00	
56	Iron 10 mm	Kg	16,100.00	
57	Iron 12 mm	Kg	16,100.00	
58	Iron 13 mm	Kg	16,100.00	
59	Iron 16 mm	Kg	16,100.00	
60	Iron 19 mm	Kg	16,100.00	
61	Concrete wire	Kg	24,000.00	
62	Ram Wire 1 x 1 cm	m^2	14,000.00	
63	Wiremesh A10	lbr	0.00	
64	Wiremesh A8	lbr	45,800.00	
65	A6 Wiremesh	lbr	37,400.00	
66	Zinc Plate 30 BJLS him. 60 cm (100m ')	rol	1,200,000.00	
67	Zinc Plate 30 BJLS him. 90 cm (100m ')	rol	1,887,000.00	
	Aluminum 1 "	m'	70,000.00	
I	**GLASS MATERIALS**			
68	Plain Glass 6 mm	m^2	110,000.00	
69	Plain Glass 8 mm	m^2		
70	Rayband 6 mm glass	m^2	140,000.00	
71	Rayband 8 mm glass	m^2	240,000.00	
72	Tempered Glass 12 mm	m^2	650,000.00	
J	**NAIL AND BOLT MATERIALS**			
73	Nail 1 1/2"	Kg	15,000.00	
74	Nail 2"	Kg	14,000.00	
75	Nail 2 1/2"	Kg	14,000.00	
76	Nail 3 1/2"	Kg	14,000.00	
77	Nail 4"	Kg	14,000.00	
78	Steel Nail	bh	2,600.00	
79	Fisher M6	bh	5,000.00	

MATERIALS AND TOOLS (CONTINUED)

NO	DESCRIPTION	UNITS	UNIT PRICE (Rp)	FACTS
K	**PIPING MATERIALS**			
	Clean Water			
80	Pipa 1 / 2 "AW	btg	38,000.00	@ 5,8 m'
81	Pipe 3/4 "AW	btg	52,000.00	@ 5,8 m'
82	Pipe 1 "AW	btg	70,000.00	@ 5,8 m'
83	Pipe 1 1/2 "AW	btg	119,000.00	@ 5,8 m'
84	Pipe 2 "AW	btg	151,000.00	@ 5,8 m'
85	Pipe 2 1/2 "AW	btg	219,000.00	@ 5,8 m'
86	Connection pipe 1/2 "AW	bh	6,000.00	
87	The connection pipe 3/4 "AW	bh	8,000.00	
88	Connection pipes 1 "AW	bh	11,000.00	
89	Connection pipe 1 1/2 "AW	bh	19,000.00	
90	Connection pipes 2 "AW	bh	26,000.00	
91	Connection pipes 2 1/2 "AW	bh	32,000.00	
	Slop			
92	Pipe 1 1/4 "D	btg	67,000.00	@ 5,8 m'
	Pipe 1 1/2 "D	btg	72,000.00	@ 5,8 m'
	Pipe 2 "D	btg	92,000.00	@ 5,8 m'
93	Pipe 3 "D	btg	160,000.00	@ 5,8 m'
94	Pipe 4 "D	btg	250,000.00	@ 5,8 m'
95	Pipe 6 "D	btg	523,000.00	@ 5,8 m'
96	Pipe 8 "D	btg	909,000.00	@ 5,8 m'
97	Connection pipe 1 1/4 "D	bh	7,000.00	
	Connection pipe 1 1/2 "D	bh	8,000.00	
98	Connection pipes 2 "D	bh	12,000.00	
99	Connection pipes 3 "D	bh	30,000.00	
100	The connection pipe 4 "D	bh	48,000.00	
101	Connection pipes 6 "D	bh	126,000.00	
102	Connection pipes 8 "D	bh	270,000.00	
103	Glue PVC	tb	11,000.00	
104	Solatip Leideng	gl	3,000.00	
	Hot Water			
105	Tigris Pipe 1/2 "	btg	95,000.00	@ 4 m'
106	Tigris Pipe 3/4 "	btg	144,000.00	@ 4 m'
107	Pipe tigris 1 "	btg	237,000.00	@ 4 m'
108	Tigris Pipe 1 1/2 "	btg	364,000.00	@ 4 m'
109	Tigris pipe connection 1/2 "	bh	11,000.00	
110	Tigris pipe joints 3/4 "	bh	14,000.00	
111	Tigris pipe connection 1 "	bh	17,000.00	
112	Tigris pipe connection 1 1/2 "	bh	62,000.00	

MATERIALS AND TOOLS (CONTINUED)

NO	DESCRIPTION	UNITS	UNIT PRICE (Rp)	FACTS
L	**CLOSING ROOF MATERIAL**			
113	Monier Roof Tile	bh	24,000.00	9,5 bh/m2
114	Ceramic Roof	bh	70,000.00	10,5 bh/m2
115	Monier Bubung	bh	26,000.00	3,5 bh/m'
116	Bubung Koramic	bh	112,000.00	3,5 bh/m'
117	Zinc width 60 cm	m'	32,000.00	
118	Zinc width 90 cm	m'	40,000.00	
M	**ELECTRICAL MATERIALS**			
119	Cable NYM 2 x 6	m'	9,000.00	1 rol = 50 m'
120	Cable NYM 3 x 6	m'	1,200.00	1 rol = 50 m'
121	NYM cable 4 x 6	m'	16,000.00	1 rol = 50 m'
122	Cable NYM 2 x 10	m'	15,000.00	1 rol = 50 m'
123	Cable NYM 3 x 10	m'	20,000.00	1 rol = 50 m'
124	NYM cable 4 x 10	m'	22,000.00	1 rol = 50 m'
125	NYM cable 4 x 16	m'	30,000.00	1 rol = 50 m'
126	Cable NYY 2 x 4	m'	9,000.00	1 rol = 50 m'
127	Cable NYY 3 x 4	m'	12,000.00	1 rol = 50 m'
128	Cable NYY 4 x 4	m'	20,000.00	1 rol = 50 m'
129	Cable NYY 2 x 6	m'	9,000.00	1 rol = 50 m'
130	Cable NYY 3 x 6	m'	15,000.00	1 rol = 50 m'
131	Cable NYY 4 x 6	m'	18,500.00	1 rol = 50 m'
132	Cable NYY 2 x 10	m'	16,000.00	1 rol = 50 m'
133	Cable NYY 3 x 10	m'	22,000.00	1 rol = 50 m'
134	Cable NYY 4 x 10	m'	27,000.00	1 rol = 50 m'
135	Cable NYY 4 x 16	m'	43,000.00	1 rol = 50 m'
136	The house panel 30 x 60 cm (empty)	unit	150,000.00	
137	MCB 1 PAS	bh	51,000.00	
138	MCB 3 PAS	bh	64,000.00	
139	Down Light + SL 25 W	bh	302,000.00	
140	Lightning arresters needle 16	bh	105,800.00	
141	BC Wire (Copper)	Kg	23,100.00	

MATERIALS AND TOOLS (CONTINUED)

NO	DESCRIPTION	UNITS	UNIT PRICE (Rp)	FACTS
N	**HANGER AND KEY MATERIALS**			
142	Lock Cylinder ALFA for Aluminum Doors	bh	300,000.00	
143	Aluminum Door Pull	bh	300,000.00	
144	Key 2 Slaag ROYAL	bh	90,000.00	
145	Rel Full Henderson	bh	906,000.00	
146	Rel Maralon 1 Door	unit	100,000.00	
147	Key 2 Slaag Seis Cylinder Original Type 210 s / d 226	bh	312,000.00	
148	Key 2 Slaag original Ancor	bh	130,000.00	
149	Key 2 Slaag ISO	bh	150,000.00	
150	Key KM Spherical Plain Quality	bh	60,000.00	
151	Key KM Round ALFA	bh	80,000.00	
152	Key 2 Slaag Main Cylinder Standard	bh	380,000.00	
153	Lock Padlock Large	bh	90,000.00	
154	Key 2 Slaag Flying Horse	bh	80,000.00	
155	Espangolet	ps	45,000.00	
156	Grendel 15 cm	bh	16,000.00	
157	Grendel 5 cm	bh	4,000.00	
158	Rights Ordinary Wind Window Hooks	ps	6,000.00	
159	Antique Window Wind Rights	ps	26,000.00	
160	Rights Spoon Stainless Wind / Brass	bh	35,000.00	
161	Complete Nako Bars 1 Leaf	dn	20,000.00	
162	Doors Sloot Here Ranrai	bh	35,000.00	
163	Sloot Single Window	bh	13,000.00	
164	Door Hinge Union Standard	ps	14,000.00	
165	Window Hinges Union	ps	12,600.00	
166	Hinge cartridge	ps	8,000.00	
167	Hinge Harmonica	m'	17,000.00	
168	Door Closer Standard Class (Medium Grade)	unit	190,000.00	
169	Door Closer Standard Class (Class Good)	unit	700,000.00	
170	Low Grade Door Closer	unit	160,000.00	
171	Pull Almari average	bh	14,000.00	

DAILY WAGE

NO	DESCRIPTION	UNITS	UNIT PRICE (Rp)	FACTS
1	Foreman	mpd	160,000.00	
2	Artisan	mpd	150,000.00	
3	Kenek	mpd	110,000.00	
4	Gypsum ceiling	m2	190,000.00	
5	Roof Truss	m2	300,000.00	
	FINISIHING			
1	Plamur	m2	6,000.00	
2	Sealer In	m2	5,000.00	
3	Paint Interior	m2	5,000.00	
4	Outside Sealer	m2	6,000.00	
5	Exterior Paint	m2	7,000.00	
6	Coating of Natural Stone	m2	11,000.00	
7	Concrete Waterproofing	m2	100,000.00	

EQUIPMENT

NO	DESCRIPTION	UNITS	UNIT PRICE (Rp)	FACTS
1	Jack Hammer	bh	1,260,000.00	
2	Hammer	bh	84,000.00	
3	Steger / Scaffolding	/hr/set	7,350.00	

PRICE RECAPITULATION

NO	DESCRIPTION	TOTAL PRICE	
1	**STRUCTURE WORK**	**Rp**	**1,423,306,000.00**
2	**ARCHITECTURAL WORK**	**Rp**	**937,542,000.00**
3	**MECHANICAL & ELECTRICAL WORK**	**Rp**	**72,815,000.00**
	TOTAL :	**Rp**	**2,433,663,000.00**
	ROUNDING :	**Rp**	**2,433,660,000.00**
	BUILDING AREA (M2)		**665.01**
	PRICE PER METER BUILDING		**3,660,000.00**

NO	POSITION	LENGTH	HEIGHT	TRASRAM HEIGHT	REDUCTION	NET AREA	TRASRAM AREA	PLINT
	COUPLE WALL							
A	**FLOOR 1**							
	EXTERNAL WALL	76.35	4.20	1.00		244.32	76.35	76.35
	INTERNAL WALL	57.00	4.50	1.00		199.50	57.00	57.00
	WALL THICKENING	10.00	4.00	1.00		30.00	10.00	10.00
		143.35			**109.00**	**364.83**	**143.35**	**143.35**
B	**FLOOR 2**							
	EXTERNAL WALL	75.35	4.00	1.00		226.05	75.35	75.35
	INTERNAL WALL	100.00	4.00	1.00		300.00	100.00	100.00
	WALL THICKENING	14.50	4.00	1.00		43.50	14.50	14.50
		189.85			**60.87**	**508.69**	**189.85**	**189.85**
C	**FLOOR 3**							
	GYM WALL	24.75	3.50	1.00		61.88	24.75	24.75
	ROOF WALL	35.60	1.00	1.00		0.00	35.60	35.60
	MBR WALL	11.50	1.15	1.00		1.73	11.50	11.50
	WALL EMBANKMENT	61.40	0.50	0.50		0.00	30.70	61.40
	WALL THICKENING	5.00	3.50			17.50	0.00	10.00
					0.00	**81.10**	**102.55**	**143.25**
	FENCE WALL							
	FRONT WALL	8.00	4.50			36.00		
	BACK WALL	8.00	4.50			36.00		
	LEFT SIDE WALLS	1.50	4.50			6.75		
	RIGHT SIDE WALLS	8.00	4.50			36.00		
						114.75		
	STUCCO							
	FLOOR1					699.65	276.70	
	FLOOR 2					973.87	365.20	
	FLOOR 3					162.20	205.10	
	TOTAL					**1835.72**	**847.00**	**0.00**
	EXTERNAL WALL PAINT							
	FLOOR 1					364.83		
	FLOOR 2					508.69		
	TOTAL					**873.51**		**0.00**
	FENCE WALL PAINT					114.75		
						0.00		
	TOTAL					**114.75**		**476.45**

BUDGET IMPLEMENTATION PLAN
PLUMBING WORK

NO	JOB DESCRIPTION	VOLUME	UNITS	UNIT PRICE		TOTAL PRICE		UNIT PRICE	TOTAL PRICE	SPECIFICATION
				MATERIALS & EQUIPMENTS	WAGE	MATERIALS & EQUIPMENTS	WAGE			
				Rp.	Rp.	Rp.	Rp.	Rp.	Rp.	
(a)	(b)	(c)	(d)	(e)	(f)	(g = c x e)	(h = c x f)	(i)	(j = c x i)	(k)
A	**Groundtank**									
1	Land Excavation	7.500	m3	28,700.00	82,000.00	215,250.00	615,000.00	110,700.00	830,250.00	
2	Concrete K175	1.980	m3	1,354,400.00	147,600.00	2,681,712.00	292,248.00	1,502,000.00	2,973,960.00	
3	Reinforcing Bar D8 and D10	285.054	kg	17,200.00	2,300.00	4,902,928.80	655,624.20	19,500.00	5,558,553.00	
4	Formwork	33.000	m2	87,600.00	75,300.00	2,890,800.00	2,484,900.00	162,900.00	5,375,700.00	
5	Tiles Installation	13.500	m2	400,600.00	63,200.00	5,408,100.00	853,200.00	463,800.00	6,261,300.00	
6	Waterproofing	33.000	m2		100,000.00		3,300,000.00	100,000.00	3,300,000.00	
	SubTotal					**16,098,790.80**	**4,900,972.20**		**20,999,763.00**	
B	**Water Installation**									
1	Pipe 1/2 "AW	54.000	m'	7,600.00	10,000.00	410,400.00	540,000.00	17,600.00	950,400.00	
2	Pipe 3/4 "AW	63.000	m'	10,400.00	10,000.00	655,200.00	630,000.00	20,400.00	1,285,200.00	
3	Pipe 1 "AW	151.000	m'	14,000.00	10,000.00	2,114,000.00	1,510,000.00	24,000.00	3,624,000.00	
4	Complementary Accessories	1.000	ls	2,500,000.00				2,500,000.00	2,500,000.00	
	SubTotal								**8,359,600.00**	

BUDGET IMPLEMENTATION PLAN
PLUMBING WORK (CONTINUED)

(a)	(b)	(c)	(d)	(e)	(f)	(g = c x e)	(h = c x f)	(i)	(j = c x i)	(k)
C	**Drainage Installation**									
1	Pipe 1 1/4 "D	13.500	m'	13,400.00	10,000.00	180,900.00	135,000.00	23,400.00	315,900.00	
2	Pipe 2 "D	12.000	m'	18,400.00	10,000.00	220,800.00	120,000.00	28,400.00	340,800.00	
3	Pipe 3 "D	73.000	m'	32,000.00	10,000.00	2,336,000.00	730,000.00	42,000.00	3,066,000.00	
4	Pipe 4 "D	112.000	m'	50,000.00	10,000.00	5,600,000.00	1,120,000.00	60,000.00	6,720,000.00	
10	Complementary Accessories	1.000	ls	3,500,000.00	100,000.00	3,500,000.00	100,000.00	3,600,000.00	3,600,000.00	
	Sub Total					**3,500,000.00**	**100,000.00**		**14,042,700.00**	
D	**Septic Tank**									
1	Land Excavation	13.125	m3	28,700.00	82,000.00	376,687.50	1,076,250.00	110,700.00	1,452,937.50	
2	Concrete K175	4.189	m3	1,354,400.00	147,600.00	5,673,243.00	618,259.50	1,502,000.00	6,291,502.50	
3	Reinforcing Bar D8 and D10	220.608	kg	17,200.00	2,300.00	3,794,449.00	507,397.25	19,500.00	4,301,846.25	
4	Formwork	55.850	m2	87,600.00	75,300.00	4,892,460.00	4,205,505.00	162,900.00	9,097,965.00	
	Sub Total					**14,736,839.50**	**6,407,411.75**		**21,144,251.25**	
	TOTAL :					**40,094,280.30**	**15,450,883.95**		**Rp 66,196,314.25**	
	CONTRACTOR FEE (10 %) :								**Rp 6,619,631.43**	
	GRAND TOTAL :								**Rp 72,815,945.68**	
	PEMBULATAN :								**Rp 72,815,000.00**	

COMPOSITION BASED ON PUBLIC WORKS DEPARTMENT (PWD) REGULATION NO. 45 YEAR 2007

Element		average
Foundation	5%-10% 3%-7%	10%
Structure	25%-35% 20%-25%	30%
Floor	5%-10% 10%-15%	15%
Wall	7%-10% 10%-15%	15%
Plafond	6%-8% 8%-10%	5%
Roof	8%-10% 10%-15%	10%
Utility	5%-8% 8%-10%	5%
Finishing	10%-15% 15%-20%	10%
	Total	100%

BUILDING ELEMENT BASED ON PWD			Composition	Structure Element			Per square metre
	Cost			Foundation	Frame	Roof	
				1,419,960,131			
FOUNDATION	287,845,627		11.84%	0.20271			432,844
STRUCTURE	997,785,476		41.06%		0.70269		1,500,407
FLOOR	353,884,854		14.56%				532,150
WALL	344,935,734		14.19%				518,693
PLAFOND	87,315,781		3.59%				131,300
ROOF	134,329,028		5.53%			0.09460	201,996
UTILITY	72,815,000		3.00%				109,495
		2,278,911,500					
FINISHING		151,398,500	6.23%				227,664
Total Budget Cost		2,430,310,000					
Contractors Profit		243,031,000					
Total New Replacement Cost		2,673,341,000					

APPENDIX 2

BUDGET IMPLEMENTATION PLAN

BUDGET IMPLEMENTATION PLAN STRUCTURE WORK

NO	JOB DESCRIPTION	VOLUME	UNIT	UNIT PRICE MATERIALS & TOOLS	UNIT PRICE WAGE	TOTAL PRICE MATERIAL & TOOLS	TOTAL PRICE WAGE	UNIT PRICE	TOTAL PRICE	WORK CATEGORY Foundation	WORK CATEGORY Roof	WORK CATEGORY Structure	NOTES
				Rp.	Rp.	Rp.	Rp.	Rp.	Rp.				
(a)	(b)	(c)	(d)	(h)	(i)	(j = c x h)	(k = c x i)	(e)	(f = c x e)				(g)
A	**PREPARATORY WORK**												
1	Electricity and water work	12.000	mth	2,000,000.00		24,000,000.00		2,000,000.00	24,000,000.00				
2	Mobilization and demobilization of workers	12.000	mth		1,500,000.00		18,000,000.00	1,500,000.00	18,000,000.00				
3	Barak workers	1.000	ls	5,000,000.00	1,000,000.00	5,000,000.00	1,000,000.00	6,000,000.00	6,000,000.00				
4	warehouse	1.000	ls	5,000,000.00	1,000,000.00	5,000,000.00	1,000,000.00	6,000,000.00	6,000,000.00				
		Sub Total			**34,000,000.00**	**20,000,000.00**		**54,000,000.00**		54,000,000.00			
B	**GROUND WORK**												
1	Measurement / bowplank	120.00	m'	52,600.00	19,000.00	6,312,000	2,280,000	71,600	8,592,000				
2	Excavation foundation soil	78.90	m3	28,700.00	82,000.00	2,264,430	6,469,800	110,700	8,734,230				
3	Mining land Sloof	14.53	m3	28,700.00	82,000.00	416,954	1,191,296	110,700	1,608,250				
4	Urug back ground (foundation & Sloof)	74.74	m3	500.00	18,900.00	37,371	1,412,631	19,400	1,450,003				
5	Urug dense sand (under foundation & Sloof)	95.79	m2	24,500.00	18,900.00	2,346,855	1,810,431	43,400	4,157,286				
6	Floor work (under foundation & Sloof)	95.79	m2	10,500.00	11,000.00	1,005,795	1,053,690	21,500	2,059,485				plastic sheet
			Sub Total			**12,383,404.80**	**14,217,848.36**		**80,601,253**	**80,601,253**			
C	**CONCRETE WORK**												
2	Stump Column									28,602,363			
	C1	0.288	m3	1,613,300.00	186,100.00	464,630	53,597	1,799,400	518,227				
	C2	0.088	m3	1,613,300.00	186,100.00	141,164	16,284	1,799,400	157,448				
	C3	0.250	m3	1,613,300.00	186,100.00	403,325	46,525	1,799,400	449,850				
	C4	0.263	m3	1,613,300.00	186,100.00	423,491	48,851	1,799,400	472,343				
	C5	0.088	m3	1,613,300.00	186,100.00	141,164	16,284	1,799,400	157,448				
	C6	0.360	m3	1,613,300.00	186,100.00	580,788	66,996	1,799,400	647,784				
	C7	0.088	m3	1,613,300.00	186,100.00	141,164	16,284	1,799,400	157,448				
	C8	0.450	m3	1,613,300.00	186,100.00	725,985	83,745	1,799,400	809,730				
	TANGGA	0.113	m3	1,613,300.00	186,100.00	181,496	20,936	1,799,400	202,433				
4	Plate Floor 1	33.500	m3	1,613,300.00	186,100.00	54,045,550	6,234,350	1,799,400	60,279,900				
5	Column LT. 1												
	C1	1.037	m3	1,613,300.00	186,100.00	1,672,669	192,948	1,799,400	1,865,618				
	C2	0.315	m3	1,613,300.00	186,100.00	508,190	58,622	1,799,400	566,811				
	C3	0.900	m3	1,613,300.00	186,100.00	1,451,970	167,490	1,799,400	1,619,460				
	C4	0.945	m3	1,613,300.00	186,100.00	1,524,569	175,865	1,799,400	1,700,433				
	C5	0.630	m3	1,613,300.00	186,100.00	1,016,379	117,243	1,799,400	1,133,622				
	C6	1.296	m3	1,613,300.00	186,100.00	2,090,837	241,186	1,799,400	2,332,022				
	C7	0.315	m3	1,613,300.00	186,100.00	508,190	58,622	1,799,400	566,811				
	C8	1.620	m3	1,613,300.00	186,100.00	2,613,546	301,482	1,799,400	2,915,028				
6	Beams LT. 2												
	B1	7.626	m3	1,613,300.00	186,100.00	12,303,026	1,419,199	1,799,400	13,722,224				
	B2	2.640	m3	1,613,300.00	186,100.00	4,259,112	491,304	1,799,400	4,750,416				
	B3	7.350	m3	1,613,300.00	186,100.00	11,857,755	1,367,835	1,799,400	13,225,590				
	B4	3.179	m3	1,613,300.00	186,100.00	5,127,874	591,519	1,799,400	5,719,393				
7	Plate Floor 2	36.210	m3	1,613,300.00	186,100.00	58,417,593	6,738,681	1,799,400	65,156,274				

BUDGET IMPLEMENTATION PLAN STRUCTURE WORK (CONTINUED)

NO	JOB DESCRIPTION	VOLUME	UNIT	UNIT PRICE		TOTAL PRICE		UNIT PRICE	TOTAL PRICE	WORK CATEGORY			NOTES
				MATERIALS & TOOLS	WAGE	MATERIAL & TOOLS	WAGE						
				Rp.	Rp.	Rp.	Rp.	Rp.	Rp.	Foundation	Roof	Structure	
(a)	(b)	(c)	(d)	(h)	(i)	(j = c x h)	(k = c x i)	(e)	(f = c x e)				(g)
8	Column LT. 2												
	C3	0.900	m3	1,613,300.00	186,100.00	1,451,970	167,490	1,799,400	1,619,460				
	C4	1.575	m3	1,613,300.00	186,100.00	2,540,948	293,108	1,799,400	2,834,055				
	C6	1.080	m3	1,613,300.00	186,100.00	1,742,364	200,988	1,799,400	1,943,352				
	C7	0.216	m3	1,613,300.00	186,100.00	348,473	40,198	1,799,400	388,670				
	C8	0.648	m3	1,613,300.00	186,100.00	1,045,418	120,593	1,799,400	1,166,011				
	TC1	0.810	m3	1,613,300.00	186,100.00	1,306,773	150,741	1,799,400	1,457,514				
9	beams Lt.3												
	B1	10.221	m3	1,613,300.00	186,100.00	16,489,539	1,902,128	1,799,400	18,391,667				
	B3	3.500	m3	1,613,300.00	186,100.00	5,646,550	651,350	1,799,400	6,297,900				
10	Plat Level 3	37.590	m3	1,613,300.00	186,100.00	60,643,947	6,995,499	1,799,400	67,639,446				
11	Column LT. 3												
	C3	0.252	m3	1,613,300.00	186,100.00	406,552	46,897	1,799,400	453,449				
	C4	1.440	m3	1,613,300.00	186,100.00	2,323,152	267,984	1,799,400	2,591,136				
12	Beams LT. roof												
	B1	3.270	m3	1,613,300.00	186,100.00	5,275,491	608,547	1,799,400	5,884,038				
13	Plate Floor Roof	13.536	m3	1,613,300.00	186,100.00	21,837,629	2,519,050	1,799,400	24,356,678		24,356,678		
14	ladder												
	Stairs Beams LT. 1	1.440	m3	1,613,300.00	186,100.00	2,323,152	267,984	1,799,400	2,591,136				
	Steps LT. 1	1.173	m3	1,613,300.00	186,100.00	1,892,401	218,295	1,799,400	2,110,696				
	Plate Stairs LT. 2	0.544	m3	1,613,300.00	186,100.00	877,377	101,209	1,799,400	978,586				
	Steps LT. 2	0.450	m3	1,613,300.00	186,100.00	725,985	83,745	1,799,400	809,730				
			Sub Total			**334,957,057**	**38,638,510**		**373,595,567**			**346,781,520**	
D	STRUCTURE WORK												
1	Foundation												
	P1	557.053	kg	17,200.00	2,300.00	9,581,315	1,281,222	19,500	10,862,537				
	P2	455.146	kg	17,200.00	2,300.00	7,828,504	1,046,835	19,500	8,875,339				
	P3	525.168	kg	17,200.00	2,300.00	9,032,890	1,207,886	19,500	10,240,776				
	P4	525.168	kg	17,200.00	2,300.00	9,032,890	1,207,886	19,500	10,240,776	40,219,429			
	P Ladder	13.338	kg	17,200.00	2,300.00	229,407	30,676	19,500	260,083				
2	Stump Column												
	C1	71.214	kg	17,200.00	2,300.00	1,224,881	163,792	19,500	1,388,673				
	C2	16.754	kg	17,200.00	2,300.00	288,165	38,534	19,500	326,699				
	C3	29.056	kg	17,200.00	2,300.00	499,763	66,829	19,500	566,592				
	C4	50.261	kg	17,200.00	2,300.00	864,496	115,601	19,500	980,097				
	C5	16.754	kg	17,200.00	2,300.00	288,165	38,534	19,500	326,699				
	C6	89.018	kg	17,200.00	2,300.00	1,531,101	204,740	19,500	1,735,841				
	C7	16.754	kg	17,200.00	2,300.00	288,165	38,534	19,500	326,699				
	C8	101.534	kg	17,200.00	2,300.00	1,746,385	233,528	19,500	1,979,913				
	Ladder	15.311	kg	17,200.00	2,300.00	263,349	35,215	19,500	298,565				
3	Sloof												
	S1	1174.773	kg	17,200.00	2,300.00	20,206,096	2,701,978	19,500	22,908,074				
	S2	184.824	kg	17,200.00	2,300.00	3,178,973	425,095	19,500	3,604,068	26,512,142			

BUDGET IMPLEMENTATION PLAN STRUCTURE WORK (CONTINUED)

NO	JOB DESCRIPTION	VOLUME	UNIT	UNIT PRICE		TOTAL PRICE		UNIT PRICE	TOTAL PRICE	WORK CATEGORY			NOTES
				MATERIALS & TOOLS	WAGE	MATERIAL & TOOLS	WAGE						
				Rp.	Rp.	Rp.	Rp.	Rp.	Rp.	Foundation	Roof	Structure	
(a)	(b)	(c)	(d)	(h)	(i)	(j = c x h)	(k = c x i)	(e)	(f = c x e)				(g)
6	Plate Floor 1	1323.250	kg	17,200.00	2,300.00	22,759,900	3,043,475	19,500	25,803,375				
5	Column LT. 1												
	C1	258.456	kg	17,200.00	2,300.00	4,445,443	594,449	19,500	5,039,892				
	C2	60.873	kg	17,200.00	2,300.00	1,047,016	140,008	19,500	1,187,024				
	C3	105.834	kg	17,200.00	2,300.00	1,820,345	243,418	19,500	2,063,763				
	C4	182.619	kg	17,200.00	2,300.00	3,141,047	420,024	19,500	3,561,071				
	C5	121.746	kg	17,200.00	2,300.00	2,094,031	280,016	19,500	2,374,047				
	C6	323.070	kg	17,200.00	2,300.00	5,556,804	743,061	19,500	6,299,865				
	C7	60.873	kg	17,200.00	2,300.00	1,047,016	140,008	19,500	1,187,024				
	C8	369.030	kg	17,200.00	2,300.00	6,347,316	848,769	19,500	7,196,085				
6	Beams LT. 2	D:\topx aveiro\New World\edit topik\grafik 2.doc											
	B1	1303.928	kg	17,200.00	2,300.00	22,427,553	2,999,033	19,500	25,426,586				
	B2	367.226	kg	17,200.00	2,300.00	6,316,285	844,620	19,500	7,160,905				
	B3	1160.124	kg	17,200.00	2,300.00	19,954,133	2,668,285	19,500	22,622,418				
	B4	463.320	kg	17,200.00	2,300.00	7,969,104	1,065,636	19,500	9,034,740				
7	Plate Floor 2	2383.825	kg	17,200.00	2,300.00	41,001,790	5,482,798	19,500	46,484,588				
8	Column LT. 2												
	C3	105.834	kg	17,200.00	2,300.00	1,820,345	243,418	19,500	2,063,763				
	C4	304.365	kg	17,200.00	2,300.00	5,235,078	700,040	19,500	5,935,118				
	C6	243.255	kg	17,200.00	2,300.00	4,183,986	559,487	19,500	4,743,473				
	C7	48.651	kg	17,200.00	2,300.00	836,797	111,897	19,500	948,695				
	C8	147.612	kg	17,200.00	2,300.00	2,538,926	339,508	19,500	2,878,434				
	TC1	184.515	kg	17,200.00	2,300.00	3,173,658	424,385	19,500	3,598,043				
9	Beams Lt.3												
	B1	1747.910	kg	17,200.00	2,300.00	30,064,043	4,020,192	19,500	34,084,235				
	B3	552.282	kg	17,200.00	2,300.00	9,499,250	1,270,249	19,500	10,769,499				
10	Plat Level 3	2474.675	kg	17,200.00	2,300.00	42,564,410	5,691,753	19,500	48,256,163				
11	Column LT. 3												
	C3	49.836	kg	17,200.00	2,300.00	857,179	114,623	19,500	971,802				
	C4	199.300	kg	17,200.00	2,300.00	3,427,960	458,390	19,500	3,886,350				
14	Plate Stairs LT. 2												
	Steps LT. 2	162.972	kg	17,200.00	2,300.00	2,803,118	374,836	19,500	3,177,954				
		144.748	kg	17,200.00	2,300.00	2,489,669	332,921	19,500	2,822,590				
	Formwork	55.925	kg	17,200.00	2,300.00	961,908	128,627	19,500	1,090,535				
	Foundation	41.709	kg	17,200.00	2,300.00	717,398	95,931	19,500	813,329			354,461,710	
	P1		***Sub Total***			**346,449,698**	**46,327,576**		**392,777,274**				
E	P2												
1	P3												
	P4	15.120	m2	91,980.00	79,065.00	1,390,738	1,195,463	171,045	2,586,200				
	P Ladder	15.600	m2	91,980.00	79,065.00	1,434,888	1,233,414	171,045	2,668,302				
	Stump Column	12.600	m2	91,980.00	79,065.00	1,158,948	996,219	171,045	2,155,167				
	C1	0.420	m2	91,980.00	79,065.00	38,632	33,207	171,045	71,839	7,481,508			
	C2	0.420	m2	91,980.00	79,065.00	38,632	33,207	171,045	71,839				

BUDGET IMPLEMENTATION PLAN STRUCTURE WORK (CONTINUED)

NO	JOB DESCRIPTION	VOLUME	UNIT	UNIT PRICE		TOTAL PRICE		UNIT PRICE	TOTAL PRICE	WORK CATEGORY			NOTES
				MATERIALS & TOOLS	WAGE	MATERIAL & TOOLS	WAGE						
				Rp.	Rp.	Rp.	Rp.	Rp.	Rp.	Foundation	Roof	Structure	
(a)	(b)	(c)	(d)	(h)	(i)	(j = c x h)	(k = c x i)	(e)	(f = c x e)				(g)
2	C3												
	C4	6.000	m2	91,980.00	79,065.00	551,880	474,390	171,045	1,026,270				
	C5	1.600	m2	91,980.00	79,065.00	147,168	126,504	171,045	273,672				
	C6	3.500	m2	91,980.00	79,065.00	321,930	276,728	171,045	598,658				
	C7	4.800	m2	91,980.00	79,065.00	441,504	379,512	171,045	821,016				
	C8	1.600	m2	91,980.00	79,065.00	147,168	126,504	171,045	273,672				
	Ladder	7.500	m2	91,980.00	79,065.00	689,850	592,988	171,045	1,282,838				
	Column LT. 1	1.600	m2	91,980.00	79,065.00	147,168	126,504	171,045	273,672				
	C1	10.500	m2	91,980.00	79,065.00	965,790	830,183	171,045	1,795,973				
	C2	1.500	m2	91,980.00	79,065.00	137,970	118,598	171,045	256,568				
4	C6												
	C7	21.600	m2	91,980.00	79,065.00	1,986,768	1,707,804	171,045	3,694,572				
	C8	5.760	m2	91,980.00	79,065.00	529,805	455,414	171,045	985,219				
	Beams LT. 2	12.600	m2	91,980.00	79,065.00	1,158,948	996,219	171,045	2,155,167				
	B1	17.280	m2	91,980.00	79,065.00	1,589,414	1,366,243	171,045	2,955,658				
	B2	11.520	m2	91,980.00	79,065.00	1,059,610	910,829	171,045	1,970,438				
	B3	27.000	m2	91,980.00	79,065.00	2,483,460	2,134,755	171,045	4,618,215				
	B4	5.760	m2	91,980.00	79,065.00	529,805	455,414	171,045	985,219				
	2nd floor plate	37.800	m2	91,980.00	79,065.00	3,476,844	2,988,657	171,045	6,465,501			56,379,853	
5	Column LT. 2												
	C3	101.680	m2	178,200.00	75,300.00	18,119,376	7,656,504	253,500	25,775,880				
	C4	47.300	m2	178,200.00	75,300.00	8,428,860	3,561,690	253,500	11,990,550				
	C6	77.175	m2	178,200.00	75,300.00	13,752,585	5,811,278	253,500	19,563,863				
	C7	26.080	m2	178,200.00	75,300.00	4,647,456	1,963,824	253,500	6,611,280				
6	C8	301.750	m2	178,200.00	75,300.00	53,771,850	22,721,775	253,500	76,493,625				
7	TC1												
	Beams Lt.3	12.600	m2	178,200.00	75,300.00	2,245,320	948,780	253,500	3,194,100				
	B1	28.800	m2	178,200.00	75,300.00	5,132,160	2,168,640	253,500	7,300,800				
	B3	23.400	m2	178,200.00	75,300.00	4,169,880	1,762,020	253,500	5,931,900				
	3rd Floor Plate	4.680	m2	178,200.00	75,300.00	833,976	352,404	253,500	1,186,380				
	C8	15.120	m2	178,200.00	75,300.00	2,694,384	1,138,536	253,500	3,832,920				
	TC1	18.900	m2	178,200.00	75,300.00	3,367,980	1,423,170	253,500	4,791,150				
8	Beams Lt.3												
	B1	136.280	m2	178,200.00	75,300.00	24,285,096	10,261,884	253,500	34,546,980				
	B3	36.750	m2	178,200.00	75,300.00	6,548,850	2,767,275	253,500	9,316,125				
9	3rd Floor Plate	313.250	m2	178,200.00	75,300.00	55,821,150	23,587,725	253,500	79,408,875				

BUDGET IMPLEMENTATION PLAN STRUCTURE WORK (CONTINUED)

NO	JOB DESCRIPTION	VOLUME	UNIT	UNIT PRICE		TOTAL PRICE		UNIT PRICE	TOTAL PRICE	WORK CATEGORY			NOTES
				MATERIALS & TOOLS	WAGE	MATERIAL & TOOLS	WAGE						
				Rp.	Rp.	Rp.	Rp.	Rp.	Rp.	Foundation	Roof	Structure	
(a)	(b)	(c)	(d)	(h)	(i)	(j = c x h)	(k = c x i)	(e)	(f = c x e)				(g)
13	Ladder												
	Stairs Beams LT. 1	12.000	m2	178,200.00	75,300.00	2,138,400	903,600	253,500	3,042,000				
	Steps LT. 1	11.730	m2	178,200.00	75,300.00	2,090,286	883,269	253,500	2,973,555				
	Plate Stairs LT. 2	4.532	m2	178,200.00	75,300.00	807,602	341,260	253,500	1,148,862				
	Steps LT. 2	3.600	m2	178,200.00	75,300.00	641,520	271,080	253,500	912,600				
	Sub Total					276,760,477.80	131,955,945.90		408,716,424			346,916,525	
F	ROOF STRUCTURE WORK												
1	Roof Truss	115.000	m2	125,000.00	30,000.00	14,375,000	3,450,000	155,000	17,825,000				
2	Roofing (tile)	115.000	m2	99,000.00	12,000.00	11,385,000	1,380,000	111,000	12,765,000				Monier
3	Ridge	29.650	m'	49,500.00	25,000.00	1,467,675	741,250	74,500	2,208,925				Monier
4	Liistplank GRC	40.400	m'	48,000.00	15,000.00	1,939,200	606,000	63,000	2,545,200				
5	MS Lip Channel 125mmx50mmx20mmx2,3mmx6m	25.000	m'	52,000.00	50,000.00	1,300,000	1,250,000	102,000	2,550,000				
	Sub Total					27,227,675.00	5,571,250.00		32,798,925.00		32,798,925.00		
					TOTAL :	1,028,763,807	248,150,056		Rp 1,293,913,863.46				
					CONTRACTOR SERVICES:	102,876,381	24,815,006		Rp 129,391,386.35				
					GRAND TOTAL :	1,131,640,188	272,965,062		Rp 1,423,305,249.80	Rp 289,434,065.06	Rp 134,329,027.65	Rp 999,542,157.09	
					ROUNDING :	1,131,641,000	272,966,000		Rp 1,423,306,000.00	0.203353365	0.094378178	0.702267929	

BUDGET IMPLEMENTATION PLAN ARCHITECTURAL WORK

NO	JOB DESCRIPTION	VOLUME	UNIT	UNIT PRICE		TOTAL PRICE		UNIT PRICE	TOTAL PRICE	WALL	FLOOR	WALL	PLAFOND	ROOF	FINISHING	SPECIFICA TION
				MATERIALS & TOOLS	WAGE	MATERIALS & TOOLS	WAGE									
				Rp.	Rp.	Rp.	Rp.	Rp.	Rp.							
(a)	(b)	(c)	(d)	(h)	(i)	(j = c x h)	(k = c x i)	(e)	(f = c x e)							(g)
A	**Wall Work**															
1	Couple brick wall 1: 3	435.750	m2	213,500.00	37,200.00	93,032,625.00	16,209,900.00	250,700.00	109,242,525.00							
2	Couple brick wall 1: 5	954.610	m2	209,700.00	37,200.00	200,181,717.00	35,511,492.00	246,900.00	235,693,209.00							
										344,935,734.00						
3	Plastering and acian 1: 3	847.000	m2	41,600.00	49,900.00	35,235,200.00	42,265,300.00	91,500.00	77,500,500.00							
4	Plastering and acian 1: 5	1835.720	m2	36,400.00	49,900.00	66,820,208.00	91,602,428.00	86,300.00	158,422,636.00							
5	Finishing aluminum window and door openings	302.200	m'	26,700.00	63,100.00	8,068,740.00	19,068,820.00	89,800.00	27,137,560.00							
6	columns	543.200	m'	105,900.00	16,600.00	57,524,880.00	9,017,120.00	122,500.00	66,542,000.00							
7	Ring beam	121.500	m'	105,900.00	16,600.00	12,866,850.00	2,016,900.00	122,500.00	14,883,750.00							
8	lintel beam	124.130	m'	123,400.00	20,200.00	15,317,642.00	2,507,426.00	143,600.00	17,825,068.00							
9	The kitchen table	6.550	m2	322,000.00	54,200.00	2,109,100.00	355,010.00	376,200.00	2,464,110.00							
10	table washtafel	2.550	m2	322,000.00	54,200.00	821,100.00	138,210.00	376,200.00	959,310.00							
11	Plat canopy															
	front	38.520	m2	333,500.00	107,100.00	12,846,420.00	4,125,492.00	440,600.00	16,971,912.00							
	side	26.120	m2	333,500.00	107,100.00	8,711,020.00	2,797,452.00	440,600.00	11,508,472.00							
	back	18.690	m2	333,500.00	107,100.00	6,233,115.00	2,001,699.00	440,600.00	8,234,814.00							
12	Finishing plate canopy	166.660	m2	36,400.00	64,400.00	6,066,424.00	10,732,904.00	100,800.00	16,799,328.00							
13	finishing listplank	39.050	m2	36,400.00	27,300.00	1,421,420.00	1,066,065.00	63,700.00	2,487,485.00							
14	Finishing walls minorshading	46.500	m3	62,900.00	427,100.00	2,924,850.00	19,860,150.00	490,000.00	22,785,000.00							
15	Finishing the shading wall	96.790	m4	41,100.00	350,900.00	3,978,069.00	33,963,611.00	392,000.00	37,941,680.00							
16	Finishing walls of natural stone	97.060	m5	402,000.00	159,700.00	39,018,120.00	15,500,482.00	561,700.00	54,518,602.00							
			Sub Total			**527,256,461.00**	**239,416,218.00**		**766,672,679.00**			766,672,679.00				
B	**WORK woodframe**															
1	Pas. Wooden Door & Window Frames															
	P1	2.000	unit	737,000.00	100,500.00	1,474,000.00	201,000.00	837,500.00	1,675,000.00							

UNIT VOLUME

IDENTITY	DIMENSION			DEPTH	TOTAL POINTS	REINFORCEMENT		CONCRETE VOLUME	FORMWORK VOLUME	EXCAVATION VOLUME	VOL SAND URUG	WORK SPACE	REINFORCEMENT VOLUME						
	L	W	THICK			DISTANCE	DIA						D16	D13	D12	D10	D8	D6	TOTAL
FOUNDATIONS																			
P1	1.4	1.4	0.3	1.5	9	0.15	13	5.292	15.12	25.38	17.64	0.882		557.0532					557.0532
P2	1.2	1.2	0.25	1.5	13	0.2	13	4.68	15.6	31.98	18.72	0.936		455.1456					455.1456
P3	1.8	1.8	0.35	1.5	5	0.15	13	5.67	12.6	17.7	16.2	0.81		525.168					525.168
P4	0.7	0.7	0.15	1.5	1	0.2	13	0.0735	0.42	1.56	0.49	0.0245		13.3376					13.3376
P STAIR	1.2	0.6	0.25	1.5	1	0.2	16	0.18	0.9	2.28	0.72	0.036	28.404						28.404
STAIR CASE PLATE 2	1	0.25	0.15		8	0.2	10	0.3	3		2	0.1				28.1352			28.1352
PLAT Bordes	1	1	0.15		1	0.2	10	0.15	0.6		1	0.05				13.574			13.574
							Jumlah	16.3455	48.24	78.9	56.77	2.8385	28.404	1550.7044		41.7092			1620.8176

IDENTITY	DIMENSION		LENGTH		MAIN REINFORCEMENT		REINFORCEMENT		CONCRETE VOLUME	FORMWORK VOLUME	EXCAVATION VOLUME	VOL SAND URUG	WORK SPACE	REINFORCEMENT VOLUME						
	B	H	VER	HOR	QUANTITY	DIA	DISTANCE	DIA						D16	D13	D12	D10	D8	D6	TOTAL
SLOOF																				
S1	0.2	0.4	79.6	79.5	5	13	0.2	8	12.728	127.28	12.728	31.82	1.591		828.911			345.862		1174.773
S2	0.15	0.25	22.5	25.5	4	10	0.2	8	1.8	24	1.8	7.2	0.36				118.464	66.36		184.824
								Jumlah	14.528	151.28	14.528	39.02	1.951		828.911		118.464	412.222		1359.597

UNIT VOLUME (CONTINIUED)

IDENTITY	DIMENSION		TOTAL POINTS	FLOOR HEIGHT	MAIN REINFORCEMENT		REINFORCEMENT		CONCRETE VOLUME	FORMWORK VOLUME	REINFORCEMENT VOLUME						
	L	W			QUANTITY	DIA	DISTANCE	DIA			D16	D13	D12	D10	D8	D6	TOTAL
STUMP																	
C1	0.48	0.12	4	1.25	11	13	0.15	8	0.288	6		57.31			13.904		71.214
C2	0.5	0.14	1	1.25	10	13	0.15	8	0.0875	1.6		13.025			3.7288		16.7538
C3	0.5	0.2	2	1.25	8	13	0.15	8	0.25	3.5		20.84			8.216		29.056
C4	0.5	0.14	3	1.25	10	13	0.15	8	0.2625	4.8		39.075			11.1864		50.2614
C5	0.5	0.14	1	1.25	10	13	0.15	8	0.0875	1.6		13.025			3.7288		16.7538
C6	0.48	0.12	5	1.25	11	13	0.15	8	0.36	7.5		71.6375			17.38		89.0175
C7	0.5	0.14	1	1.25	10	13	0.15	8	0.0875	1.6		13.025			3.7288		16.7538
C8	0.3	0.12	10	1.25	6	13	0.15	8	0.45	10.5		78.15			23.384		101.534
Ladder	0.3	0.3	1	1.25	6	16	0.15	8	0.1125	1.5	11.835				3.476		15.311
								Total	1.9855	38.6	11.835	306.0875			88.7328		
COLUMN FL 1																	
C1	0.48	0.12	4	4.5	11	13	0.15	8	1.0368	21.6		206.316			52.14		258.456
C2	0.5	0.14	1	4.5	10	13	0.15	8	0.315	5.76		46.89			13.983		60.873
C3	0.5	0.2	2	4.5	8	13	0.15	8	0.9	12.6		75.024			30.81		105.834
C4	0.5	0.14	3	4.5	10	13	0.15	8	0.945	17.28		140.67			41.949		182.619
C5	0.5	0.14	2	4.5	10	13	0.15	8	0.63	11.52		93.78			27.966		121.746
C6	0.48	0.12	5	4.5	11	13	0.15	8	1.296	27		257.895			65.175		323.07
C7	0.5	0.14	1	4.5	10	13	0.15	8	0.315	5.76		46.89			13.983		60.873
C8	0.3	0.12	10	4.5	6	13	0.15	8	1.62	37.8		281.34			87.69		369.03
								Total	7.0578	139.32		1148.805			333.696		
COLUMN FL 2																	
C3	0.5	0.2	2	4.5	8	13	0.15	8	0.9	12.6		75.024			30.81		105.834
C4	0.5	0.14	5	4.5	10	13	0.15	8	1.575	28.8		234.45			69.915		304.365
C6	0.4	0.12	5	4.5	8	13	0.15	8	1.08	23.4		187.56			55.695		243.255
C7	0.4	0.12	1	4.5	8	13	0.15	8	0.216	4.68		37.512			11.139		48.651
C8	0.3	0.12	4	4.5	6	13	0.15	8	0.648	15.12		112.536			35.076		147.612
TC1	0.3	0.12	5	4.5	6	13	0.15	8	0.81	18.9		140.67			43.845		184.515
								Total	5.229	103.5		787.752			246.48		
COLUMN FL 3																	
C2	0.3	0.14	2	3	6	13	0.15	8	0.252	5.28		37.512			12.324		49.836
TC2	0.4	0.12	10	3	4	13	0.15	8	1.44	31.2		125.04			74.26		199.3
								Total	1.692	36.48		162.552			86.584		

UNIT VOLUME (CONTINIUED)

IDENTITY	DIMENSION		LENGTH		MAIN REINFORCEMENT		REINFORCEMENT		CONCRETE VOLUME	FORMWORK VOLUME	REINFORCEMENT VOLUME						
	B	H	VER	HOR	QUANTITY	DIA	DISTANCE	DIA			D16	D13	D12	D10	D8	D6	TOTAL
BEAM FL 2																	
B1	0.2	0.3	46.85	80.25	5	16	0.15	8	7.626	101.68	1002.819				301.1085		1303.9275
B2	0.12	0.8	17.75	9.75	4	16	0.15	8	2.64	47.3	173.58			67.87	125.7759		367.2259
B3	0.25	0.4	46	27.5	8	16	0.15	8	7.35	77.175	927.864				232.26		1160.124
B4	0.3	0.65		16.3	15	16	0.15	8	3.1785	26.08	385.821				77.499		463.32
								Total	20.7945	252.235	2490.084			67.87	736.6434		3294.5974
BEAM FL 3																	
B1	0.2	0.3	102.1	68.25	5	16	0.15	8	10.221	136.28	1344.0615				403.848		1747.9095
B3	0.25	0.4	7	28	8	16	0.15	8	3.5	36.75	441.84				110.442		552.282
								Total	13.721	173.03	1785.9015				514.29		2300.1915
BEAM FL ROOF																	
B1	0.2	0.3	28	26.5	5	16	0.15	8	3.27	43.6	430.005				129.0465		559.0515
								Total	3.27	43.6	430.005				129.0465		559.0515

IDENTITY	DIMENSION				REIN BAR LAYER	REINFORCEMENT		CONCRETE VOLUME	FORMWORK VOLUME	REINFORCEMENT VOLUME						
	L	W	THICK/H	AREA		DISTANCE	DIA			D16	D13	D12	D10	D8	D6	TOTAL
FLOOR PLATE																
BASIC LT			0.1	335	1	0.2	8	33.5	335					1323.25		1323.25
LT 2			0.12	301.75	2	0.2	8	36.21	301.75					2383.825		2383.825
LT 3			0.12	313.25	2	0.2	8	37.59	313.25					2474.675		2474.675
CONCRETE ROOF			0.12	112.8	2	0.2	8	13.536	112.8					891.12		891.12
CANOPY																
FRONT				38.52					38.52							
LEFT				12.51					12.51							
RIGHT				13.61					13.61							
BACK				18.69					18.69							

UNIT VOLUME (CONTINIUED)

IDENTITY	DIMENSION				REIN BAR LAYER	REINFORCEMENT		CONCRETE VOLUME	FORMWORK VOLUME	REINFORCEMENT VOLUME						
		QUANTITY	THICKNESS	AREA		DISTANCE	DIA			D16	D13	D12	D10	D8	D6	TOTAL
STAIR																
STAIRCASE PLATE 1		23	0.1	0.51	2	0.2	10	1.173	11.73				144.7482			144.7482
STAIR PLATE 2			0.12	4.532	2	0.2	10	0.54384	4.532				55.92488			55.92488
STAIRCASE PLATE 2																
GROUNDTANK			0.12	16.5	2	0.15	10	1.98	33				285.054			285.054
SEPTIC TANK			0.15	27.925	2	0.2	8	4.18875	55.85					220.6075		220.6075
Total								7.88559	105.112				485.72708	220.6075		

IDENTITY	DIMENSION		LENGTH		MAIN REINFORCEMENT		REINFORCEMENT		CONCRETE VOLUME	FORMWORK VOLUME	REINFORCEMENT VOLUME						
	B	H	VER	HOR	QUANTITY	DIA	DISTANCE	DIA			D16	D13	D12	D10	D8	D6	TOTAL
STAIR BEAM																	
B1	0.3	0.6	8		10	16	0.2	8	1.44	12	126.24			9.872	26.86		162.972
Jumlah									1.44	12	126.24			9.872	26.86		

IDENTITY	DIMENSION			VOLUME
	L	W	AREA	
ROOF				
FRAME ROOF			115	115
Total				115
ROOF TILES	AREA		PCS/AREA	
	115		11	1265
Total				1265
RIDGE	L		PCS/LGTH	
	29.65		3	89
Jumlah				89

APPENDIX 3

SENSITIVITY ANALYSIS

Input Variable - Percentage Change from Base Case Value (Mean)

Element	Mean	5%	10%	15%	20%	25%	30%	35%	40%	45%	55%	60%	65%	70%	75%	80%	85%	90%	95%
Frame	1,864,603.59	-24.45%	-19.04%	-16.09%	-14.73%	-11.54%	-9.49%	-7.90%	-5.57%	-3.53%	-0.66%	1.93%	3.54%	4.88%	7.08%	8.94%	13.39%	16.39%	24.53%
Concrete	557,652.44	-27.11%	-20.93%	-16.28%	-14.71%	-12.83%	-9.42%	-6.19%	-3.77%	-1.05%	3.60%	5.00%	7.35%	8.34%	10.46%	12.94%	14.76%	20.65%	26.47%
Reinforcement	571,076.58	-31.31%	-18.67%	-15.85%	-13.21%	-10.00%	-4.58%	-2.77%	-0.02%	1.32%	7.82%	8.64%	9.90%	11.26%	13.43%	15.11%	17.77%	21.07%	27.79%
Formwork	75,569.51	-30.40%	-24.03%	-17.13%	-12.31%	-8.64%	-4.37%	-3.23%	-2.02%	0.87%	4.24%	6.36%	8.54%	9.29%	13.18%	15.47%	19.60%	21.48%	27.07%
Formwork 1	557,292.85	-27.70%	-22.14%	-18.44%	-14.68%	-12.62%	-8.11%	-4.87%	-3.77%	-1.61%	1.73%	3.58%	5.19%	6.91%	10.23%	13.80%	15.26%	18.82%	23.93%

Output Variable - Percentage Change from Base Case Value (Mean)

Element	5%	10%	15%	20%	25%	30%	35%	40%	45%	55%	60%	65%	70%	75%	80%	85%	90%	95%
Frame	-10.04%	-7.82%	-6.60%	-6.05%	-4.74%	-3.90%	-3.25%	-2.29%	-1.45%	-0.27%	0.79%	1.45%	2.00%	2.91%	3.67%	5.50%	6.73%	10.07%
Concrete	-3.87%	-2.99%	-2.32%	-2.10%	-1.83%	-1.34%	-0.88%	-0.54%	-0.15%	0.51%	0.71%	1.05%	1.19%	1.49%	1.85%	2.11%	2.95%	3.78%
Reinforcement	-4.57%	-2.72%	-2.31%	-1.93%	-1.46%	-0.67%	-0.40%	0.00%	0.19%	1.14%	1.26%	1.44%	1.64%	1.96%	2.20%	2.59%	3.07%	4.05%
Formwork	-0.67%	-0.53%	-0.38%	-0.27%	-0.19%	-0.10%	-0.07%	-0.04%	0.02%	0.09%	0.14%	0.19%	0.21%	0.29%	0.34%	0.43%	0.47%	0.60%
Formwork 1	-3.95%	-3.16%	-2.63%	-2.10%	-1.80%	-1.16%	-0.70%	-0.54%	-0.23%	0.25%	0.51%	0.74%	0.99%	1.46%	1.97%	2.18%	2.69%	3.42%

SIMULATION OUTPUT I

Name	Cos	COE	reinforcement	frame element	PK1	RFS
Description	Output	Output	RiskNormal(31605943,2;3160594,32;RiskStatic(31605943,2);RiskName("reinforcement"))	RiskTriang(999661,5;1000318,1;4108873,2;RiskName("frame element"))	RiskBetaGeneral(2;2;14850;18150;RiskStatic(16500))	RiskBetaGeneral(2;2;-10;10)
Cell	komposisi!O78	analitical!X34	komposisi!L55	unit cost of work!H29	analitical!V48	analitical!AD48
Minimum	1,052,683.00	289,658,500.00	17,986,790	1000287	14,865	-9.901894
Maximum	1,527,713.00	543,405,400.00	44,122,850	4086435	18,131	9.891012
Mean	1,288,811.00	420,883,100.00	31,605,790	2036290	16,500	-6.61149E-06
Std Deviation	64,161.44	35,551,400.00	3,162,118	732853.9	738	4.472509
Skewness	0.0	0.0	0.0	0.6	0.0	0.0
Kurtosis	3.0	2.9	3.0	2.4	2.1	2.1
Mode	1,282,423.00	430,102,700.00	31,724,720	1007804	16,577	0.7346575
5% Perc	558,422.22	363,981,600.00	26,405,680	1078646	15,296	-7.295779
10% Perc	1,206,612.00	375,808,400.00	27,555,080	1159280	15,496	-6.084359
15% Perc	1,223,531.00	383,433,900.00	28,328,200	1242527	15,656	-5.114636
20% Perc	1,235,664.00	390,239,600.00	28,944,740	1327988	15,797	-4.260206
25% Perc	1,245,467.00	395,753,800.00	29,473,450	1416148	15,927	-3.475866
30% Perc	1,254,257.00	401,935,000.00	29,947,680	1507448	16,049	-2.73577
35% Perc	1,264,351.00	407,059,600.00	30,386,460	1602126	16,165	-2.028013
40% Perc	1,272,200.00	411,995,400.00	30,805,040	1700689	16,279	-1.342234
45% Perc	1,280,039.00	416,241,500.00	31,208,080	1802942	16,389	-0.6686898
50% Perc	1,287,337.00	420,766,500.00	31,604,620	1910126	16,500	-0.001634864

SIMULATION OUTPUT I (CONTINUED)

Name	Cos	COE	reinforcement	frame element	PK1	RFS
Description	Output	Output	RiskNormal(31605943,2;3160594,32;RiskStatic(31605943,2);RiskName("reinforcement"))	RiskTriang(999661,5;1000318,1;4108873,2;RiskName("frame element"))	RiskBetaGeneral(2;2;14850;18150;RiskStatic(16500))	RiskBetaGeneral(2;2;-10;10)
Cell	komposisi!O78	analitical!X34	komposisi!L55	unit cost of work!H29	analitical!V48	analitical!AD48
55% Perc	1,295,940.00	424,914,600.00	32,002,010	2023161	16,610	0.6660708
60% Perc	1,303,974.00	429,740,500.00	32,405,260	2142525	16,721	1.338938
65% Perc	1,312,588.00	434,527,500.00	32,823,340	2269226	16,835	2.026385
70% Perc	1,321,269.00	439,424,300.00	33,262,540	2405814	16,951	2.733221
75% Perc	1,330,849.00	445,050,600.00	33,736,020	2553951	17,073	3.471746
80% Perc	1,343,113.00	451,451,000.00	34,265,720	2717876	17,202	4.256955
85% Perc	1,356,532.00	457,899,000.00	34,880,730	2904144	17,343	5.108652
90% Perc	1,371,662.00	466,946,600.00	35,653,010	3125181	17,503	6.08008
95% Perc	1,395,699.00	479,531,200.00	36,798,880	3412961	17,703	7.290217

SIMULATION OUTPUT II

BSBTP RiskBetaGeneral(2;2;6345;7755;RiskStatic(7050)) analitical!AF48	KY RiskBetaGeneral(2;2;2700000;3300000;RiskStatic(3000000);RiskName("KY ")) analitical!O49	KB2 RiskBetaGeneral(2;2;2700000;3300000;RiskStatic(3000000)) analitical!V49	KRB RiskNormal(320000;80000;RiskStatic(320000);RiskName("KRB ")) analitical!AA49	RFS RiskBetaGeneral(2;2;-10;10) analitical!AD49	BU RiskBetaGeneral(2;2;6345;7755;RiskStatic(7050)) analitical!AF49	KL4 RiskBetaGeneral(2;2;49500;60500;RiskStatic(55000);RiskName("KL4 ")) analitical!O50
6,350	2,702,976	2,700,159	7,541	-9.8633	6,356	49,585
7,746	3,295,744	3,297,182	630,358	9.9000	7,745	60,440
7,050	3,000,000	2,999,999	319,997	0.0000	7,050	55,000
315	134,177	134,179	80,019	4.4727	315	2,460
0.0	0.0	0.0	0.0	0.0	0.0	0.0
2.1	2.1	2.1	3.0	2.1	2.1	2.1
7,055	2,993,997	2,981,978	314,982	-0.6006	6,998	54,963
6,536	2,781,178	2,781,165	188,315	-7.2956	6,536	50,987
6,621	2,817,369	2,817,393	217,426	-6.0873	6,621	51,653
6,690	2,846,542	2,846,627	237,058	-5.1121	6,689	52,188
6,750	2,872,206	2,872,208	252,633	-4.2582	6,750	52,657
6,805	2,895,792	2,895,794	266,023	-3.4759	6,805	53,090
6,857	2,917,942	2,917,946	278,008	-2.7358	6,857	53,496
6,907	2,939,086	2,939,163	289,168	-2.0304	6,907	53,883
6,955	2,959,750	2,959,709	299,720	-1.3436	6,955	54,261
7,003	2,979,941	2,979,910	309,930	-0.6681	7,003	54,632
7,050	2,999,990	2,999,965	319,974	-0.0022	7,050	54,999

SIMULATION OUTPUT II (CONTINUED)

BSBTP RiskBetaGeneral(2;2;6345;7755;RiskStatic(7050)) analitical!AF48	KY RiskBetaGeneral(2;2;2700000;3300000;RiskStatic(3000000);RiskName("KY ")) analitical!O49	KB2 RiskBetaGeneral(2;2;2700000;3300000;RiskStatic(3000000)) analitical!V49	KRB RiskNormal(320000;80000;RiskStatic(320000);RiskName("KRB ")) analitical!AA49	RFS RiskBetaGeneral(2;2;-10;10) analitical!AD49	BU RiskBetaGeneral(2;2;6345;7755;RiskStatic(7050)) analitical!AF49	KL4 RiskBetaGeneral(2;2;49500;60500;RiskStatic(55000);RiskName("KL4 ")) analitical!O50
7,097	3,019,988	3,020,025	330,026	0.6671	7,097	55,367
7,144	3,040,167	3,040,234	340,229	1.3414	7,144	55,737
7,193	3,060,819	3,060,771	350,809	2.0264	7,193	56,115
7,243	3,082,045	3,082,004	361,918	2.7336	7,243	56,503
7,295	3,104,175	3,104,100	373,925	3.4705	7,295	56,909
7,350	3,127,675	3,127,715	387,325	4.2549	7,350	57,340
7,410	3,153,326	3,153,357	402,876	5.1100	7,410	57,811
7,479	3,182,418	3,182,487	422,495	6.0836	7,479	58,344
7,564	3,218,742	3,218,747	451,546	7.2875	7,564	59,008

SIMULATION OUTPUT III

SMN RiskNormal(50000;12000;RiskStatic(50000);RiskName("SMN")) analitical!AA50	RFS RiskBetaGeneral(2;2;-10;10) analitical!AD50	KB RiskNormal(17500;4000;RiskStatic(17500)) analitical!AF50	KL12 RiskBetaGeneral(2;2;135000;165000;RiskStatic(150000)) analitical!V51	Tky RiskNormal(70000;16000;RiskStatic(70000)) analitical!V54	MNDR RiskNormal(80000;1600;RiskStatic(80000);RiskName("MNDR")) analitical!AA54	TBS RiskBetaGeneral(2;2;63000;77000;RiskStatic(70000)) analitical!AF54	LTY RiskNormal(55000;14000;RiskStatic(55000)) analitical!V55
4,218	-9.903285	2,392	135,111	10,873	23,302	63,090	4,076
96,484	9.837348	31,921	164,941	128,668	143,456	76,914	107,846
50,000	-3.52032E-06	17,500	150,000	70,000	80,001	70,000	55,001
12,001	4.472521	4,000	6,709	15,998	16,000	3,131	13,999
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3.0	2.1	3.0	2.1	3.0	3.0	2.1	3.0
50,752	-0.06666081	17,450	149,900	68,996	78,594	69,860	56,936
30,245	-7.298035	10,917	139,054	43,675	53,678	64,895	31,953
34,610	-6.086649	12,372	140,869	49,481	59,494	65,740	37,052
37,563	-5.114099	13,351	142,331	53,415	63,411	66,419	40,481
39,896	-4.258222	14,131	143,610	56,529	66,530	67,018	43,208
41,899	-3.474296	14,800	144,790	59,201	69,208	67,567	45,553
43,707	-2.736834	15,400	145,897	61,602	71,602	68,085	47,655

SIMULATION OUTPUT III (CONTINUED)

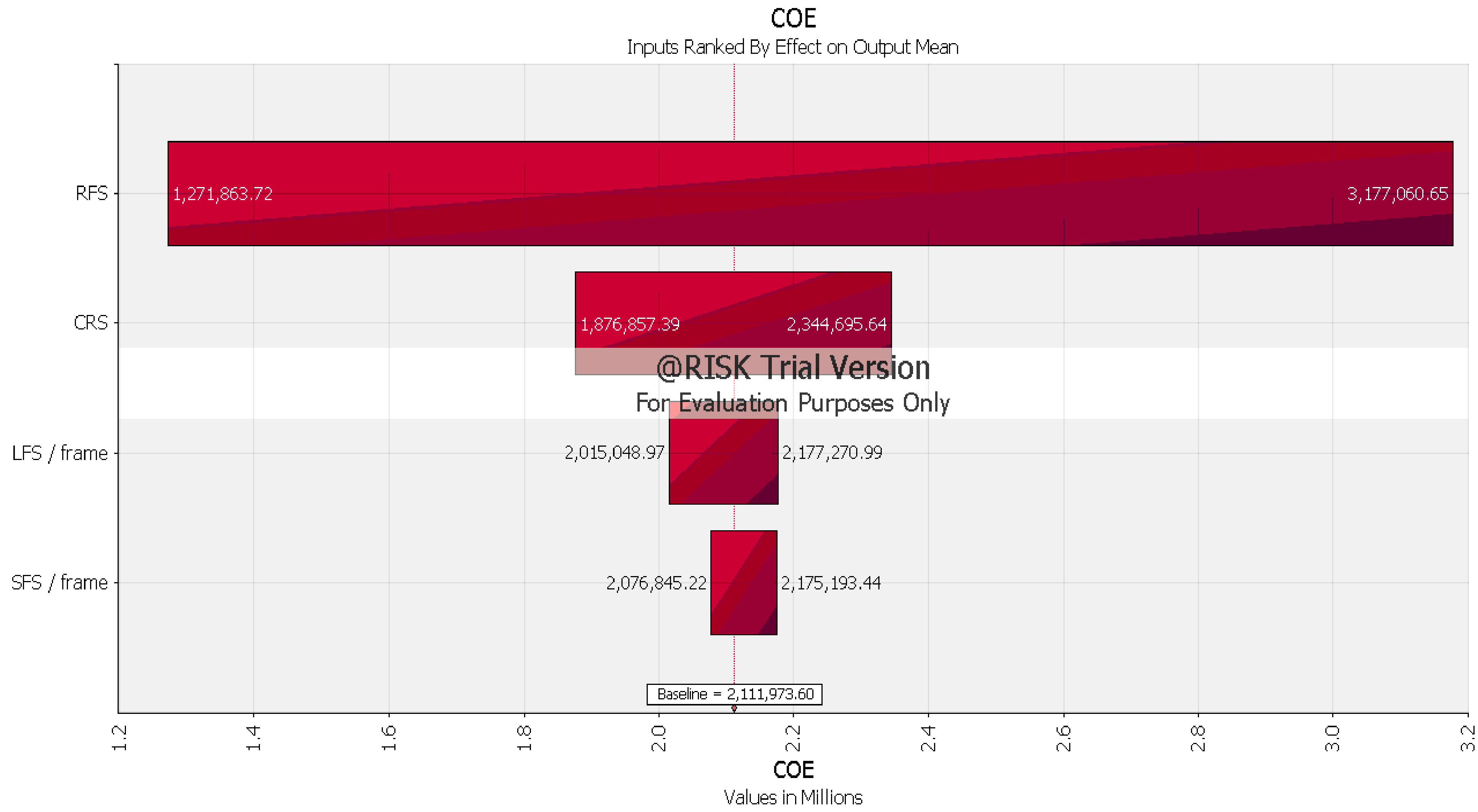
SMN RiskNormal(50000;12000;RiskStatic(50000);RiskName("SMN")) analitical!AA50	RFS RiskBetaGeneral(2;2;-10;10) analitical!AD50	KB RiskNormal(17500;4000;RiskStatic(17500)) analitical!AF50	KL12 RiskBetaGeneral(2;2;135000;165000;RiskStatic(150000)) analitical!V51	Tky RiskNormal(70000;16000;RiskStatic(70000)) analitical!V54	MNDR RiskNormal(80000;16000;RiskStatic(80000);RiskName("MNDR")) analitical!AA54	TBS RiskBetaGeneral(2;2;63000;77000;RiskStatic(70000)) analitical!AF54	LTY RiskNormal(55000;14000;RiskStatic(55000)) analitical!V55
45,373	-2.028221	15,958	146,955	63,833	73,833	68,579	49,598
46,957	-1.343857	16,485	147,986	65,946	75,946	69,060	51,451
48,490	-0.6677283	16,995	148,995	67,989	77,982	69,532	53,239
49,997	-0.002117053	17,498	149,996	69,997	79,993	69,999	54,996
51,503	0.6673291	18,002	150,998	72,004	82,011	70,467	56,754
53,034	1.34071	18,512	152,008	74,052	84,049	70,938	58,540
54,619	2.025572	19,040	153,041	76,160	86,161	71,418	60,389
56,291	2.734666	19,597	154,100	78,388	88,386	71,912	62,335
58,088	3.471322	20,196	155,209	80,789	90,788	72,430	64,436
60,099	4.254551	20,866	156,382	83,462	93,457	72,980	66,773
62,433	5.1105	21,643	157,666	86,570	96,574	73,578	69,504
65,365	6.080446	22,625	159,123	90,492	100,490	74,259	72,934
69,724	7.290724	24,078	160,934	96,301	106,312	75,101	78,003

SIMULATION OUTPUT IV

KPTR RiskNormal(75000;18000;RiskStatic(75000);RiskName("KPTR ")) analitical!AA55	LTB RiskBetaGeneral(2;2;49500;60500;RiskStatic(55000)) analitical!AF55	MND RiskNormal(80000;16000;RiskStatic(80000)) analitical!V56	TB RiskNormal(70000;16000;RiskStatic(70000);RiskName("TB ")) analitical!AA56	KPB RiskBetaGeneral(2;2;67500;82500;RiskStatic(75000)) analitical!AF56	KTR RiskNormal(75000;18000;RiskStatic(75000)) analitical!V57	LTRB RiskBetaGeneral(2;2;49500;60500;RiskStatic(55000)) analitical!AA57	MND RiskBetaGeneral(2;2;72000;88000;RiskStatic(80000)) analitical!AF57
3,040	49,528	21,527	11,419	67,596	10,027	49,562	72,064
138,944	60,423	136,917	146,947	82,439	142,001	60,449	87,958
74,998	55,000	80,000	70,004	75,000	75,000	55,000	80,000
18,002	2,460	15,995	16,013	3,354	17,998	2,460	3,578
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3.0	2.1	3.0	3.0	2.1	3.0	2.1	2.1
74,323	54,890	78,595	70,601	74,850	74,323	55,037	80,374
45,369	50,987	53,657	43,664	69,528	45,380	50,986	74,164
51,915	51,652	59,480	49,485	70,436	51,924	51,652	75,132
56,335	52,187	63,411	53,411	71,164	56,331	52,187	75,908
59,843	52,658	66,523	56,525	71,806	59,842	52,658	76,592
62,851	53,089	69,199	59,202	72,395	62,852	53,089	77,221
65,555	53,494	71,608	61,607	72,947	65,555	53,495	77,811

SIMULATION OUTPUT IV (CONTINUED)

KPTR RiskNormal(75000;18000;RiskStatic(75000);RiskName("KPTR ")) analitical!AA55	LTB RiskBetaGeneral(2;2;49500;60500;RiskStatic(55000)) analitical!AF55	MND RiskNormal(80000;16000;RiskStatic(80000)) analitical!V56	TB RiskNormal(70000;16000;RiskStatic(70000);RiskName("TB ")) analitical!AA56	KPB RiskBetaGeneral(2;2;67500;82500;RiskStatic(75000)) analitical!AF56	KTR RiskNormal(75000;18000;RiskStatic(75000)) analitical!V57	LTRB RiskBetaGeneral(2;2;49500;60500;RiskStatic(55000)) analitical!AA57	MND RiskBetaGeneral(2;2;72000;88000;RiskStatic(80000)) analitical!AF57
68,062	53,885	73,830	63,828	73,479	68,062	53,884	78,377
70,440	54,262	75,945	65,940	73,993	70,439	54,261	78,925
72,737	54,632	77,984	67,985	74,499	72,736	54,632	79,466
74,997	54,999	79,995	69,998	74,999	74,996	55,000	80,000
77,259	55,366	82,009	72,009	75,501	77,258	55,367	80,534
79,556	55,737	84,049	74,049	76,006	79,557	55,737	81,071
81,928	56,114	86,163	76,164	76,520	81,929	56,114	81,622
84,438	56,503	88,385	78,384	77,051	84,430	56,504	82,187
87,138	56,909	90,788	80,782	77,604	87,140	56,910	82,776
90,144	57,340	93,462	83,462	78,191	90,149	57,341	83,404
93,651	57,811	96,582	86,578	78,834	93,655	57,811	84,087
98,051	58,345	100,496	90,493	79,561	98,065	58,344	84,866
104,575	59,009	106,309	96,305	80,469	104,585	59,010	85,831


COE
Inputs Ranked By Effect on Output Mean
RFS
CRS
LFS / frame
SFS / frame
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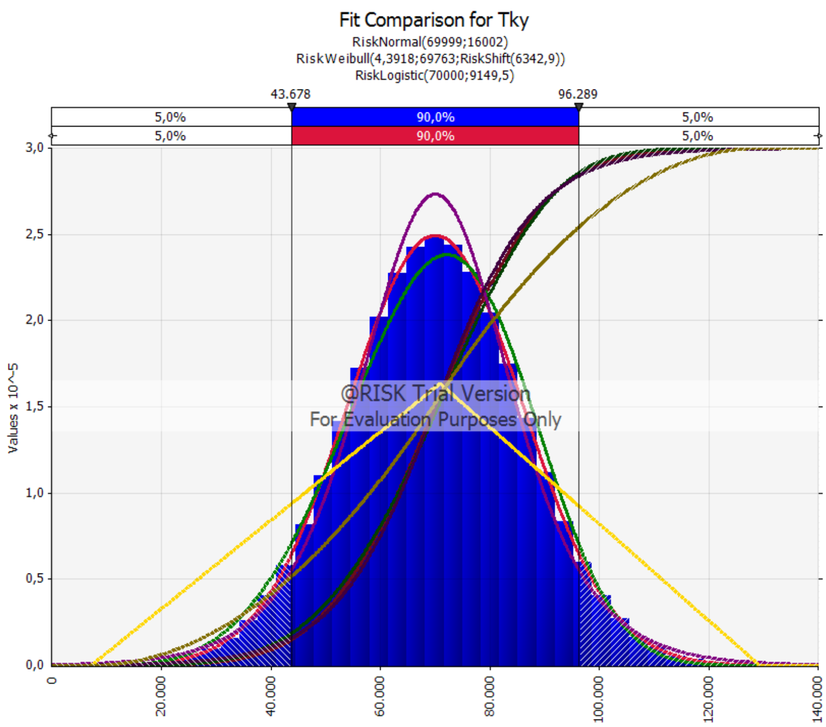
1,876,857.39
2,344,695.64
2,015,048.97
2,177,270.99
2,076,845.22
2,175,193.44
Baseline = 2,111,973.60
1.2
1.4
1.6
1.8
2.0
2.2
2.4
2.6
2.8
3.0
3.2
COE
Values in Millions

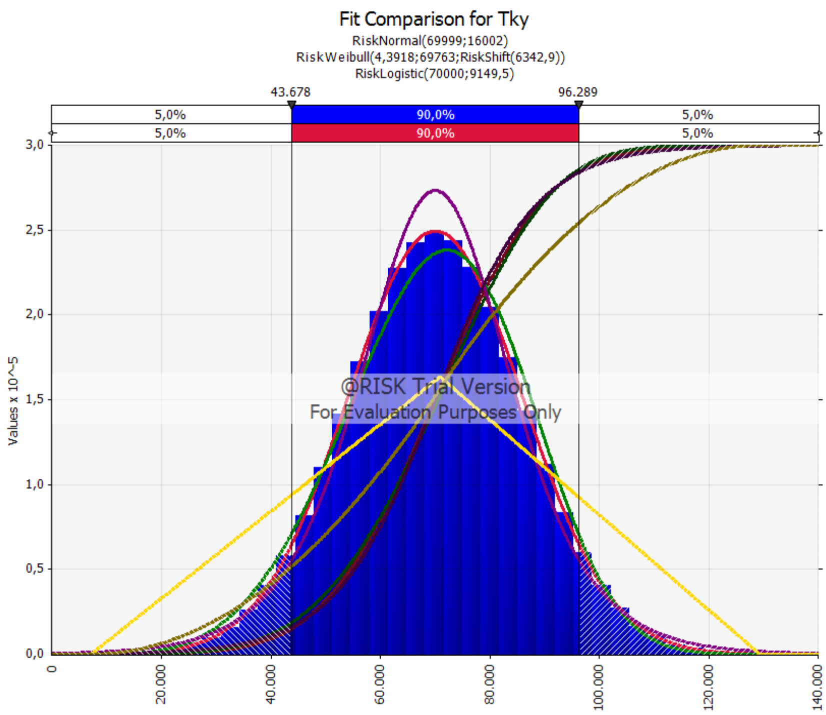
APPENDIX 4

GOODNESS-OF-FIT TEST



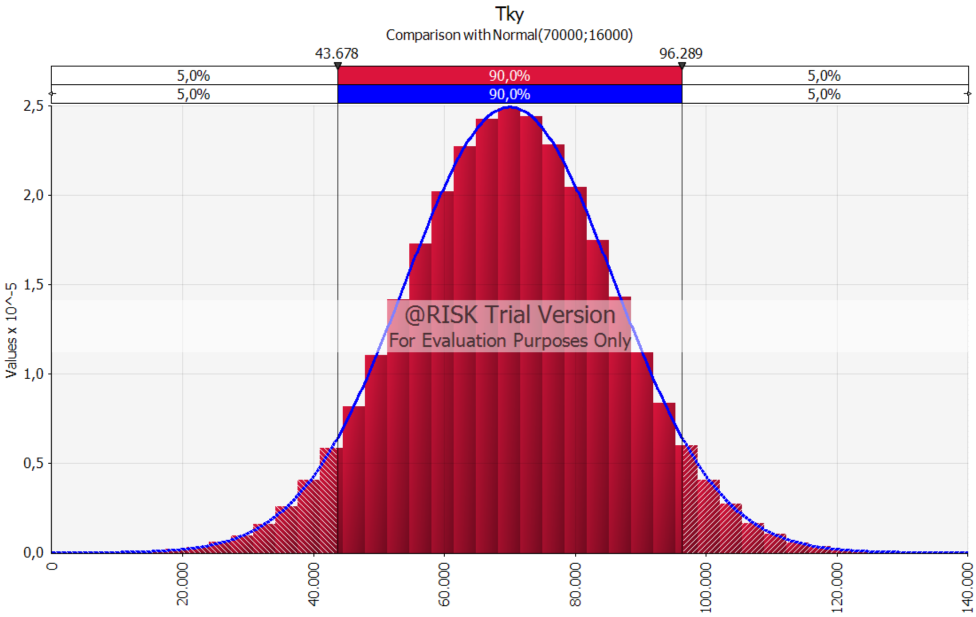
Statistics

	Input	Normal
Minimum	7.088,88	−∞
Maximum	129.291,27	+∞
Mean	69.999,91	69.999,00
Mode	≈69.398,53	69.999,00
Median	69.992,12	69.999,00
Std Dev	16.002,93	16.002,00
Skewness	-0,0007	0,0000
Kurtosis	3,0030	3,0000
Left X	43.678	43.678
Left P	5,0%	5,0%
Right X	96.289	96.289
Right P	95,0%	95,0%
Dif. X	52.611,51	52.611,51
Dif. P	90,0%	90,0%
1%	32.752,07	32.772,78
5%	43.677,56	43.678,05
10%	49.484,06	49.491,61
15%	53.429,44	53.413,99
20%	56.528,63	56.531,38
25%	59.198,74	59.205,82
30%	61.617,02	61.607,54
35%	63.841,35	63.833,10
40%	65.943,60	65.944,94
45%	67.983,08	67.988,17
50%	69.992,12	69.999,00
55%	72.002,84	72.009,83
60%	74.059,85	74.053,06
65%	76.159,64	76.164,90
70%	78.395,15	78.390,46
75%	80.791,80	80.792,18
80%	83.456,45	83.466,62
85%	86.573,19	86.584,01
90%	90.499,34	90.506,39
95%	96.289,07	96.319,95
99%	107.214,75	107.225,22



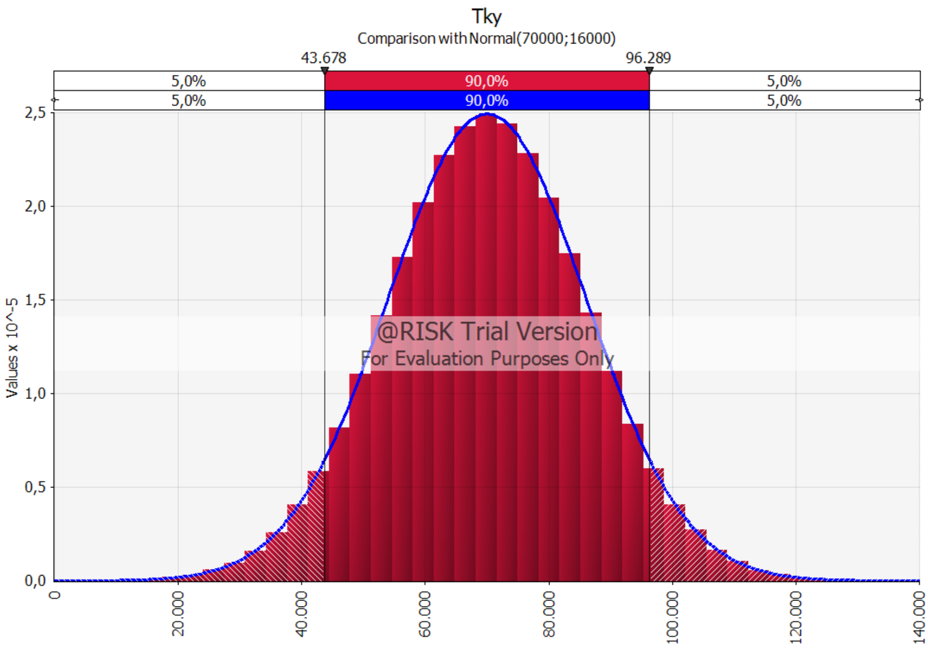
Statistics

	Input	Normal
Minimum	7.088,88	−∞
Maximum	129.291,27	+∞
Mean	69.999,91	69.999,00
Mode	≈69.398,53	69.999,00
Median	69.992,12	69.999,00
Std Dev	16.002,93	16.002,00
Skewness	-0,0007	0,0000
Kurtosis	3,0030	3,0000
Left X	43.678	43.678
Left P	5,0%	5,0%
Right X	96.289	96.289
Right P	95,0%	95,0%
Dif. X	52.611,51	52.611,51
Dif. P	90,0%	90,0%
1%	32.752,07	32.772,78
5%	43.677,56	43.678,05
10%	49.484,06	49.491,61
15%	53.429,44	53.413,99
20%	56.528,63	56.531,38
25%	59.198,74	59.205,82
30%	61.617,02	61.607,54
35%	63.841,35	63.833,10
40%	65.943,60	65.944,94
45%	67.983,08	67.988,17
50%	69.992,12	69.999,00
55%	72.002,84	72.009,83
60%	74.059,85	74.053,06
65%	76.159,64	76.164,90
70%	78.395,15	78.390,46
75%	80.791,80	80.792,18
80%	83.456,45	83.466,62
85%	86.573,19	86.584,01
90%	90.499,34	90.506,39
95%	96.289,07	96.319,95
99%	107.214,75	107.225,22



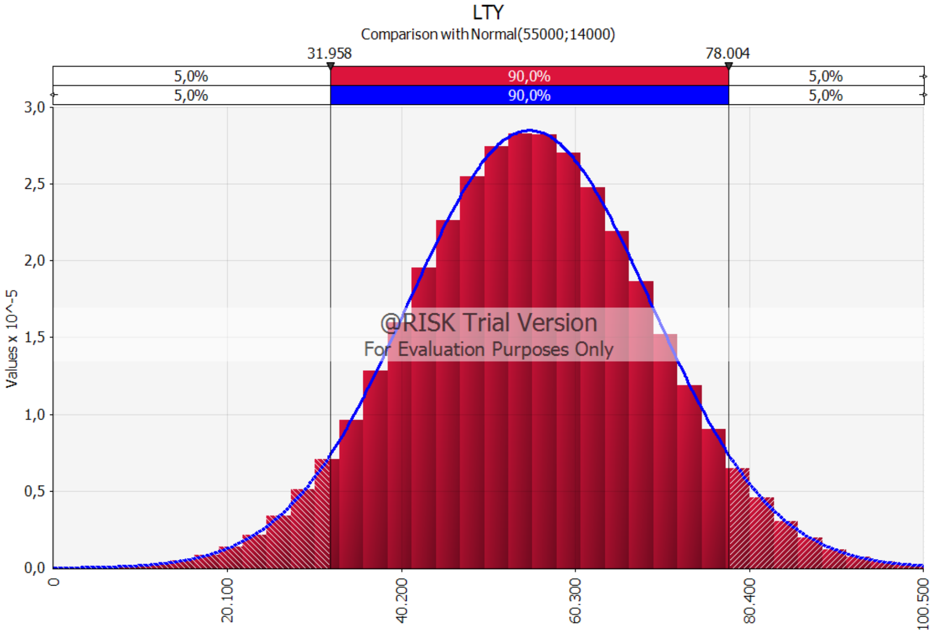
Statistics

	Tky	Normal(
Cell	analitical!V54	
Minimum	7.088,88	
Maximum	129.291,27	
Mean	69.999,91	70
Mode	69.398,53	70
Median	69.992,12	70
Std Dev	16.002,93	16
Skewness	-0,0007	
Kurtosis	3,0030	
Values	5000	
Errors	0	
Filtered	0	
Left X	43.678	
Left P	5,0%	
Right X	96.289	
Right P	95,0%	
Dif. X	52.611,51	52
Dif. P	90,0%	
1%	32.752,07	32
5%	43.677,56	43
10%	49.484,06	49
15%	53.407,43	53
20%	56.528,63	56
25%	59.198,74	59
30%	61.607,40	61
35%	63.830,30	63
40%	65.943,60	65
45%	67.983,08	67
50%	69.992,12	70
55%	72.002,84	72
60%	74.048,47	74
65%	76.159,64	76
70%	78.384,11	78
75%	80.791,80	80
80%	83.456,45	83
85%	86.573,19	86
90%	90.499,34	90
95%	96.289,07	96
99%	107.214,75	107

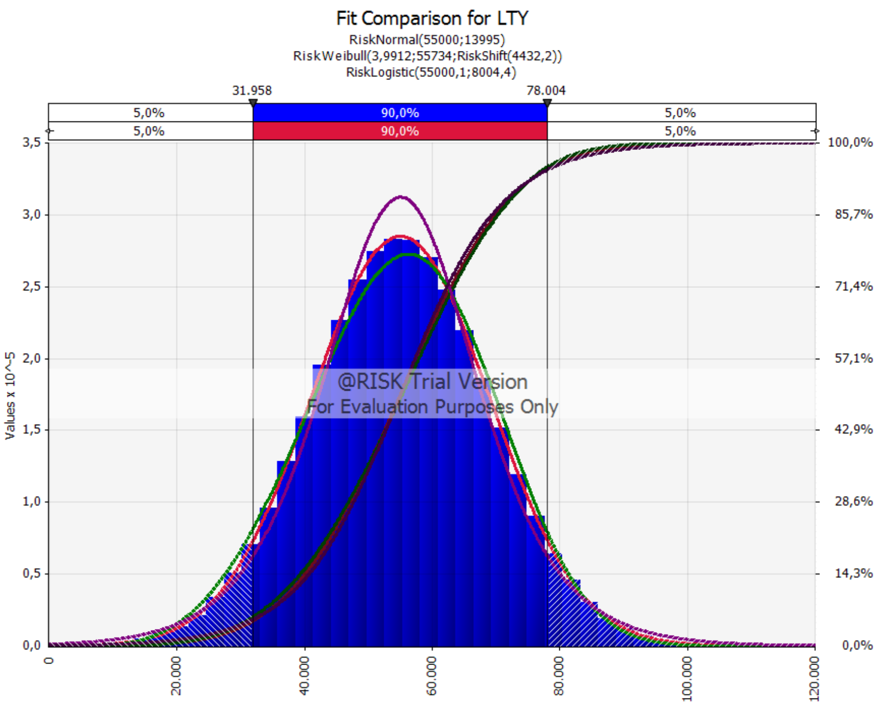


Statistics

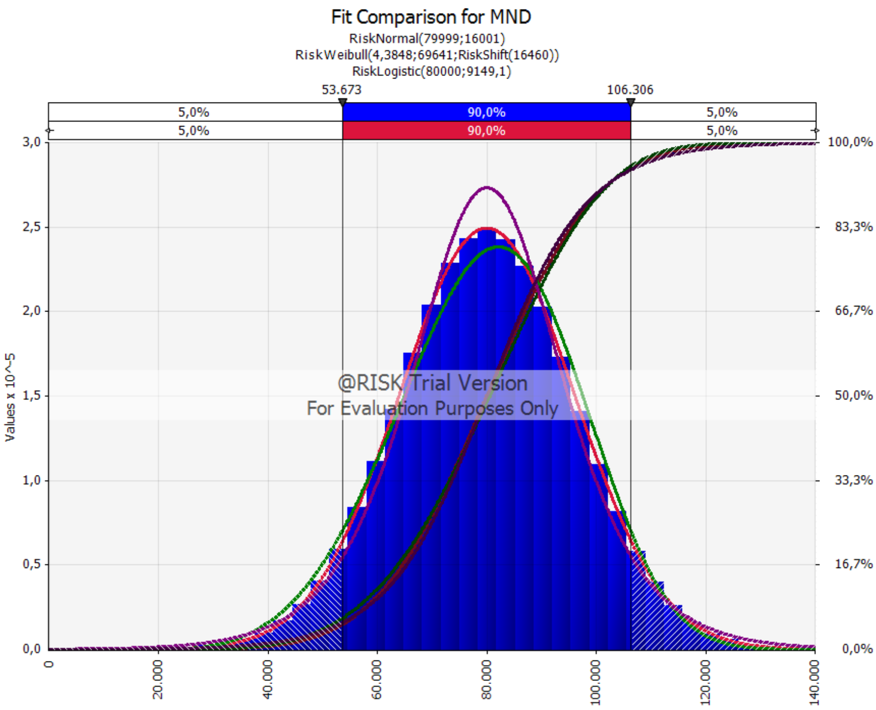
	Tky	Normal(70000..
Cell	analitical!V54	
Minimum	7.088,88	−∞
Maximum	129.291,27	+∞
Mean	69.999,91	70.000,00
Mode	69.398,53	70.000,00
Median	69.992,12	70.000,00
Std Dev	16.002,93	16.000,00
Skewness	-0,0007	0,0000
Kurtosis	3,0030	3,0000
Values	5000	
Errors	0	
Filtered	0	
Left X	43.678	43.678
Left P	5,0%	5,0%
Right X	96.289	96.289
Right P	95,0%	95,0%
Dif. X	52.611,51	52.611,51
Dif. P	90,0%	90,0%
1%	32.752,07	32.778,43
5%	43.677,56	43.682,34
10%	49.484,06	49.495,17
15%	53.407,43	53.417,07
20%	56.528,63	56.534,06
25%	59.198,74	59.208,16
30%	61.607,40	61.609,59
35%	63.830,30	63.834,87
40%	65.943,60	65.946,45
45%	67.983,08	67.989,42
50%	69.992,12	70.000,00
55%	72.002,84	72.010,58
60%	74.048,47	74.053,55
65%	76.159,64	76.165,13
70%	78.384,11	78.390,41
75%	80.791,80	80.791,84
80%	83.456,45	83.465,94
85%	86.573,19	86.582,93
90%	90.499,34	90.504,83
95%	96.289,07	96.317,66
99%	107.214,75	107.221,57



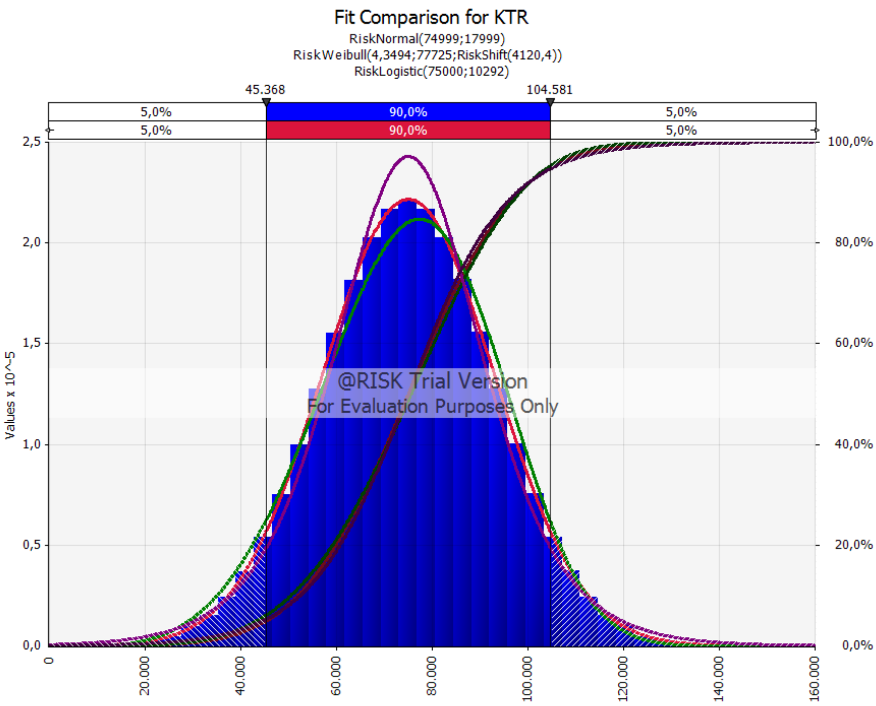
Statistics	LTY	Normal(55000..
Cell	analitical!V55	
Minimum	5.104,00	−∞
Maximum	105.616,85	+∞
Mean	55.000,34	55.000,00
Mode	55.878,04	55.000,00
Median	54.999,49	55.000,00
Std Dev	13.995,87	14.000,00
Skewness	0,0004	0,0000
Kurtosis	2,9838	3,0000
Values	5000	
Errors	0	
Filtered	0	
Left X	31.958	31.958
Left P	5,0%	5,0%
Right X	78.004	78.004
Right P	95,0%	95,0%
Dif. X	46.045,88	46.045,88
Dif. P	90,0%	90,0%
1%	22.327,36	22.431,13
5%	31.958,06	31.972,05
10%	37.054,81	37.058,28
15%	40.487,95	40.489,93
20%	43.207,34	43.217,30
25%	45.549,92	45.557,14
30%	47.650,40	47.658,39
35%	49.603,32	49.605,51
40%	51.451,07	51.453,14
45%	53.237,19	53.240,74
50%	54.999,49	55.000,00
55%	56.754,64	56.759,26
60%	58.543,64	58.546,86
65%	60.388,07	60.394,49
70%	62.337,16	62.341,61
75%	64.436,66	64.442,86
80%	66.780,20	66.782,70
85%	69.507,97	69.510,07
90%	72.933,16	72.941,72
95%	78.003,93	78.027,95
99%	87.541,23	87.568,87



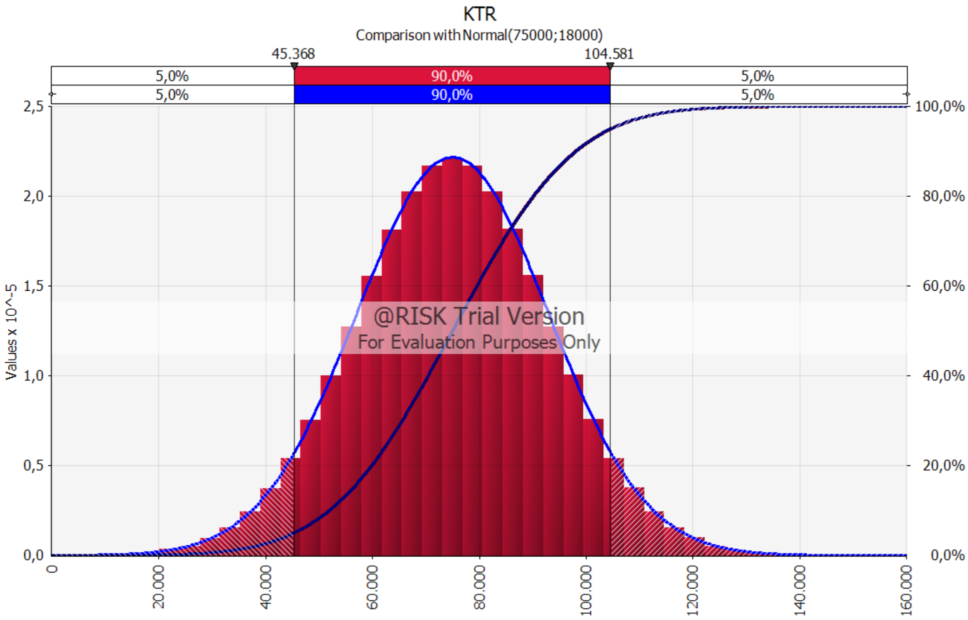
Statistics	Input	Normal	
Minimum	5.104,00	−∞	
Maximum	105.616,85	+∞	
Mean	55.000,34	55.000,00	
Mode	≈55.878,04	55.000,00	
Median	54.999,49	55.000,00	
Std Dev	13.995,87	13.995,00	
Skewness	0,0004	0,0000	
Kurtosis	2,9838	3,0000	
Left X	31.958	31.958	
Left P	5,0%	5,0%	
Right X	78.004	78.004	
Right P	95,0%	95,0%	
Dif. X	46.045,88	46.045,88	
Dif. P	90,0%	90,0%	
1%	22.327,36	22.442,76	
5%	31.958,06	31.980,27	
10%	37.054,81	37.064,69	
15%	40.496,55	40.495,11	
20%	43.207,34	43.221,51	
25%	45.549,92	45.560,52	
30%	47.660,55	47.661,01	
35%	49.607,72	49.607,44	
40%	51.451,07	51.454,41	
45%	53.237,19	53.241,37	
50%	54.999,49	55.000,00	
55%	56.754,64	56.758,63	
60%	58.551,39	58.545,59	
65%	60.388,07	60.392,56	
70%	62.347,45	62.338,99	
75%	64.436,66	64.439,48	
80%	66.780,20	66.778,49	
85%	69.507,97	69.504,89	
90%	72.933,16	72.935,31	
95%	78.003,93	78.019,73	
99%	87.541,23	87.557,24	



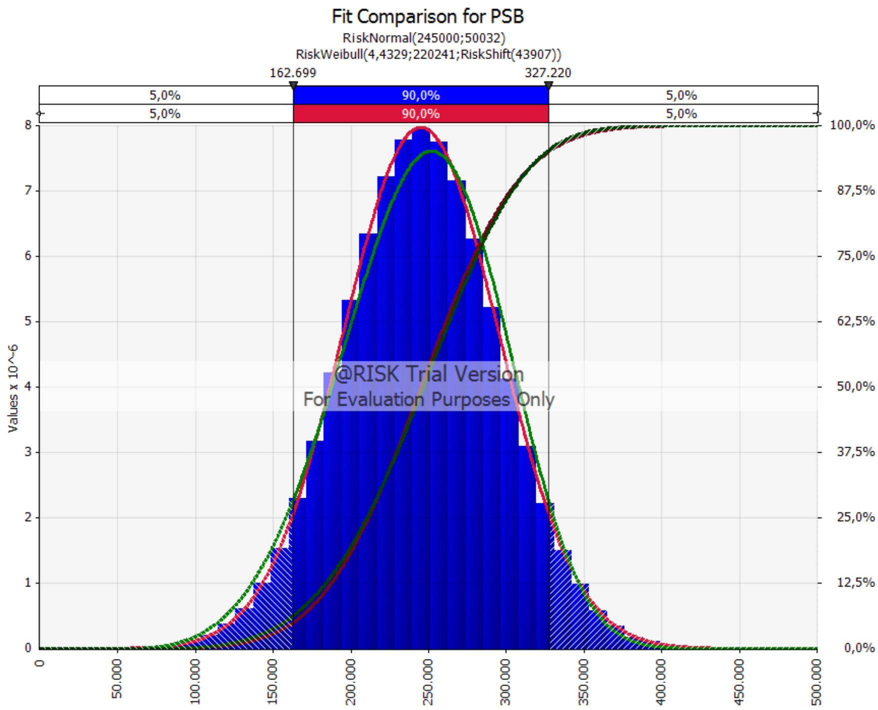
Statistics	Input	Normal	
Minimum	17.206,92	−∞	
Maximum	139.605,51	+∞	
Mean	79.999,53	79.999,00	
Mode	≈78.191,50	79.999,00	
Median	79.993,40	79.999,00	
Std Dev	16.001,64	16.001,00	
Skewness	-0,0015	0,0000	
Kurtosis	3,0006	3,0000	
Left X	53.673	53.673	
Left P	5,0%	5,0%	
Right X	106.306	106.306	
Right P	95,0%	95,0%	
Dif. X	52.632,92	52.632,92	
Dif. P	90,0%	90,0%	
1%	42.703,10	42.775,11	
5%	53.673,41	53.679,70	
10%	59.479,77	59.492,89	
15%	63.423,37	63.415,03	
20%	66.523,08	66.532,22	
25%	69.207,98	69.206,49	
30%	71.618,52	71.608,07	
35%	73.841,81	73.833,49	
40%	75.939,25	75.945,19	
45%	77.986,83	77.988,29	
50%	79.993,40	79.999,00	
55%	82.006,67	82.009,71	
60%	84.061,69	84.052,81	
65%	86.164,38	86.164,51	
70%	88.396,51	88.389,93	
75%	90.784,77	90.791,51	
80%	93.462,75	93.465,78	
85%	96.571,09	96.582,97	
90%	100.504,58	100.505,11	1
95%	106.306,34	106.318,30	1
99%	117.193,72	117.222,89	1



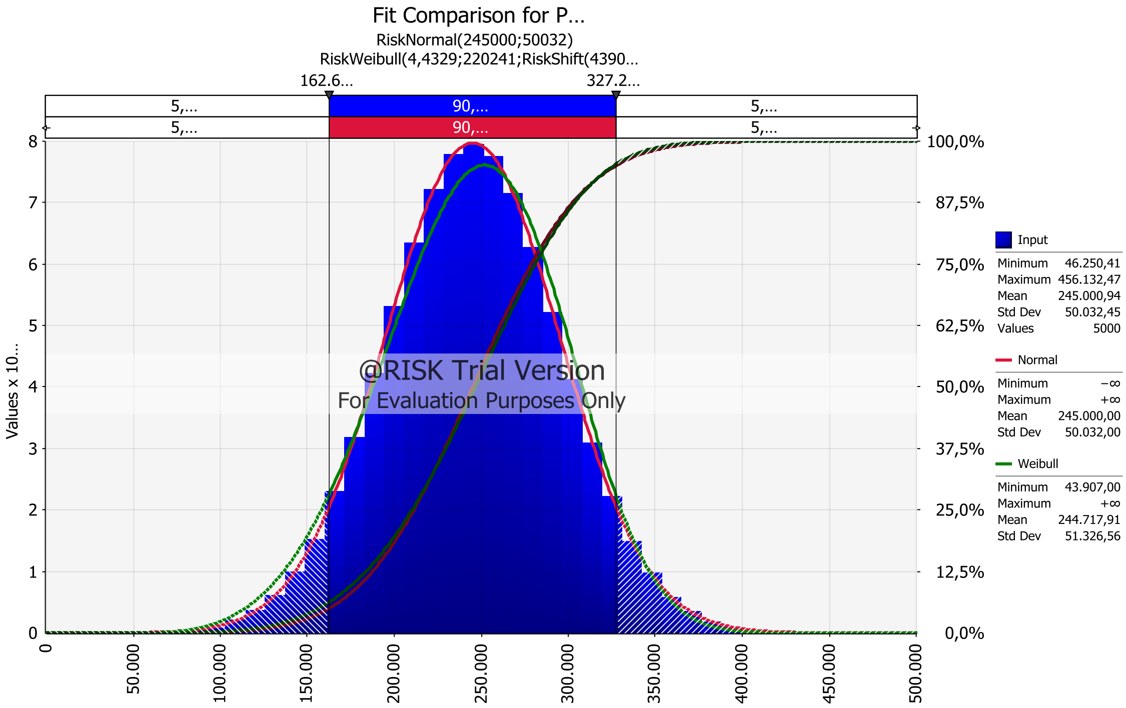
Statistics	Input	Normal	
Minimum	4.956,56	−∞	
Maximum	141.199,18	+∞	
Mean	74.999,53	74.999,00	
Mode	≈74.774,39	74.999,00	
Median	74.994,14	74.999,00	
Std Dev	17.999,61	17.999,00	
Skewness	-0,0014	0,0000	
Kurtosis	2,9961	3,0000	
Left X	45.368	45.368	
Left P	5,0%	5,0%	
Right X	104.581	104.581	
Right P	95,0%	95,0%	
Dif. X	59.213,22	59.213,22	
Dif. P	90,0%	90,0%	
1%	33.022,15	33.127,06	
5%	45.367,98	45.393,28	
10%	51.919,10	51.932,35	
15%	56.355,94	56.344,24	
20%	59.845,16	59.850,66	
25%	62.848,08	62.858,86	
30%	65.562,85	65.560,32	
35%	68.066,94	68.063,62	
40%	70.437,21	70.439,01	
45%	72.737,91	72.737,22	
50%	74.994,14	74.999,00	
55%	77.261,58	77.260,78	
60%	79.560,66	79.558,99	
65%	81.930,15	81.934,38	
70%	84.443,05	84.437,68	
75%	87.140,60	87.139,14	
80%	90.138,99	90.147,34	
85%	93.654,53	93.653,76	
90%	98.060,34	98.065,65	
95%	104.581,21	104.604,72	1
99%	116.855,49	116.870,94	1

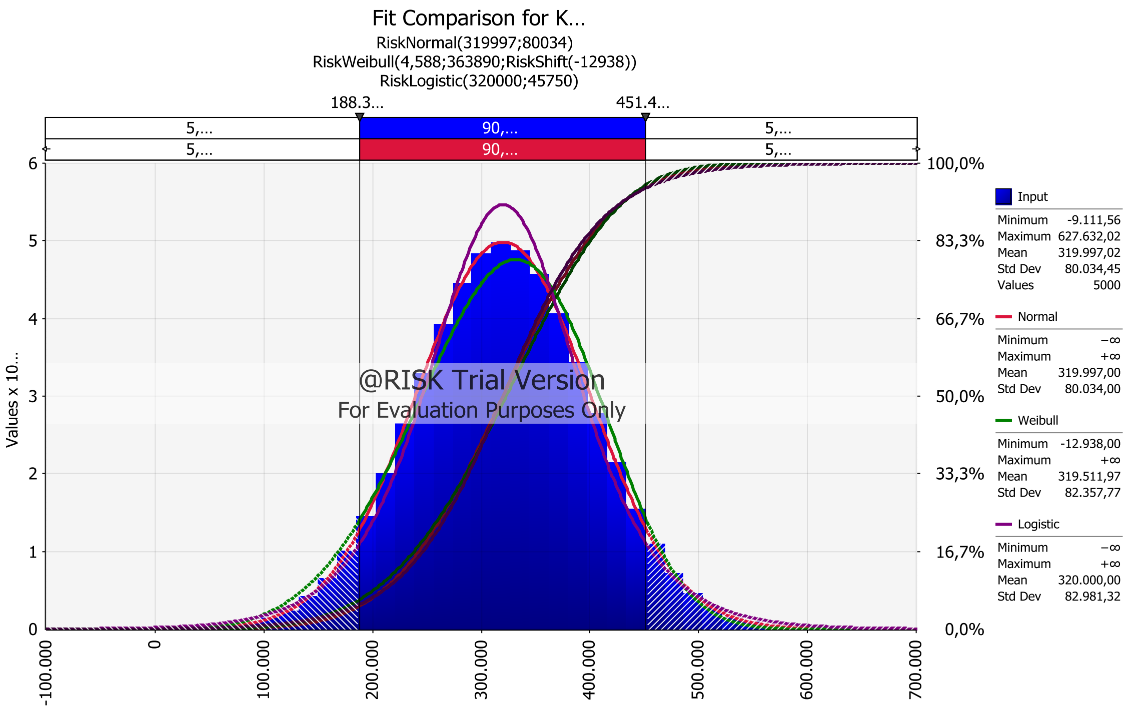


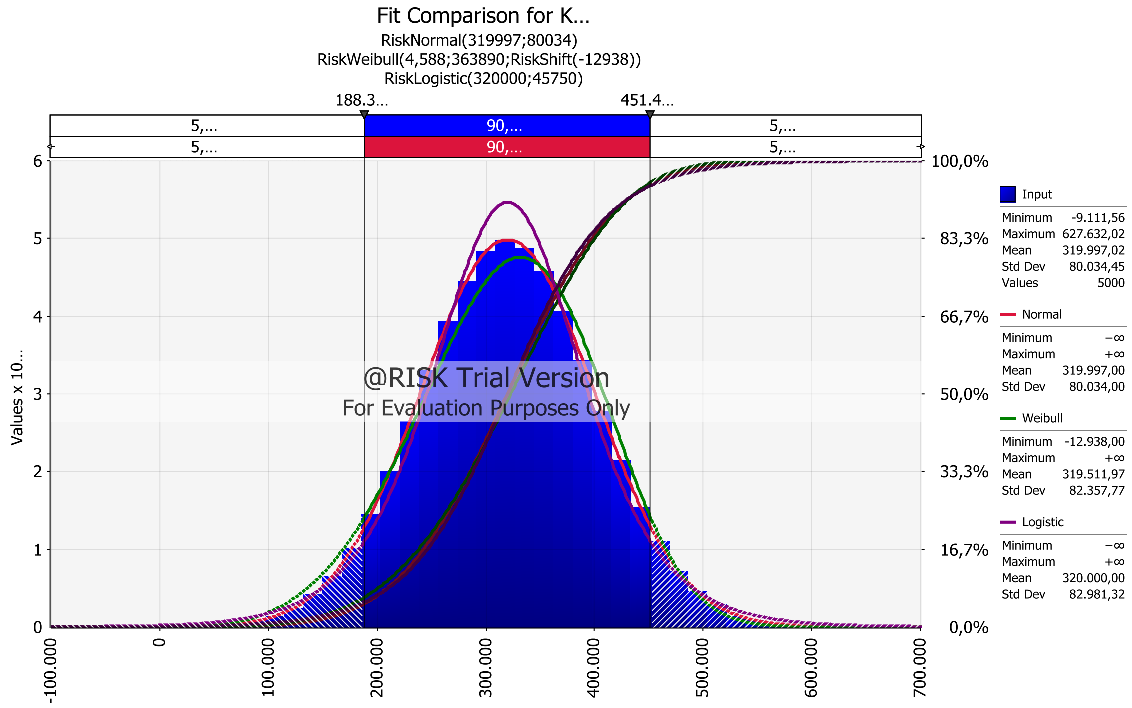
Statistics	KTR	Normal(
Cell	analitical!V57	
Minimum	4.956,56	
Maximum	141.199,18	
Mean	74.999,53	75
Mode	74.774,39	75
Median	74.994,14	75
Std Dev	17.999,61	18
Skewness	-0,0014	
Kurtosis	2,9961	
Values	5000	
Errors	0	
Filtered	0	
Left X	45.368	
Left P	5,0%	
Right X	104.581	1
Right P	95,0%	
Dif. X	59.213,22	59
Dif. P	90,0%	
1%	33.022,15	33
5%	45.367,98	45
10%	51.919,10	51
15%	56.343,19	56
20%	59.845,16	59
25%	62.848,08	62
30%	65.553,91	65
35%	68.061,68	68
40%	70.437,21	70
45%	72.737,91	72
50%	74.994,14	75
55%	77.261,58	77
60%	79.552,35	79
65%	81.930,15	81
70%	84.433,92	84
75%	87.140,60	87
80%	90.138,99	90
85%	93.654,53	93
90%	98.060,34	98
95%	104.581,21	104
99%	116.855,49	116

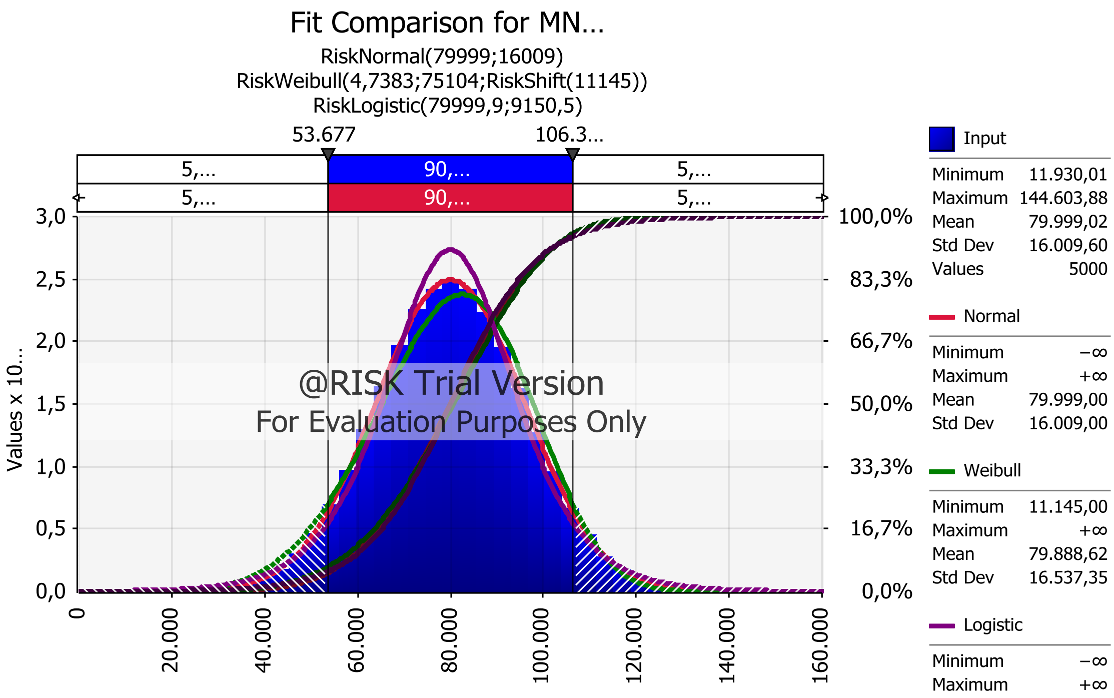


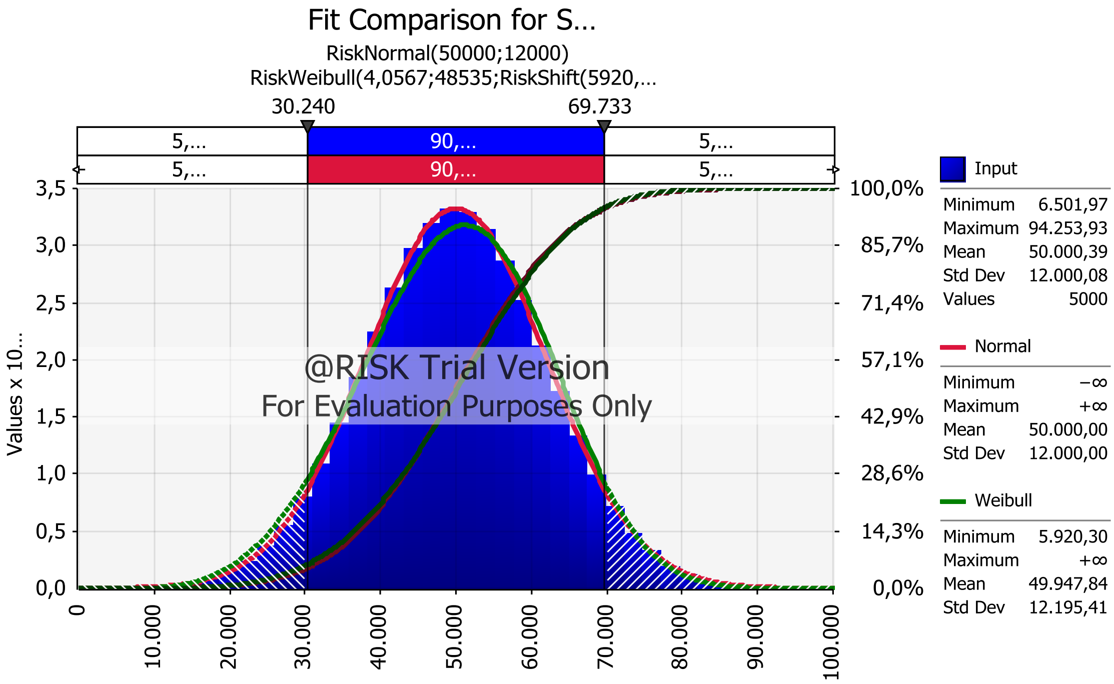
Statistics	Input	Normal	
Minimum	46.250,41	−∞	
Maximum	456.132,47	+∞	
Mean	245.000,94	245.000,00	2
Mode	≈246.880,46	245.000,00	2
Median	244.988,44	245.000,00	2
Std Dev	50.032,45	50.032,00	
Skewness	0,0014	0,0000	
Kurtosis	3,0262	3,0000	
Left X	162.699	162.699	
Left P	5,0%	5,0%	
Right X	327.220	327.220	
Right P	95,0%	95,0%	
Dif. X	164.520,66	164.520,66	1
Dif. P	90,0%	90,0%	
1%	128.546,75	128.608,16	1
5%	162.699,26	162.704,68	1
10%	180.894,52	180.881,41	1
15%	193.212,31	193.145,16	1
20%	202.911,38	202.892,01	2
25%	211.264,83	211.253,93	2
30%	218.808,20	218.763,19	2
35%	225.734,41	225.721,65	2
40%	232.315,79	232.324,54	2
45%	238.716,91	238.712,91	2
50%	244.988,44	245.000,00	2
55%	251.267,28	251.287,09	2
60%	257.671,70	257.675,46	2
65%	264.253,45	264.278,35	2
70%	271.221,24	271.236,81	2
75%	278.708,66	278.746,07	2
80%	287.046,84	287.107,99	2
85%	296.807,66	296.854,84	2
90%	309.074,21	309.118,59	3
95%	327.219,92	327.295,32	3
99%	361.272,88	361.391,84	3


Fit Comparison for P...
RiskNormal(245000;50032)
RiskWeibull(4,4329;220241;RiskShift(4390...
162.6...
327.2...
5,...
90,...
5,...
Values x 10...
@RISK Trial Version
For Evaluation Purposes Only
Input
Minimum 46.250,41
Maximum 456.132,47
Mean 245.000,94
Std Dev 50.032,45
Values 5000
Normal
Minimum −∞
Maximum +∞
Mean 245.000,00
Std Dev 50.032,00
Weibull
Minimum 43.907,00
Maximum +∞
Mean 244.717,91
Std Dev 51.326,56

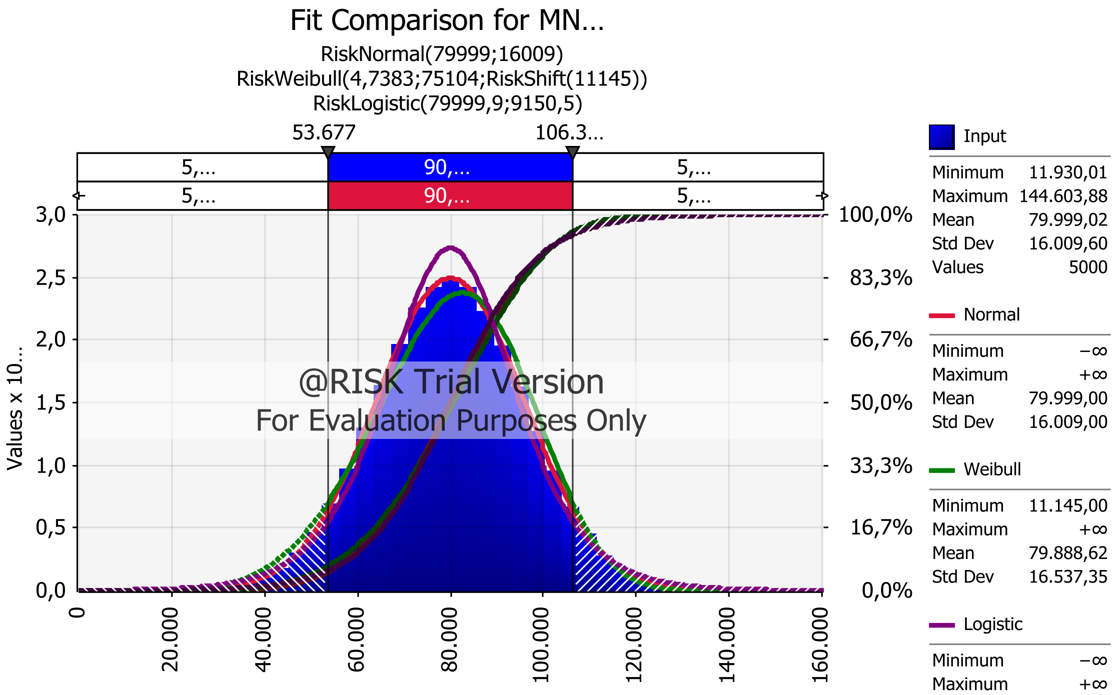

Fit Comparison for K...
RiskNormal(319997;80034)
RiskWeibull(4,588;363890;RiskShift(-12938))
RiskLogistic(320000;45750)
188.3...
451.4...
5,...
90,...
5,...
Values x 10...
@RISK Trial Version
For Evaluation Purposes Only
Input
Minimum -9.111,56
Maximum 627.632,02
Mean 319.997,02
Std Dev 80.034,45
Values 5000
Normal
Minimum −∞
Maximum +∞
Mean 319.997,00
Std Dev 80.034,00
Weibull
Minimum -12.938,00
Maximum +∞
Mean 319.511,97
Std Dev 82.357,77
Logistic
Minimum −∞
Maximum +∞
Mean 320.000,00
Std Dev 82.981,32


Fit Comparison for K...
RiskNormal(319997;80034)
RiskWeibull(4,588;363890;RiskShift(-12938))
RiskLogistic(320000;45750)
188.3...
451.4...
5,...
90,...
5,...
5,...
90,...
5,...
Values x 10...
@RISK Trial Version
For Evaluation Purposes Only
Input
Minimum -9.111,56
Maximum 627.632,02
Mean 319.997,02
Std Dev 80.034,45
Values 5000
Normal
Minimum −∞
Maximum +∞
Mean 319.997,00
Std Dev 80.034,00
Weibull
Minimum -12.938,00
Maximum +∞
Mean 319.511,97
Std Dev 82.357,77
Logistic
Minimum −∞
Maximum +∞
Mean 320.000,00
Std Dev 82.981,32

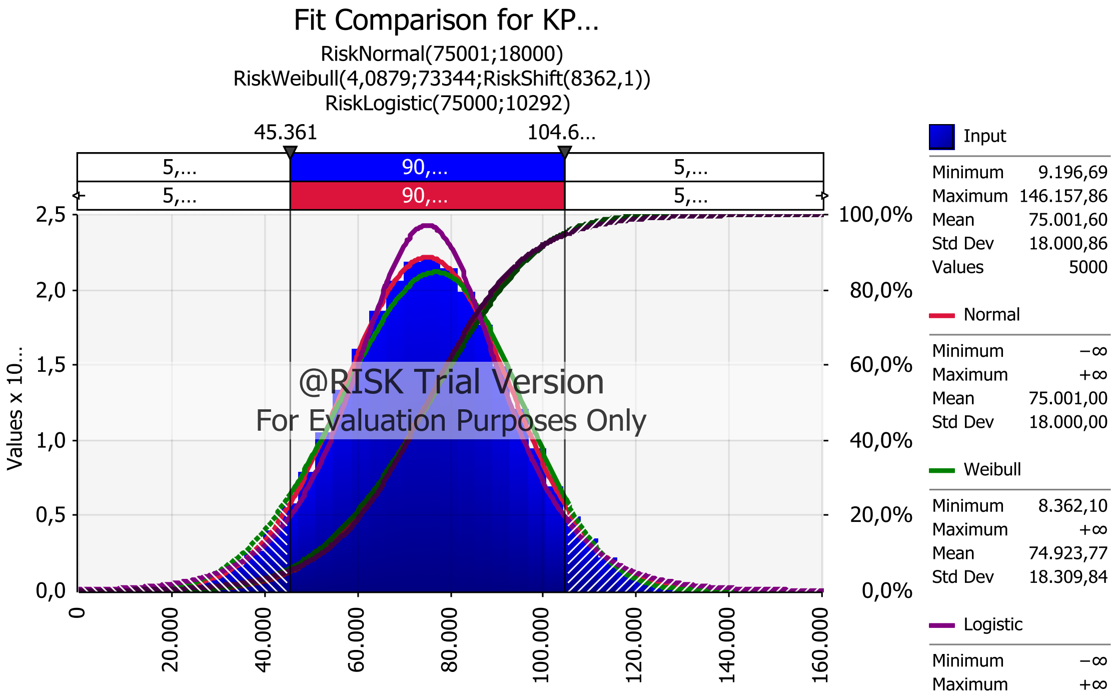

Fit Comparison for MN...
RiskNormal(79999;16009)
RiskWeibull(4,7383;75104;RiskShift(11145))
RiskLogistic(79999,9;9150,5)
53.677
106.3...
5,...
90,...
5,...
5,...
90,...
5,...
Values x 10...
@RISK Trial Version
For Evaluation Purposes Only
Input
Minimum 11.930,01
Maximum 144.603,88
Mean 79.999,02
Std Dev 16.009,60
Values 5000
Normal
Minimum −∞
Maximum +∞
Mean 79.999,00
Std Dev 16.009,00
Weibull
Minimum 11.145,00
Maximum +∞
Mean 79.888,62
Std Dev 16.537,35
Logistic
Minimum −∞
Maximum +∞



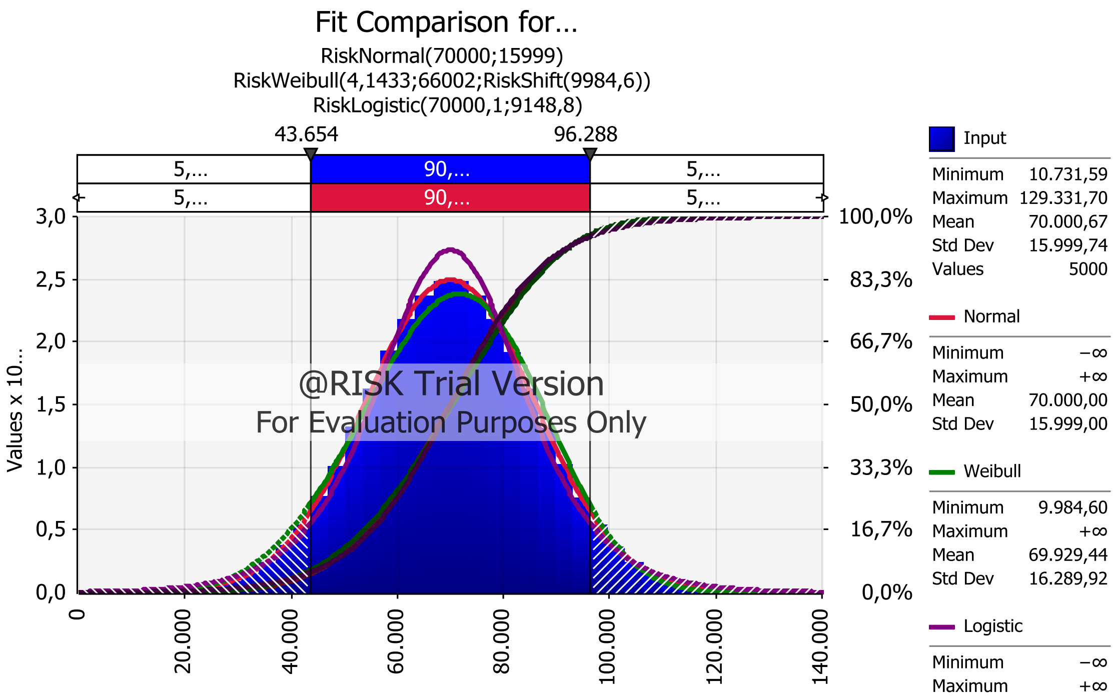
Fit Comparison for S...
RiskNormal(50000;12000)
RiskWeibull(4,0567;48535;RiskShift(5920,...
30.240
69.733
5,...
90,...
5,...
5,...
90,...
5,...
Values x 10...
3,5
3,0
2,5
2,0
1,5
1,0
0,5
0,0
100,0%
85,7%
71,4%
57,1%
42,9%
28,6%
14,3%
0,0%
@RISK Trial Version
For Evaluation Purposes Only
0
10.000
20.000
30.000
40.000
50.000
60.000
70.000
80.000
90.000
100.000
Input
Minimum 6.501,97
Maximum 94.253,93
Mean 50.000,39
Std Dev 12.000,08
Values 5000
Normal
Minimum −∞
Maximum +∞
Mean 50.000,00
Std Dev 12.000,00
Weibull
Minimum 5.920,30
Maximum +∞
Mean 49.947,84
Std Dev 12.195,41



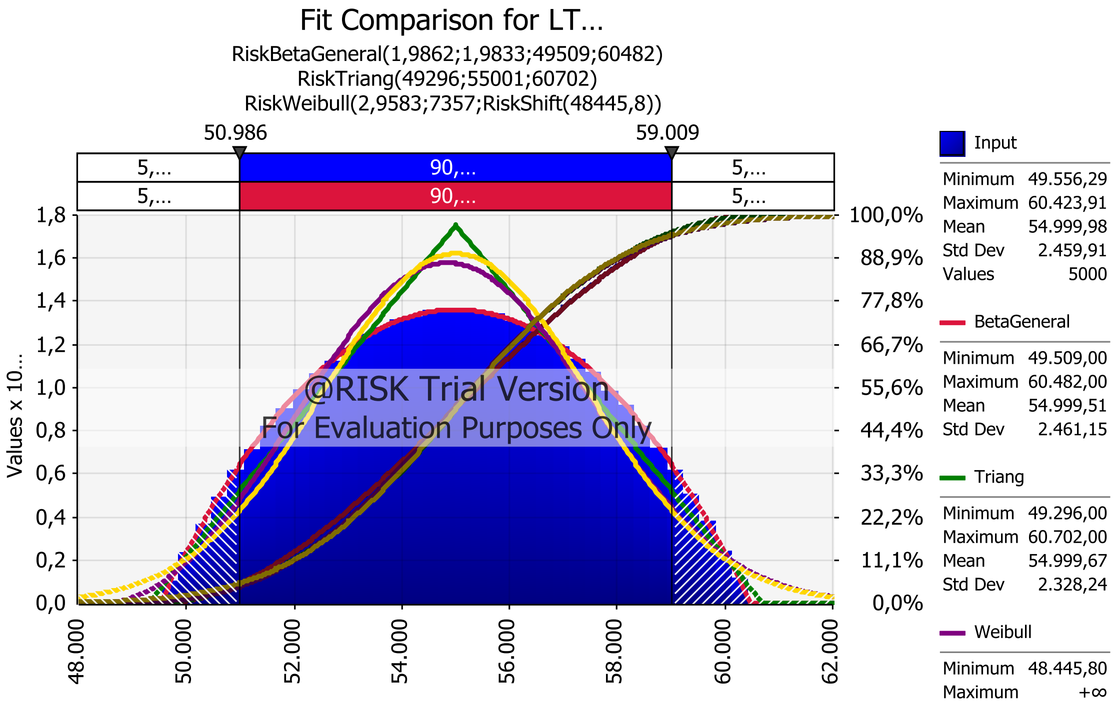
Fit Comparison for MN...
RiskNormal(79999;16009)
RiskWeibull(4,7383;75104;RiskShift(11145))
RiskLogistic(79999,9;9150,5)
53.677
106.3...
5,...
90,...
5,...
5,...
90,...
5,...
Values x 10...
3,0
2,5
2,0
1,5
1,0
0,5
0,0
100,0%
83,3%
66,7%
50,0%
33,3%
16,7%
0,0%
@RISK Trial Version
For Evaluation Purposes Only
0
20.000
40.000
60.000
80.000
100.000
120.000
140.000
160.000
Input
Minimum 11.930,01
Maximum 144.603,88
Mean 79.999,02
Std Dev 16.009,60
Values 5000
Normal
Minimum −∞
Maximum +∞
Mean 79.999,00
Std Dev 16.009,00
Weibull
Minimum 11.145,00
Maximum +∞
Mean 79.888,62
Std Dev 16.537,35
Logistic
Minimum −∞
Maximum +∞

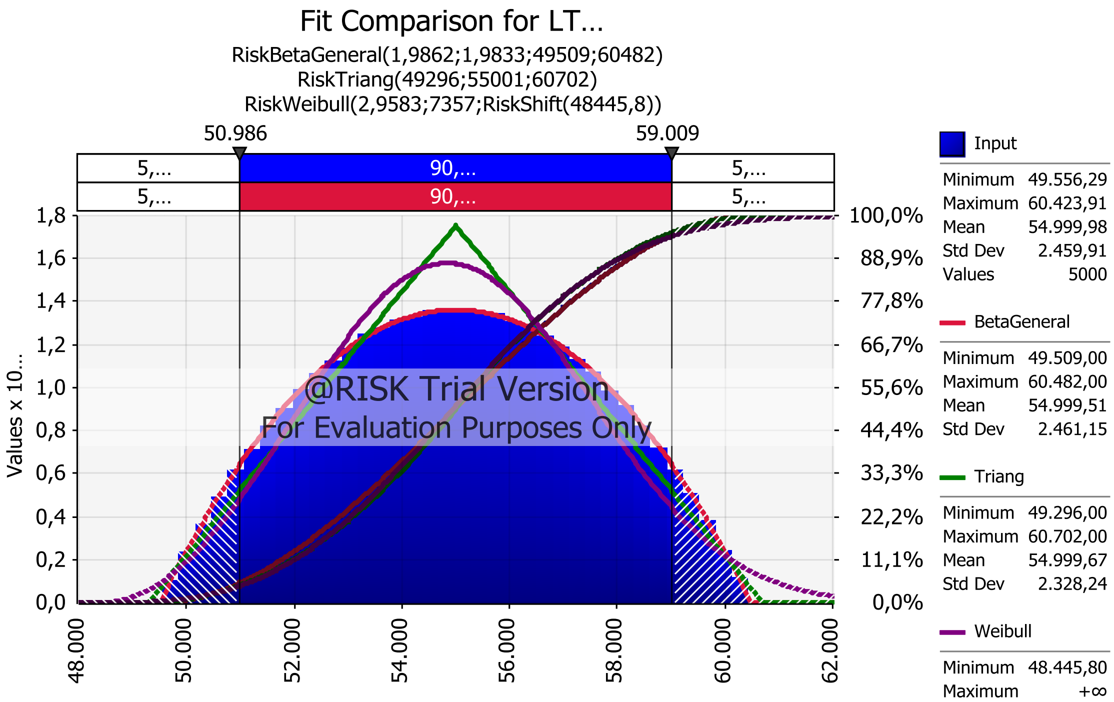


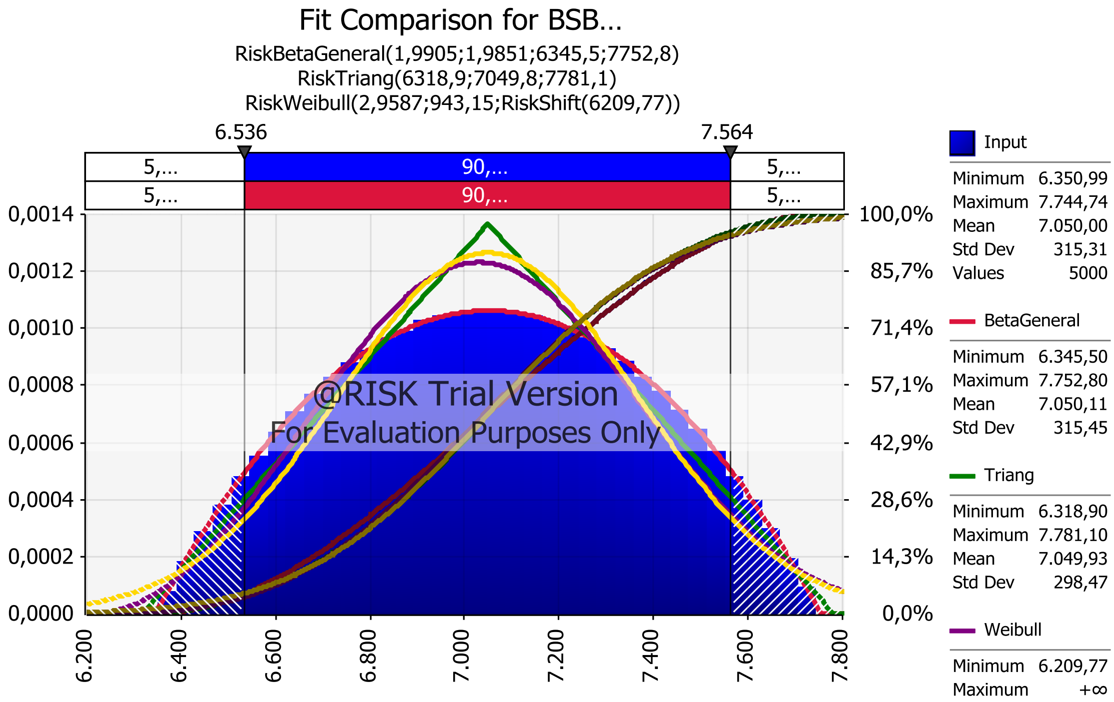
Fit Comparison for KP...
RiskNormal(75001;18000)
RiskWeibull(4,0879;73344;RiskShift(8362,1))
RiskLogistic(75000;10292)
45.361
104.6...
5,...
90,...
5,...
5,...
90,...
5,...
Values x 10...
@RISK Trial Version
For Evaluation Purposes Only
Input
Minimum 9.196,69
Maximum 146.157,86
Mean 75.001,60
Std Dev 18.000,86
Values 5000
Normal
Minimum −∞
Maximum +∞
Mean 75.001,00
Std Dev 18.000,00
Weibull
Minimum 8.362,10
Maximum +∞
Mean 74.923,77
Std Dev 18.309,84
Logistic
Minimum −∞
Maximum +∞



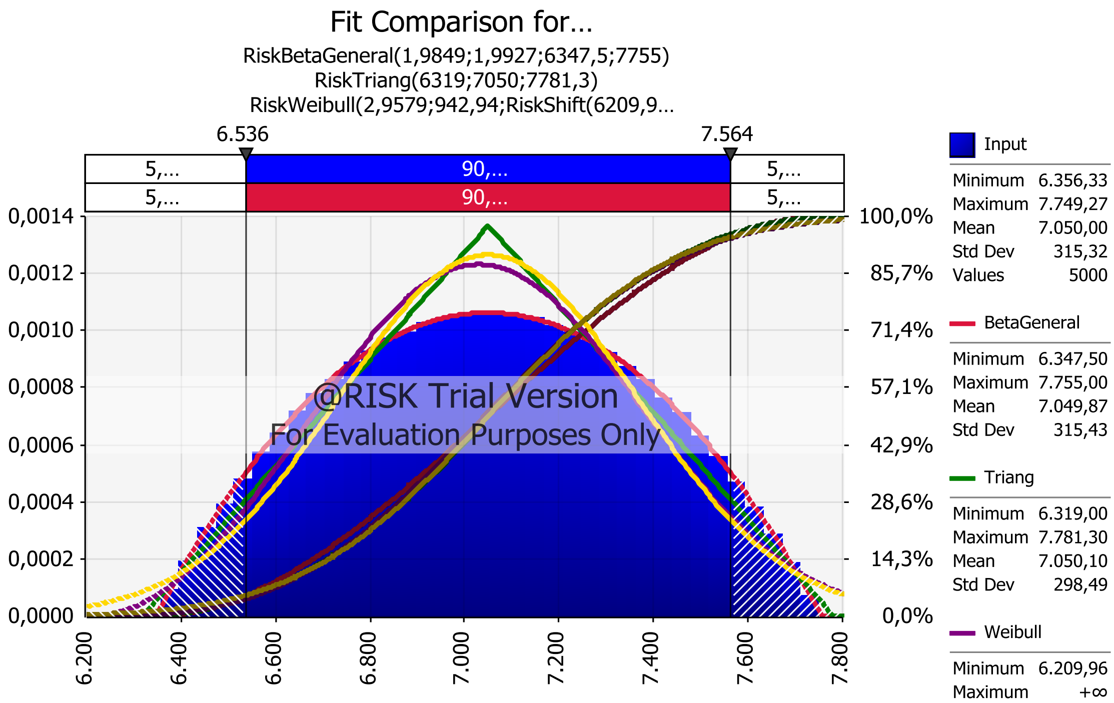
Fit Comparison for...
RiskNormal(70000;15999)
RiskWeibull(4,1433;66002;RiskShift(9984,6))
RiskLogistic(70000,1;9148,8)
43.654
96.288
5,...
90,...
5,...
5,...
90,...
5,...
Values x 10...
@RISK Trial Version
For Evaluation Purposes Only
Input
Minimum 10.731,59
Maximum 129.331,70
Mean 70.000,67
Std Dev 15.999,74
Values 5000
Normal
Minimum −∞
Maximum +∞
Mean 70.000,00
Std Dev 15.999,00
Weibull
Minimum 9.984,60
Maximum +∞
Mean 69.929,44
Std Dev 16.289,92
Logistic
Minimum −∞
Maximum +∞


Fit Comparison for LT...
RiskBetaGeneral(1,9862;1,9833;49509;60482)
RiskTriang(49296;55001;60702)
RiskWeibull(2,9583;7357;RiskShift(48445,8))
50.986
59.009
5,...
90,...
5,...
5,...
90,...
5,...
Values x 10...
1,8
1,6
1,4
1,2
1,0
0,8
0,6
0,4
0,2
0,0
100,0%
88,9%
77,8%
66,7%
55,6%
44,4%
33,3%
22,2%
11,1%
0,0%
48.000
50.000
52.000
54.000
56.000
58.000
60.000
62.000
@RISK Trial Version
For Evaluation Purposes Only
Input
Minimum 49.556,29
Maximum 60.423,91
Mean 54.999,98
Std Dev 2.459,91
Values 5000
BetaGeneral
Minimum 49.509,00
Maximum 60.482,00
Mean 54.999,51
Std Dev 2.461,15
Triang
Minimum 49.296,00
Maximum 60.702,00
Mean 54.999,67
Std Dev 2.328,24
Weibull
Minimum 48.445,80
Maximum +∞

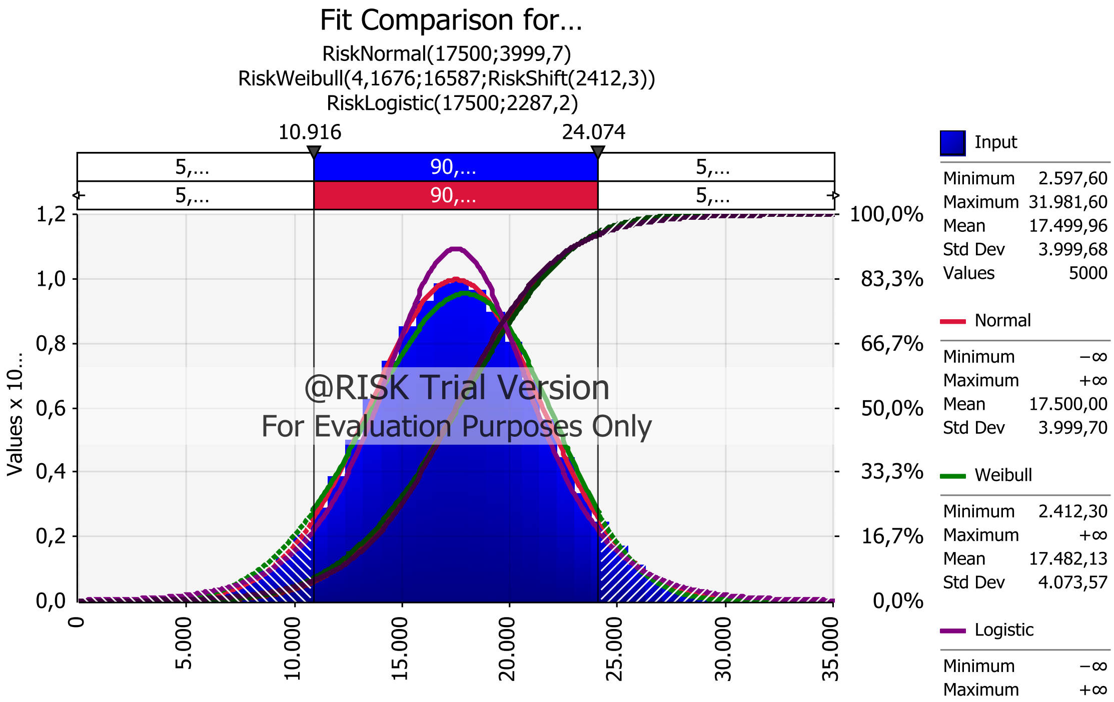

Fit Comparison for LT...
RiskBetaGeneral(1,9862;1,9833;49509;60482)
RiskTriang(49296;55001;60702)
RiskWeibull(2,9583;7357;RiskShift(48445,8))
50.986
59.009
5,...
90,...
5,...
5,...
90,...
5,...
Values x 10...
1,8
1,6
1,4
1,2
1,0
0,8
0,6
0,4
0,2
0,0
100,0%
88,9%
77,8%
66,7%
55,6%
44,4%
33,3%
22,2%
11,1%
0,0%
48.000
50.000
52.000
54.000
56.000
58.000
60.000
62.000
@RISK Trial Version
For Evaluation Purposes Only
Input
Minimum 49.556,29
Maximum 60.423,91
Mean 54.999,98
Std Dev 2.459,91
Values 5000
BetaGeneral
Minimum 49.509,00
Maximum 60.482,00
Mean 54.999,51
Std Dev 2.461,15
Triang
Minimum 49.296,00
Maximum 60.702,00
Mean 54.999,67
Std Dev 2.328,24
Weibull
Minimum 48.445,80
Maximum +∞

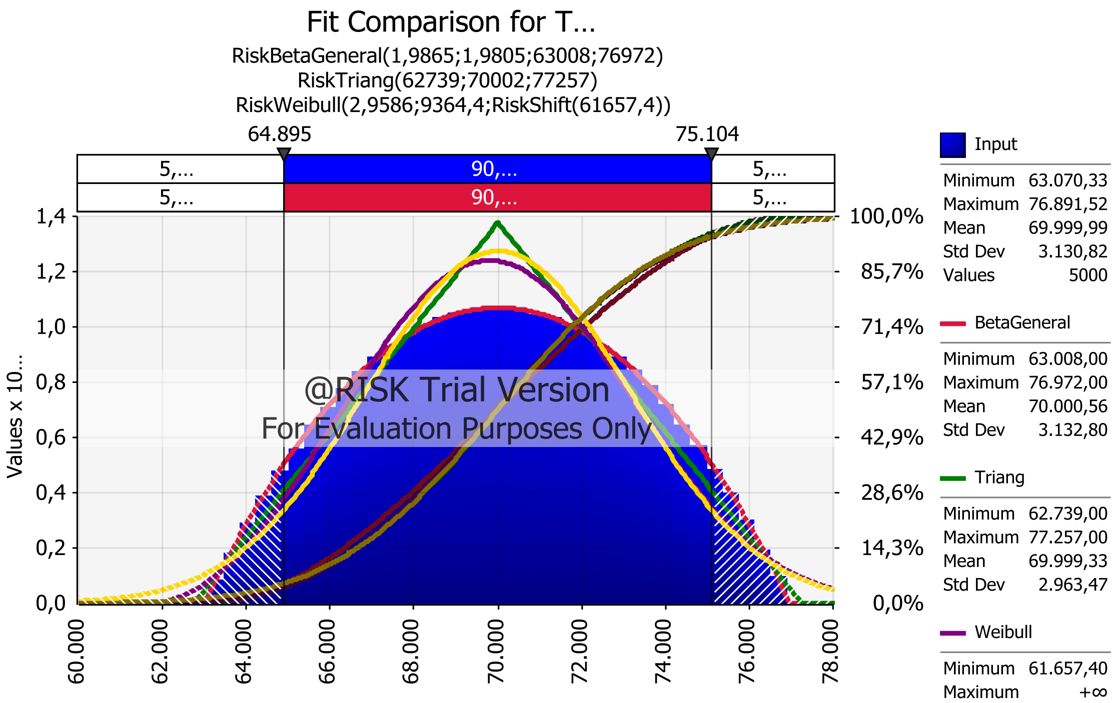


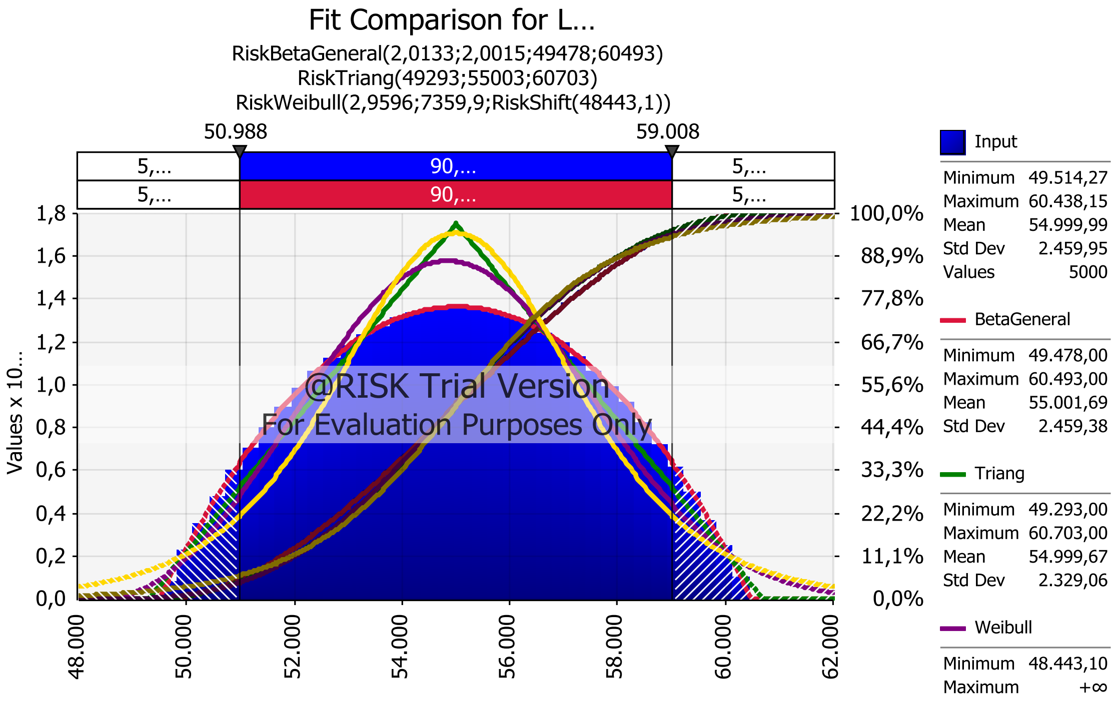
Fit Comparison for BSB...
RiskBetaGeneral(1,9905;1,9851;6345,5;7752,8)
RiskTriang(6318,9;7049,8;7781,1)
RiskWeibull(2,9587;943,15;RiskShift(6209,77))
6.536
7.564
5,...
90,...
5,...
5,...
90,...
5,...
0,0014
0,0012
0,0010
0,0008
0,0006
0,0004
0,0002
0,0000
100,0%
85,7%
71,4%
57,1%
42,9%
28,6%
14,3%
0,0%
6.200
6.400
6.600
6.800
7.000
7.200
7.400
7.600
7.800
@RISK Trial Version
For Evaluation Purposes Only
Input
Minimum 6.350,99
Maximum 7.744,74
Mean 7.050,00
Std Dev 315,31
Values 5000
BetaGeneral
Minimum 6.345,50
Maximum 7.752,80
Mean 7.050,11
Std Dev 315,45
Triang
Minimum 6.318,90
Maximum 7.781,10
Mean 7.049,93
Std Dev 298,47
Weibull
Minimum 6.209,77
Maximum +∞



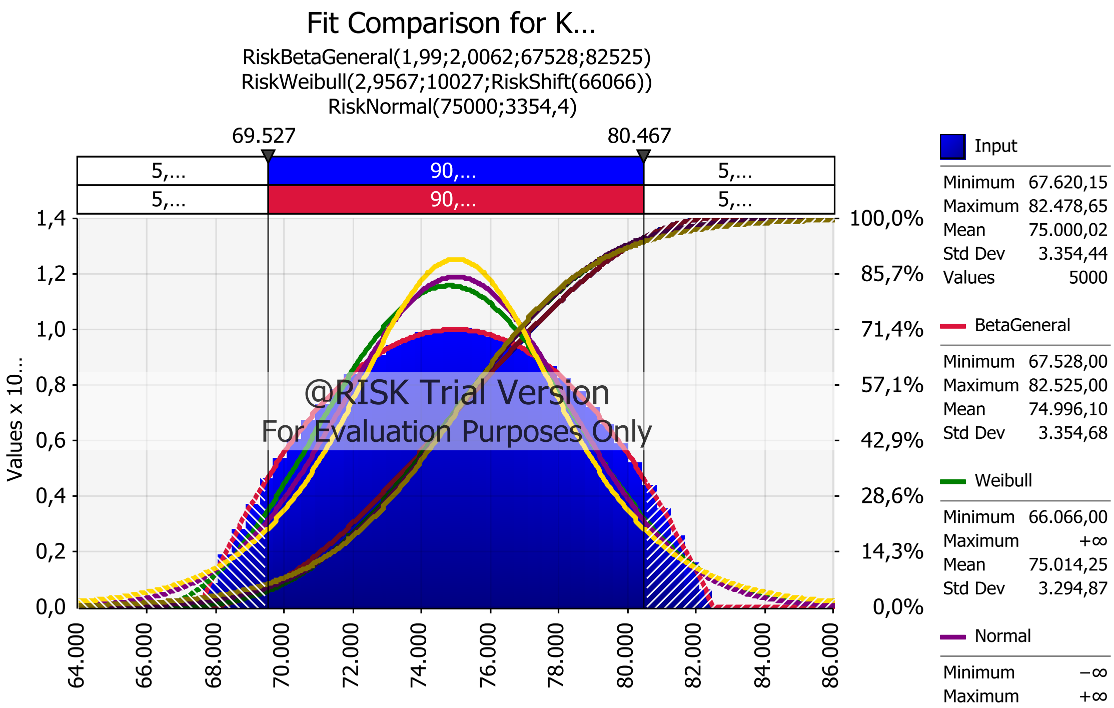
Fit Comparison for...
RiskBetaGeneral(1,9849;1,9927;6347,5;7755)
RiskTriang(6319;7050;7781,3)
RiskWeibull(2,9579;942,94;RiskShift(6209,9...
6.536
7.564
5,...
90,...
5,...
5,...
90,...
5,...
0,0014
0,0012
0,0010
0,0008
0,0006
0,0004
0,0002
0,0000
100,0%
85,7%
71,4%
57,1%
42,9%
28,6%
14,3%
0,0%
6.200
6.400
6.600
6.800
7.000
7.200
7.400
7.600
7.800
@RISK Trial Version
For Evaluation Purposes Only
Input
Minimum 6.356,33
Maximum 7.749,27
Mean 7.050,00
Std Dev 315,32
Values 5000
BetaGeneral
Minimum 6.347,50
Maximum 7.755,00
Mean 7.049,87
Std Dev 315,43
Triang
Minimum 6.319,00
Maximum 7.781,30
Mean 7.050,10
Std Dev 298,49
Weibull
Minimum 6.209,96
Maximum +∞


Fit Comparison for...
RiskNormal(17500;3999,7)
RiskWeibull(4,1676;16587;RiskShift(2412,3))
RiskLogistic(17500;2287,2)
10.916
24.074
5,...
90,...
5,...
5,...
90,...
5,...
Values x 10...
1,2
1,0
0,8
0,6
0,4
0,2
0,0
100,0%
83,3%
66,7%
50,0%
33,3%
16,7%
0,0%
0
5.000
10.000
15.000
20.000
25.000
30.000
35.000
@RISK Trial Version
For Evaluation Purposes Only
Input
Minimum 2.597,60
Maximum 31.981,60
Mean 17.499,96
Std Dev 3.999,68
Values 5000
Normal
Minimum −∞
Maximum +∞
Mean 17.500,00
Std Dev 3.999,70
Weibull
Minimum 2.412,30
Maximum +∞
Mean 17.482,13
Std Dev 4.073,57
Logistic
Minimum −∞
Maximum +∞

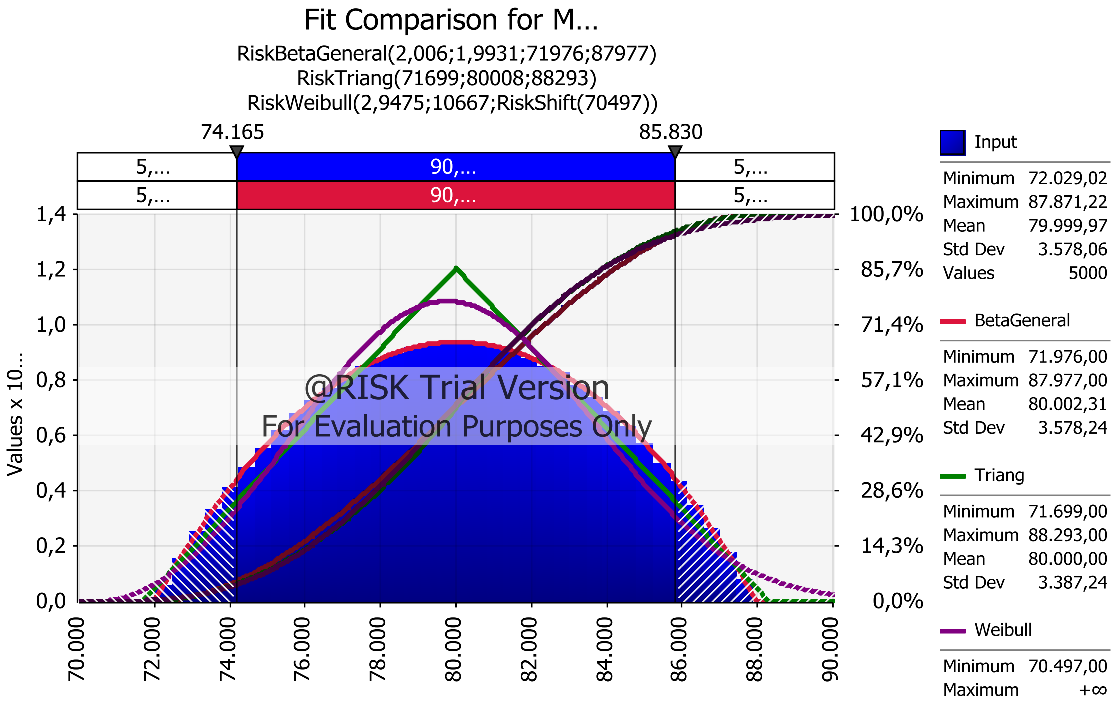

Fit Comparison for T...
RiskBetaGeneral(1,9865;1,9805;63008;76972)
RiskTriang(62739;70002;77257)
RiskWeibull(2,9586;9364,4;RiskShift(61657,4))
64.895
75.104
5,...
90,...
5,...
5,...
90,...
5,...
Values x 10...
1,4
1,2
1,0
0,8
0,6
0,4
0,2
0,0
100,0%
85,7%
71,4%
57,1%
42,9%
28,6%
14,3%
0,0%
60.000
62.000
64.000
66.000
68.000
70.000
72.000
74.000
76.000
78.000
@RISK Trial Version
For Evaluation Purposes Only
Input
Minimum 63.070,33
Maximum 76.891,52
Mean 69.999,99
Std Dev 3.130,82
Values 5000
BetaGeneral
Minimum 63.008,00
Maximum 76.972,00
Mean 70.000,56
Std Dev 3.132,80
Triang
Minimum 62.739,00
Maximum 77.257,00
Mean 69.999,33
Std Dev 2.963,47
Weibull
Minimum 61.657,40
Maximum +∞



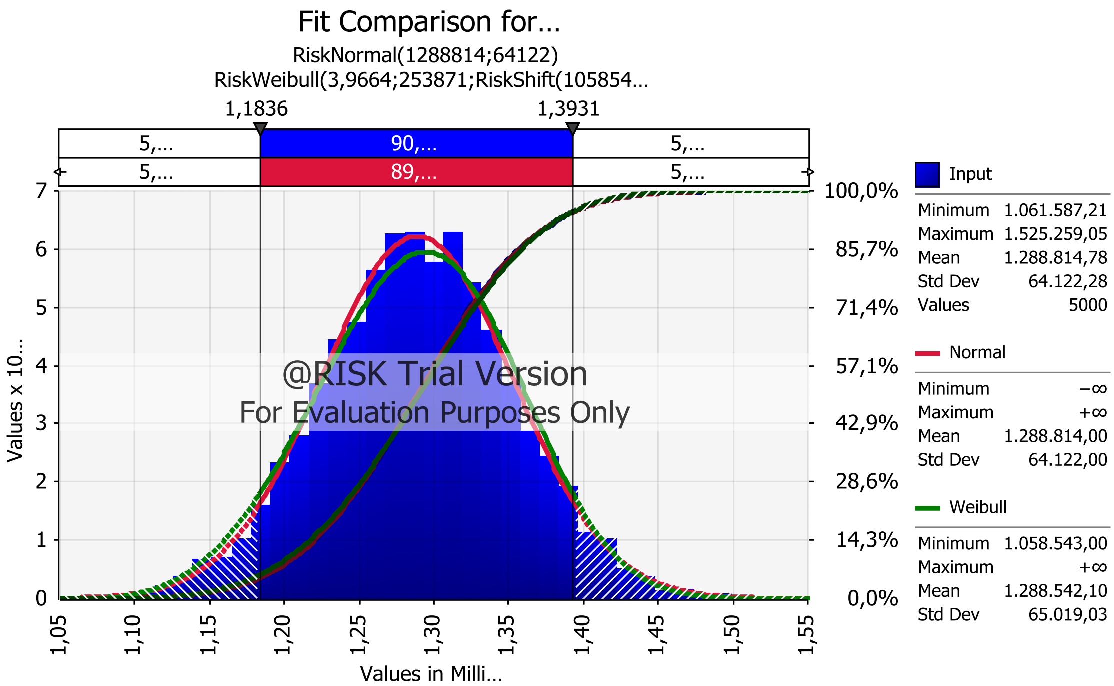
Fit Comparison for L...
RiskBetaGeneral(2,0133;2,0015;49478;60493)
RiskTriang(49293;55003;60703)
RiskWeibull(2,9596;7359,9;RiskShift(48443,1))
50.988
59.008
5,...
90,...
5,...
5,...
90,...
5,...
Values x 10...
1,8
1,6
1,4
1,2
1,0
0,8
0,6
0,4
0,2
0,0
100,0%
88,9%
77,8%
66,7%
55,6%
44,4%
33,3%
22,2%
11,1%
0,0%
48.000
50.000
52.000
54.000
56.000
58.000
60.000
62.000
@RISK Trial Version
For Evaluation Purposes Only
Input
Minimum 49.514,27
Maximum 60.438,15
Mean 54.999,99
Std Dev 2.459,95
Values 5000
BetaGeneral
Minimum 49.478,00
Maximum 60.493,00
Mean 55.001,69
Std Dev 2.459,38
Triang
Minimum 49.293,00
Maximum 60.703,00
Mean 54.999,67
Std Dev 2.329,06
Weibull
Minimum 48.443,10
Maximum +∞



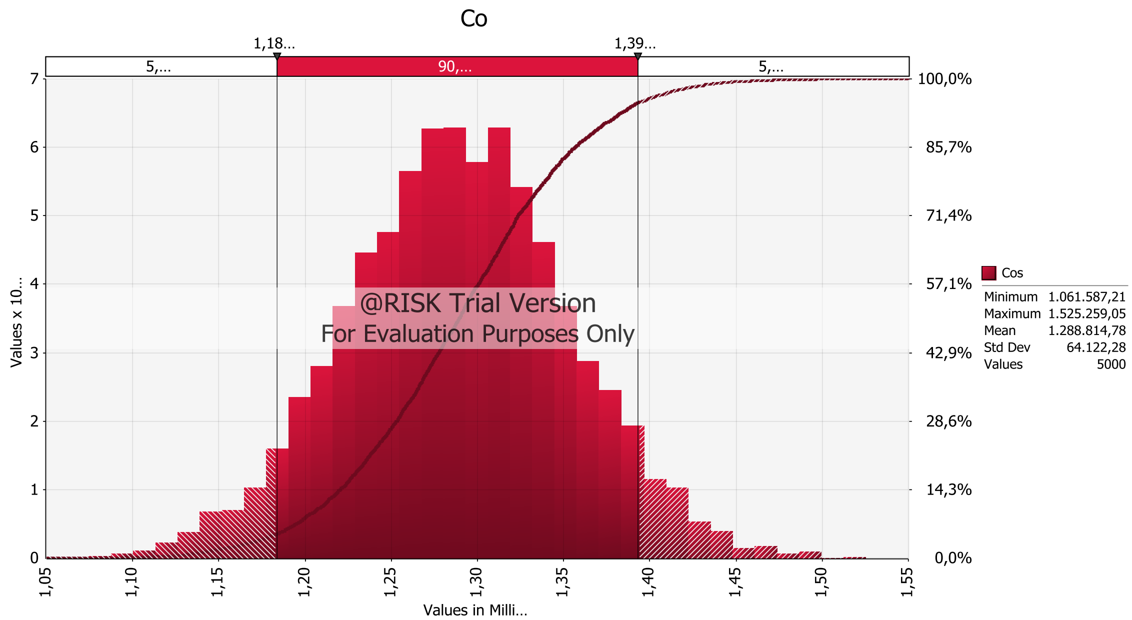
Fit Comparison for K...
RiskBetaGeneral(1,99;2,0062;67528;82525)
RiskWeibull(2,9567;10027;RiskShift(66066))
RiskNormal(75000;3354,4)
69.527
80.467
5,...
90,...
5,...
5,...
90,...
5,...
Values x 10...
1,4
1,2
1,0
0,8
0,6
0,4
0,2
0,0
100,0%
85,7%
71,4%
57,1%
42,9%
28,6%
14,3%
0,0%
64.000
66.000
68.000
70.000
72.000
74.000
76.000
78.000
80.000
82.000
84.000
86.000
@RISK Trial Version
For Evaluation Purposes Only
Input
Minimum 67.620,15
Maximum 82.478,65
Mean 75.000,02
Std Dev 3.354,44
Values 5000
BetaGeneral
Minimum 67.528,00
Maximum 82.525,00
Mean 74.996,10
Std Dev 3.354,68
Weibull
Minimum 66.066,00
Maximum +∞
Mean 75.014,25
Std Dev 3.294,87
Normal
Minimum −∞
Maximum +∞

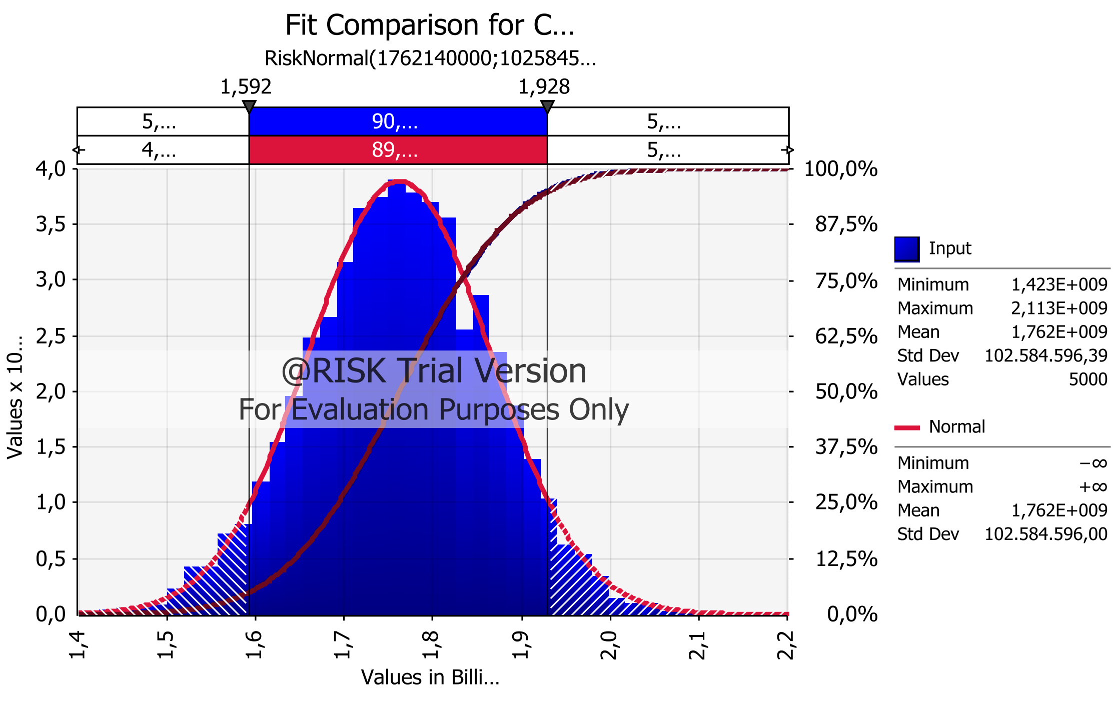


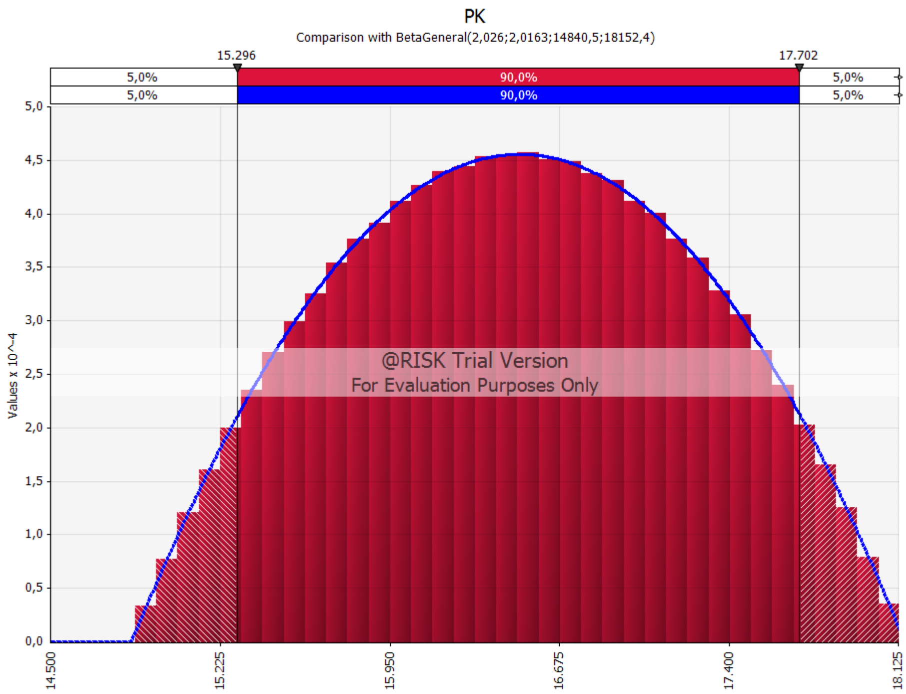
Fit Comparison for M...
RiskBetaGeneral(2,006;1,9931;71976;87977)
RiskTriang(71699;80008;88293)
RiskWeibull(2,9475;10667;RiskShift(70497))
74.165
85.830
5,...
90,...
5,...
5,...
90,...
5,...
Values x 10...
@RISK Trial Version
For Evaluation Purposes Only
Input
Minimum 72.029,02
Maximum 87.871,22
Mean 79.999,97
Std Dev 3.578,06
Values 5000
BetaGeneral
Minimum 71.976,00
Maximum 87.977,00
Mean 80.002,31
Std Dev 3.578,24
Triang
Minimum 71.699,00
Maximum 88.293,00
Mean 80.000,00
Std Dev 3.387,24
Weibull
Minimum 70.497,00
Maximum +∞



Fit Comparison for...
RiskNormal(1288814;64122)
RiskWeibull(3,9664;253871;RiskShift(105854...
1,1836
1,3931
5,...
90,...
5,...
5,...
89,...
5,...
Values x 10...
@RISK Trial Version
For Evaluation Purposes Only
Values in Milli...
Input
Minimum 1.061.587,21
Maximum 1.525.259,05
Mean 1.288.814,78
Std Dev 64.122,28
Values 5000
Normal
Minimum −∞
Maximum +∞
Mean 1.288.814,00
Std Dev 64.122,00
Weibull
Minimum 1.058.543,00
Maximum +∞
Mean 1.288.542,10
Std Dev 65.019,03

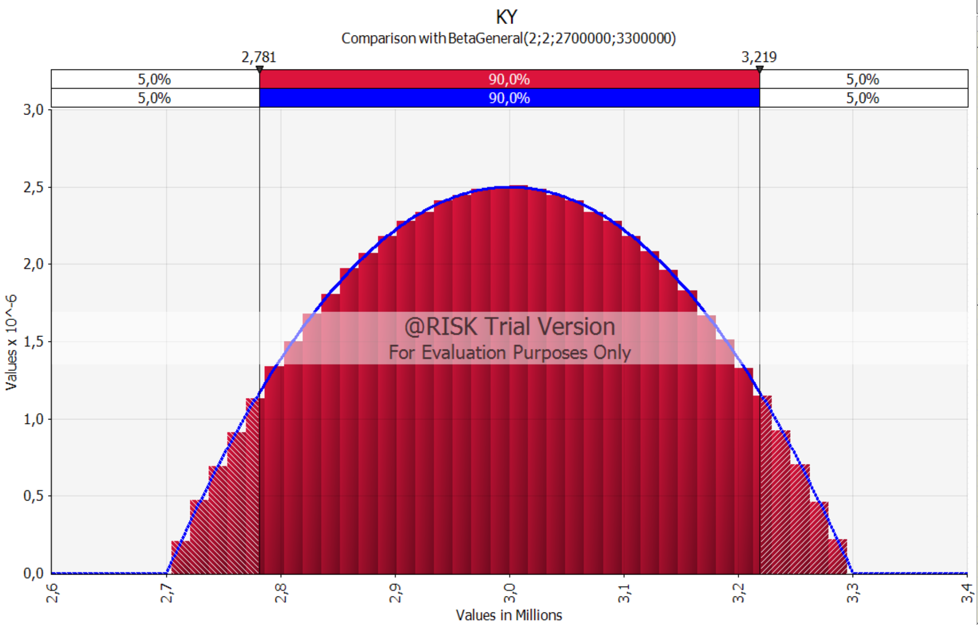

Co
1,18...
1,39...
5,...
90,...
5,...
@RISK Trial Version
For Evaluation Purposes Only
Values x 10...
Values in Milli...
Cos
Minimum 1.061.587,21
Maximum 1.525.259,05
Mean 1.288.814,78
Std Dev 64.122,28
Values 5000


Fit Comparison for C...
RiskNormal(1762140000;1025845...
1,592
1,928
5,...
90,...
5,...
4,...
89,...
5,...
@RISK Trial Version
For Evaluation Purposes Only
Values x 10...
Values in Billi...
Input
Minimum 1,423E+009
Maximum 2,113E+009
Mean 1,762E+009
Std Dev 102.584.596,39
Values 5000
Normal
Minimum −∞
Maximum +∞
Mean 1,762E+009
Std Dev 102.584.596,00



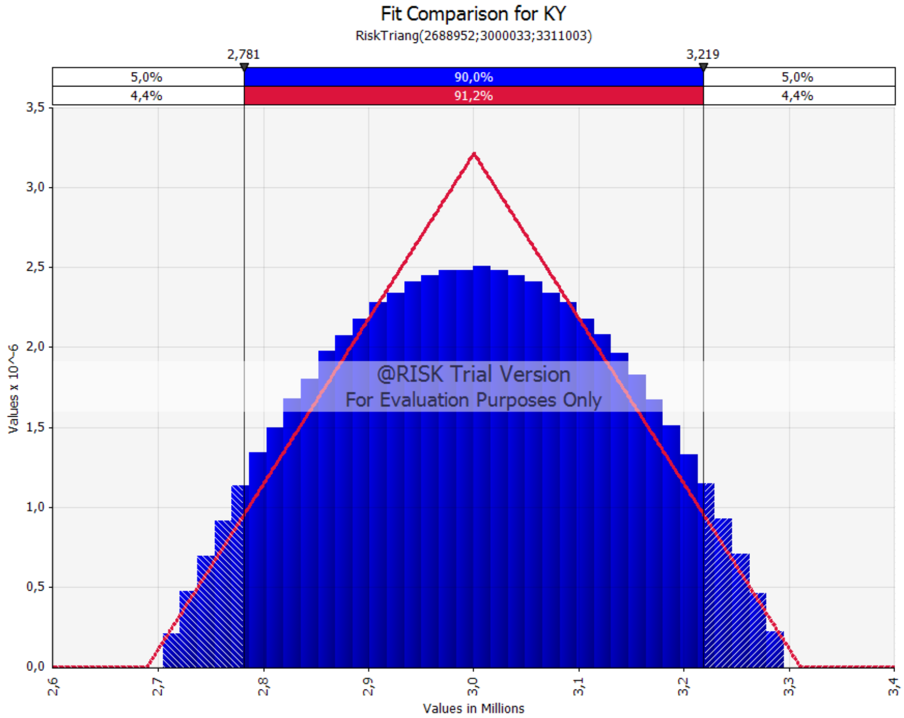
Statistics

	PK	BetaGeneral(2..
Cell	analitical!O48	analitical!O48
Minimum	14.859,47	14.840,50
Maximum	18.132,78	18.152,40
Mean	16.500,42	16.500,42
Mode	16.490,13	16.504,32
Median	16.500,81	16.501,14
Std Dev	737,52	737,45
Skewness	-0,0035	-0,0036
Kurtosis	2,1484	2,1480
Values	5000	
Errors	0	
Filtered	0	
Left X	15.296	15.296
Left P	5,0%	5,0%
Right X	17.702	17.702
Right P	95,0%	95,0%
Dif. X	2.405,91	2.405,91
Dif. P	90,0%	90,0%
1%	15.039,41	15.040,78
5%	15.295,74	15.296,21
10%	15.496,95	15.497,00
15%	15.657,84	15.657,98
20%	15.798,80	15.799,30
25%	15.928,62	15.928,80
30%	16.050,27	16.050,58
35%	16.166,84	16.167,14
40%	16.279,82	16.280,25
45%	16.391,14	16.391,21
50%	16.500,81	16.501,14
55%	16.610,82	16.611,04
60%	16.721,70	16.721,91
65%	16.834,77	16.834,86
70%	16.950,74	16.951,21
75%	17.072,27	17.072,68
80%	17.201,76	17.201,77
85%	17.342,18	17.342,53
90%	17.502,62	17.502,71
95%	17.701,66	17.702,20
99%	17.955,21	17.955,31



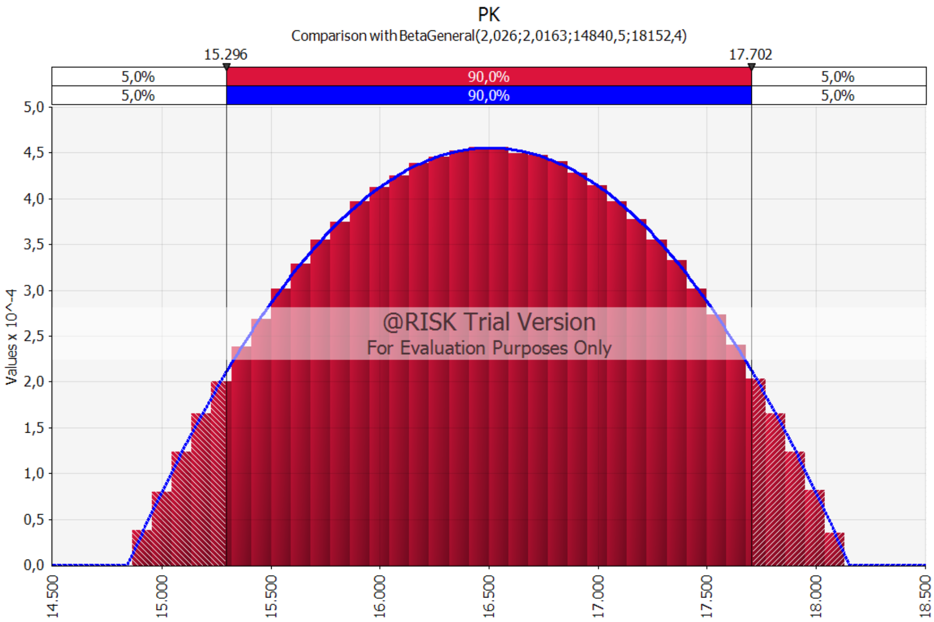
Statistics

	KY	BetaGer
Cell	analitical!O49	
Minimum	2.704.346,06	2.700
Maximum	3.295.317,45	3.300
Mean	3.000.000,19	3.000
Mode	2.965.851,87	3.000
Median	2.999.999,23	3.000
Std Dev	134.174,95	134
Skewness	0,0000	
Kurtosis	2,1431	
Values	5000	
Errors	0	
Filtered	0	
Left X	2.781.052,20	2.781
Left P	5,0%	
Right X	3.218.733,88	3.218
Right P	95,0%	
Dif. X	437.681,68	437
Dif. P	90,0%	
1%	2.735.133,43	2.735
5%	2.781.052,20	2.781
10%	2.817.430,92	2.817
15%	2.846.601,70	2.846
20%	2.872.254,46	2.872
25%	2.895.808,34	2.895
30%	2.917.922,84	2.917
35%	2.939.130,40	2.939
40%	2.959.734,52	2.959
45%	2.979.918,73	2.979
50%	2.999.999,23	3.000
55%	3.020.005,57	3.020
60%	3.040.238,93	3.040
65%	3.060.809,19	3.060
70%	3.082.019,23	3.082
75%	3.104.165,18	3.104
80%	3.127.651,33	3.127
85%	3.153.316,59	3.153
90%	3.182.441,87	3.182
95%	3.218.733,88	3.218
99%	3.264.361,68	3.264



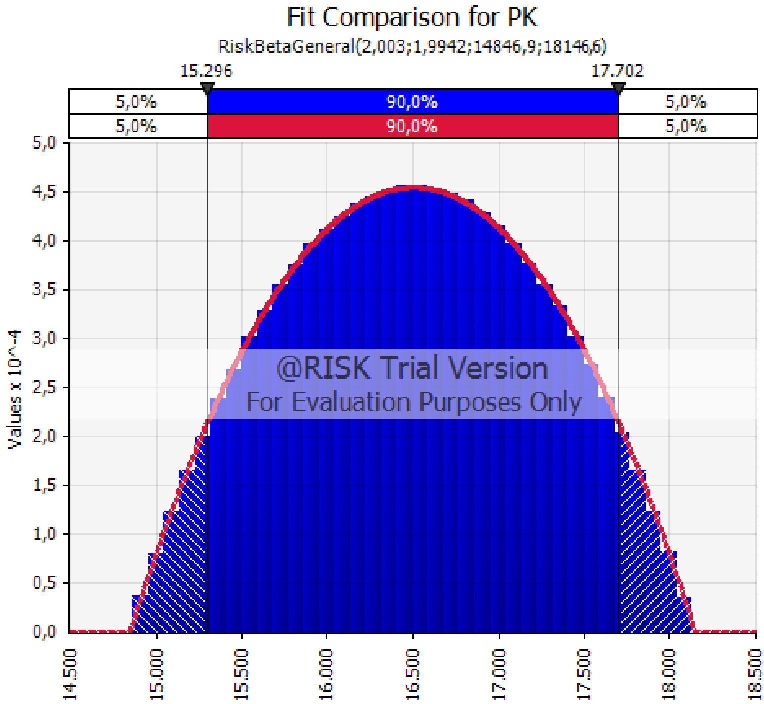
Statistics

	Input	Triang
Minimum	2.704.346,06	2.688.952,00
Maximum	3.295.317,45	3.311.003,00
Mean	3.000.000,19	2.999.996,00
Mode	≈2.965.851,87	3.000.033,00
Median	2.999.999,23	3.000.005,25
Std Dev	134.174,95	126.975,63
Skewness	0,0000	-0,0002
Kurtosis	2,1431	2,4000
Left X	2.781.052,20	2.781.052,20
Left P	5,0%	4,4%
Right X	3.218.733,88	3.218.733,88
Right P	95,0%	95,6%
Dif. X	437.681,68	437.681,68
Dif. P	90,0%	91,2%
1%	2.735.133,43	2.732.941,57
5%	2.781.052,20	2.787.315,67
10%	2.817.430,92	2.828.059,24
15%	2.846.728,46	2.859.322,88
20%	2.872.254,46	2.885.679,35
25%	2.895.808,34	2.908.899,86
30%	2.918.023,82	2.929.892,81
35%	2.939.229,96	2.949.197,82
40%	2.959.734,52	2.967.166,48
45%	2.979.918,73	2.984.043,02
50%	2.999.999,23	3.000.005,25
55%	3.020.005,57	3.015.964,63
60%	3.040.293,90	3.032.838,16
65%	3.060.809,19	3.050.803,62
70%	3.082.045,52	3.070.105,18
75%	3.104.165,18	3.091.094,38
80%	3.127.651,33	3.114.310,75
85%	3.153.316,59	3.140.662,52
90%	3.182.441,87	3.171.920,58
95%	3.218.733,88	3.212.656,88
99%	3.264.361,68	3.267.021,28

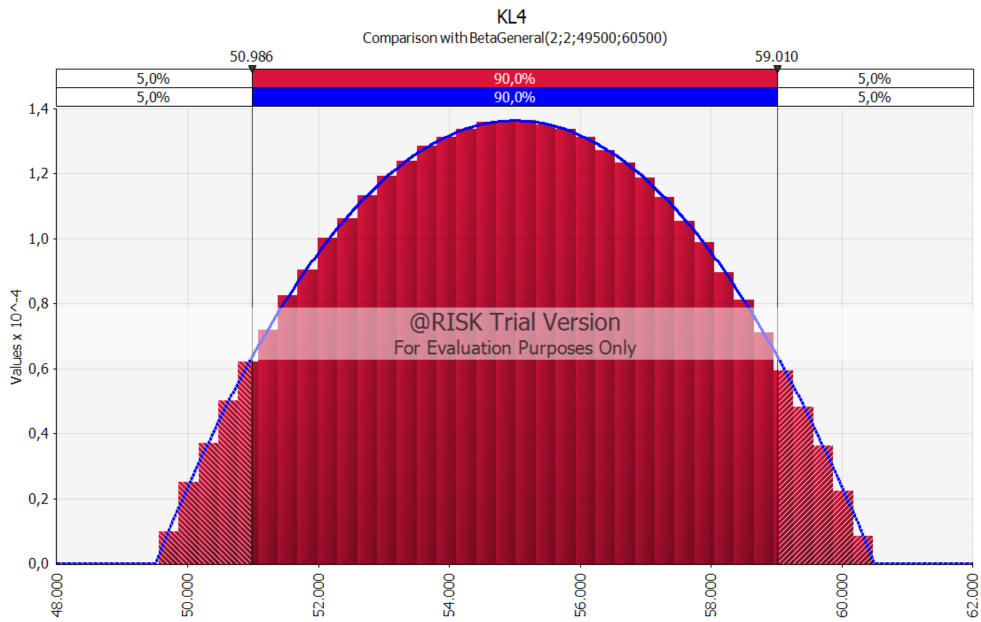


Statistics

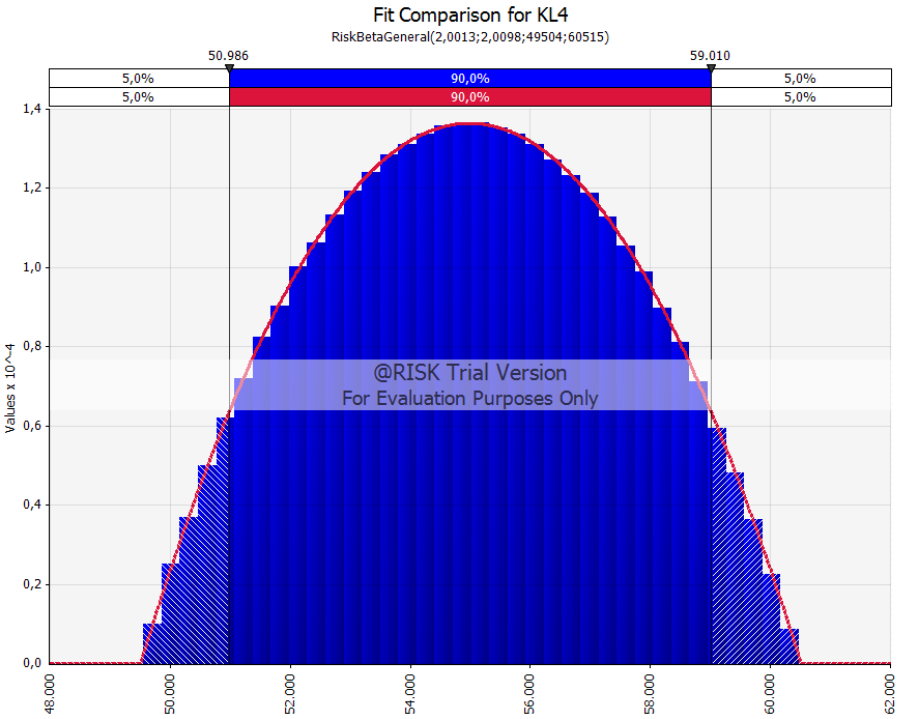
	PK	BetaGeneral(2..
Cell	analitical!O48	
Minimum	14.865,87	14.840,50
Maximum	18.131,71	18.152,40
Mean	16.500,42	16.500,42
Mode	16.446,24	16.504,32
Median	16.500,77	16.501,14
Std Dev	737,52	737,45
Skewness	-0,0036	-0,0036
Kurtosis	2,1482	2,1480
Values	5000	
Errors	0	
Filtered	0	
Left X	15.296	15.296
Left P	5,0%	5,0%
Right X	17.702	17.702
Right P	95,0%	95,0%
Dif. X	2.406,14	2.406,14
Dif. P	90,0%	90,0%
1%	15.040,59	15.040,78
5%	15.295,98	15.296,21
10%	15.496,30	15.497,00
15%	15.657,51	15.657,98
20%	15.799,26	15.799,30
25%	15.928,60	15.928,80
30%	16.050,22	16.050,58
35%	16.166,96	16.167,14
40%	16.280,10	16.280,25
45%	16.390,81	16.391,21
50%	16.500,77	16.501,14
55%	16.610,84	16.611,04
60%	16.721,56	16.721,91
65%	16.834,82	16.834,86
70%	16.950,74	16.951,21
75%	17.072,34	17.072,68
80%	17.201,40	17.201,77
85%	17.342,01	17.342,53
90%	17.502,58	17.502,71
95%	17.702,12	17.702,20
99%	17.955,23	17.955,31



Statistics	Input	BetaGeneral
Minimum	14.865,87	14.846,90
Maximum	18.131,71	18.146,60
Mean	16.500,42	16.500,38
Mode	≈16.446,24	16.504,02
Median	16.500,77	16.501,04
Std Dev	737,52	738,04
Skewness	-0,0036	-0,0033
Kurtosis	2,1482	2,1425
Left X	15.296	15.296
Left P	5,0%	5,0%
Right X	17.702	17.702
Right P	95,0%	95,0%
Dif. X	2.406,14	2.406,14
Dif. P	90,0%	90,0%
1%	15.040,59	15.042,47
5%	15.295,98	15.295,71
10%	15.496,30	15.495,78
15%	15.658,07	15.656,55
20%	15.799,26	15.797,87
25%	15.928,60	15.927,48
30%	16.050,99	16.049,44
35%	16.167,21	16.166,24
40%	16.280,10	16.279,60
45%	16.390,81	16.390,83

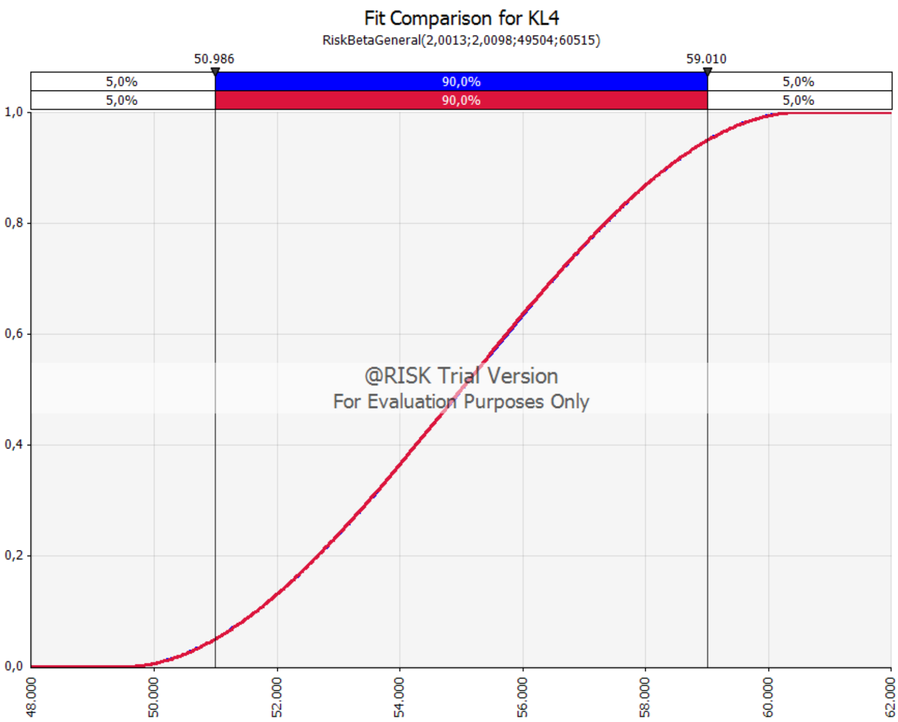


Statistics	KL4	BetaGen
Cell	analitical!O50	
Minimum	49.559,48	49
Maximum	60.479,49	60
Mean	54.999,99	55
Mode	54.669,50	55
Median	54.998,82	55
Std Dev	2.459,94	2
Skewness	0,0000	
Kurtosis	2,1433	
Values	5000	
Errors	0	
Filtered	0	
Left X	50.986	
Left P	5,0%	
Right X	59.010	
Right P	95,0%	
Dif. X	8.023,84	8
Dif. P	90,0%	
1%	50.142,46	50
5%	50.985,72	50
10%	51.652,33	51
15%	52.186,99	52
20%	52.658,36	52
25%	53.088,23	53
30%	53.495,43	53
35%	53.884,55	53
40%	54.261,49	54
45%	54.632,31	54
50%	54.998,82	55
55%	55.366,52	55
60%	55.737,32	55
65%	56.114,04	56
70%	56.503,37	56
75%	56.909,94	56
80%	57.341,35	57
85%	57.810,55	57
90%	58.345,47	58
95%	59.009,56	59
99%	59.849,75	59



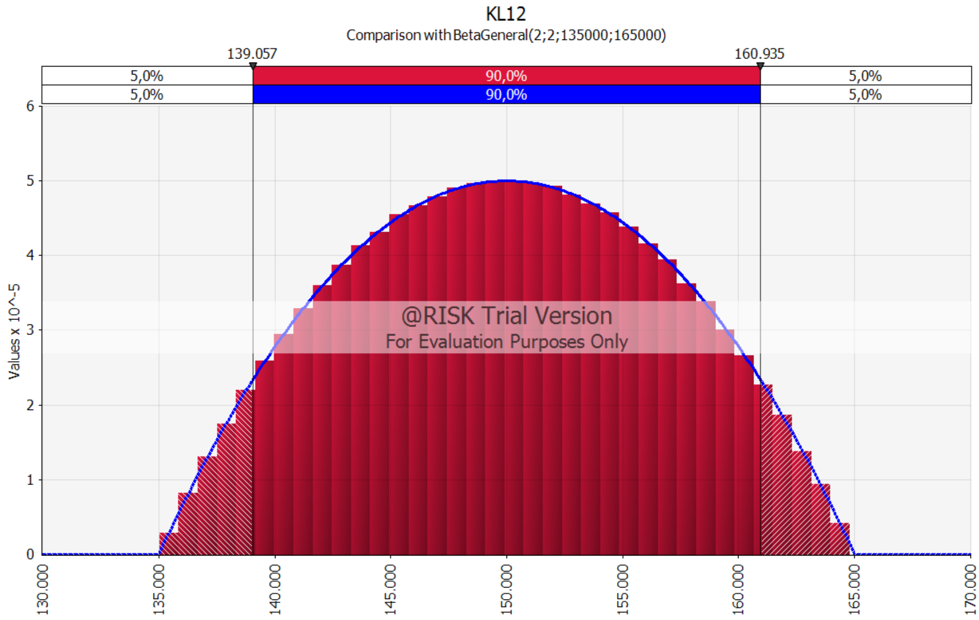
Statistics

	Input	BetaGeneral
Minimum	49.559,48	49.504,00
Maximum	60.479,49	60.515,00
Mean	54.999,99	54.997,83
Mode	≈54.669,50	54.986,23
Median	54.998,82	54.995,72
Std Dev	2.459,94	2.459,40
Skewness	0,0000	0,0032
Kurtosis	2,1433	2,1442
Left X	50.986	50.986
Left P	5,0%	5,0%
Right X	59.010	59.010
Right P	95,0%	95,0%
Dif. X	8.023,84	8.023,84
Dif. P	90,0%	90,0%
1%	50.142,46	50.151,09
5%	50.985,72	50.990,39
10%	51.652,33	51.654,05
15%	52.188,47	52.187,68
20%	52.658,36	52.656,99
25%	53.088,23	53.087,63
30%	53.496,55	53.493,02
35%	53.885,96	53.881,41
40%	54.261,49	54.258,53
45%	54.632,31	54.628,75
50%	54.998,82	54.995,72
55%	55.366,52	55.362,77
60%	55.738,88	55.733,25
65%	56.114,04	56.110,82
70%	56.505,53	56.499,86
75%	56.909,94	56.906,15
80%	57.341,35	57.338,02
85%	57.810,55	57.809,00
90%	58.345,47	58.345,01
95%	59.009,56	59.012,49
99%	59.849,75	59.858,62



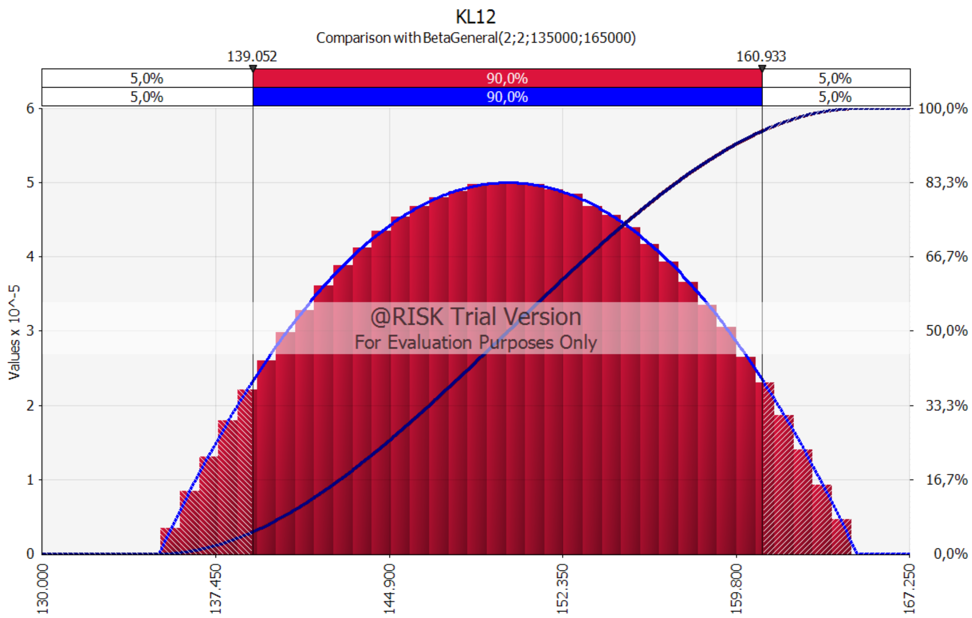
Statistics

	Input	BetaGeneral
Minimum	49.559,48	49.504,00
Maximum	60.479,49	60.515,00
Mean	54.999,99	54.997,83
Mode	≈54.669,50	54.986,23
Median	54.998,82	54.995,72
Std Dev	2.459,94	2.459,40
Skewness	0,0000	0,0032
Kurtosis	2,1433	2,1442
Left X	50.986	50.986
Left P	5,0%	5,0%
Right X	59.010	59.010
Right P	95,0%	95,0%
Dif. X	8.023,84	8.023,84
Dif. P	90,0%	90,0%
1%	50.142,46	50.151,09
5%	50.985,72	50.990,39
10%	51.652,33	51.654,05
15%	52.188,47	52.187,68
20%	52.658,36	52.656,99
25%	53.088,23	53.087,63
30%	53.496,55	53.493,02
35%	53.885,96	53.881,41
40%	54.261,49	54.258,53
45%	54.632,31	54.628,75
50%	54.998,82	54.995,72
55%	55.366,52	55.362,77
60%	55.738,88	55.733,25
65%	56.114,04	56.110,82
70%	56.505,53	56.499,86
75%	56.909,94	56.906,15
80%	57.341,35	57.338,02
85%	57.810,55	57.809,00
90%	58.345,47	58.345,01
95%	59.009,56	59.012,49
99%	59.849,75	59.858,62



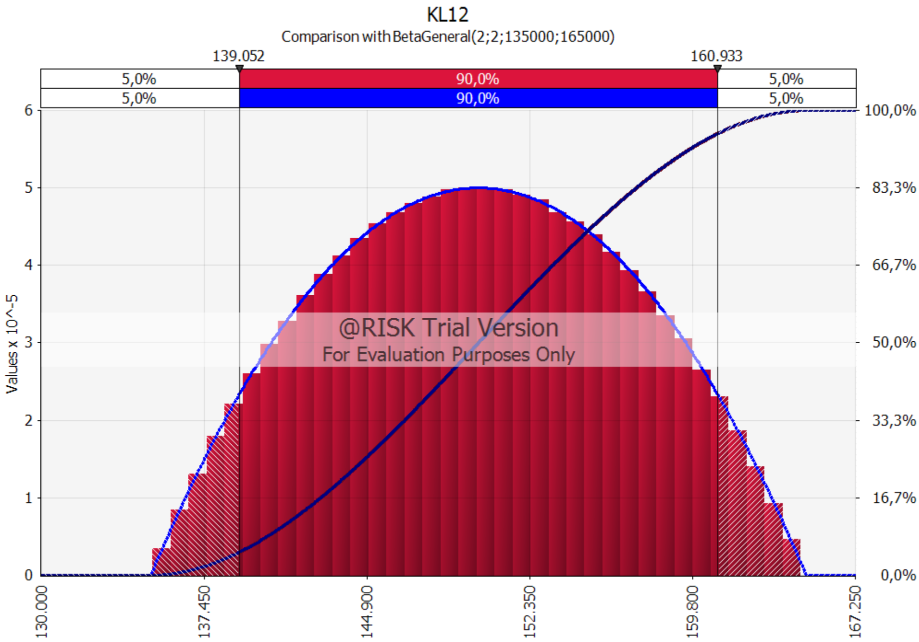
Statistics

	KL12	BetaGen
Cell	analitical!V51	
Minimum	135.038,06	135
Maximum	164.793,11	165
Mean	149.999,99	150
Mode	149.899,85	150
Median	149.997,03	150
Std Dev	6.708,80	6
Skewness	0,0000	
Kurtosis	2,1432	
Values	5000	
Errors	0	
Filtered	0	
Left X	139.057	
Left P	5,0%	
Right X	160.935	
Right P	95,0%	
Dif. X	21.877,29	21
Dif. P	90,0%	
1%	136.764,76	136
5%	139.057,28	139
10%	140.872,35	140
15%	142.328,79	142
20%	143.610,54	143
25%	144.788,08	144
30%	145.894,25	145
35%	146.957,99	146
40%	147.984,58	147
45%	148.995,30	148
50%	149.997,03	150
55%	150.998,46	151
60%	152.009,04	152
65%	153.040,36	153
70%	154.099,92	154
75%	155.209,20	155
80%	156.381,62	156
85%	157.663,24	157
90%	159.124,61	159
95%	160.934,57	160
99%	163.231,18	163

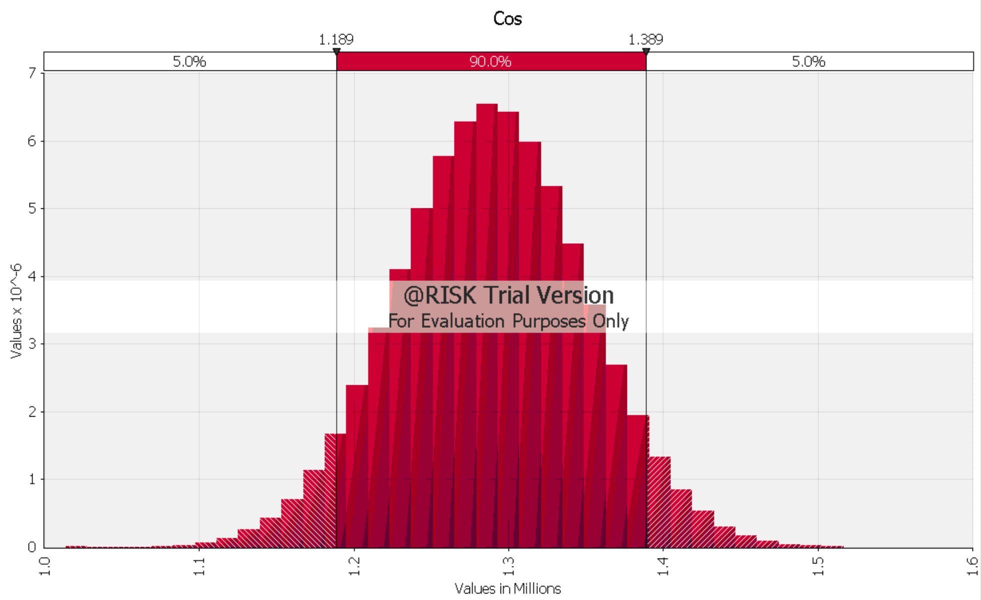


Statistics

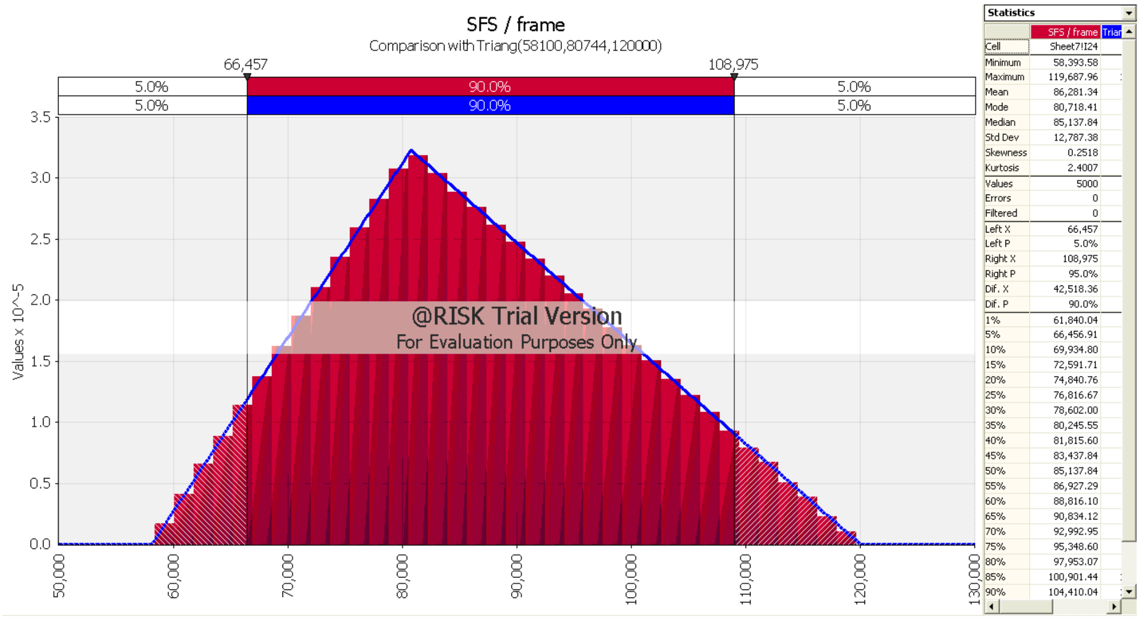
	KL12	BetaGen
Cell	analitical!V51	analit
Minimum	135.087,86	135
Maximum	164.757,62	165
Mean	149.999,93	150
Mode	150.700,66	150
Median	149.997,40	150
Std Dev	6.708,92	6
Skewness	-0,0001	
Kurtosis	2,1433	
Values	5000	
Errors	0	
Filtered	0	
Left X	139.052	
Left P	5,0%	
Right X	160.933	
Right P	95,0%	
Dif. X	21.880,36	21
Dif. P	90,0%	
1%	136.752,69	136
5%	139.052,36	139
10%	140.870,92	140
15%	142.330,01	142
20%	143.610,84	143
25%	144.788,24	144
30%	145.893,71	145
35%	146.957,68	146
40%	147.987,10	147
45%	148.997,57	148
50%	149.997,40	150
55%	151.000,94	151
60%	152.012,01	152
65%	153.041,30	153
70%	154.099,44	154
75%	155.205,09	155
80%	156.381,22	156
85%	157.664,02	157
90%	159.124,61	159
95%	160.932,72	160
99%	163.232,78	163

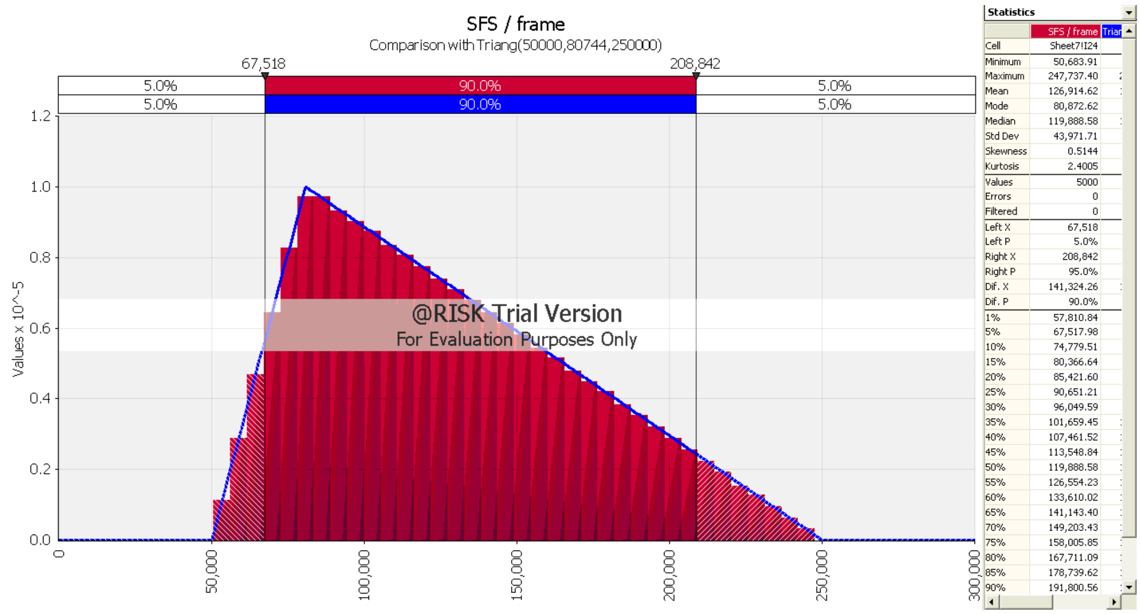


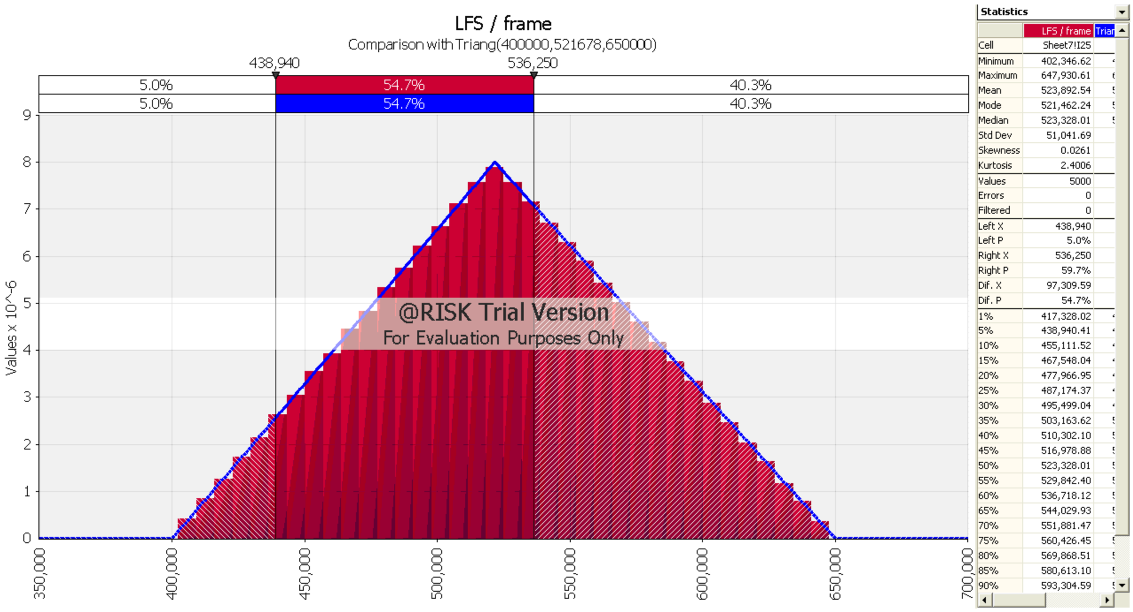
Statistics	KL12	BetaGeneral(2..
Cell	analitical!V51	analitical!V51
Minimum	135.087,86	135.000,00
Maximum	164.757,62	165.000,00
Mean	149.999,93	150.000,00
Mode	150.700,66	150.000,00
Median	149.997,40	150.000,00
Std Dev	6.708,92	6.708,20
Skewness	-0,0001	0,0000
Kurtosis	2,1433	2,1429
Values	5000	
Errors	0	
Filtered	0	
Left X	139.052	139.052
Left P	5,0%	5,0%
Right X	160.933	160.933
Right P	95,0%	95,0%
Dif. X	21.880,36	21.880,36
Dif. P	90,0%	90,0%
1%	136.752,69	136.767,09
5%	139.052,36	139.060,51
10%	140.870,92	140.874,00
15%	142.330,01	142.332,07
20%	143.610,84	143.614,22
25%	144.788,24	144.790,55
30%	145.893,71	145.897,72
35%	146.957,68	146.958,31
40%	147.987,10	147.987,93
45%	148.997,57	148.998,51
50%	149.997,40	150.000,00
55%	151.000,94	151.001,49
60%	152.012,01	152.012,07
65%	153.041,30	153.041,69
70%	154.099,44	154.102,28
75%	155.205,09	155.209,45
80%	156.381,22	156.385,78
85%	157.664,02	157.667,93
90%	159.124,61	159.126,00
95%	160.932,72	160.939,49
99%	163.232,78	163.232,91

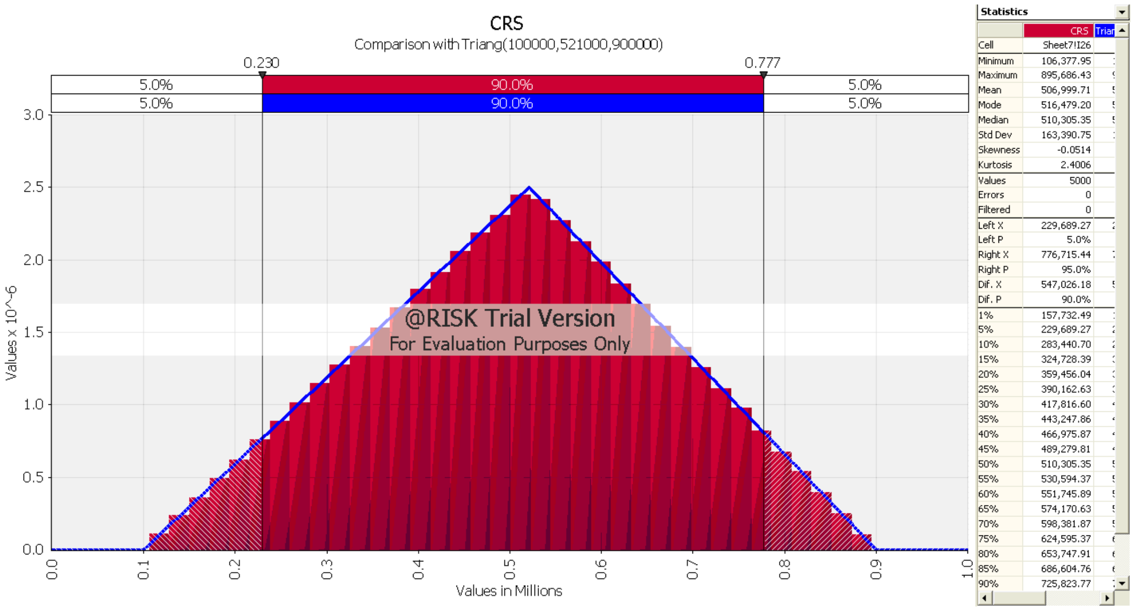


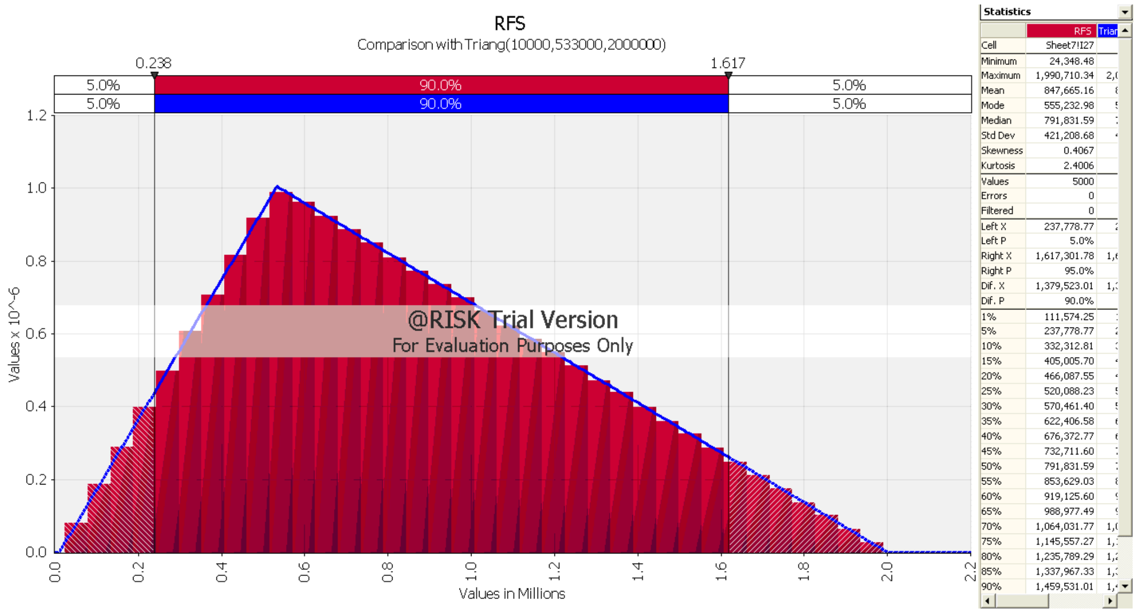
Statistics	Cos
Cell	komposisi!O77
Minimum	1,013,503.56
Maximum	1,516,740.00
Mean	1,288,804.89
Mode	1,291,104.70
Median	1,288,785.66
Std Dev	60,963.37
Skewness	-0.0071
Kurtosis	3.0328
Values	5000
Errors	0
Filtered	0
Left X	1,188,567.17
Left P	5.0%
Right X	1,388,923.79
Right P	95.0%
Dif. X	200,356.62
Dif. P	90.0%
1%	1,147,054.76
5%	1,188,567.17
10%	1,210,707.16
15%	1,225,661.44
20%	1,237,534.61
25%	1,247,718.65
30%	1,256,834.23
35%	1,265,327.36
40%	1,273,358.98
45%	1,281,132.96
50%	1,288,785.66
55%	1,296,468.64
60%	1,304,238.68
65%	1,312,276.98
70%	1,320,744.76
75%	1,329,870.42
80%	1,340,083.85
85%	1,351,949.50
90%	1,366,853.77
95%	1,388,923.79

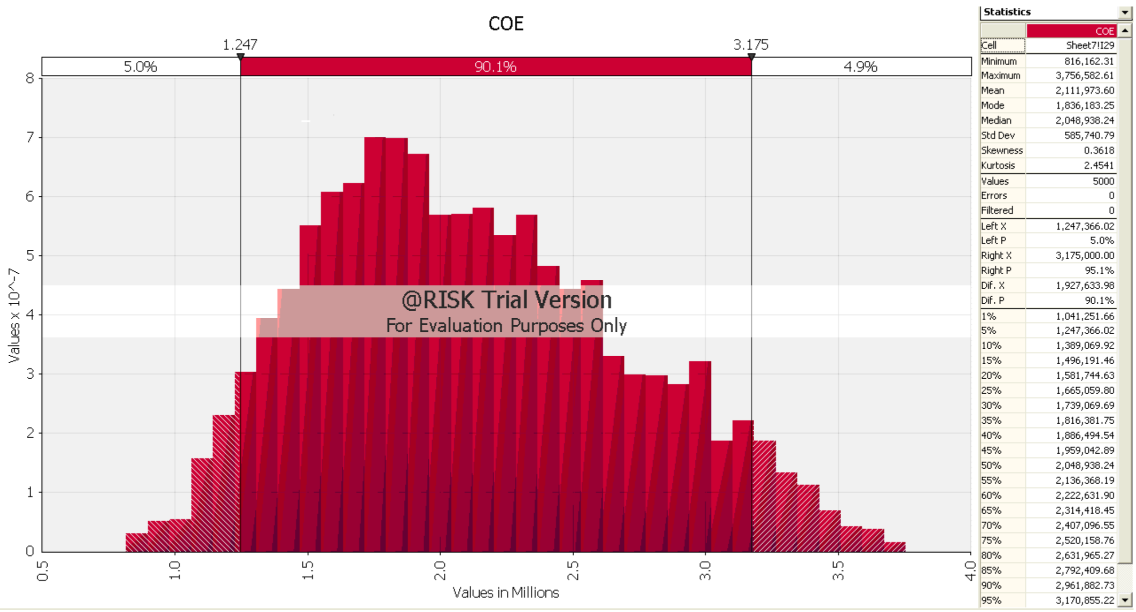

SFS / frame
Comparison with Triang(58100,80744,120000)
66,457
108,975
5.0%
90.0%
5.0%
Values x 10^-5
@RISK Trial Version
For Evaluation Purposes Only
Statistics
Cell Sheet7!I24
Minimum 58,393.58
Maximum 119,687.96
Mean 86,281.34
Mode 80,718.41
Median 85,137.84
Std Dev 12,787.38
Skewness 0.2518
Kurtosis 2.4007
Values 5000
Errors 0
Filtered 0
Left X 66,457
Left P 5.0%
Right X 108,975
Right P 95.0%
Dif. X 42,518.36
Dif. P 90.0%
1% 61,840.04
5% 66,456.91
10% 69,934.80
15% 72,591.71
20% 74,840.76
25% 76,816.67
30% 78,602.00
35% 80,245.55
40% 81,815.60
45% 83,437.84
50% 85,137.84
55% 86,927.29
60% 88,816.10
65% 90,834.12
70% 92,992.95
75% 95,348.60
80% 97,953.07
85% 100,901.44
90% 104,410.04

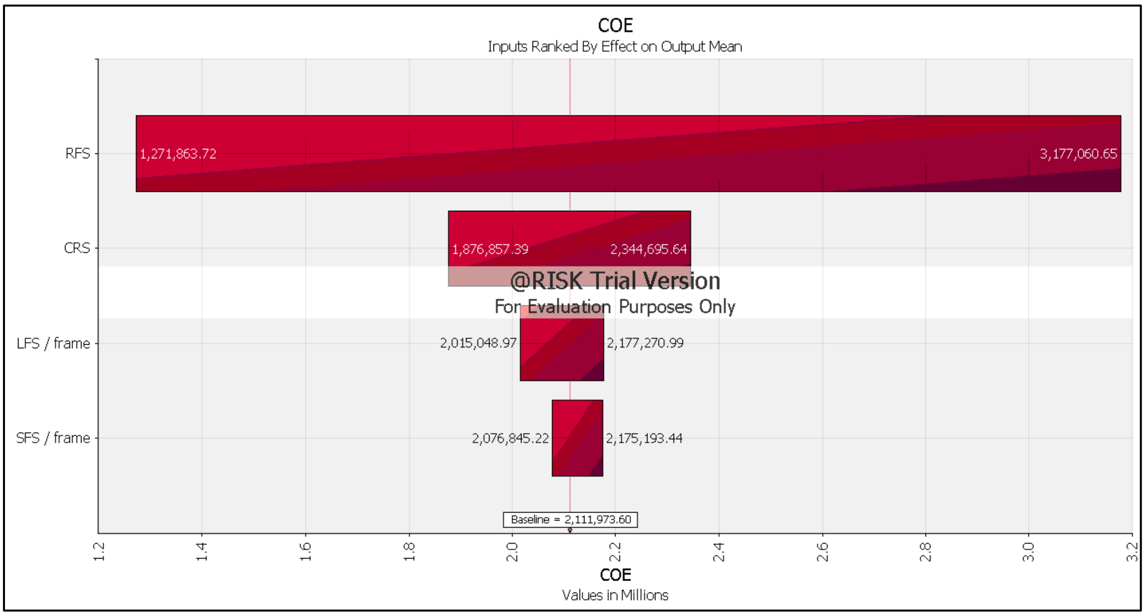

SFS / frame
Comparison with Triang(50000,80744,250000)
67,518
208,842
5.0%
90.0%
5.0%
Values x 10^-5
@RISK Trial Version
For Evaluation Purposes Only
Statistics
Cell Sheet7!I24
Minimum 50,683.91
Maximum 247,737.40
Mean 126,914.62
Mode 80,872.62
Median 119,888.58
Std Dev 43,971.71
Skewness 0.5144
Kurtosis 2.4005
Values 5000
Errors 0
Filtered 0
Left X 67,518
Left P 5.0%
Right X 208,842
Right P 95.0%
Dif. X 141,324.26
Dif. P 90.0%
1% 57,810.84
5% 67,517.98
10% 74,779.51
15% 80,366.64
20% 85,421.60
25% 90,651.21
30% 96,049.59
35% 101,659.45
40% 107,461.52
45% 113,548.84
50% 119,888.58
55% 126,554.23
60% 133,610.02
65% 141,143.40
70% 149,203.43
75% 158,005.85
80% 167,711.09
85% 178,739.62
90% 191,800.56

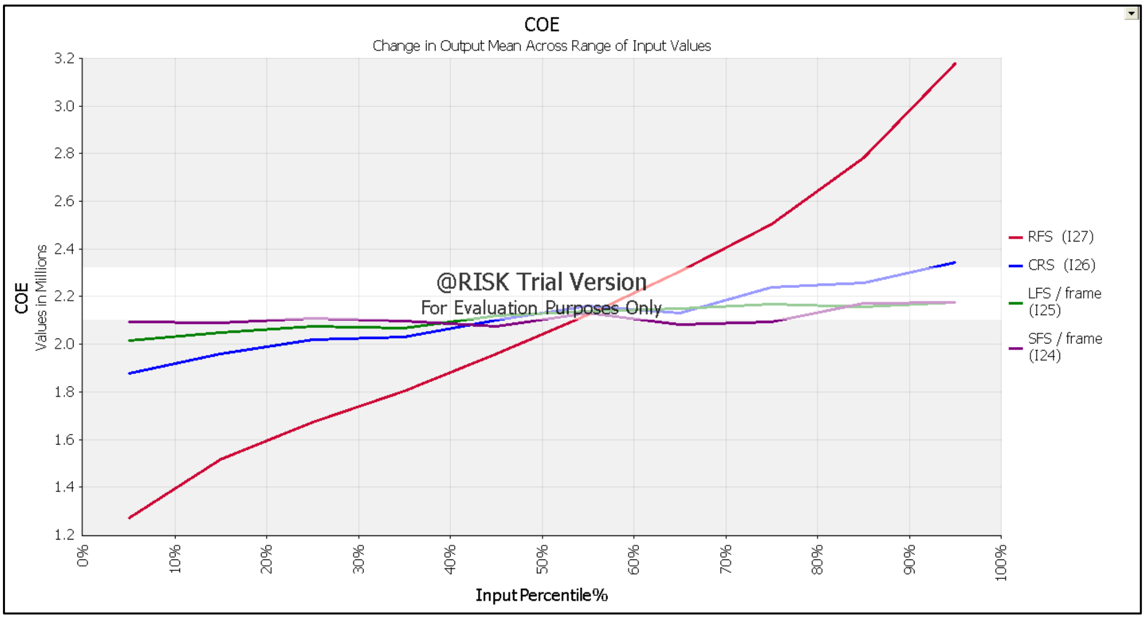

LFS / frame
Comparison with Triang(400000,521678,650000)
438,940
536,250
5.0%
54.7%
40.3%
5.0%
54.7%
40.3%
Values x 10^-6
350,000
400,000
450,000
500,000
550,000
600,000
650,000
700,000
@RISK Trial Version
For Evaluation Purposes Only
Statistics
LFS / frame
Cell Sheet7!I25
Minimum 402,346.62
Maximum 647,930.61
Mean 523,892.54
Mode 521,462.24
Median 523,328.01
Std Dev 51,041.69
Skewness 0.0261
Kurtosis 2.4006
Values 5000
Errors 0
Filtered 0
Left X 438,940
Left P 5.0%
Right X 536,250
Right P 59.7%
Dif. X 97,309.59
Dif. P 54.7%
1% 417,328.02
5% 438,940.41
10% 455,111.52
15% 467,548.04
20% 477,966.95
25% 487,174.37
30% 495,499.04
35% 503,163.62
40% 510,302.10
45% 516,978.88
50% 523,328.01
55% 529,842.40
60% 536,718.12
65% 544,029.93
70% 551,881.47
75% 560,426.45
80% 569,868.51
85% 580,613.10
90% 593,304.59

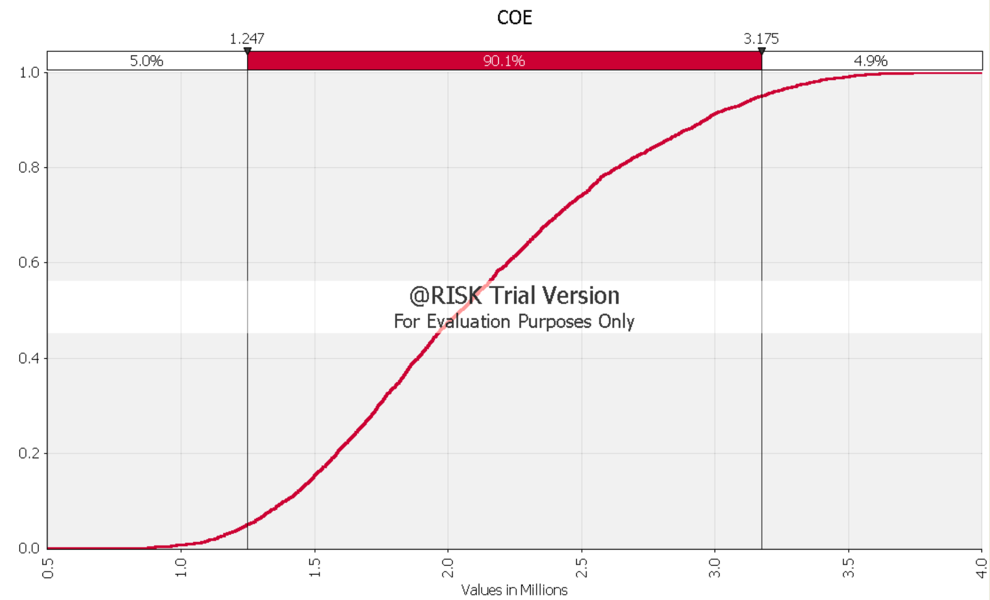

CRS
Comparison with Triang(100000,521000,900000)
0.230
0.777
5.0%
90.0%
5.0%
5.0%
90.0%
5.0%
Values x 10^-6
Values in Millions
@RISK Trial Version
For Evaluation Purposes Only
Statistics
CRS
Cell Sheet7!I26
Minimum 106,377.95
Maximum 895,686.43
Mean 506,999.71
Mode 516,479.20
Median 510,305.35
Std Dev 163,390.75
Skewness -0.0514
Kurtosis 2.4006
Values 5000
Errors 0
Filtered 0
Left X 229,689.27
Left P 5.0%
Right X 776,715.44
Right P 95.0%
Dif. X 547,026.18
Dif. P 90.0%
1% 157,732.49
5% 229,689.27
10% 283,440.70
15% 324,728.39
20% 359,456.04
25% 390,162.63
30% 417,816.60
35% 443,247.86
40% 466,975.87
45% 489,279.81
50% 510,305.35
55% 530,594.37
60% 551,745.89
65% 574,170.63
70% 598,381.87
75% 624,595.37
80% 653,747.91
85% 686,604.76
90% 725,823.77


RFS
Comparison with Triang(10000,533000,2000000)
0.238
1.617
5.0%
90.0%
5.0%
5.0%
90.0%
5.0%
Values x 10^-6
Values in Millions
@RISK Trial Version
For Evaluation Purposes Only
Statistics
RFS
Cell Sheet7!I27
Minimum 24,348.48
Maximum 1,990,710.34
Mean 847,665.16
Mode 555,232.98
Median 791,831.59
Std Dev 421,208.68
Skewness 0.4067
Kurtosis 2.4006
Values 5000
Errors 0
Filtered 0
Left X 237,778.77
Left P 5.0%
Right X 1,617,301.78
Right P 95.0%
Dif. X 1,379,523.01
Dif. P 90.0%
1% 111,574.25
5% 237,778.77
10% 332,312.81
15% 405,005.70
20% 466,087.55
25% 520,088.23
30% 570,461.40
35% 622,406.58
40% 676,372.77
45% 732,711.60
50% 791,831.59
55% 853,629.03
60% 919,125.60
65% 988,977.49
70% 1,064,031.77
75% 1,145,557.27
80% 1,235,789.29
85% 1,337,967.33
90% 1,459,531.01

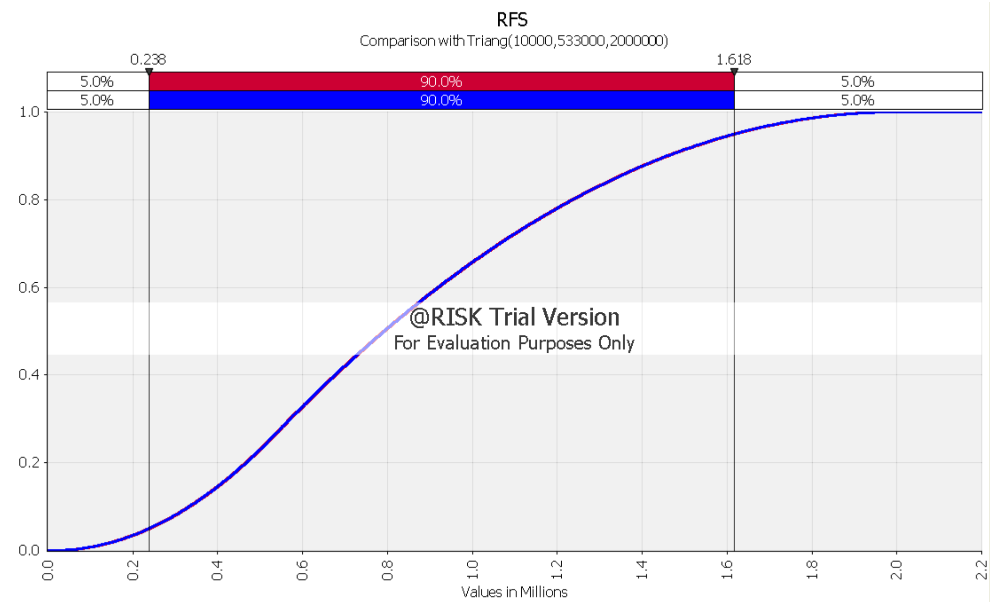

COE
1.247
3.175
5.0%
90.1%
4.9%
Values x 10^-7
Values in Millions
@RISK Trial Version
For Evaluation Purposes Only
Statistics
COE
Cell Sheet7!I29
Minimum 816,162.31
Maximum 3,756,582.61
Mean 2,111,973.60
Mode 1,836,183.25
Median 2,048,938.24
Std Dev 585,740.79
Skewness 0.3618
Kurtosis 2.4541
Values 5000
Errors 0
Filtered 0
Left X 1,247,366.02
Left P 5.0%
Right X 3,175,000.00
Right P 95.1%
Dif. X 1,927,633.98
Dif. P 90.1%
1% 1,041,251.66
5% 1,247,366.02
10% 1,389,069.92
15% 1,496,191.46
20% 1,581,744.63
25% 1,665,059.80
30% 1,739,069.69
35% 1,816,381.75
40% 1,886,494.54
45% 1,959,042.89
50% 2,048,938.24
55% 2,136,368.19
60% 2,222,631.90
65% 2,314,418.45
70% 2,407,096.55
75% 2,520,158.76
80% 2,631,965.27
85% 2,792,409.68
90% 2,961,882.73
95% 3,170,855.22


COE
Inputs Ranked By Effect on Output Mean
RFS
CRS
LFS / frame
SFS / frame
1,271,863.72
3,177,060.65
1,876,857.39
2,344,695.64
2,015,048.97
2,177,270.99
2,076,845.22
2,175,193.44
Baseline = 2,111,973.60
@RISK Trial Version
For Evaluation Purposes Only
COE
Values in Millions

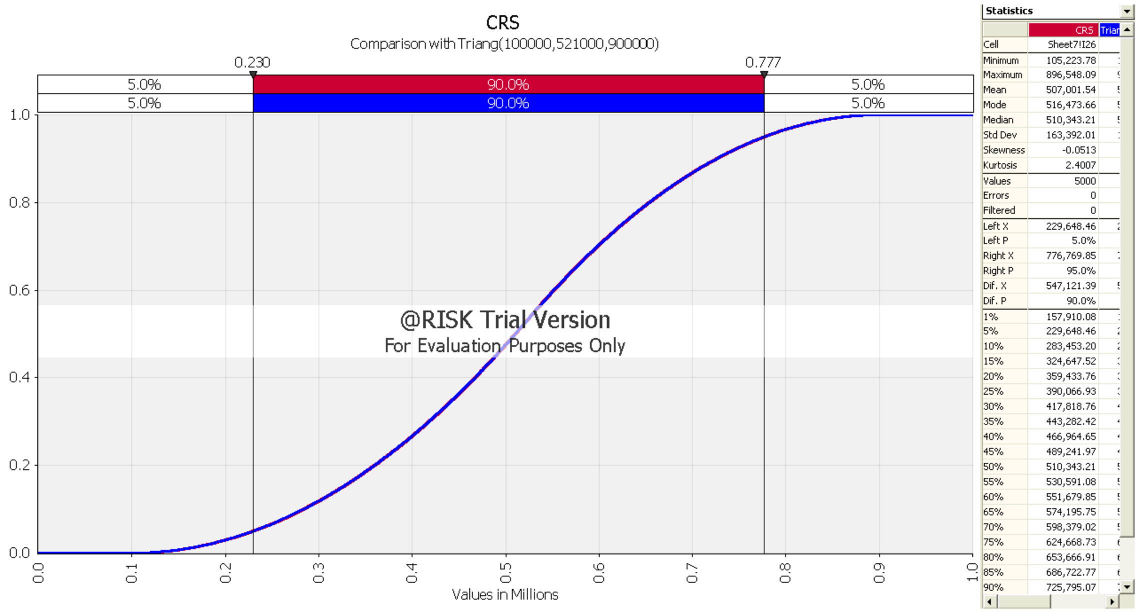

COE
Change in Output Mean Across Range of Input Values
@RISK Trial Version
For Evaluation Purposes Only
COE
Values in Millions
Input Percentile%
RFS (I27)
CRS (I26)
LFS / frame (I25)
SFS / frame (I24)

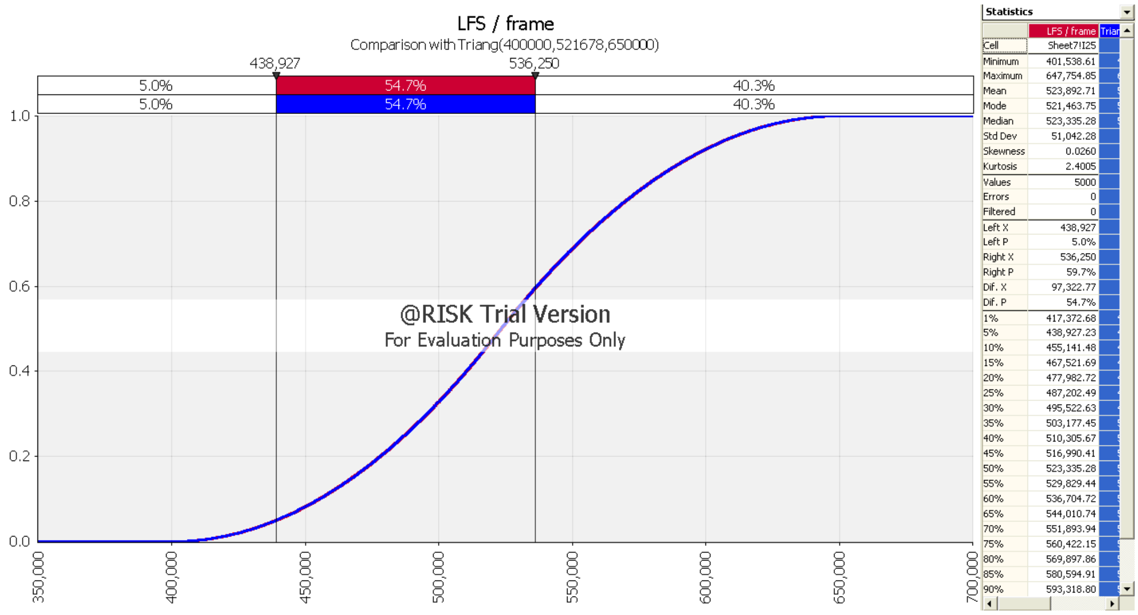


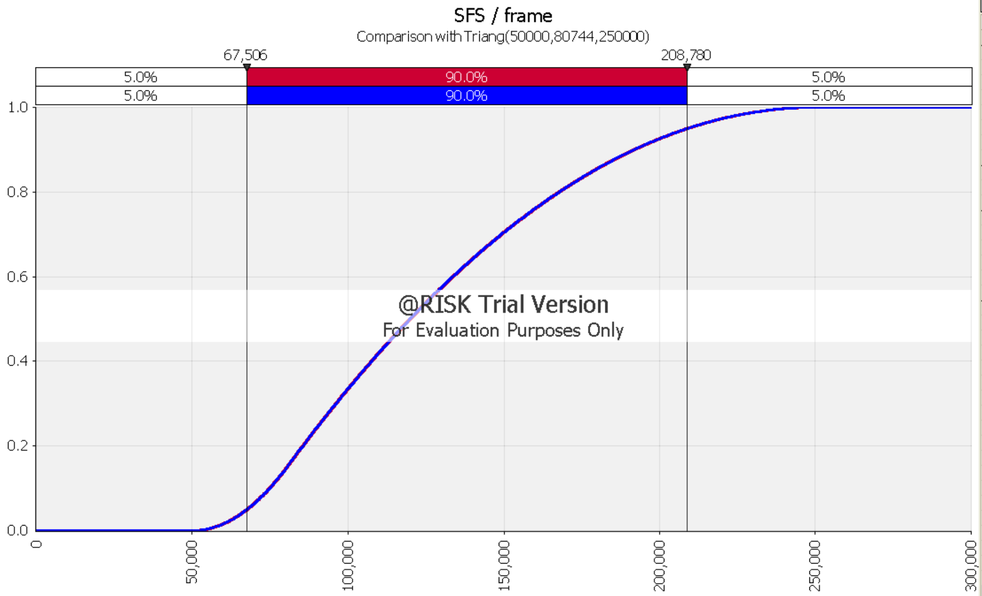
Statistics	COE
Cell	Sheet7!I29
Minimum	816,162.31
Maximum	3,756,582.61
Mean	2,111,973.60
Mode	1,836,183.25
Median	2,048,938.24
Std Dev	585,740.79
Skewness	0.3618
Kurtosis	2.4541
Values	5000
Errors	0
Filtered	0
Left X	1,247,366.02
Left P	5.0%
Right X	3,175,000.00
Right P	95.1%
Dif. X	1,927,633.98
Dif. P	90.1%
1%	1,041,251.66
5%	1,247,366.02
10%	1,389,069.92
15%	1,496,191.46
20%	1,581,744.63
25%	1,665,059.80
30%	1,739,069.69
35%	1,816,381.75
40%	1,886,494.54
45%	1,959,042.89
50%	2,048,938.24
55%	2,136,368.19
60%	2,222,631.90
65%	2,314,418.45
70%	2,407,096.55
75%	2,520,158.76
80%	2,631,965.27
85%	2,792,409.68
90%	2,961,882.73
95%	3,170,855.22



Statistics	RFS
Cell	Sheet7!I27
Minimum	22,948.43
Maximum	1,984,848.56
Mean	847,665.87
Mode	535,178.57
Median	791,758.48
Std Dev	421,210.74
Skewness	0.4067
Kurtosis	2.4006
Values	5000
Errors	0
Filtered	0
Left X	238,119.42
Left P	5.0%
Right X	1,617,689.81
Right P	95.0%
Dif. X	1,379,570.39
Dif. P	90.0%
1%	111,200.23
5%	238,119.42
10%	332,513.69
15%	405,012.34
20%	466,178.51
25%	519,937.56
30%	570,293.84
35%	622,317.83
40%	676,496.91
45%	732,707.51
50%	791,758.48
55%	853,698.76
60%	919,287.10
65%	989,151.72
70%	1,064,076.28
75%	1,145,632.49
80%	1,235,586.45
85%	1,338,213.27
90%	1,459,368.78


CRS
Comparison with Triang(100000,521000,900000)
0.230
0.777
5.0%
90.0%
5.0%
5.0%
90.0%
5.0%
1.0
0.8
0.6
0.4
0.2
0.0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
Values in Millions
@RISK Trial Version
For Evaluation Purposes Only
Statistics
CRS
Trian
Cell Sheet7!I26
Minimum 105,223.78
Maximum 896,548.09
Mean 507,001.54
Mode 516,473.66
Median 510,343.21
Std Dev 163,392.01
Skewness -0.0513
Kurtosis 2.4007
Values 5000
Errors 0
Filtered 0
Left X 229,648.46
Left P 5.0%
Right X 776,769.85
Right P 95.0%
Dif. X 547,121.39
Dif. P 90.0%
1% 157,910.08
5% 229,648.46
10% 283,453.20
15% 324,647.52
20% 359,433.76
25% 390,066.93
30% 417,818.76
35% 443,282.42
40% 466,964.65
45% 489,241.97
50% 510,343.21
55% 530,591.08
60% 551,679.85
65% 574,195.75
70% 598,379.02
75% 624,668.73
80% 653,666.91
85% 686,722.77
90% 725,795.07


LFS / frame
Comparison with Triang(400000,521678,650000)
438,927
536,250
5.0%
54.7%
40.3%
5.0%
54.7%
40.3%
1.0
0.8
0.6
0.4
0.2
0.0
350,000
400,000
450,000
500,000
550,000
600,000
650,000
700,000
@RISK Trial Version
For Evaluation Purposes Only
Statistics
LFS / frame
Trian
Cell Sheet7!I25
Minimum 401,538.61
Maximum 647,754.85
Mean 523,892.71
Mode 521,463.75
Median 523,335.28
Std Dev 51,042.28
Skewness 0.0260
Kurtosis 2.4005
Values 5000
Errors 0
Filtered 0
Left X 438,927
Left P 5.0%
Right X 536,250
Right P 59.7%
Dif. X 97,322.77
Dif. P 54.7%
1% 417,372.68
5% 438,927.23
10% 455,141.48
15% 467,521.69
20% 477,982.72
25% 487,202.49
30% 495,522.63
35% 503,177.45
40% 510,305.67
45% 516,990.41
50% 523,335.28
55% 529,829.44
60% 536,704.72
65% 544,010.74
70% 551,893.94
75% 560,422.15
80% 569,897.86
85% 580,594.91
90% 593,318.80

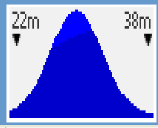
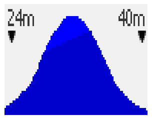
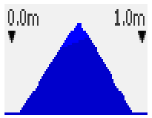
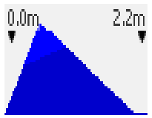
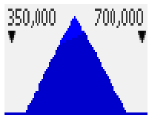
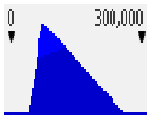


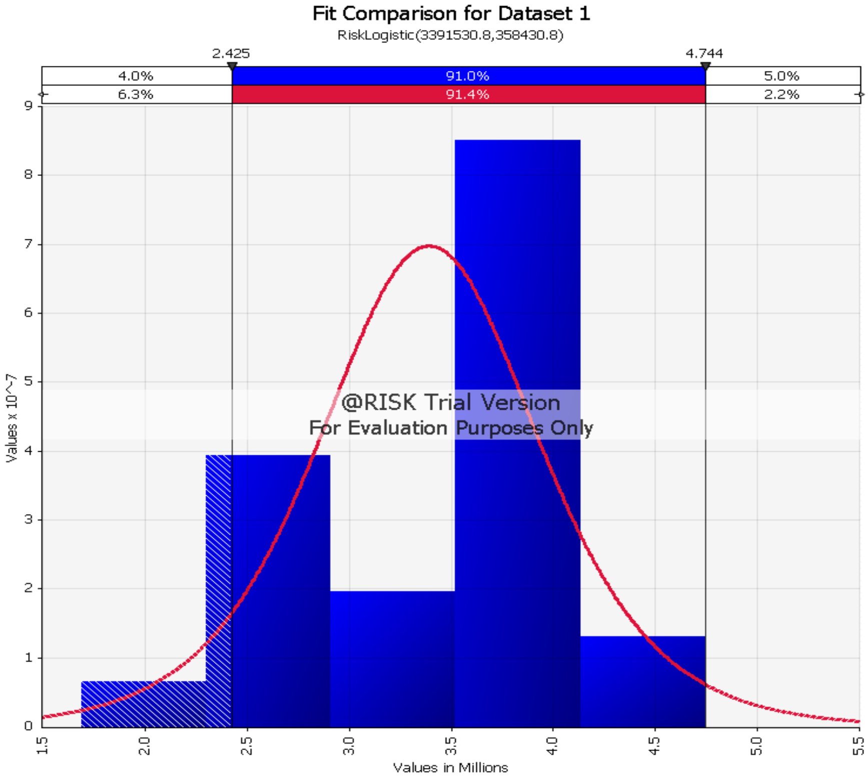
Statistics

	SFS / frame
Cell	Sheet7!I24
Minimum	50,898.59
Maximum	248,404.67
Mean	126,915.02
Mode	82,885.73
Median	119,881.43
Std Dev	43,972.00
Skewness	0.5144
Kurtosis	2.4005
Values	5000
Errors	0
Filtered	0
Left X	67,506
Left P	5.0%
Right X	208,780
Right P	95.0%
Dif. X	141,273.68
Dif. P	90.0%
1%	57,776.73
5%	67,506.27
10%	74,773.80
15%	80,369.27
20%	85,430.71
25%	90,651.85
30%	96,046.35
35%	101,642.22
40%	107,477.94
45%	113,546.32
50%	119,881.43
55%	126,557.85
60%	133,636.39
65%	141,130.88
70%	149,199.60
75%	157,973.42
80%	167,707.16
85%	178,727.82
90%	191,809.77

MODEL INPUT IN OPEN WORKBOOKS

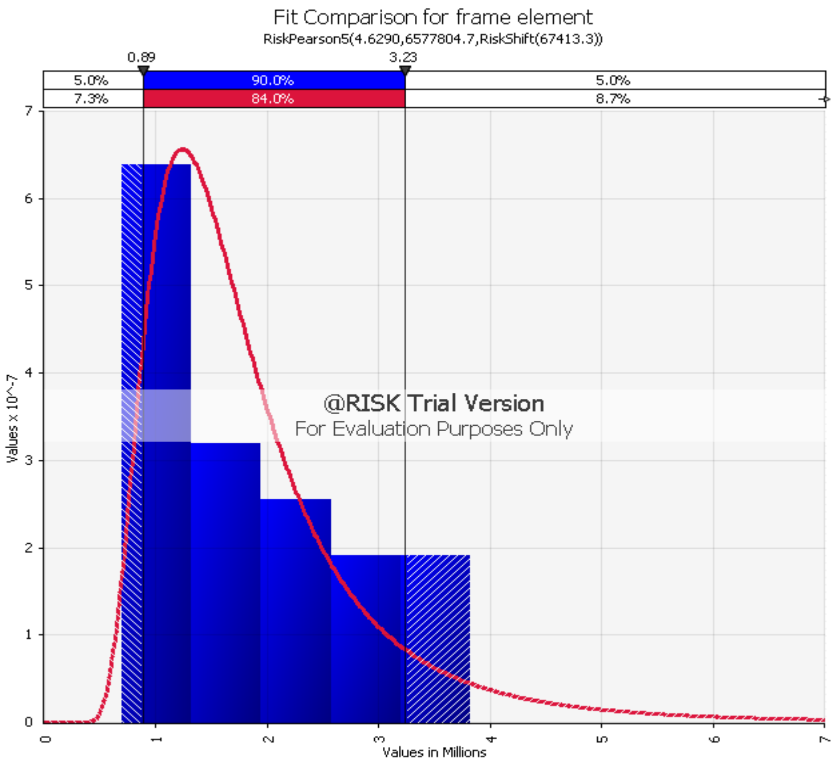
Model Inputs in Open Workbooks: Inputs= 6, Outputs= 2

Name	Worksheet	Cell	Graph	Function	Min	Mean	Max
roof	komposisi	L54		RiskNormal(29412092.7,2941209.27,RiskStatic(29412092.7))	-∞	2.941209E+07	+∞
reinforcement	komposisi	L55		RiskNormal(31605943.2,3160594.32,RiskStatic(31605943.2),RiskName("reinforcement"))	-∞	3.160594E+07	+∞
CRS	Sheet7	I26		RiskTriang(100000,521000,900000,RiskName("CRS "))	100000	507000	900000
RFS	Sheet7	I27		RiskTriang(10000,533000,2000000,RiskName("RFS "))	10000	847666.7	2000000
− Category: LFS							
LFS / frame	Sheet7	I25		RiskTriang(400000,521678,650000)	400000	523892.7	650000
− Category: SFS							
SFS / frame	Sheet7	I24		RiskTriang(50000,80744,250000)	50000	126914.7	250000



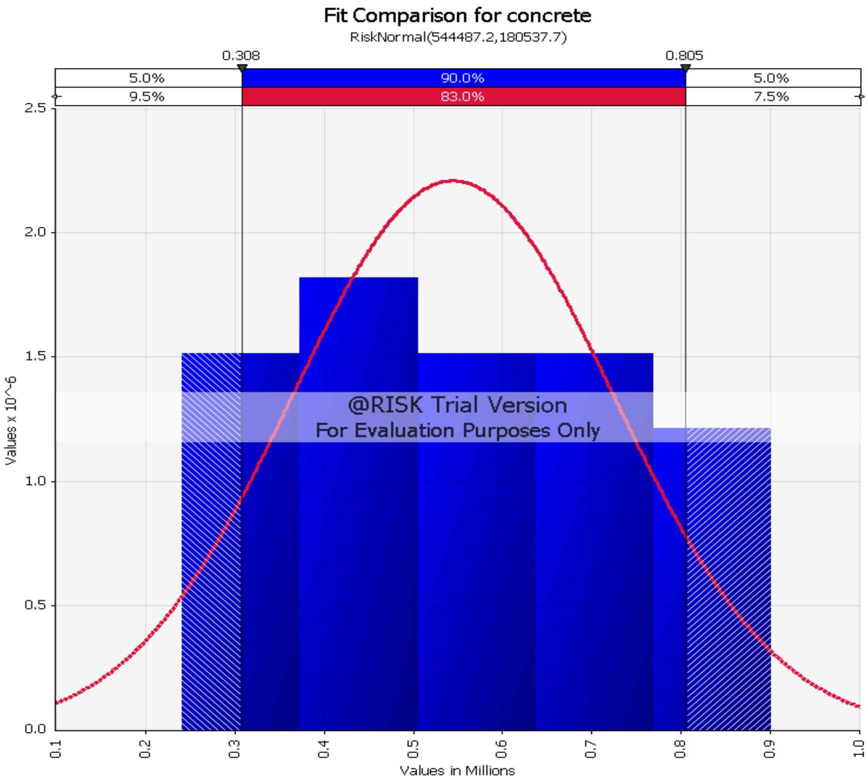
Statistics

	Input	Logistic
Minimum	1,690,865.00	−∞
Maximum	4,743,795.00	+∞
Mean	3,366,269.76	3,391,530.80
Mode	≈3,654,547.00	3,391,530.80
Median	3,654,547.00	3,391,530.80
Std Dev	670,990.85	650,121.56
Skewness	-0.2204	0.0000
Kurtosis	4.0594	4.2000
Left X	2,425,000.00	2,425,000.00
Left P	4.0%	6.3%
Right X	4,743,795.00	4,743,795.00
Right P	95.0%	97.8%
Dif. X	2,318,795.00	2,318,795.00
Dif. P	91.0%	91.4%
1%	1,690,865.00	1,744,498.32
5%	2,436,470.00	2,336,153.18
10%	2,572,357.00	2,603,977.84
15%	2,602,195.00	2,769,796.36
20%	2,796,817.00	2,894,640.20
25%	2,825,732.00	2,997,754.32
30%	3,063,145.00	3,087,833.15
35%	3,177,646.00	3,169,648.08
40%	3,223,377.00	3,246,199.62
45%	3,654,547.00	3,319,604.24
50%	3,654,547.00	3,391,530.80
55%	3,654,547.00	3,463,457.36
60%	3,654,547.00	3,536,861.98
65%	3,654,547.00	3,613,413.52
70%	3,654,547.00	3,695,228.45
75%	3,654,547.00	3,785,307.28
80%	3,654,547.00	3,888,421.40
85%	3,654,547.00	4,013,265.24
90%	3,654,547.00	4,179,083.76
95%	4,743,795.00	4,446,908.42
99%	4,743,795.00	5,038,563.28



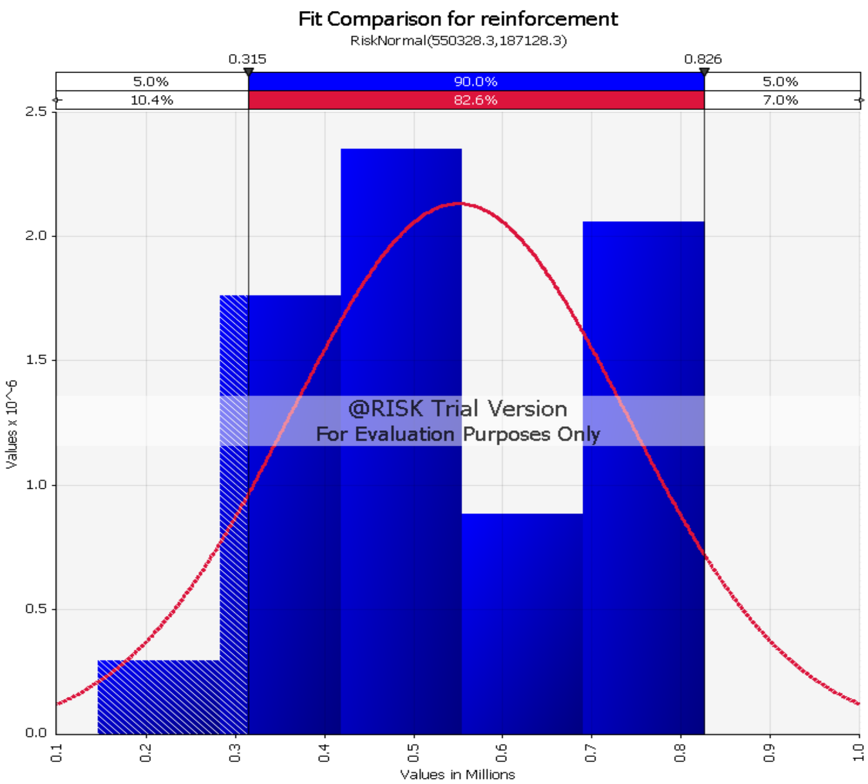
Statistics

	Input	Pearson5
Minimum	694,199.87	67,413.30
Maximum	3,825,202.00	+∞
Mean	1,852,866.65	1,879,980.04
Mode	≈1,067,492.28	1,235,969.83
Median	1,482,355.83	1,597,037.78
Std Dev	889,618.17	1,117,889.08
Skewness	0.7547	3.9814
Kurtosis	2.3730	74.1176
Left X	885,617.00	885,617.00
Left P	5.0%	7.3%
Right X	3,232,978.17	3,232,978.17
Right P	95.0%	91.3%
Dif. X	2,347,361.17	2,347,361.17
Dif. P	90.0%	84.0%
1%	694,199.87	663,578.81
5%	885,617.00	828,768.88
10%	1,000,314.65	943,192.04
15%	1,056,104.23	1,033,968.65
20%	1,068,354.61	1,115,436.59
25%	1,148,258.53	1,192,889.37
30%	1,257,601.94	1,269,154.20
35%	1,294,946.06	1,346,146.70
40%	1,304,611.00	1,425,435.60
45%	1,461,819.00	1,508,523.02
50%	1,482,355.83	1,597,037.78
55%	1,500,407.00	1,692,924.63
60%	1,947,607.00	1,798,689.17
65%	2,164,139.31	1,917,778.22
70%	2,335,811.08	2,055,246.40
75%	2,404,715.71	2,219,053.12
80%	2,631,176.77	2,422,900.57
85%	3,165,920.82	2,693,499.88
90%	3,229,305.00	3,094,226.49
95%	3,232,978.17	3,845,796.93
99%	3,825,202.00	6,029,217.81



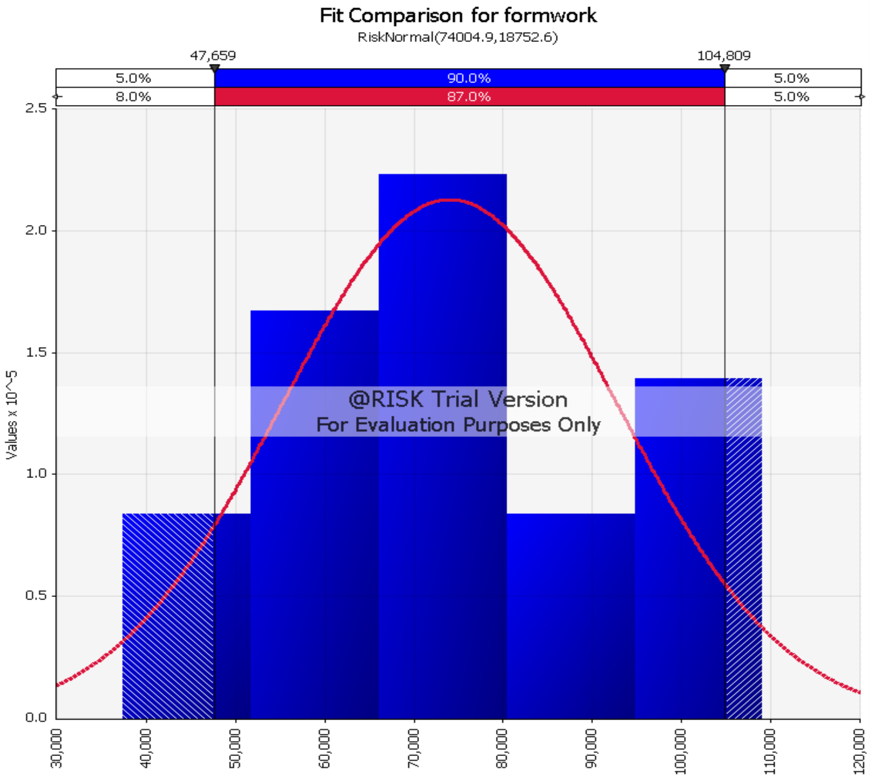
Statistics

	Input	Normal
Minimum	241,269.98	−∞
Maximum	901,174.40	+∞
Mean	544,487.24	544,487.20
Mode	≈371,008.20	544,487.20
Median	515,194.52	544,487.20
Std Dev	180,537.70	180,537.70
Skewness	0.3302	0.0000
Kurtosis	2.0698	3.0000
Left X	307,797.56	307,797.56
Left P	5.0%	9.5%
Right X	804,531.44	804,531.44
Right P	95.0%	92.5%
Dif. X	496,733.88	496,733.88
Dif. P	90.0%	83.0%
1%	241,269.98	124,493.71
5%	307,797.56	247,529.11
10%	347,660.54	313,118.83
15%	367,050.27	357,371.90
20%	371,307.91	392,542.84
25%	399,078.61	422,716.37
30%	422,027.65	449,813.14
35%	437,081.04	474,922.33
40%	453,419.19	498,748.50
45%	508,056.97	521,800.59
50%	515,194.52	544,487.20
55%	521,468.32	567,173.81
60%	608,125.21	590,225.90
65%	642,041.59	614,052.07
70%	655,363.71	639,161.26
75%	676,893.39	666,258.03
80%	698,065.31	696,431.56
85%	793,117.46	731,602.50
90%	803,909.00	775,855.57
95%	804,531.44	841,445.29
99%	901,174.40	964,480.69



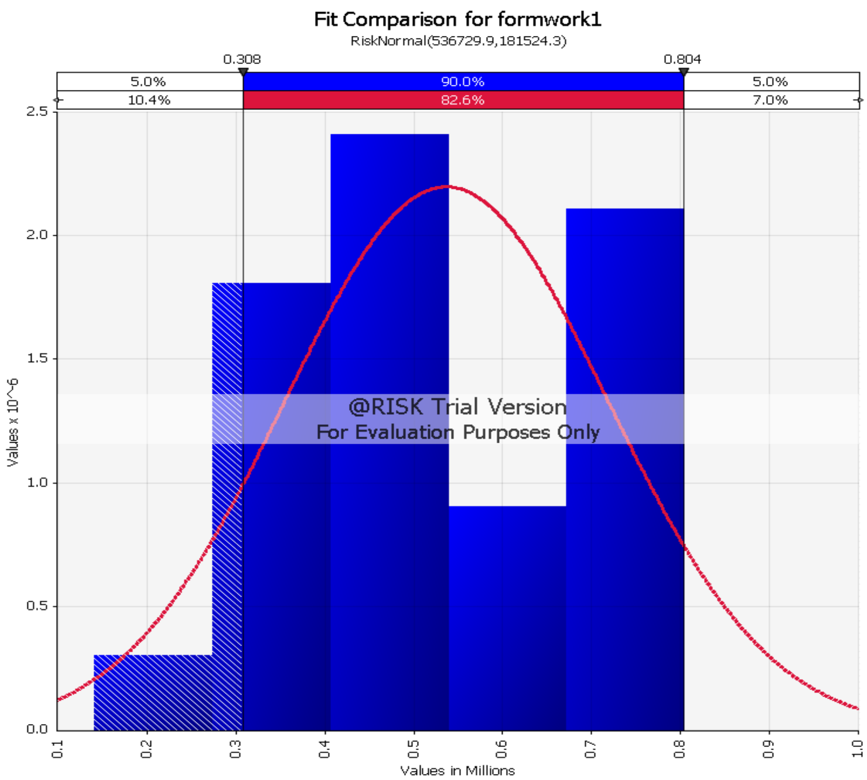
Statistics

	Input	Normal
Minimum	146,613.40	−∞
Maximum	827,046.72	+∞
Mean	550,328.25	550,328.30
Mode	≈379,224.94	550,328.30
Median	526,604.56	550,328.30
Std Dev	187,128.27	187,128.30
Skewness	-0.0142	0.0000
Kurtosis	2.2725	3.0000
Left X	314,614.37	314,614.37
Left P	5.0%	10.4%
Right X	826,406.86	826,406.86
Right P	95.0%	93.0%
Dif. X	511,792.50	511,792.50
Dif. P	90.0%	82.6%
1%	146,613.40	115,002.78
5%	314,614.37	242,529.64
10%	355,360.20	310,513.73
15%	375,179.35	356,382.28
20%	379,531.28	392,837.15
25%	407,917.02	424,112.18
30%	433,838.34	452,198.12
35%	446,761.10	478,223.94
40%	463,461.09	502,919.89
45%	519,308.94	526,813.51
50%	526,604.56	550,328.30
55%	533,017.31	573,843.09
60%	625,143.95	597,736.71
65%	660,009.49	622,432.66
70%	673,704.44	648,458.48
75%	691,884.59	676,544.42
80%	717,601.08	707,819.45
85%	815,313.31	744,274.32
90%	826,394.29	790,142.87
95%	826,406.86	858,126.96
99%	827,046.72	985,653.82



Statistics

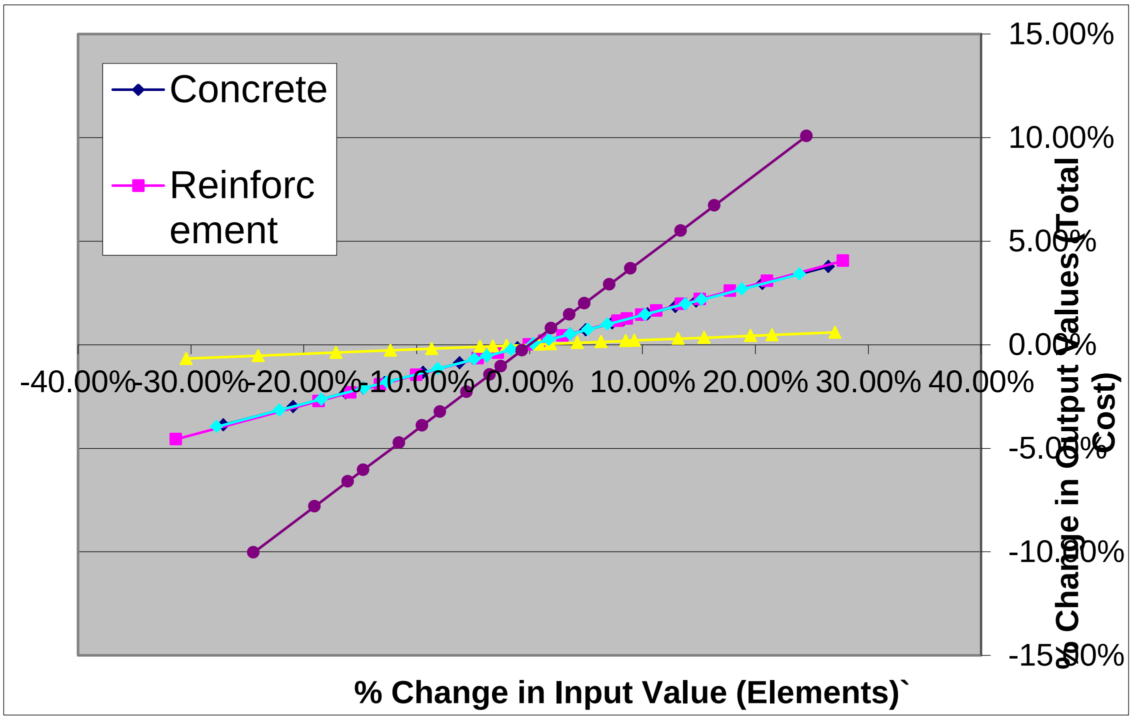
	Input	Normal
Minimum	37,357.86	−∞
Maximum	109,120.50	+∞
Mean	74,004.86	74,004.90
Mode	≈79,957.08	74,004.90
Median	73,636.05	74,004.90
Std Dev	18,752.64	18,752.60
Skewness	0.0888	0.0000
Kurtosis	2.3431	3.0000
Left X	47,659	47,659
Left P	5.0%	8.0%
Right X	104,809	104,809
Right P	95.0%	95.0%
Dif. X	57,150.21	57,150.21
Dif. P	90.0%	87.0%
1%	37,357.86	30,379.83
5%	47,658.88	43,159.62
10%	51,102.06	49,972.48
15%	53,831.20	54,569.08
20%	56,833.48	58,222.31
25%	58,012.75	61,356.46
30%	61,792.70	64,171.03
35%	65,192.90	66,779.14
40%	67,676.93	69,253.98
45%	71,217.07	71,648.42
50%	73,636.05	74,004.90
55%	77,742.89	76,361.38
60%	79,356.02	78,755.82
65%	79,771.90	81,230.66
70%	80,743.32	83,838.77
75%	84,526.63	86,653.34
80%	92,575.72	89,787.49
85%	97,342.93	93,440.72
90%	97,418.29	98,037.32
95%	104,809.09	104,850.18
99%	109,120.50	117,629.97



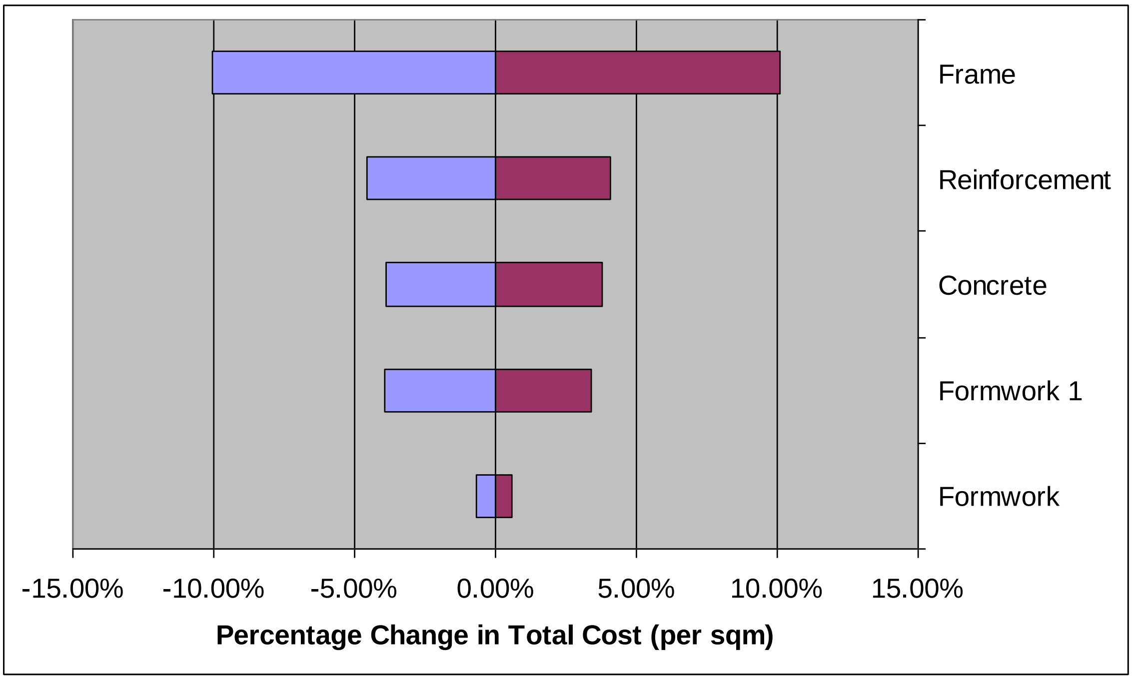
Statistics

	Input	Normal
Minimum	141,363.91	−∞
Maximum	804,925.46	+∞
Mean	536,729.88	536,729.90
Mode	≈371,152.64	536,729.90
Median	515,395.09	536,729.90
Std Dev	181,524.26	181,524.30
Skewness	-0.0320	0.0000
Kurtosis	2.3024	3.0000
Left X	307,917.39	307,917.39
Left P	5.0%	10.4%
Right X	804,302.72	804,302.72
Right P	95.0%	93.0%
Dif. X	496,385.34	496,385.34
Dif. P	90.0%	82.6%
1%	141,363.91	114,441.23
5%	307,917.39	238,149.00
10%	347,795.88	304,097.15
15%	367,193.17	348,592.05
20%	371,452.46	383,955.19
25%	399,233.97	414,293.62
30%	422,234.34	441,538.46
35%	437,251.20	466,784.87
40%	453,595.71	490,741.24
45%	508,254.76	513,919.31
50%	515,395.09	536,729.90
55%	521,671.33	559,540.49
60%	608,423.05	582,718.56
65%	642,356.03	606,674.93
70%	655,684.68	631,921.34
75%	677,156.91	659,166.18
80%	698,407.19	689,504.61
85%	793,505.89	724,867.75
90%	801,615.76	769,362.65
95%	804,302.72	835,310.80
99%	804,925.46	959,018.57

Spiderplots – Sensitivity Analysis of Total Cost

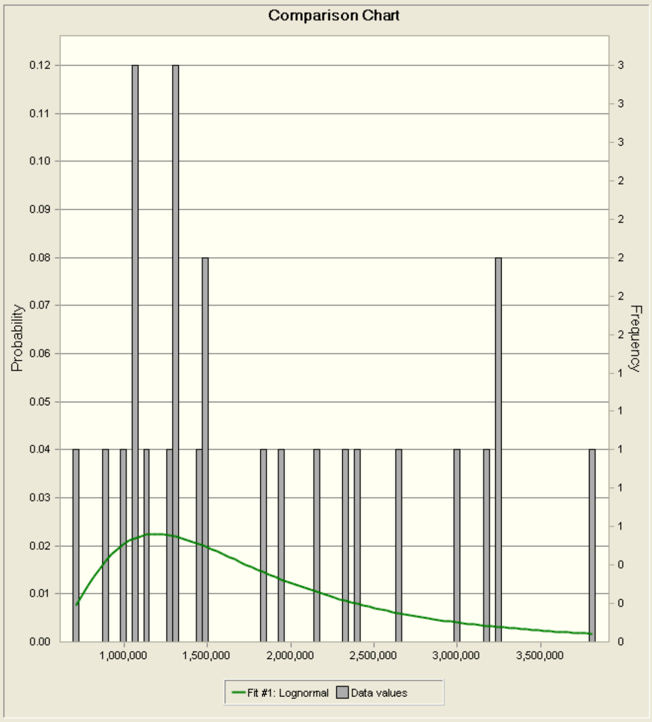


Tornado Graph – Sensitivity Analysis of Total Cost



Frame - Indentified distribution by A-D test

25 Values Split View 25 Displayed



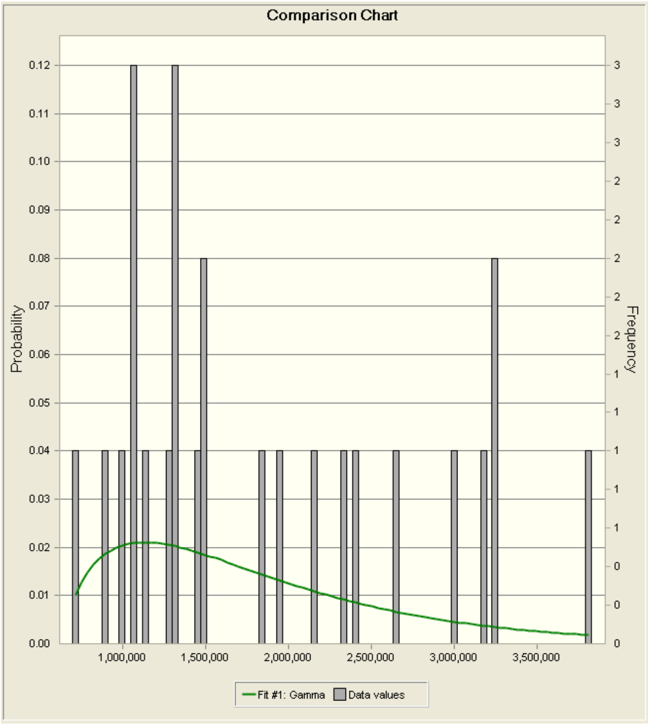
Ranked by: Anderson-Darling

Distribution	A-D	P-Value	Parameters
Lognormal	.3525	0.282	Location=416,587,Mean=1,881,500,Std. Dev.=1,
Gamma	.3605	0.811	Location=645,353,Scale=727,991,Shape=1.658
Triangular	.4852	---	Minimum=632,808,Likeliest=694,200,Maximum=
Weibull	.6061	0.171	Location=621,301,Scale=1,455,851,Shape=1.50
Max Extreme	.6943	0.068	Likeliest=1,453,158,Scale=647,109
Logistic	.9315	0.000	Mean=1,762,111,Scale=525,570
Normal	1.0126	0.000	Mean=1,852,867,Std. Dev.=889,618
Min Extreme	1.3704	0.000	Likeliest=2,314,741,Scale=924,908
Student's t	1.6619	---	Midpoint=1,852,867,Scale=447,232,Deg. Freedo
Pareto	2.4958	---	Location=669,364,Shape=1.09793
Uniform	2.6703	0.017	Minimum=573,777,Maximum=3,945,625
Exponential	3.5171	0.000	Rate=0
Beta	5.2956	---	Minimum=909,012,Maximum=3,885,386,Alpha=
BetaPERT	10.4988	---	Minimum=909,012,Likeliest=1,580,701,Maximu

Statistic	Fit #1: Lognormal	Data values
Values	---	25
Mean	1,881,500	1,852,867
Median	1,600,036	1,482,356
Mode	1,188,957	---
Standard Dev	1,068,715	889,618
Variance	1,142,152,157,217	791,420,488,138
Skewness	2.58	0.6665
Kurtosis	16.75	2.08
Coeff. of Vari	0.5680	0.4801
Minimum	416,587	694,200
Maximum	Infinity	3,825,202
Mean Std. Err	---	177,924

<< Previous Next >> Accept Cancel Help

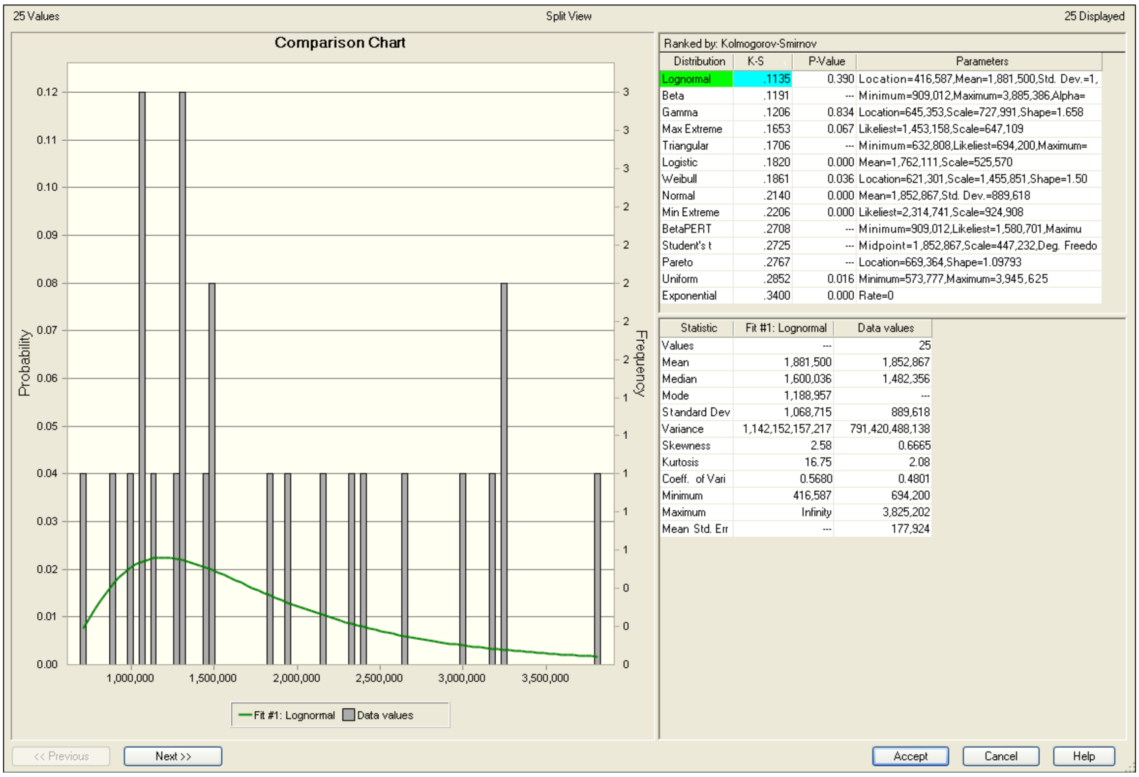
Frame - Indentified distribution by Chi-Square test



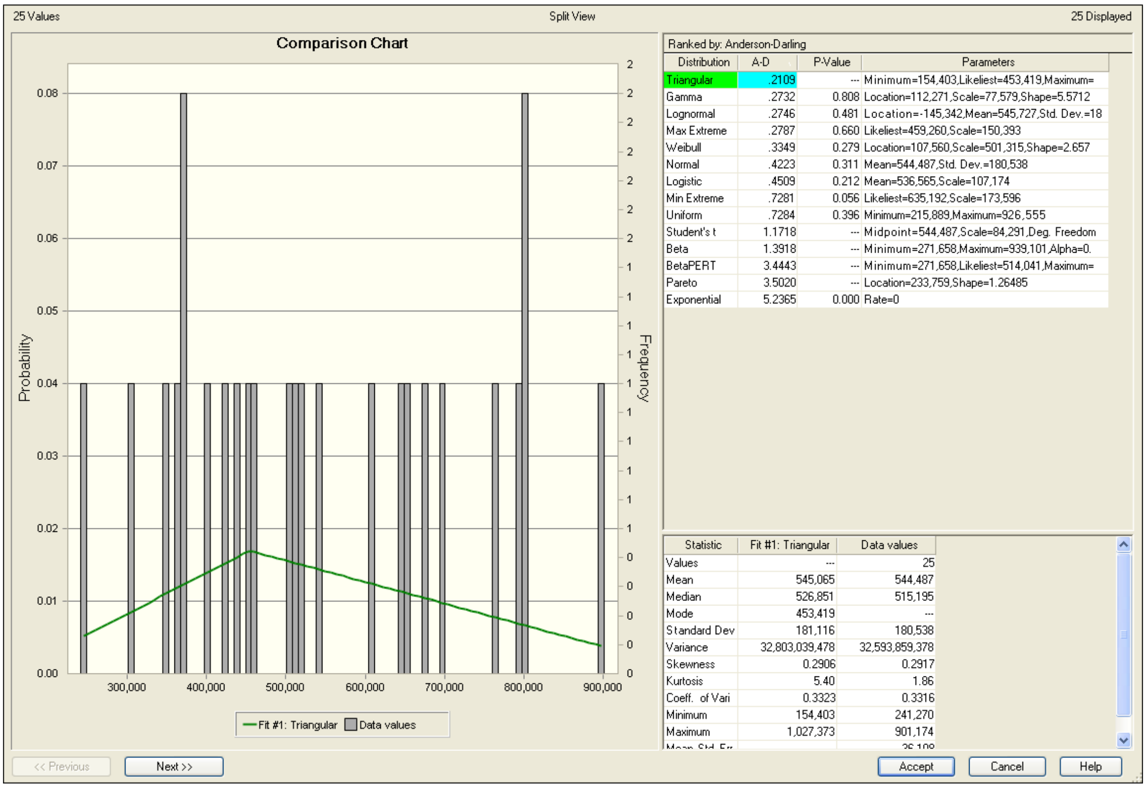
Ranked by: Chi-Square

Distribution	Chi-Square	P-Value	Parameters
Gamma	.8000	0.371	Location=645,353,Scale=727,991,Shape=1.658
Lognormal	1.2000	0.273	Location=416,587,Mean=1,881,500,Std. Dev.=1,
Beta	2.8000	---	Minimum=909,012,Maximum=3,885,386,Alpha=
Weibull	4.4000	0.036	Location=621,301,Scale=1,455,851,Shape=1.50
Student's t	4.4000	0.036	Midpoint=1,852,867,Scale=447,232,Deg. Freedo
Normal	4.8000	0.091	Mean=1,852,867,Std. Dev.=889,618
Max Extreme	5.6000	0.061	Likeliest=1,453,158,Scale=647,109
Uniform	6.0000	0.050	Minimum=573,777,Maximum=3,945,625
Triangular	7.2000	0.007	Minimum=632,808,Likeliest=694,200,Maximum=
Pareto	9.2000	0.010	Location=669,364,Shape=1.09793
Logistic	10.8000	0.005	Mean=1,762,111,Scale=525,570
Min Extreme	13.2000	0.001	Likeliest=2,314,741,Scale=924,908
BetaPERT	14.8000	0.000	Minimum=909,012,Likeliest=1,580,701,Maximu
Exponential	16.8000	0.001	Rate=0

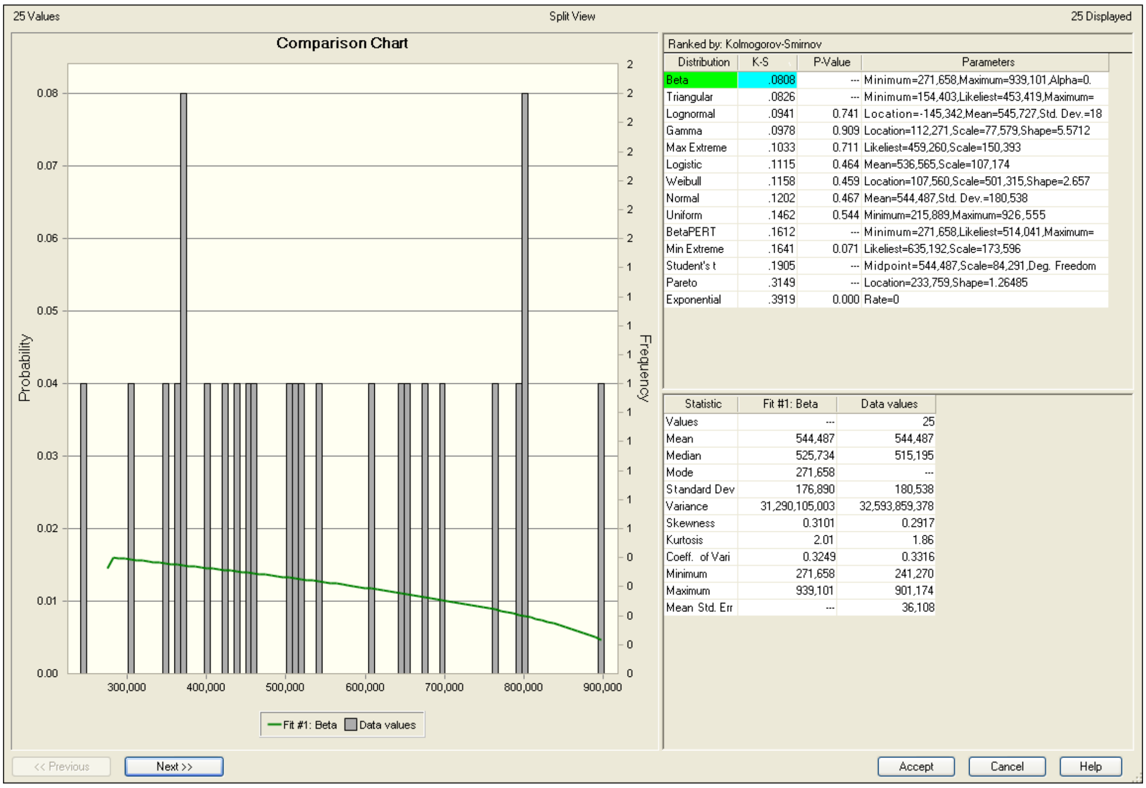
Frame - Indentified distribution by K-S test



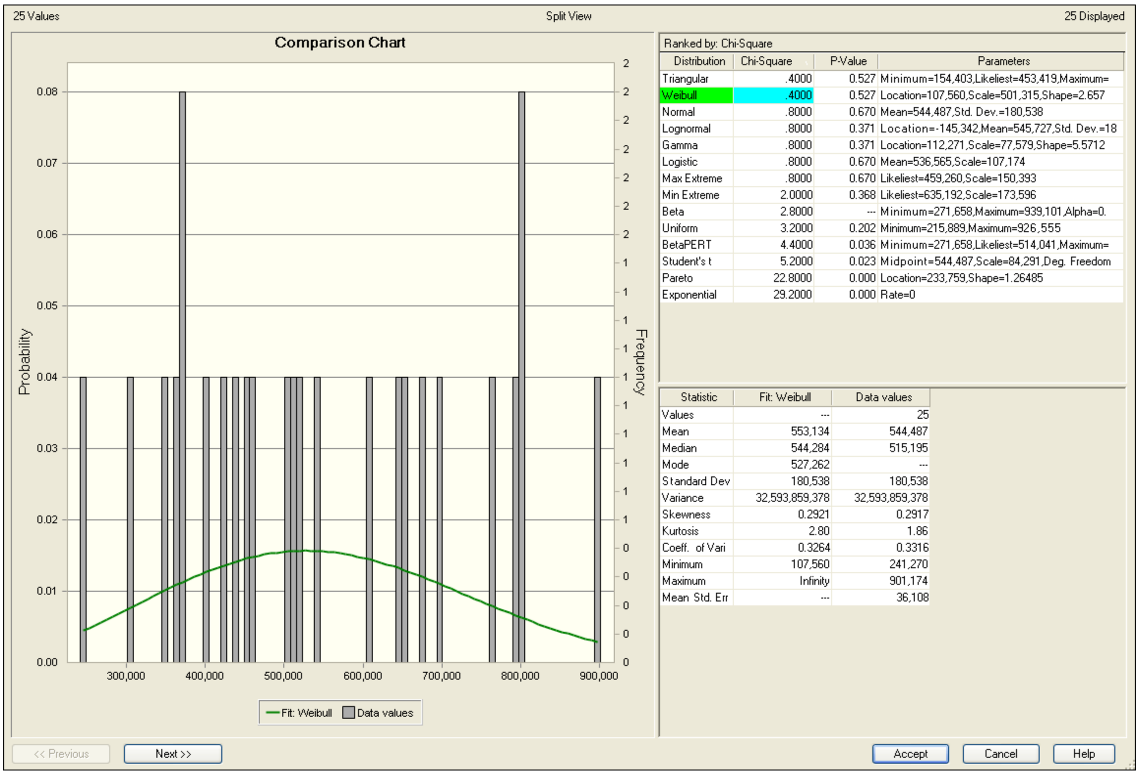
Concrete – Identified distribution by A-D test



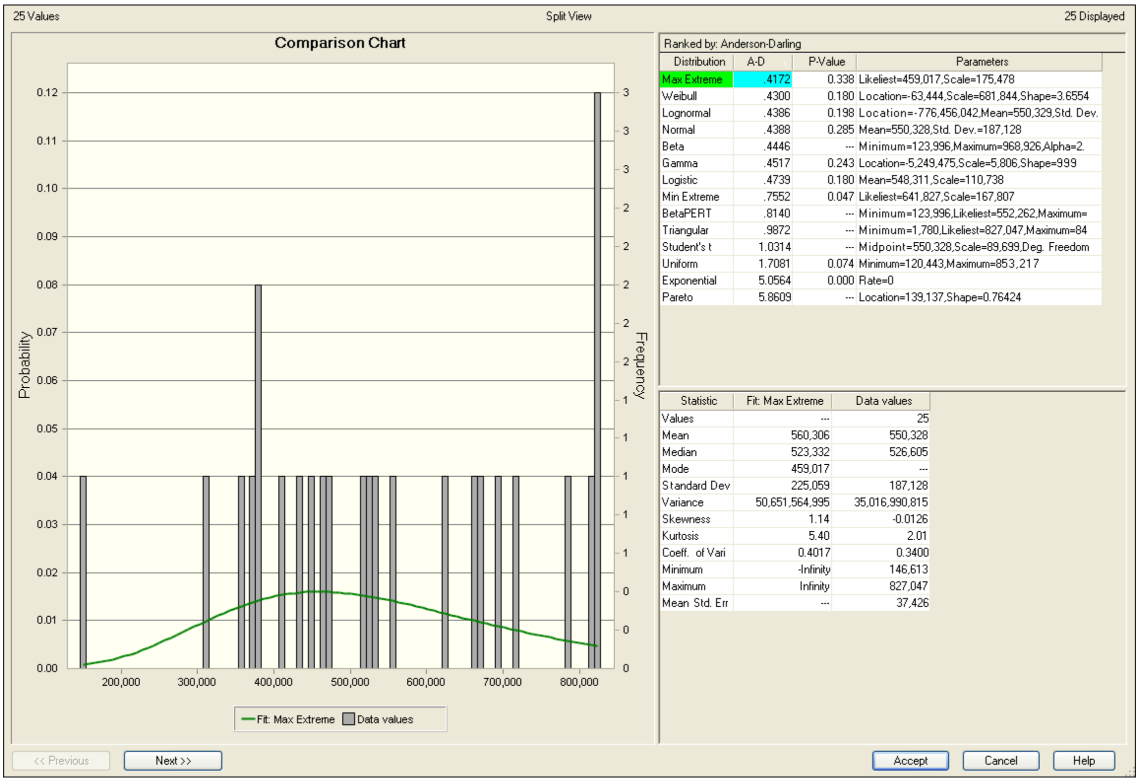
Concrete – Identified distribution by K-S test



Concrete – Identified distribution by Chi-Square test



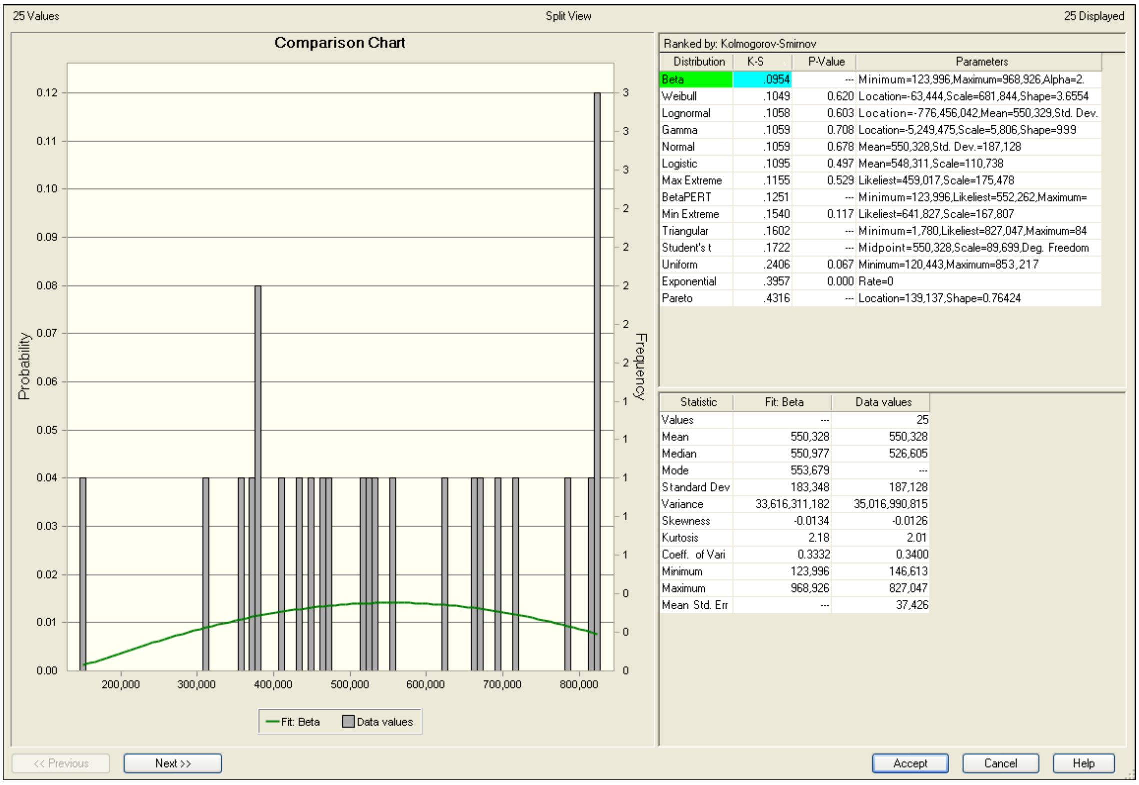
Reinforcement – Identified distribution by A-D test



Distribution	A-D	P-Value	Parameters
Max Extreme	.4172	0.338	Likeliest=459,017,Scale=175,478
Weibull	.4300	0.180	Location=-63,444,Scale=681,844,Shape=3.6554
Lognormal	.4386	0.198	Location=-776,456,042,Mean=550,329,Std. Dev.
Normal	.4388	0.285	Mean=550,328,Std. Dev.=187,128
Beta	.4446	---	Minimum=123,996,Maximum=968,926,Alpha=2.
Gamma	.4517	0.243	Location=-5,249,475,Scale=5,806,Shape=999
Logistic	.4739	0.180	Mean=548,311,Scale=110,738
Min Extreme	.7552	0.047	Likeliest=641,827,Scale=167,807
BetaPERT	.8140	---	Minimum=123,996,Likeliest=552,262,Maximum=
Triangular	.9872	---	Minimum=1,780,Likeliest=827,047,Maximum=84
Student's t	1.0314	---	Midpoint=550,328,Scale=89,699,Deg. Freedom
Uniform	1.7081	0.074	Minimum=120,443,Maximum=853,217
Exponential	5.0564	0.000	Rate=0
Pareto	5.8609	---	Location=139,137,Shape=0.76424

Statistic	Fit: Max Extreme	Data values
Values	---	25
Mean	560,306	550,328
Median	523,332	526,605
Mode	459,017	---
Standard Dev	225,059	187,128
Variance	50,651,564,995	35,016,990,815
Skewness	1.14	-0.0126
Kurtosis	5.40	2.01
Coeff. of Vari	0.4017	0.3400
Minimum	-Infinity	146,613
Maximum	Infinity	827,047
Mean Std. Err	---	37,426

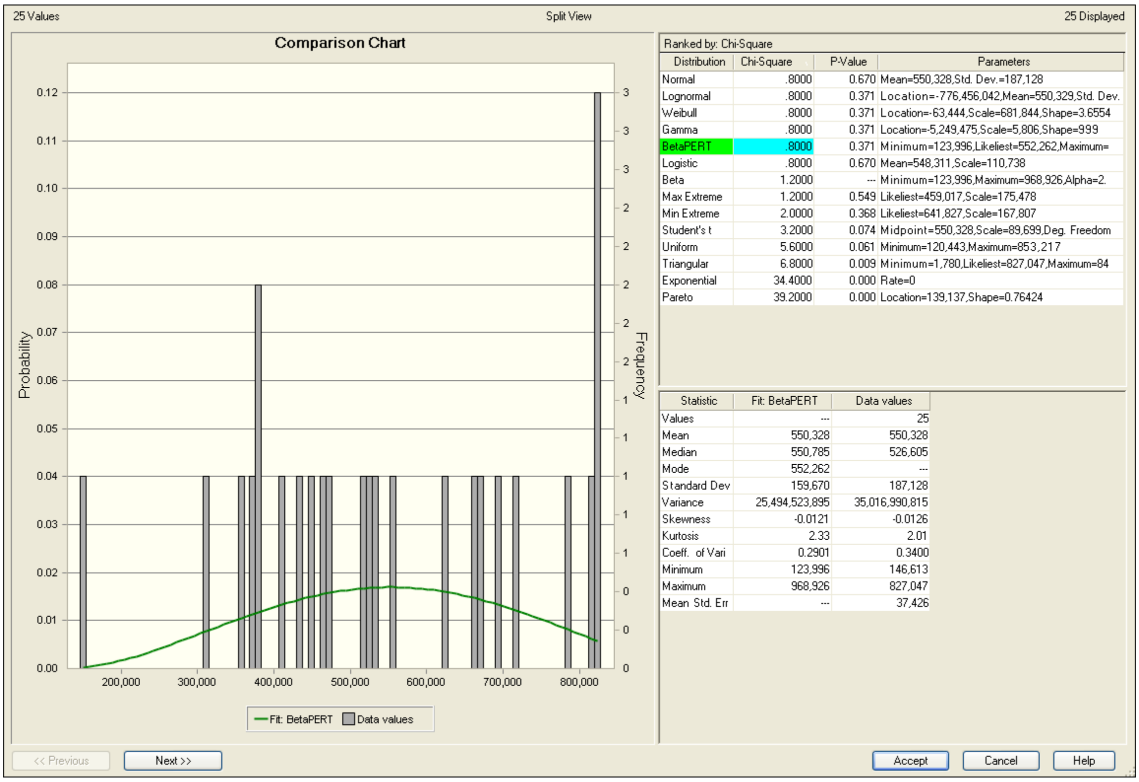
Reinforcement – Identified distribution by K-S test



Distribution	K-S	P-Value	Parameters
Beta	.0954	---	Minimum=123,996,Maximum=968,926,Alpha=2.
Weibull	.1049	0.620	Location=-63,444,Scale=681,844,Shape=3.6554
Lognormal	.1058	0.603	Location=-776,456,042,Mean=550,329,Std. Dev.
Gamma	.1059	0.708	Location=-5,249,475,Scale=5,806,Shape=999
Normal	.1059	0.678	Mean=550,328,Std. Dev.=187,128
Logistic	.1095	0.497	Mean=548,311,Scale=110,738
Max Extreme	.1155	0.529	Likeliest=459,017,Scale=175,478
BetaPERT	.1251	---	Minimum=123,996,Likeliest=552,262,Maximum=
Min Extreme	.1540	0.117	Likeliest=641,827,Scale=167,807
Triangular	.1602	---	Minimum=1,780,Likeliest=827,047,Maximum=84
Student's t	.1722	---	Midpoint=550,328,Scale=89,699,Deg. Freedom
Uniform	.2406	0.067	Minimum=120,443,Maximum=853,217
Exponential	.3957	0.000	Rate=0
Pareto	.4316	---	Location=139,137,Shape=0.76424

Statistic	Fit: Beta	Data values
Values	---	25
Mean	550,328	550,328
Median	550,977	526,605
Mode	553,679	---
Standard Dev	183,348	187,128
Variance	33,616,311,182	35,016,990,815
Skewness	-0.0134	-0.0126
Kurtosis	2.18	2.01
Coeff. of Vari	0.3332	0.3400
Minimum	123,996	146,613
Maximum	968,926	827,047
Mean Std. Err	---	37,426

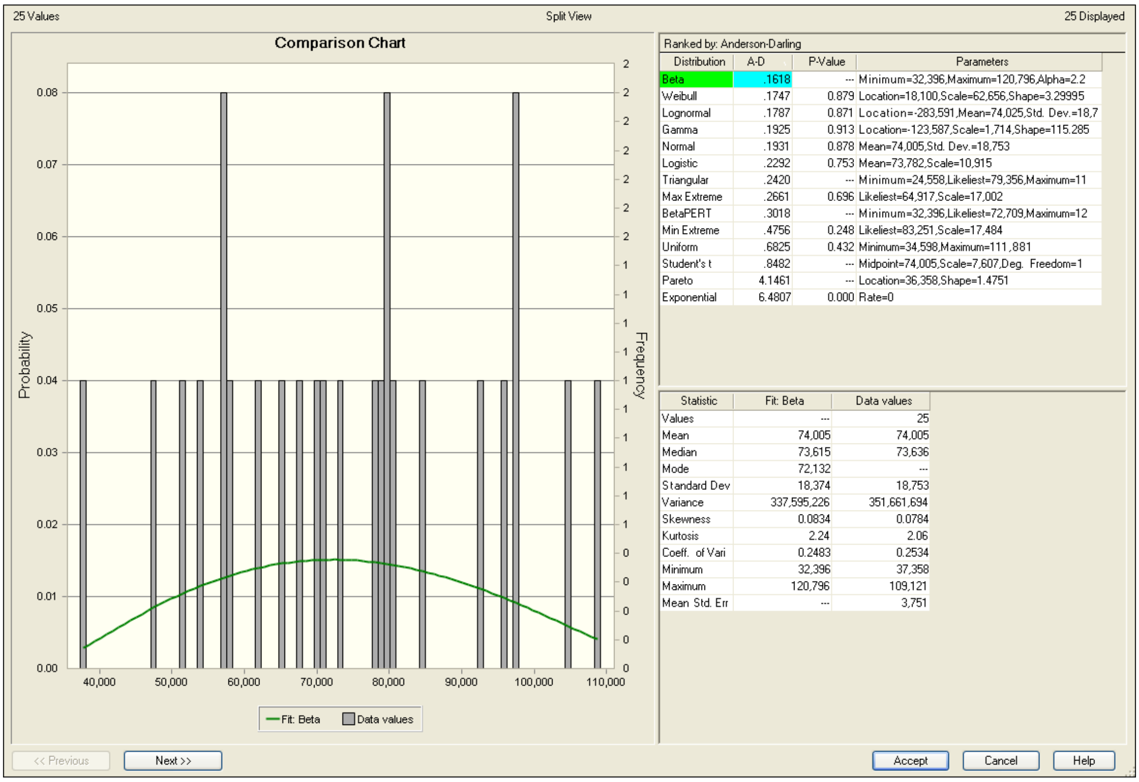
Reinforcement – Identified distribution by Chi-Square test



Distribution	Chi-Square	P-Value	Parameters
Normal	.8000	0.670	Mean=550,328,Std. Dev.=187,128
Lognormal	.8000	0.371	Location=-776,456,042,Mean=550,329,Std. Dev.
Weibull	.8000	0.371	Location=-63,444,Scale=681,844,Shape=3.6554
Gamma	.8000	0.371	Location=-5,249,475,Scale=5,806,Shape=999
BetaPERT	.8000	0.371	Minimum=123,996,Likeliest=552,262,Maximum=
Logistic	.8000	0.670	Mean=548,311,Scale=110,738
Beta	1.2000	---	Minimum=123,996,Maximum=968,926,Alpha=2.
Max Extreme	1.2000	0.549	Likeliest=459,017,Scale=175,478
Min Extreme	2.0000	0.368	Likeliest=641,827,Scale=167,807
Student's t	3.2000	0.074	Midpoint=550,328,Scale=89,699,Deg. Freedom
Uniform	5.6000	0.061	Minimum=120,443,Maximum=853,217
Triangular	6.8000	0.009	Minimum=1,780,Likeliest=827,047,Maximum=84
Exponential	34.4000	0.000	Rate=0
Pareto	39.2000	0.000	Location=139,137,Shape=0.76424

Statistic	Fit: BetaPERT	Data values
Values	---	25
Mean	550,328	550,328
Median	550,785	526,605
Mode	552,262	---
Standard Dev	159,670	187,128
Variance	25,494,523,895	35,016,990,815
Skewness	-0.0121	-0.0126
Kurtosis	2.33	2.01
Coeff. of Vari	0.2901	0.3400
Minimum	123,996	146,613
Maximum	968,926	827,047
Mean Std. Err	---	37,426

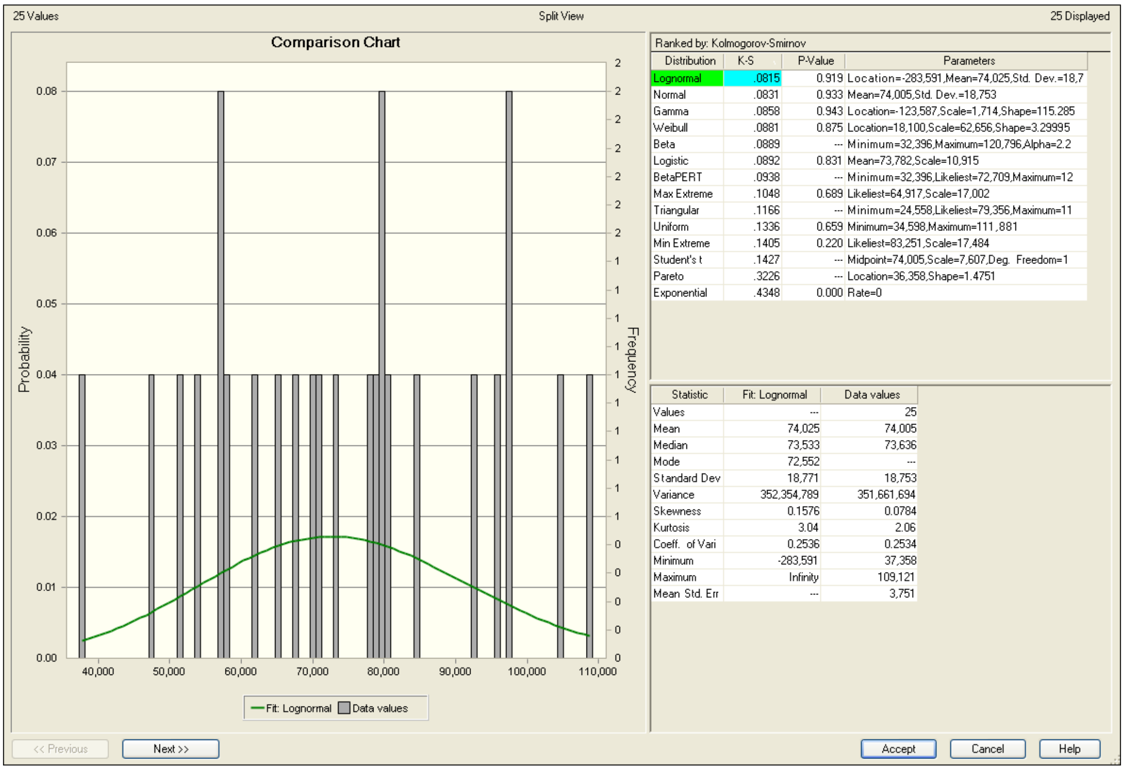
Formwork – Identified distribution by A-D test



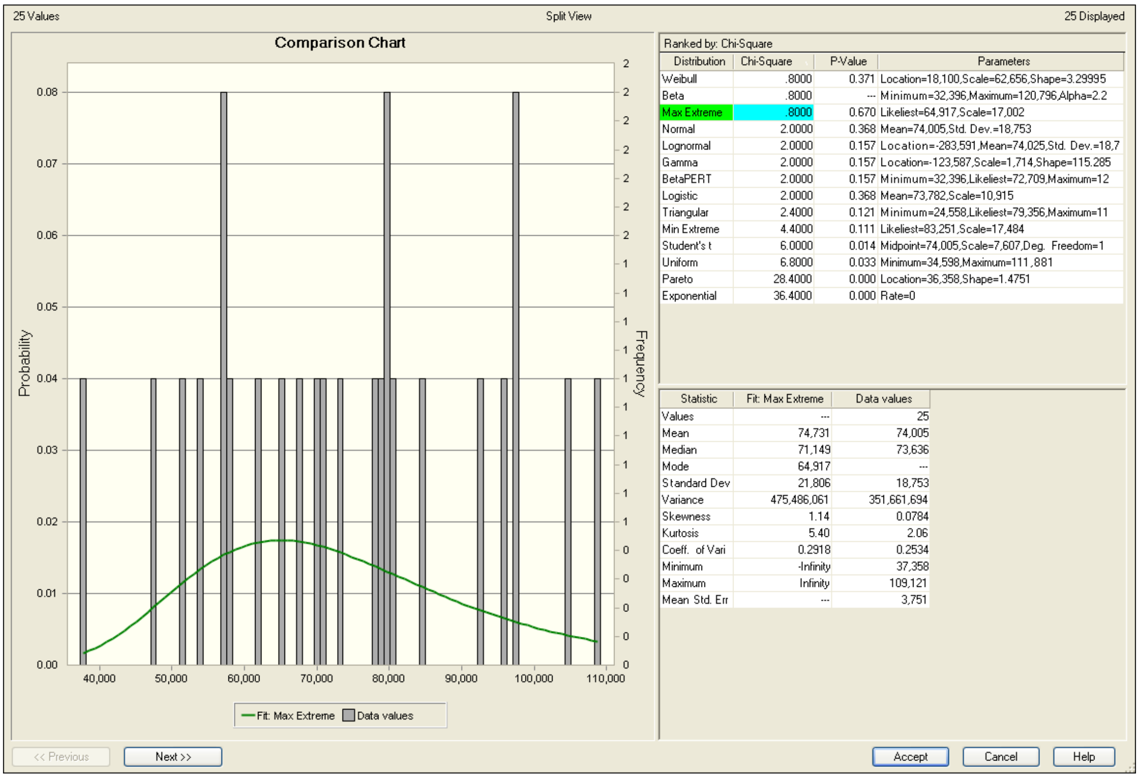
Distribution	A-D	P-Value	Parameters
Beta	.1618	---	Minimum=32,396,Maximum=120,796,Alpha=2.2
Weibull	.1747	0.879	Location=18,100,Scale=62,656,Shape=3.29995
Lognormal	.1787	0.871	Location=-283,591,Mean=74,025,Std. Dev.=18,7
Gamma	.1925	0.913	Location=-123,587,Scale=1,714,Shape=115.285
Normal	.1931	0.878	Mean=74,005,Std. Dev.=18,753
Logistic	.2292	0.753	Mean=73,782,Scale=10,915
Triangular	.2420	---	Minimum=24,558,Likeliest=79,356,Maximum=11
Max Extreme	.2661	0.696	Likeliest=64,917,Scale=17,002
BetaPERT	.3018	---	Minimum=32,396,Likeliest=72,709,Maximum=12
Min Extreme	.4756	0.248	Likeliest=83,251,Scale=17,484
Uniform	.6825	0.432	Minimum=34,598,Maximum=111,881
Student's t	.8482	---	Midpoint=74,005,Scale=7,607,Deg. Freedom=1
Pareto	4.1461	---	Location=36,358,Shape=1.4751
Exponential	6.4807	0.000	Rate=0

Statistic	Fit: Beta	Data values
Values	---	25
Mean	74,005	74,005
Median	73,615	73,636
Mode	72,132	---
Standard Dev	18,374	18,753
Variance	337,595,226	351,661,694
Skewness	0.0834	0.0784
Kurtosis	2.24	2.06
Coeff. of Vari	0.2483	0.2534
Minimum	32,396	37,358
Maximum	120,796	109,121
Mean Std. Err	---	3,751

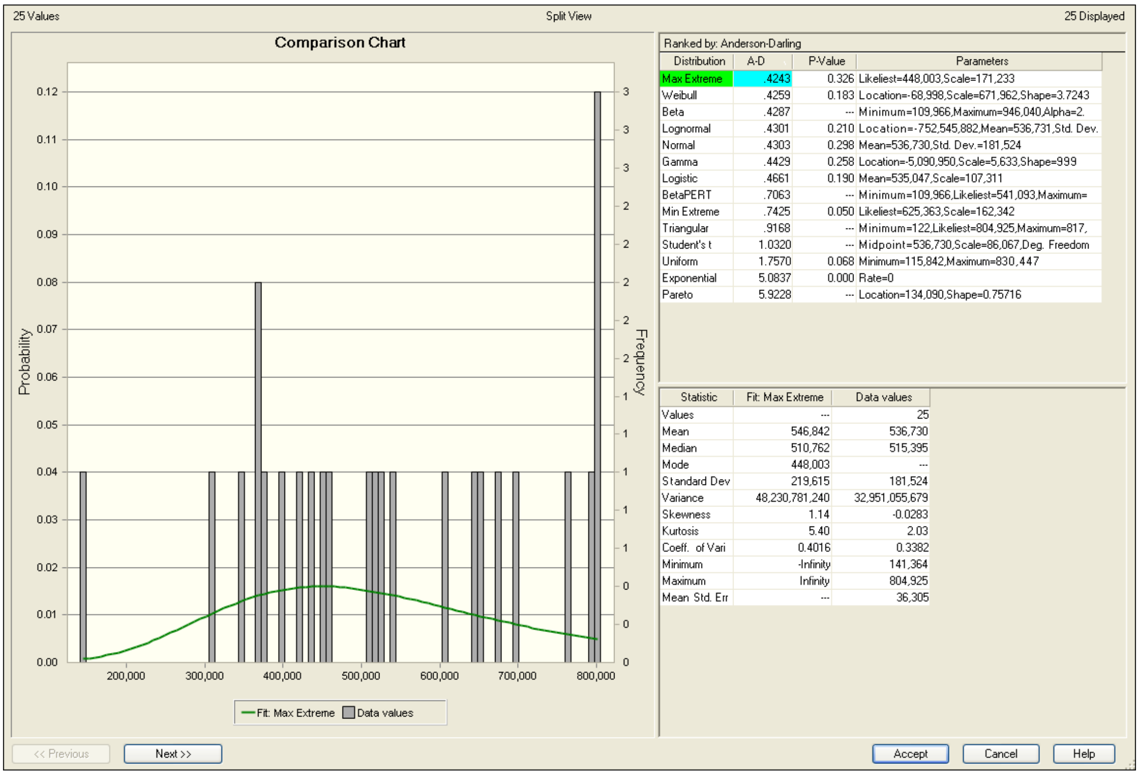
Formwork – Identified distribution by K-S test



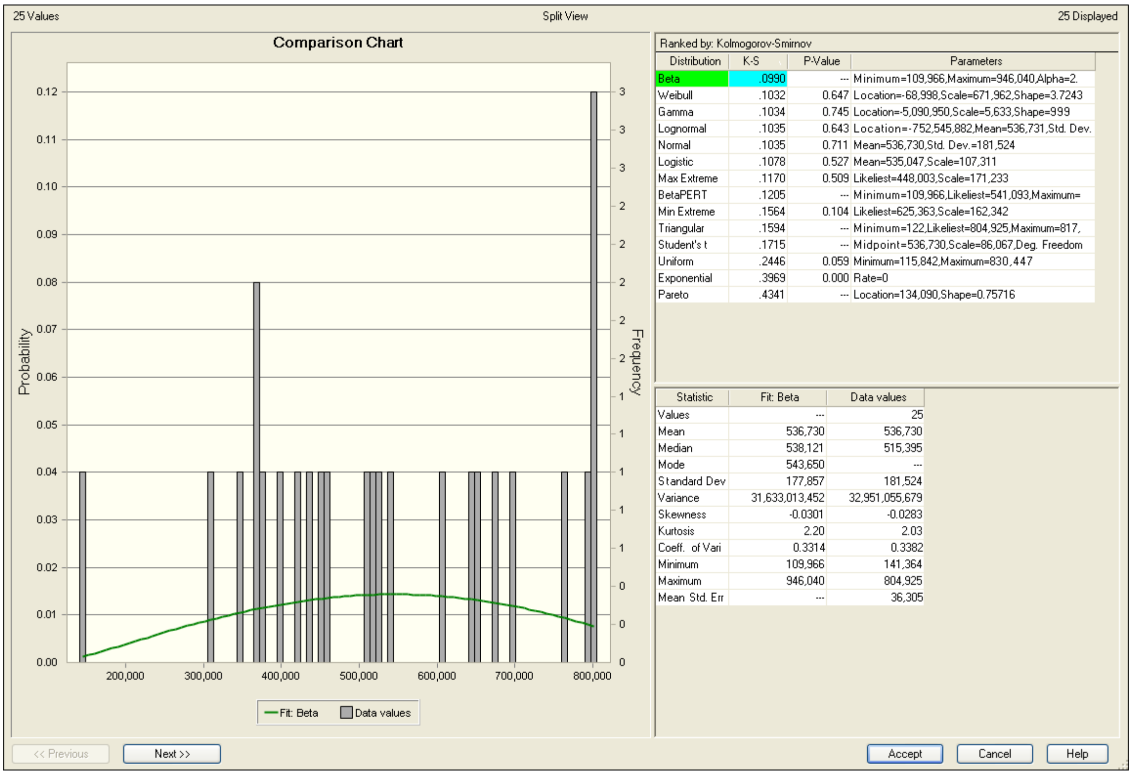
Formwork – Identified distribution by Chi-Square test



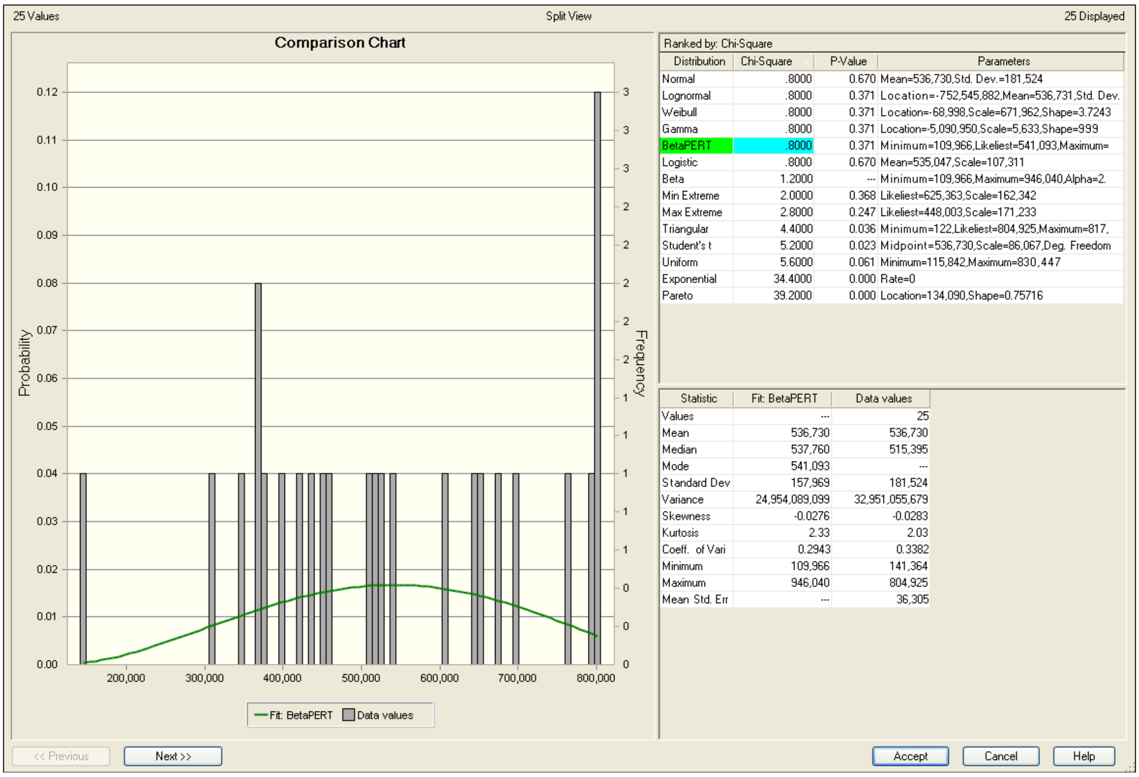
Formwork 1 – Identified distribution by A-D test

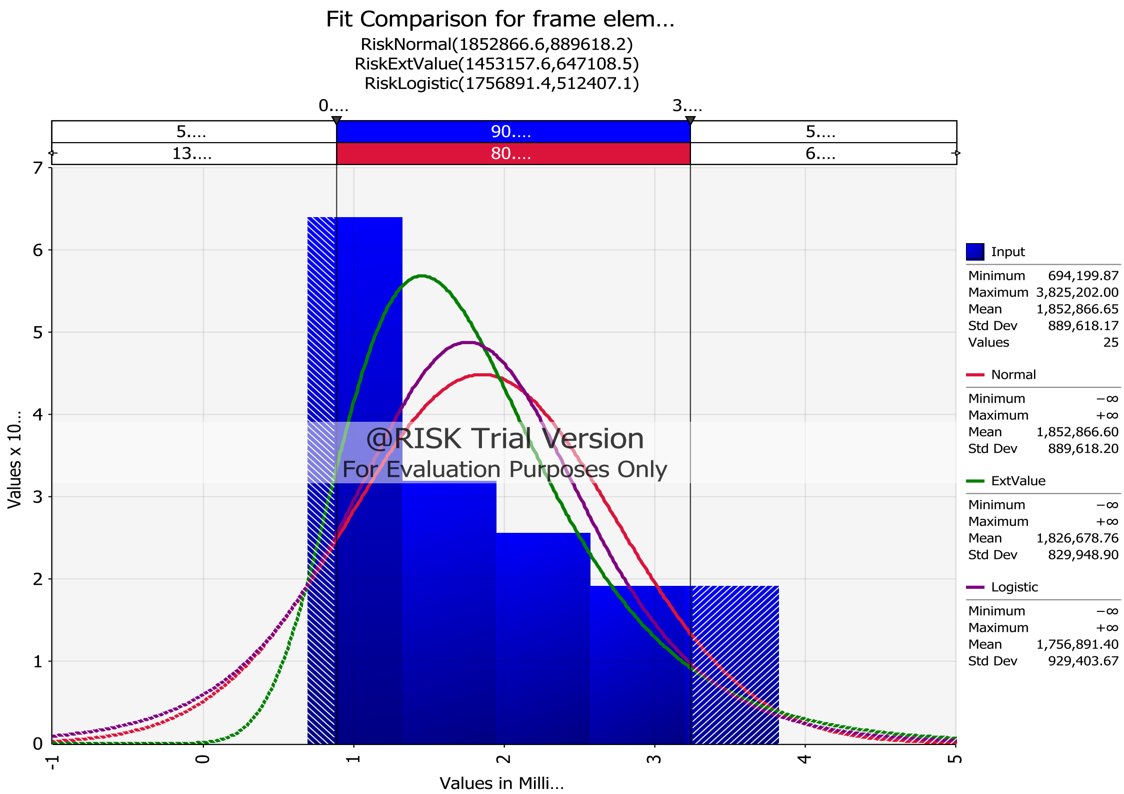


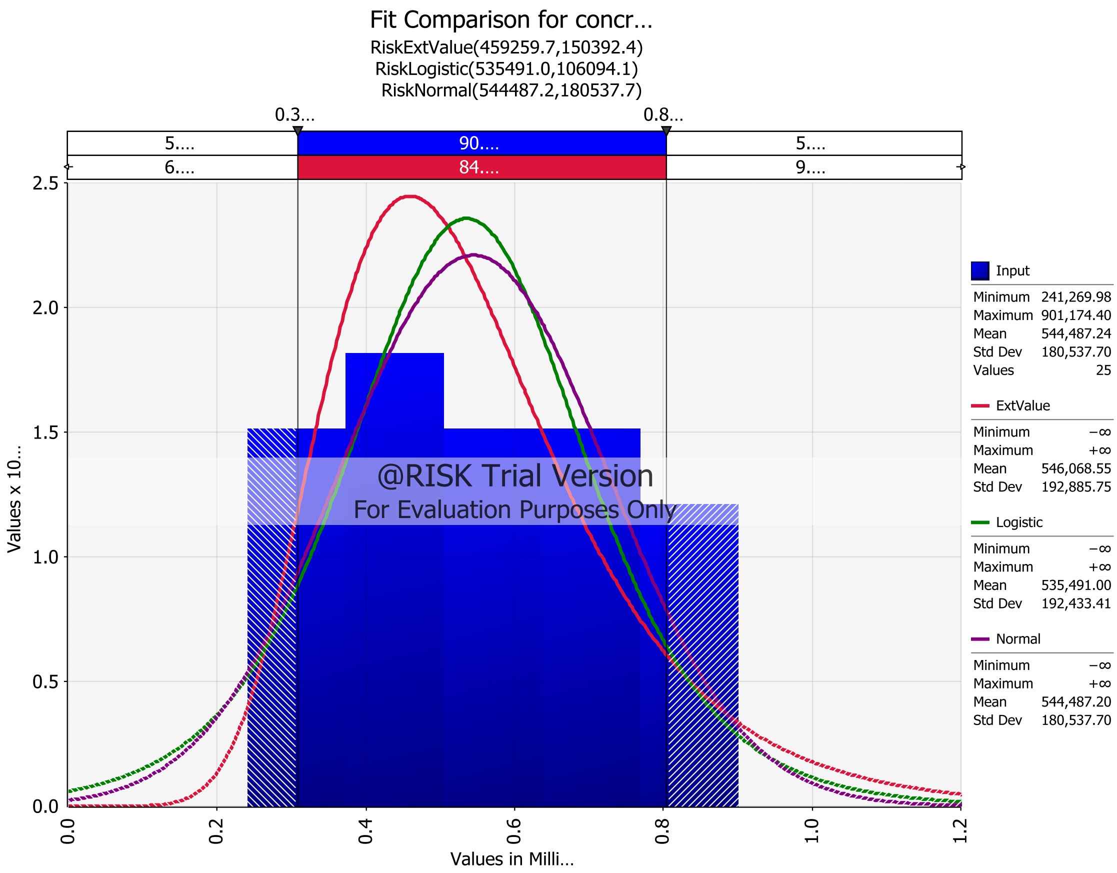
Formwork 1 – Identified distribution by K-S test

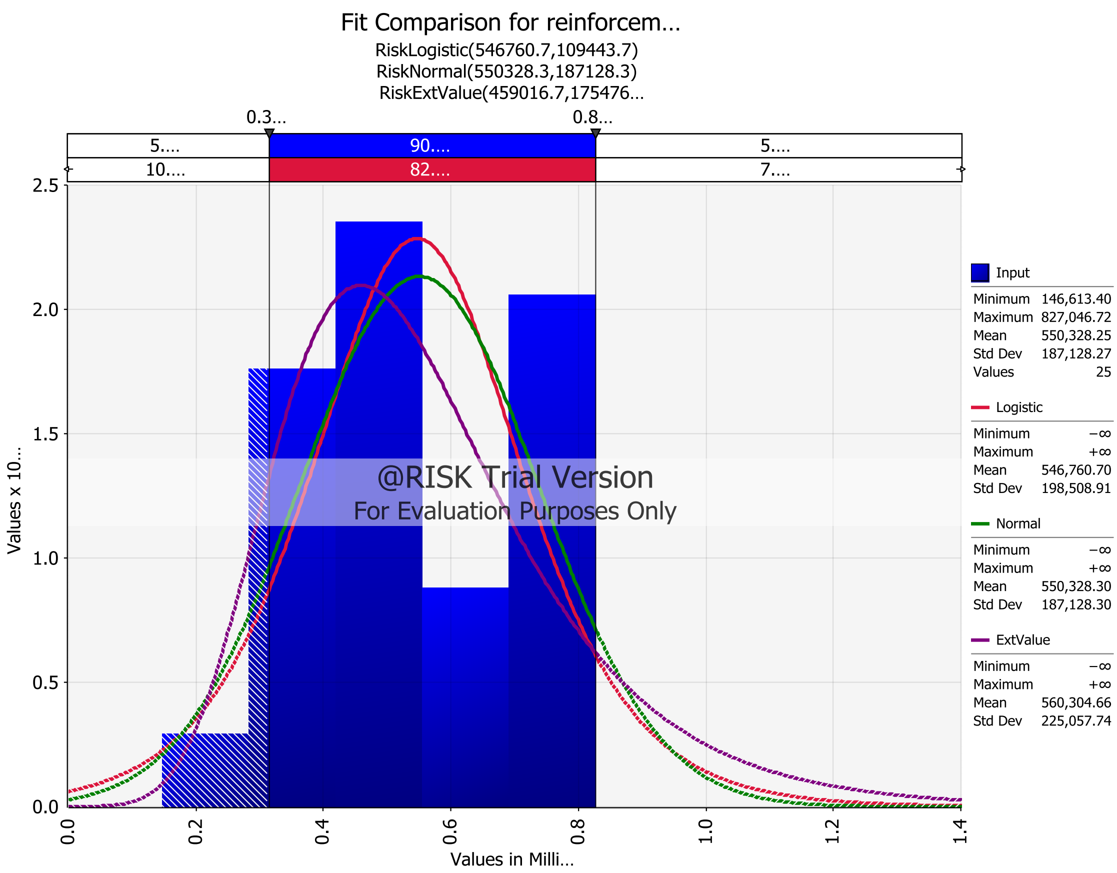


Formwork 1 – Identified distribution by Chi-Square test






Fit Comparison for concr...
RiskExtValue(459259.7,150392.4)
RiskLogistic(535491.0,106094.1)
RiskNormal(544487.2,180537.7)
0.3...
0.8...
5....
90....
5....
6....
84....
9....
Values x 10...
Values in Milli...
@RISK Trial Version
For Evaluation Purposes Only
Input
Minimum 241,269.98
Maximum 901,174.40
Mean 544,487.24
Std Dev 180,537.70
Values 25
ExtValue
Minimum −∞
Maximum +∞
Mean 546,068.55
Std Dev 192,885.75
Logistic
Minimum −∞
Maximum +∞
Mean 535,491.00
Std Dev 192,433.41
Normal
Minimum −∞
Maximum +∞
Mean 544,487.20
Std Dev 180,537.70


Fit Comparison for reinforcem...
RiskLogistic(546760.7,109443.7)
RiskNormal(550328.3,187128.3)
RiskExtValue(459016.7,175476...
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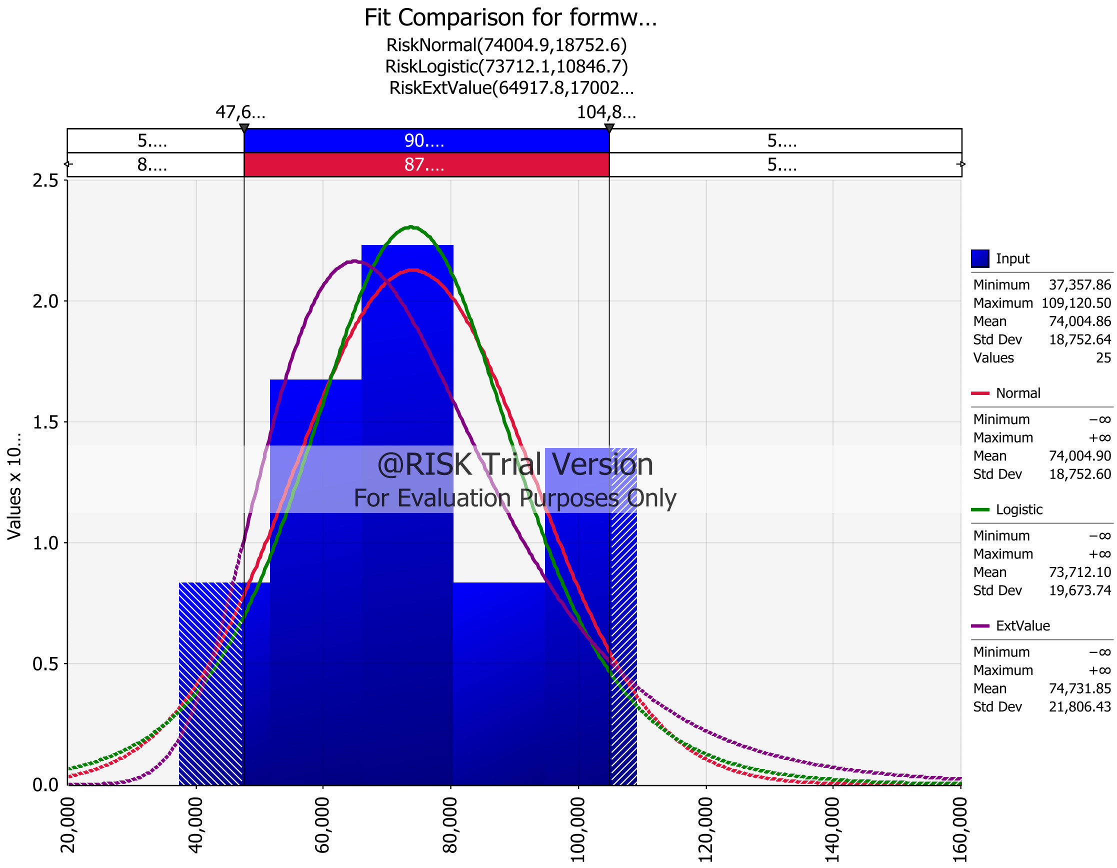
0.8...
5....
90....
5....
10....
82....
7....
Values x 10...
Values in Milli...
@RISK Trial Version
For Evaluation Purposes Only
Input
Minimum 146,613.40
Maximum 827,046.72
Mean 550,328.25
Std Dev 187,128.27
Values 25
Logistic
Minimum −∞
Maximum +∞
Mean 546,760.70
Std Dev 198,508.91
Normal
Minimum −∞
Maximum +∞
Mean 550,328.30
Std Dev 187,128.30
ExtValue
Minimum −∞
Maximum +∞
Mean 560,304.66
Std Dev 225,057.74



Fit Comparison for formw...
RiskNormal(74004.9,18752.6)
RiskLogistic(73712.1,10846.7)
RiskExtValue(64917.8,17002...
47,6...
104,8...
5....
90....
5....
8....
87....
5....
Values x 10...
@RISK Trial Version
For Evaluation Purposes Only
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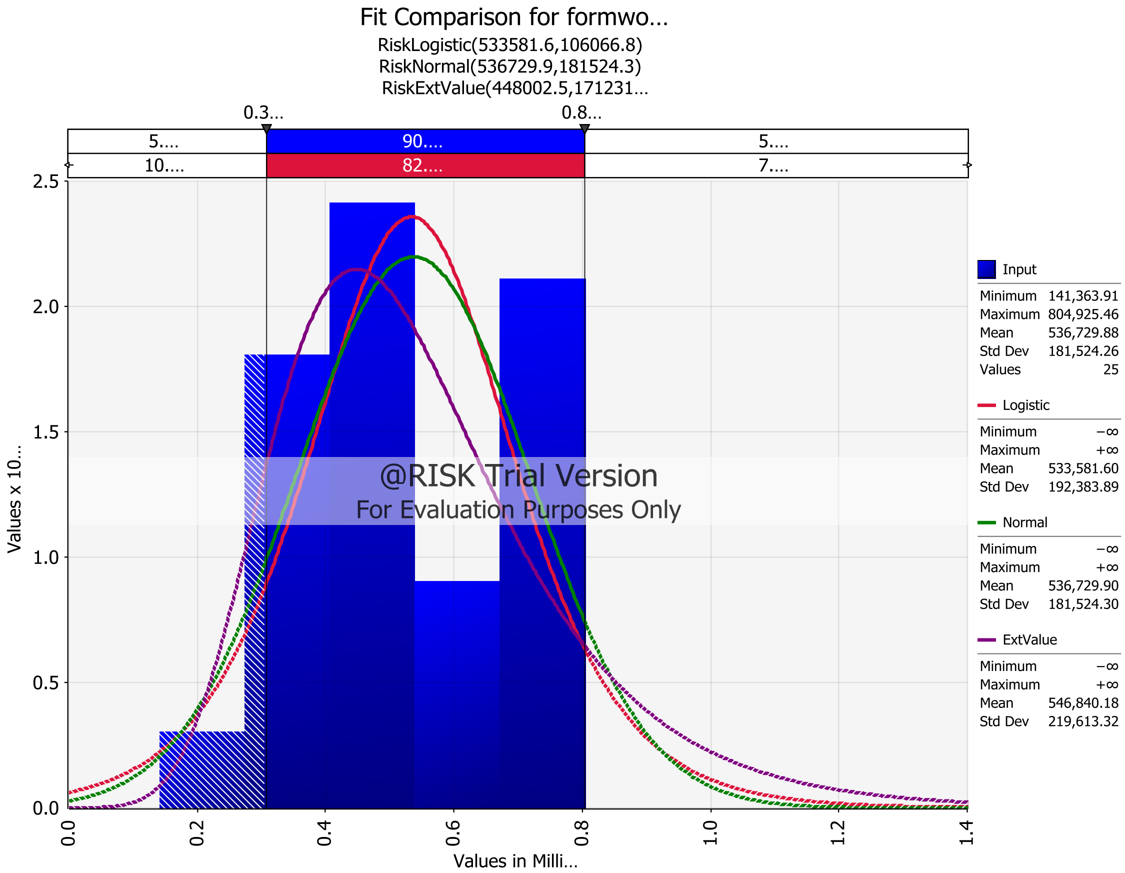
2.0
1.5
1.0
0.5
0.0
20,000
40,000
60,000
80,000
100,000
120,000
140,000
160,000
Input
Minimum 37,357.86
Maximum 109,120.50
Mean 74,004.86
Std Dev 18,752.64
Values 25
Normal
Minimum −∞
Maximum +∞
Mean 74,004.90
Std Dev 18,752.60
Logistic
Minimum −∞
Maximum +∞
Mean 73,712.10
Std Dev 19,673.74
ExtValue
Minimum −∞
Maximum +∞
Mean 74,731.85
Std Dev 21,806.43



Fit Comparison for formwo...
RiskLogistic(533581.6,106066.8)
RiskNormal(536729.9,181524.3)
RiskExtValue(448002.5,171231...
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0.8...
5....
90....
5....
10....
82....
7....
Values x 10...
@RISK Trial Version
For Evaluation Purposes Only
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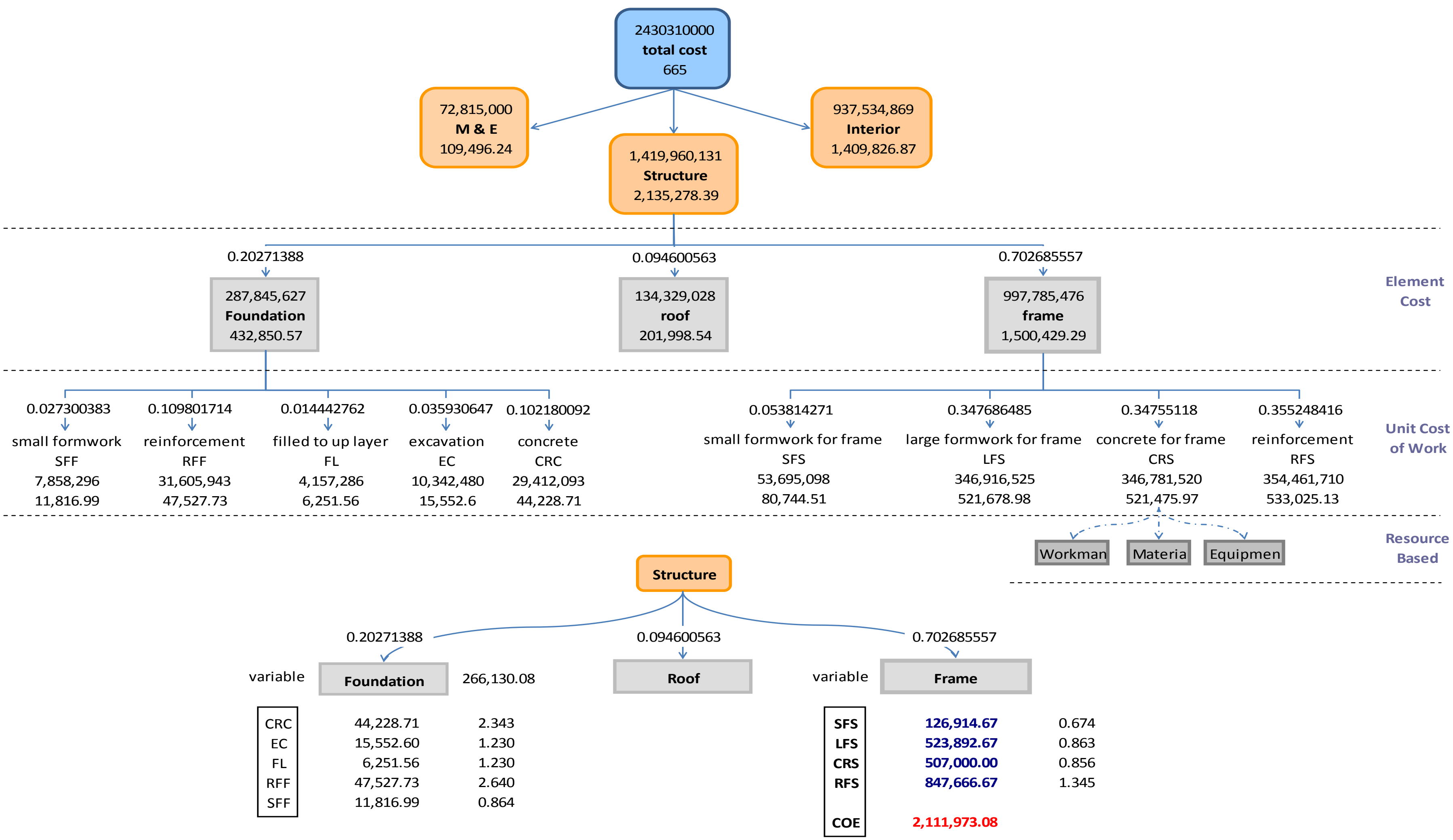
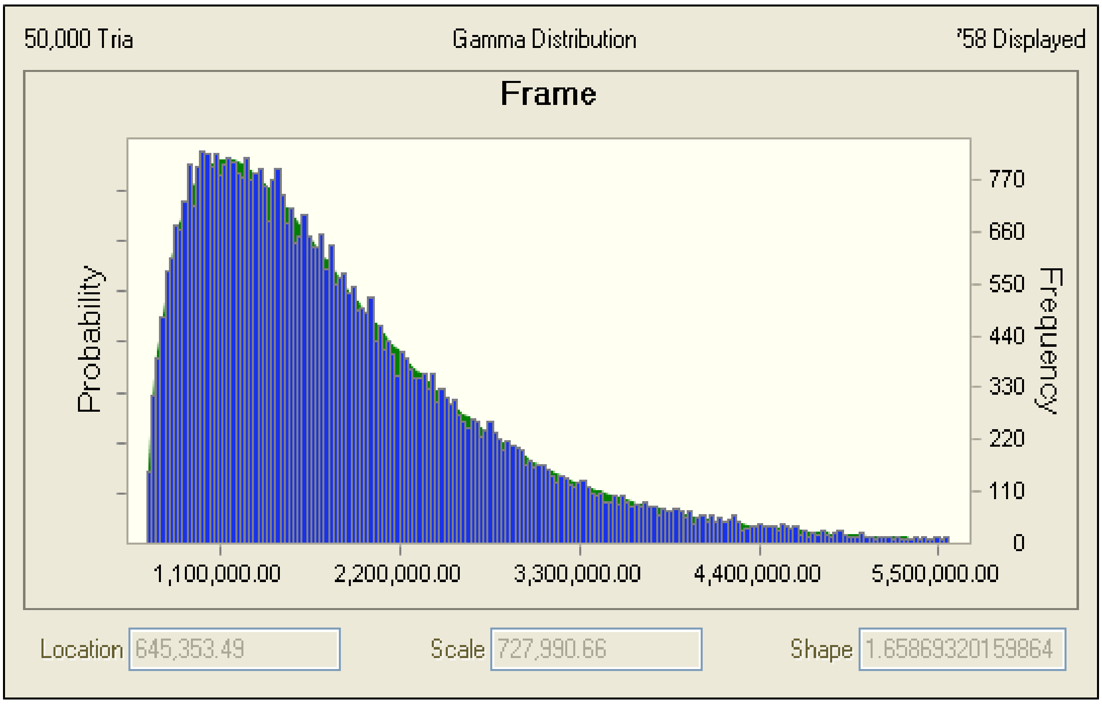
2.0
1.5
1.0
0.5
0.0
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
Values in Milli...
Input
Minimum 141,363.91
Maximum 804,925.46
Mean 536,729.88
Std Dev 181,524.26
Values 25
Logistic
Minimum −∞
Maximum +∞
Mean 533,581.60
Std Dev 192,383.89
Normal
Minimum −∞
Maximum +∞
Mean 536,729.90
Std Dev 181,524.30
ExtValue
Minimum −∞
Maximum +∞
Mean 546,840.18
Std Dev 219,613.32

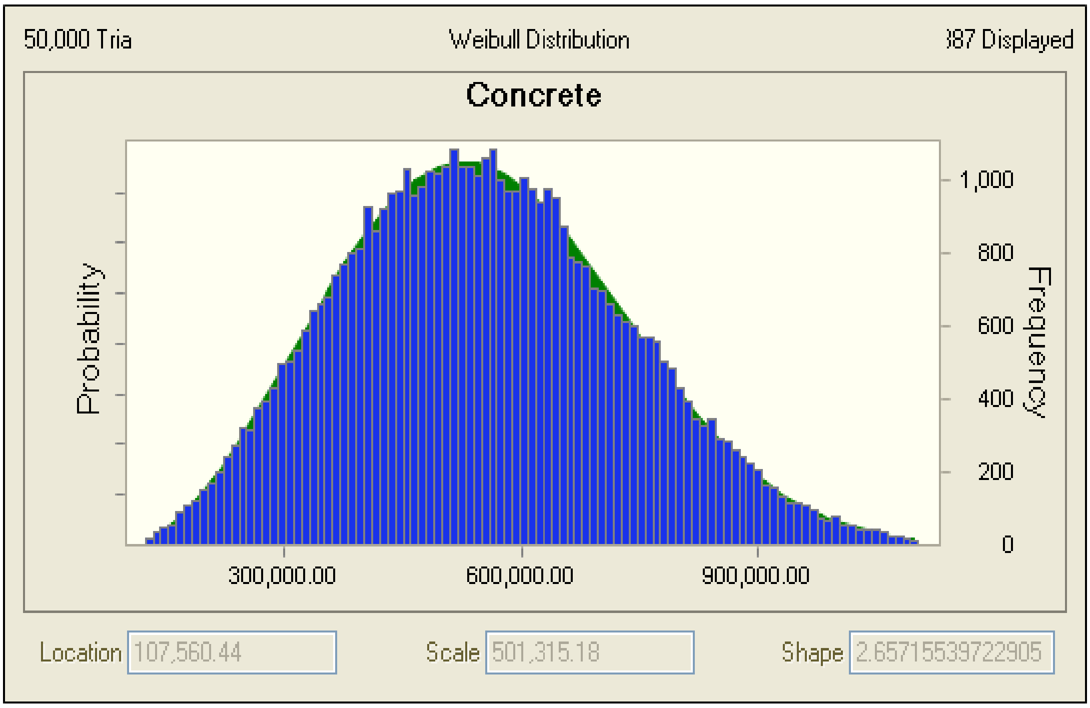
ANALYTICAL MODEL





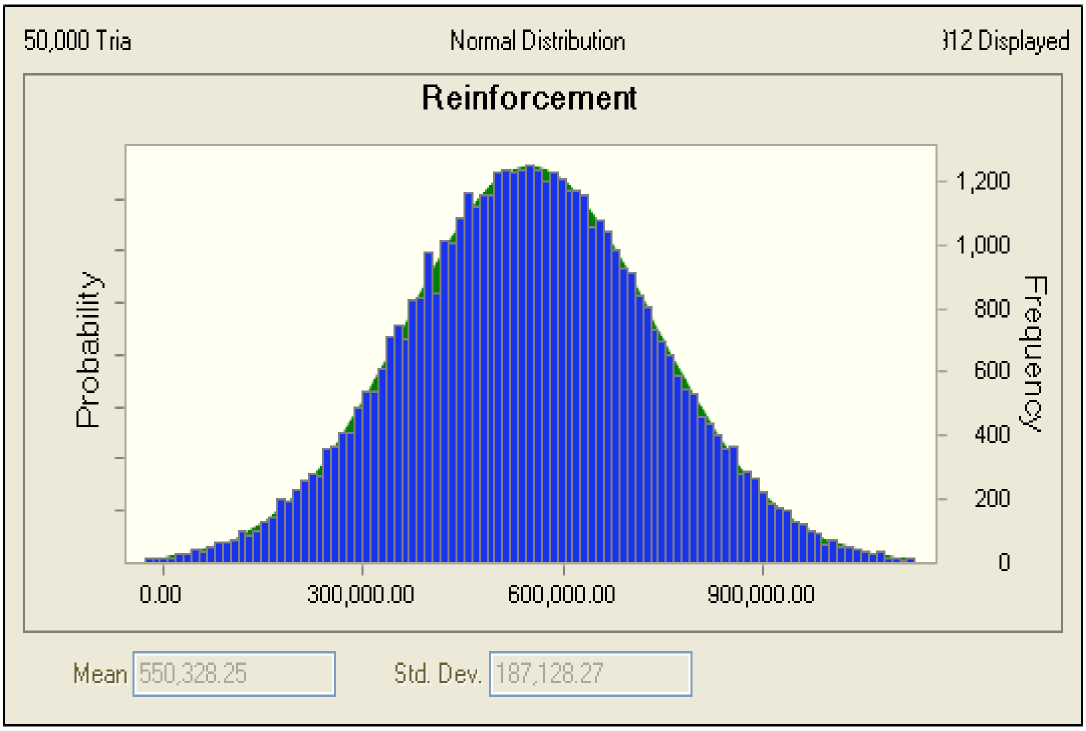
Assumption: Frame

Statistic	Assumption values	Gamma distribution
Trials	50,000	---
Mean	1,850,333.18	1,852,866.65
Median	1,618,538.57	1,620,762.98
Mode	---	1,124,875.99
Standard Deviation	940,129.09	937,581.09
Variance	883,842,711,984.82	879,058,301,331.88
Skewness	1.56	1.55
Kurtosis	6.65	6.62
Coeff. of Variability	0.5081	0.506
Minimum	646,009.68	645,353.49
Maximum	10,481,655.78	Infinity
Mean Std. Error	4,204.39	---



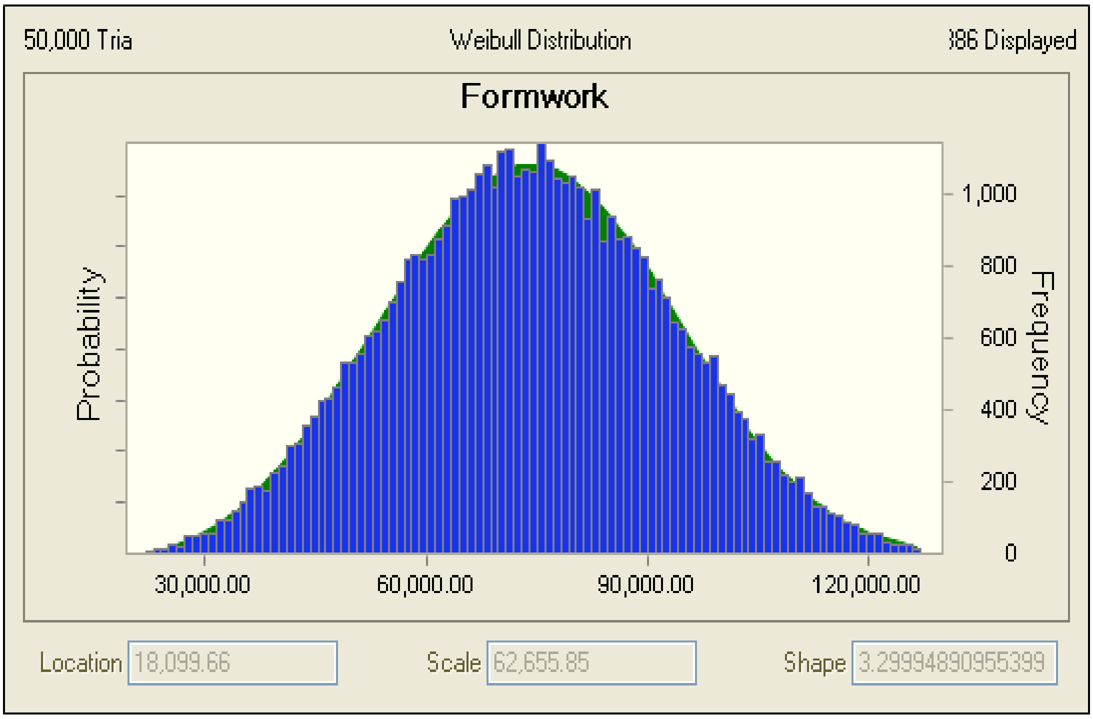
Assumption: Concrete

Statistic	Assumption values	Weibull distribution
Trials	50,000	---
Mean	554,278.80	553,134.49
Median	545,556.55	544,284.12
Mode	---	527,261.89
Standard Deviation	181,179.88	180,537.70
Variance	32,826,148,208.20	32,593,859,378.14
Skewness	0.2914	0.2921
Kurtosis	2.82	2.8
Coeff. of Variability	0.3269	0.3264
Minimum	118,438.13	107,560.44
Maximum	1,402,878.17	Infinity
Mean Std. Error	810.26	---



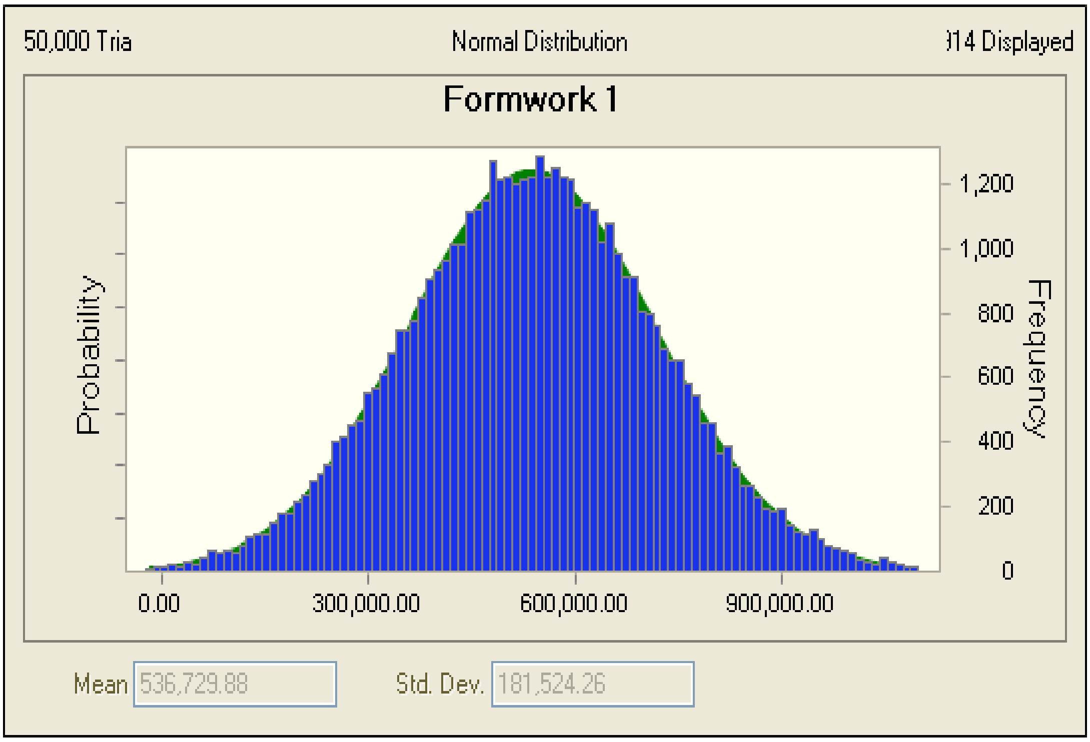
Assumption: Reinforcement

Statistic	Assumption values	Normal distribution
Trials	50,000	---
Mean	549,847.76	550,328.25
Median	549,456.73	550,328.25
Mode	---	550,328.25
Standard Deviation	187,234.32	187,128.27
Variance	35,056,689,206.71	35,016,990,814.71
Skewness	0.0104	0
Kurtosis	2.97	3
Coeff. of Variability	0.3405	0.34
Minimum	-224,727.93	-Infinity
Maximum	1,300,118.18	Infinity
Mean Std. Error	837.34	---



Assumption: Formwork

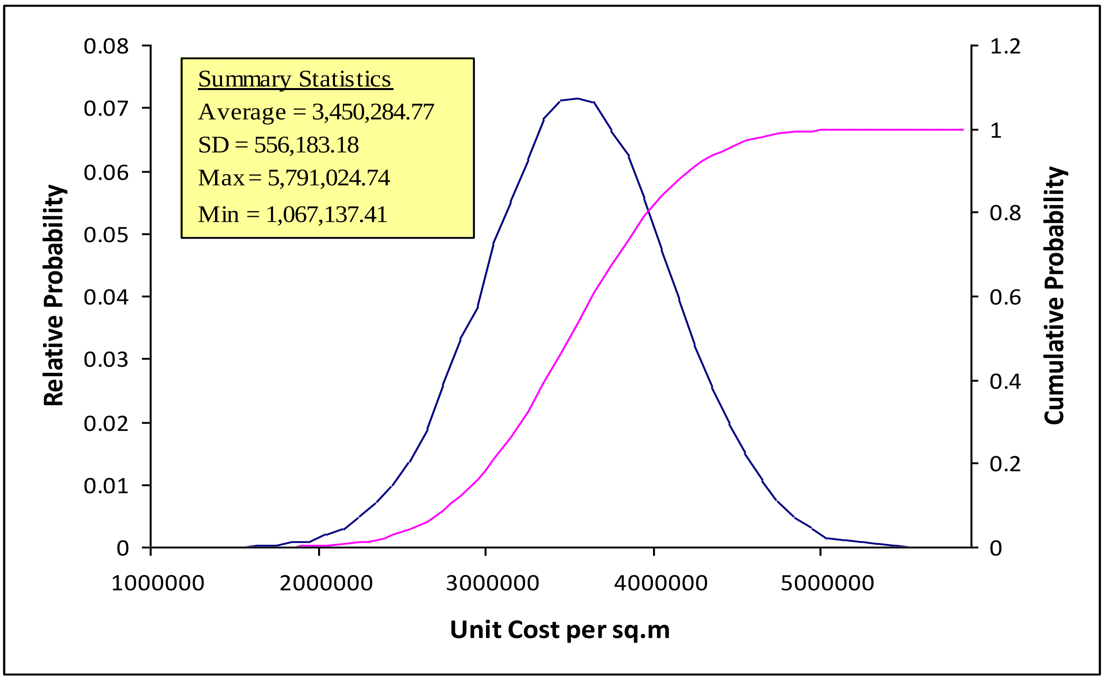
Statistic	Assumption values	Weibull distribution
Trials	50,000	---
Mean	74,237.33	74,302.88
Median	74,022.76	74,169.10
Mode	---	74,262.51
Standard Deviation	18,742.83	18,752.64
Variance	351,293,517.88	351,661,694.03
Skewness	0.0805	0.0779
Kurtosis	2.7	2.71
Coeff. of Variability	0.2525	0.2524
Minimum	19,749.27	18,099.66
Maximum	146,535.20	Infinity
Mean Std. Error	83.82	---



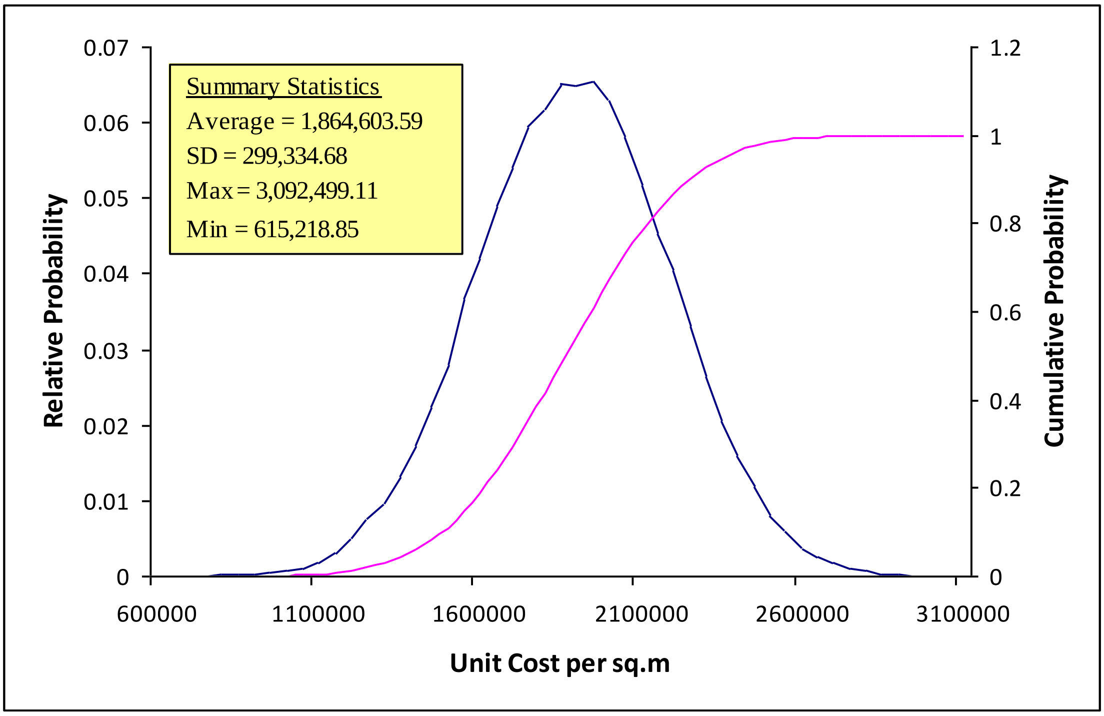
Assumption: Formwork 1

Statistic	Assumption values	Normal distribution
Trials	50,000	---
Mean	536,875.06	536,729.88
Median	537,109.04	536,729.88
Mode	---	536,729.88
Standard Deviation	181,471.53	181,524.26
Variance	32,931,916,359.01	32,951,055,678.74
Skewness	0.0169	0
Kurtosis	2.98	3
Coeff. of Variability	0.338	0.3382
Minimum	-225,420.02	-Infinity
Maximum	1,272,078.42	Infinity
Mean Std. Error	811.57	---

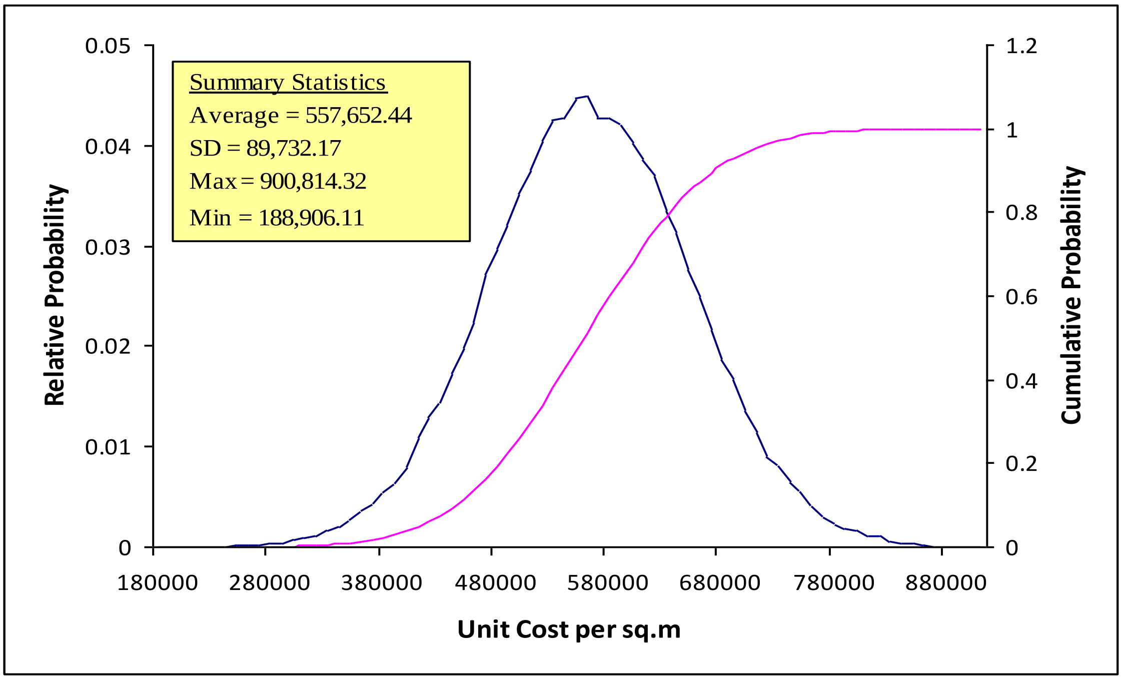
TOTAL COST



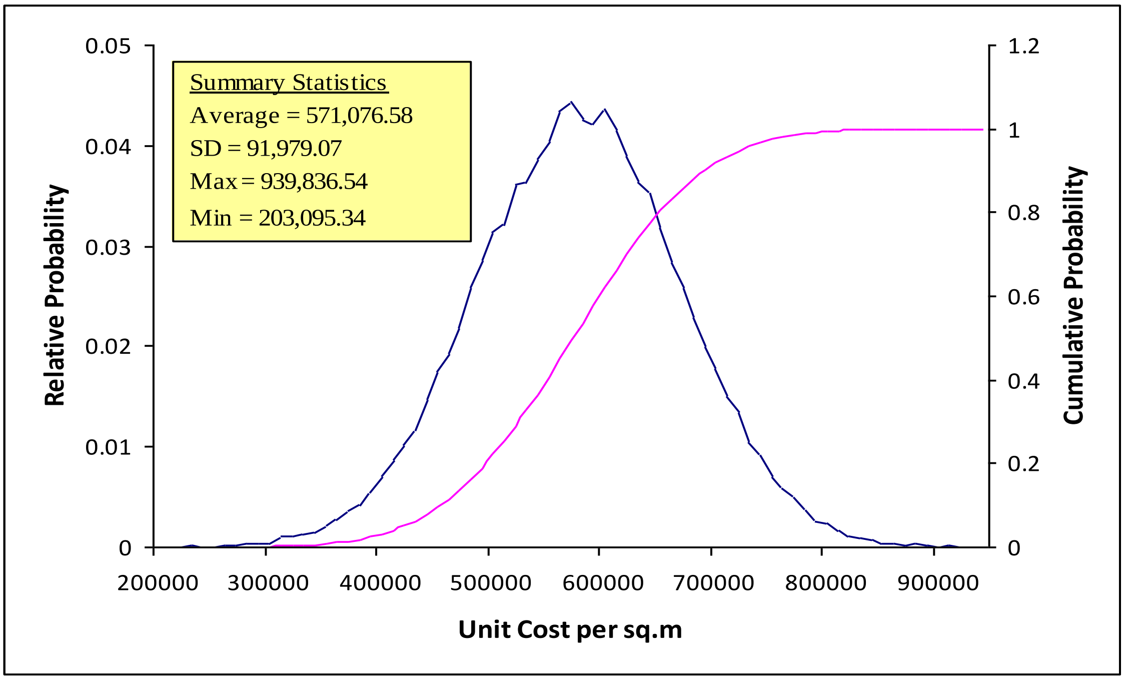
FRAME



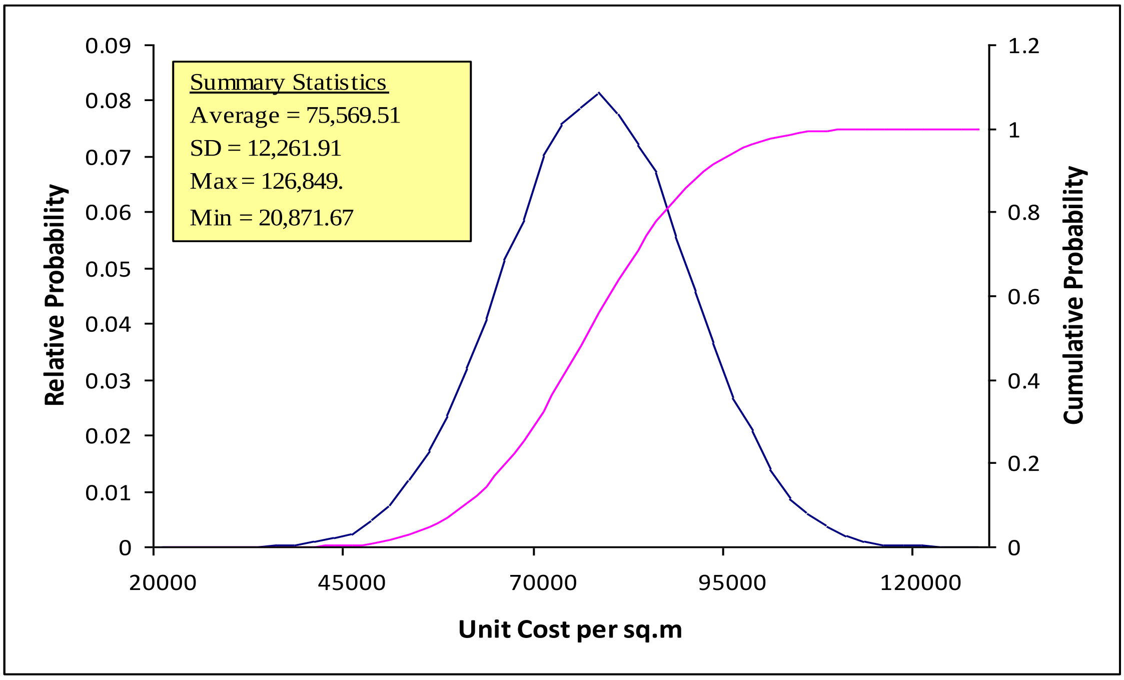
CONCRETE



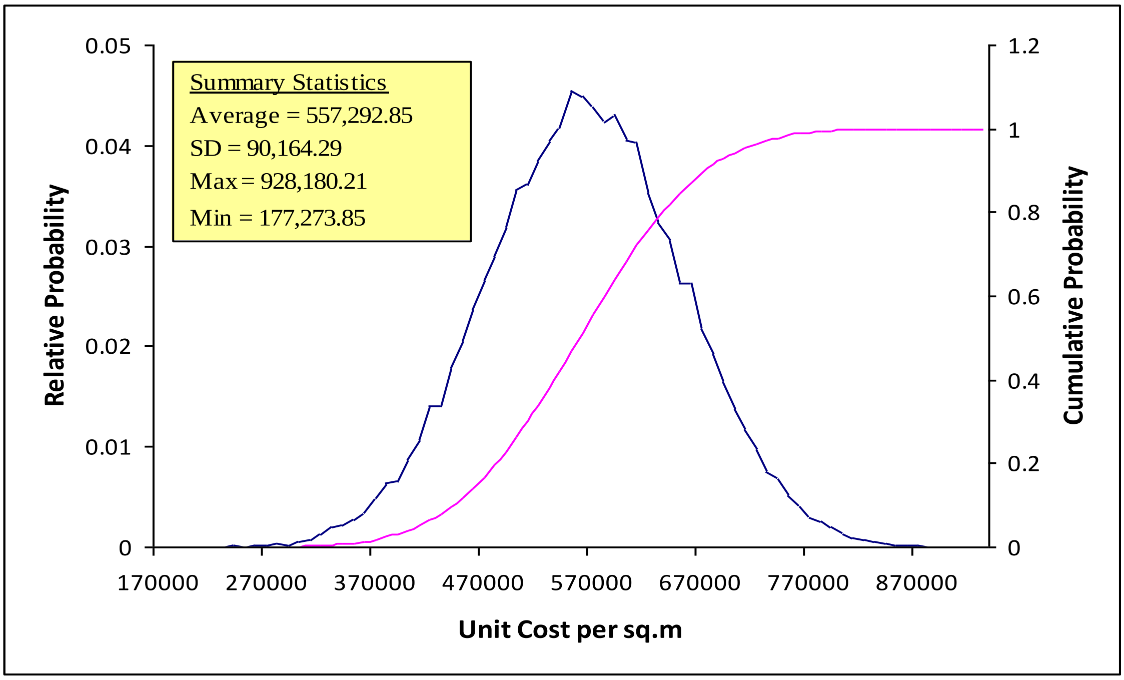
REINFORCEMENT



FORMWORK



FORMWORK 1



variable KL12

	Input	BetaGeneral
Minimum	135,087.86	134,980.00
Maximum	164,757.62	164,938.00
Mean	149,999.93	150,004.52
Mode	150,700.66	150,050.44
Median	149,997.40	150,012.83
Std Dev	6,708.92	6,710.80
Skewness	-0.0001	-0.0045
Kurtosis	2.1433	2.1407
Left X	139,052	139,052
Left P	5.00%	5.00%
Right X	160,933	160,933
Right P	95.00%	95.00%
Dif. X	21,880.36	21,880.36
Dif. P	90.00%	90.00%
1%	136,752.69	136,748.83
5%	139,052.36	139,048.17
10%	140,870.92	140,866.81
15%	142,332.73	142,328.97
20%	143,610.84	143,614.56
25%	144,788.24	144,793.84
30%	145,901.13	145,903.58
35%	146,958.60	146,966.38
40%	147,987.10	147,997.90
45%	148,997.57	149,010.07
50%	149,997.40	150,012.83
55%	151,000.94	151,015.25
60%	152,014.84	152,026.40
65%	153,041.30	153,056.17
70%	154,106.03	154,116.39
75%	155,205.09	155,222.56
80%	156,381.22	156,397.03
85%	157,664.02	157,676.05
90%	159,124.61	159,128.86
95%	160,932.72	160,932.51
99%	163,232.78	163,205.10

Variable Mdn

	Input	Normal	Weibull	Logistic
Minimum	17,206.92	$-\infty$	16,460.00	$-\infty$
Maximum	139,605.51	∞	∞	∞
Mean	79,999.53	79,999.00	79,916.99	80,000.00
Mode	78,191.50	79,999.00	82,108.86	80,000.00
Median	79,993.40	79,999.00	80,516.55	80,000.00
Std Dev	16,001.64	16,001.00	16,380.87	16,594.63
Skewness	-0.0015	0	-0.1589	0
Kurtosis	3.0006	3	2.7928	4.2
Left X	53,673	53,673	53,673	53,673
Left P	5.00%	5.00%	6.20%	5.30%
Right X	106,306	106,306	106,306	106,306
Right P	95.00%	95.00%	95.30%	94.70%
Dif. X	52,632.92	52,632.92	52,632.92	52,632.92
Dif. P	90.00%	90.00%	89.10%	89.30%
1%	42,703.10	42,775.11	40,851.65	37,958.79
5%	53,673.41	53,679.70	51,833.72	53,061.03
10%	59,479.77	59,492.89	58,144.67	59,897.37
15%	63,423.37	63,415.03	62,475.41	64,129.96
20%	66,523.08	66,532.22	65,925.54	67,316.65
25%	69,207.98	69,206.49	68,876.06	69,948.69
30%	71,618.52	71,608.07	71,509.84	72,247.99
35%	73,841.81	73,833.49	73,931.66	74,336.35
40%	75,939.25	75,945.19	76,209.39	76,290.36
45%	77,986.83	77,988.29	78,391.61	78,164.04
50%	79,993.40	79,999.00	80,516.55	80,000.00
55%	82,006.67	82,009.71	82,617.44	81,835.96
60%	84,061.69	84,052.81	84,726.29	83,709.64
65%	86,164.38	86,164.51	86,877.51	85,663.65
70%	88,396.51	88,389.93	89,112.49	87,752.01
75%	90,784.77	90,791.51	91,486.84	90,051.31
80%	93,462.75	93,465.78	94,084.58	92,683.35
85%	96,571.09	96,582.97	97,051.17	95,870.04
90%	100,504.58	100,505.11	100,691.03	100,102.63
95%	106,306.34	106,318.30	105,900.98	106,938.97
99%	117,193.72	117,222.89	115,116.38	122,041.21

Variable KTR

	Input	Normal	Weibull	Logistic
Minimum	4,956.56	$-\infty$	4,120.40	$-\infty$
Maximum	141,199.18	∞	∞	∞
Mean	74,999.53	74,999.00	74,910.30	75,000.00
Mode	74,774.39	74,999.00	77,314.12	75,000.00
Median	74,994.14	74,999.00	75,564.08	75,000.00
Std Dev	17,999.61	17,999.00	18,408.75	18,667.62
Skewness	-0.0014	0	-0.1528	0
Kurtosis	2.9961	3	2.7883	4.2
Left X	45,368	45,368	45,368	45,368
Left P	5.00%	5.00%	6.20%	5.30%
Right X	104,581	104,581	104,581	104,581
Right P	95.00%	95.00%	95.30%	94.70%
Dif. X	59,213.22	59,213.22	59,213.22	59,213.22
Dif. P	90.00%	90.00%	89.10%	89.30%
1%	33,022.15	33,127.06	31,111.99	27,707.03
5%	45,367.98	45,393.28	43,383.27	44,695.83
10%	51,919.10	51,932.35	50,449.94	52,386.16
15%	56,355.94	56,344.24	55,304.41	57,147.49
20%	59,845.16	59,850.66	59,174.46	60,732.26
25%	62,848.08	62,858.86	62,485.83	63,693.08
30%	65,562.85	65,560.32	65,443.02	66,279.61
35%	68,066.94	68,063.62	68,163.25	68,628.85
40%	70,437.21	70,439.01	70,722.47	70,826.95
45%	72,737.91	72,737.22	73,175.12	72,934.70
50%	74,994.14	74,999.00	75,564.08	75,000.00
55%	77,261.58	77,260.78	77,926.64	77,065.30
60%	79,560.66	79,558.99	80,298.75	79,173.05
65%	81,930.15	81,934.38	82,719.14	81,371.15
70%	84,443.05	84,437.68	85,234.41	83,720.39
75%	87,140.60	87,139.14	87,907.21	86,306.92
80%	90,138.99	90,147.34	90,832.28	89,267.74
85%	93,654.53	93,653.76	94,173.65	92,852.51
90%	98,060.34	98,065.65	98,274.71	97,613.84
95%	104,581.21	104,604.72	104,147.29	105,304.17
99%	116,855.49	116,870.94	114,541.49	122,292.97

Variable
PSB

	Input	Normal	Weibull
Minimum	46,250.41	−∞	43,907.00
Maximum	456,132.47	∞	∞
Mean	245,000.94	245,000.00	244,717.91
Mode	≈246.880,46	245,000.00	251,805.85
Median	244,988.44	245,000.00	246,670.90
Std Dev	50,032.45	50,032.00	51,326.56
Skewness	0.0014	0	-0.1671
Kurtosis	3.0262	3	2.7991
Left X	162,699	162,699	162,699
Left P	5.00%	5.00%	6.30%
Right X	327,220	327,220	327,220
Right P	95.00%	95.00%	95.30%
Dif. X	164,520.66	164,520.66	164,520.66
Dif. P	90.00%	90.00%	89.00%
1%	128,546.75	128,608.16	121,929.19
5%	162,699.26	162,704.68	156,602.34
10%	180,894.52	180,881.41	176,471.74
15%	193,212.31	193,145.16	190,087.41
20%	202,911.38	202,892.01	200,924.46
25%	211,264.83	211,253.93	210,185.65
30%	218,808.20	218,763.19	218,447.88
35%	225,734.41	225,721.65	226,041.42
40%	232,315.79	232,324.54	233,179.96
45%	238,716.91	238,712.91	240,016.39
50%	244,988.44	245,000.00	246,670.90
55%	251,267.28	251,287.09	253,247.72
60%	257,671.70	257,675.46	259,847.16
65%	264,253.45	264,278.35	266,576.93
70%	271,221.24	271,236.81	273,566.37
75%	278,708.66	278,746.07	280,989.10
80%	287,046.84	287,107.99	289,107.29
85%	296,807.66	296,854.84	298,374.58
90%	309,074.21	309,118.59	309,740.03
95%	327,219.92	327,295.32	325,998.86
99%	361,272.88	361,391.84	354,732.82

Variable KRB

	Input	Normal(320000;80000)
Minimum	-9,111.56	−∞
Maximum	627,632.02	∞
Mean	319,997.02	320,000.00
Mode	312,971.23	320,000.00
Median	319,998.81	320,000.00
Std Dev	80,034.45	80,000.00
Skewness	-0.0018	0
Kurtosis	3.0161	3
Values	5000	
Errors	0	
Filtered	0	
Left X	188,370	188,370
Left P	5.00%	5.00%
Right X	451,482	451,482
Right P	95.00%	95.00%
Dif. X	263,111.93	263,111.93
Dif. P	90.00%	90.00%
1%	133,858.24	133,892.17
5%	188,369.84	188,411.71
10%	217,454.08	217,475.87
15%	237,064.57	237,085.33
20%	252,649.99	252,670.30
25%	266,037.11	266,040.82
30%	278,030.86	278,047.96
35%	289,158.02	289,174.36
40%	299,731.30	299,732.23
45%	309,914.18	309,947.09
50%	319,998.81	320,000.00
55%	330,024.19	330,052.91
60%	340,265.93	340,267.77
65%	350,809.98	350,825.64
70%	361,911.66	361,952.04
75%	373,956.17	373,959.18
80%	387,298.89	387,329.70
85%	402,866.35	402,914.67
90%	422,505.51	422,524.13
95%	451,481.77	451,588.29
99%	505,974.31	506,107.83

Variable
SMN

	Input	Normal	Weibull
Minimum	6,501.97	−∞	5,920.30
Maximum	94,253.93	∞	∞
Mean	50,000.39	50,000.00	49,947.84
Mode	50,752.66	50,000.00	51,184.47
Median	49,996.67	50,000.00	50,262.54
Std Dev	12,000.08	12,000.00	12,195.41
Skewness	0.0008	0	-0.0985
Kurtosis	2.9943	3	2.7537
Left X	30,240	30,240	30,240
Left P	5.00%	5.00%	5.90%
Right X	69,733	69,733	69,733
Right P	95.00%	95.00%	95.20%
Dif. X	39,492.64	39,492.64	39,492.64
Dif. P	90.00%	90.00%	89.30%
1%	22,081.38	22,083.83	21,536.70
5%	30,240.04	30,261.76	29,259.05
10%	34,610.76	34,621.38	33,790.46
15%	37,566.62	37,562.80	36,932.91
20%	39,894.00	39,900.55	39,453.68
25%	41,904.63	41,906.12	41,620.77
30%	43,712.39	43,707.19	43,563.60
35%	45,381.62	45,376.15	45,356.73
40%	46,957.13	46,959.83	47,048.77
45%	48,487.29	48,492.06	48,674.76
50%	49,996.67	50,000.00	50,262.54
55%	51,504.07	51,507.94	51,836.53
60%	53,042.81	53,040.17	53,420.56
65%	54,617.67	54,623.85	55,040.51
70%	56,298.57	56,292.81	56,727.76
75%	58,090.95	58,093.88	58,524.84
80%	60,096.89	60,099.45	60,496.27
85%	62,432.05	62,437.20	62,754.14
90%	65,366.55	65,378.62	65,533.62
95%	69,732.69	69,738.24	69,528.89
99%	77,910.36	77,916.17	76,641.39

Variable MNDR

	Input	Normal	Weibull	Logistic
Minimum	11,930.01	$-\infty$	11,145.00	$-\infty$
Maximum	144,603.88	∞	∞	∞
Mean	79,999.02	79,999.00	79,888.62	79,999.90
Mode	80,199.91	79,999.00	82,584.14	79,999.90
Median	79,992.26	79,999.00	80,658.62	79,999.90
Std Dev	16,009.60	16,009.00	16,537.35	16,597.17
Skewness	-0.0024	0	-0.2161	0
Kurtosis	3.0272	3	2.8416	4.2
Left X	53,677	53,677	53,677	53,677
Left P	5.00%	5.00%	6.50%	5.30%
Right X	106,315	106,315	106,315	106,315
Right P	95.00%	95.00%	95.40%	94.70%
Dif. X	52,637.59	52,637.59	52,637.59	52,637.59
Dif. P	90.00%	90.00%	88.80%	89.30%
1%	42,694.17	42,756.50	39,591.64	37,952.26
5%	53,677.11	53,666.54	51,271.04	53,056.81
10%	59,483.60	59,482.64	57,854.26	59,894.20
15%	63,430.60	63,406.74	62,328.19	64,127.43
20%	66,528.37	66,525.49	65,869.81	67,314.61
25%	69,205.17	69,201.09	68,883.93	69,947.05
30%	71,611.81	71,603.87	71,563.78	72,246.70
35%	73,840.56	73,830.40	74,019.53	74,335.38
40%	75,940.44	75,943.17	76,322.12	76,289.69
45%	77,981.51	77,987.29	78,522.01	78,163.66
50%	79,992.26	79,999.00	80,658.62	79,999.90
55%	82,006.29	82,010.71	82,765.85	81,836.14
60%	84,058.20	84,054.83	84,876.04	83,710.11
65%	86,161.96	86,167.60	87,023.63	85,664.42
70%	88,391.01	88,394.13	89,249.65	87,753.10
75%	90,784.81	90,796.91	91,608.91	90,052.75
80%	93,458.79	93,472.51	94,183.76	92,685.19
85%	96,570.88	96,591.26	97,116.38	95,872.37
90%	100,491.96	100,515.36	100,703.60	100,105.60
95%	106,314.70	106,331.46	105,818.23	106,942.99
99%	117,207.13	117,241.50	114,811.52	122,047.54

Variable
KPTR

	Input	Normal	Weibull	Logistic
Minimum	9,196.69	$-\infty$	8,362.10	$-\infty$
Maximum	146,157.86	∞	∞	∞
Mean	75,001.60	75,001.00	74,923.77	75,000.00
Mode	74,322.84	75,001.00	76,841.55	75,000.00
Median	74,992.71	75,001.00	75,416.40	75,000.00
Std Dev	18,000.86	18,000.00	18,309.84	18,667.62
Skewness	0.0032	0	-0.1046	0
Kurtosis	2.9992	3	2.7571	4.2
Left X	45,361	45,361	45,361	45,361
Left P	5.00%	5.00%	5.90%	5.30%
Right X	104,606	104,606	104,606	104,606
Right P	95.00%	95.00%	95.20%	94.70%
Dif. X	59,245.36	59,245.36	59,245.36	59,245.36
Dif. P	90.00%	90.00%	89.30%	89.40%
1%	33,107.63	33,126.74	32,166.06	27,707.03
5%	45,360.98	45,393.63	43,828.24	44,695.83
10%	51,914.38	51,933.07	50,656.98	52,386.16
15%	56,345.14	56,345.20	55,387.50	57,147.49
20%	59,847.50	59,851.82	59,179.50	60,732.26
25%	62,854.82	62,860.18	62,437.72	63,693.08
30%	65,567.62	65,561.79	65,357.47	66,279.61
35%	68,070.78	68,065.23	68,051.24	68,628.85
40%	70,437.23	70,440.75	70,592.27	70,826.95
45%	72,734.15	72,739.10	73,033.36	72,934.70
50%	74,992.71	75,001.00	75,416.40	75,000.00
55%	77,256.30	77,262.90	77,778.12	77,065.30
60%	79,561.80	79,561.25	80,154.26	79,173.05
65%	81,933.16	81,936.77	82,583.65	81,371.15
70%	84,439.97	84,440.21	85,113.34	83,720.39
75%	87,137.94	87,141.82	87,806.98	86,306.92
80%	90,137.64	90,150.18	90,761.14	89,267.74
85%	93,643.70	93,656.80	94,143.55	92,852.51
90%	98,052.40	98,068.93	98,305.93	97,613.84
95%	104,606.34	104,608.37	104,286.44	105,304.17
99%	116,854.46	116,875.26	114,926.13	122,292.97

Variable TB

	Input	Normal	Weibull	Logistic
Minimum	10,731.59	$-\infty$	9,984.60	$-\infty$
Maximum	129,331.70	∞	∞	∞
Mean	70,000.67	70,000.00	69,929.44	70,000.10
Mode	68,995.97	70,000.00	71,729.94	70,000.10
Median	69,993.17	70,000.00	70,398.90	70,000.10
Std Dev	15,999.74	15,999.00	16,289.92	16,594.09
Skewness	0.0009	0	-0.1152	0
Kurtosis	2.9948	3	2.7633	4.2
Left X	43,654	43,654	43,654	43,654
Left P	5.00%	5.00%	6.00%	5.30%
Right X	96,288	96,288	96,288	96,288
Right P	95.00%	95.00%	95.20%	94.70%
Dif. X	52,634.02	52,634.02	52,634.02	52,634.02
Dif. P	90.00%	90.00%	89.20%	89.30%
1%	32,762.32	32,780.76	31,730.45	27,960.27
5%	43,653.65	43,683.99	42,212.03	43,062.02
10%	49,484.80	49,496.46	48,326.80	49,898.13
15%	53,417.27	53,418.10	52,554.83	54,130.58
20%	56,529.65	56,534.90	55,939.90	57,317.17
25%	59,202.78	59,208.84	58,845.76	59,949.12
30%	61,616.69	61,610.12	61,447.77	62,248.34
35%	63,838.83	63,835.26	63,846.80	64,336.63
40%	65,938.39	65,946.70	66,108.48	66,290.58
45%	67,982.79	67,989.54	68,280.04	68,164.20
50%	69,993.17	70,000.00	70,398.90	70,000.10
55%	72,005.01	72,010.46	72,497.81	71,836.00
60%	74,061.83	74,053.30	74,608.58	73,709.62
65%	76,164.04	76,164.74	76,765.68	75,663.57
70%	78,397.95	78,389.88	79,010.84	77,751.86
75%	80,787.91	80,791.16	81,400.42	80,051.08
80%	83,455.26	83,465.10	84,019.87	82,683.03
85%	86,579.73	86,581.90	87,017.50	85,869.62
90%	90,488.79	90,503.54	90,704.22	90,102.07
95%	96,287.67	96,316.01	95,997.34	96,938.18
99%	107,113.77	107,219.24	105,403.36	112,039.93

Variable
LTRB

	Input	BetaGeneral	Triang	Weibull	Normal
Minimum	49,556.29	49,509.00	49,296.00	48,445.80	$-\infty$
Maximum	60,423.91	60,482.00	60,702.00	∞	∞
Mean	54,999.98	54,999.51	54,999.67	55,011.46	55,000.00
Mode	54,595.96	55,003.58	55,001.00	54,845.18	55,000.00
Median	54,998.56	55,000.24	55,000.00	54,945.52	55,000.00
Std Dev	2,459.91	2,461.15	2,328.24	2,416.39	2,459.90
Skewness	0	-0.0011	-0.0003	0.1819	0
Kurtosis	2.1432	2.1391	2.4	2.7347	3
Left X	50,986	50,986	50,986	50,986	50,986
Left P	5.00%	5.00%	4.40%	4.20%	5.10%
Right X	59,009	59,009	59,009	59,009	59,009
Right P	95.00%	95.00%	95.60%	94.60%	94.80%
Dif. X	8,022.56	8,022.56	8,022.56	8,022.56	8,022.56
Dif. P	90.00%	90.00%	91.20%	90.40%	89.70%
1%	50,146.99	50,148.30	50,102.67	49,999.52	49,277.42
5%	50,986.03	50,985.67	51,099.76	51,141.43	50,953.82
10%	51,653.37	51,649.77	51,846.91	51,884.03	51,847.51
15%	52,189.60	52,184.40	52,420.21	52,426.51	52,450.48
20%	52,657.97	52,654.88	52,903.53	52,876.80	52,929.70
25%	53,088.65	53,086.73	53,329.34	53,274.12	53,340.82
30%	53,496.57	53,493.32	53,714.30	53,638.04	53,710.03
35%	53,884.80	53,882.87	54,068.31	53,980.17	54,052.15
40%	54,261.46	54,261.10	54,397.81	54,308.36	54,376.79
45%	54,631.58	54,632.34	54,707.29	54,628.51	54,690.89
50%	54,998.56	55,000.24	55,000.00	54,945.52	55,000.00
55%	55,366.66	55,368.11	55,292.61	55,263.97	55,309.11
60%	55,738.32	55,739.27	55,601.98	55,588.57	55,623.21
65%	56,114.52	56,117.34	55,931.36	55,924.71	55,947.85
70%	56,504.58	56,506.66	56,285.25	56,279.23	56,289.97
75%	56,910.00	56,912.93	56,670.08	56,661.65	56,659.18
80%	57,339.68	57,344.36	57,095.74	57,086.79	57,070.30
85%	57,810.61	57,814.26	57,578.89	57,580.74	57,549.52
90%	58,344.29	58,348.07	58,151.99	58,198.87	58,152.49
95%	59,008.58	59,010.84	58,898.87	59,106.21	59,046.18
99%	59,851.89	59,845.85	59,895.62	60,773.98	60,722.58

Variable BSBTRB

	Input	BetaGeneral	Triang	Weibull	Normal
Minimum	6,350.99	6,345.50	6,318.90	6,209.77	$-\infty$
Maximum	7,744.74	7,752.80	7,781.10	∞	∞
Mean	7,050.00	7,050.11	7,049.93	7,051.48	7,050.00
Mode	7,045.30	7,051.07	7,049.80	7,030.19	7,050.00
Median	7,049.82	7,050.28	7,049.90	7,043.03	7,050.00
Std Dev	315.31	315.45	298.47	309.74	315.31
Skewness	0	-0.002	0.0003	0.1817	0
Kurtosis	2.1432	2.1399	2.4	2.7346	3
Left X	6,536	6,536	6,536	6,536	6,536
Left P	5.00%	5.00%	4.40%	4.20%	5.10%
Right X	7,564	7,564	7,564	7,564	7,564
Right P	95.00%	95.00%	95.60%	94.60%	94.80%
Dif. X	1,028.30	1,028.30	1,028.30	1,028.30	1,028.30
Dif. P	90.00%	90.00%	91.20%	90.40%	89.70%
1%	6,427.56	6,427.89	6,422.28	6,409.00	6,316.48
5%	6,535.69	6,535.48	6,550.06	6,555.39	6,531.36
10%	6,620.91	6,620.72	6,645.81	6,650.59	6,645.91
15%	6,689.62	6,689.31	6,719.29	6,720.13	6,723.20
20%	6,749.85	6,749.65	6,781.22	6,777.85	6,784.63
25%	6,805.12	6,805.02	6,835.80	6,828.78	6,837.33
30%	6,857.38	6,857.15	6,885.13	6,875.43	6,884.65
35%	6,907.22	6,907.08	6,930.50	6,919.29	6,928.50
40%	6,955.30	6,955.56	6,972.73	6,961.36	6,970.12
45%	7,002.80	7,003.14	7,012.39	7,002.40	7,010.38
50%	7,049.82	7,050.28	7,049.90	7,043.03	7,050.00
55%	7,097.02	7,097.42	7,087.42	7,083.85	7,089.62
60%	7,144.58	7,144.97	7,127.09	7,125.46	7,129.88
65%	7,192.77	7,193.41	7,169.33	7,168.55	7,171.50
70%	7,242.92	7,243.29	7,214.71	7,213.99	7,215.35
75%	7,294.83	7,295.34	7,264.06	7,263.01	7,262.67
80%	7,349.99	7,350.61	7,318.65	7,317.50	7,315.37
85%	7,410.20	7,410.82	7,380.61	7,380.81	7,376.80
90%	7,478.64	7,479.21	7,454.10	7,460.04	7,454.09
95%	7,564.00	7,564.14	7,549.87	7,576.34	7,568.64
99%	7,671.94	7,671.17	7,677.69	7,790.10	7,783.52

Variable BU

	Input	BetaGeneral	Triang	Weibull	Normal
Minimum	6,356.33	6,347.50	6,319.00	6,209.96	−∞
Maximum	7,749.27	7,755.00	7,781.30	∞	∞
Mean	7,050.00	7,049.87	7,050.10	7,051.47	7,050.00
Mode	7,082.93	7,048.47	7,050.00	7,030.13	7,050.00
Median	7,049.97	7,049.62	7,050.08	7,043.01	7,050.00
Std Dev	315.32	315.43	298.49	309.74	315.32
Skewness	0.0001	0.0029	0.0002	0.182	0
Kurtosis	2.1432	2.1401	2.4	2.7347	3
Left X	6,536	6,536	6,536	6,536	6,536
Left P	5.00%	5.00%	4.40%	4.20%	5.10%
Right X	7,564	7,564	7,564	7,564	7,564
Right P	95.00%	95.00%	95.60%	94.60%	94.80%
Dif. X	1,028.32	1,028.32	1,028.32	1,028.32	1,028.32
Dif. P	90.00%	90.00%	91.20%	90.40%	89.70%
1%	6,428.01	6,429.05	6,422.39	6,409.06	6,316.46
5%	6,535.78	6,535.99	6,550.19	6,555.41	6,531.34
10%	6,621.00	6,620.86	6,645.95	6,650.59	6,645.90
15%	6,689.74	6,689.21	6,719.43	6,720.12	6,723.19
20%	6,749.67	6,749.38	6,781.37	6,777.84	6,784.62
25%	6,805.00	6,804.63	6,835.95	6,828.77	6,837.32
30%	6,857.39	6,856.66	6,885.29	6,875.41	6,884.65
35%	6,907.12	6,906.52	6,930.66	6,919.27	6,928.50
40%	6,955.28	6,954.94	6,972.89	6,961.34	6,970.11
45%	7,002.87	7,002.49	7,012.56	7,002.37	7,010.38
50%	7,049.97	7,049.62	7,050.08	7,043.01	7,050.00
55%	7,096.95	7,096.76	7,087.60	7,083.83	7,089.62
60%	7,144.73	7,144.33	7,127.27	7,125.44	7,129.89
65%	7,192.87	7,192.81	7,169.51	7,168.53	7,171.50
70%	7,242.81	7,242.75	7,214.90	7,213.97	7,215.35
75%	7,294.68	7,294.89	7,264.25	7,262.99	7,262.68
80%	7,350.05	7,350.28	7,318.83	7,317.49	7,315.38
85%	7,410.27	7,410.65	7,380.79	7,380.81	7,376.81
90%	7,478.89	7,479.28	7,454.29	7,460.05	7,454.10
95%	7,564.10	7,564.61	7,550.07	7,576.36	7,568.66
99%	7,671.26	7,672.36	7,677.89	7,790.16	7,783.54

Variable KB

	Input	Normal	Weibull	Logistic
Minimum	2,597.60	$-\infty$	2,412.30	$-\infty$
Maximum	31,981.60	∞	∞	∞
Mean	17,499.96	17,500.00	17,482.13	17,500.00
Mode	17,249.23	17,500.00	17,942.49	17,500.00
Median	17,498.25	17,500.00	17,602.89	17,500.00
Std Dev	3,999.68	3,999.70	4,073.57	4,148.52
Skewness	-0.0004	0	-0.1198	0
Kurtosis	2.9922	3	2.7661	4.2
Left X	10,916	10,916	10,916	10,916
Left P	5.00%	5.00%	6.00%	5.30%
Right X	24,074	24,074	24,074	24,074
Right P	95.00%	95.00%	95.20%	94.70%
Dif. X	13,157.46	13,157.46	13,157.46	13,157.46
Dif. P	90.00%	90.00%	89.20%	89.30%
1%	8,190.38	8,195.31	7,912.75	6,990.04
5%	10,916.26	10,921.08	10,545.32	10,765.48
10%	12,370.12	12,374.18	12,078.66	12,474.51
15%	13,355.33	13,354.58	13,138.04	13,532.62
20%	14,132.96	14,133.77	13,985.76	14,329.27
25%	14,800.74	14,802.24	14,713.17	14,987.25
30%	15,403.81	15,402.56	15,364.31	15,562.06
35%	15,959.80	15,958.83	15,964.49	16,084.13
40%	16,484.70	16,486.69	16,530.16	16,572.62
45%	16,995.38	16,997.39	17,073.17	17,041.03
50%	17,498.25	17,500.00	17,602.89	17,500.00
55%	18,002.55	18,002.61	18,127.51	17,958.97
60%	18,513.93	18,513.31	18,654.99	18,427.38
65%	19,040.20	19,041.17	19,193.94	18,915.87
70%	19,599.70	19,597.44	19,754.79	19,437.94
75%	20,197.38	20,197.76	20,351.60	20,012.75
80%	20,865.24	20,866.23	21,005.69	20,670.73
85%	21,645.49	21,645.42	21,754.04	21,467.38
90%	22,623.44	22,625.82	22,674.20	22,525.49
95%	24,073.72	24,078.92	23,994.86	24,234.52
99%	26,799.05	26,804.69	26,340.56	28,009.96

Variable TBS

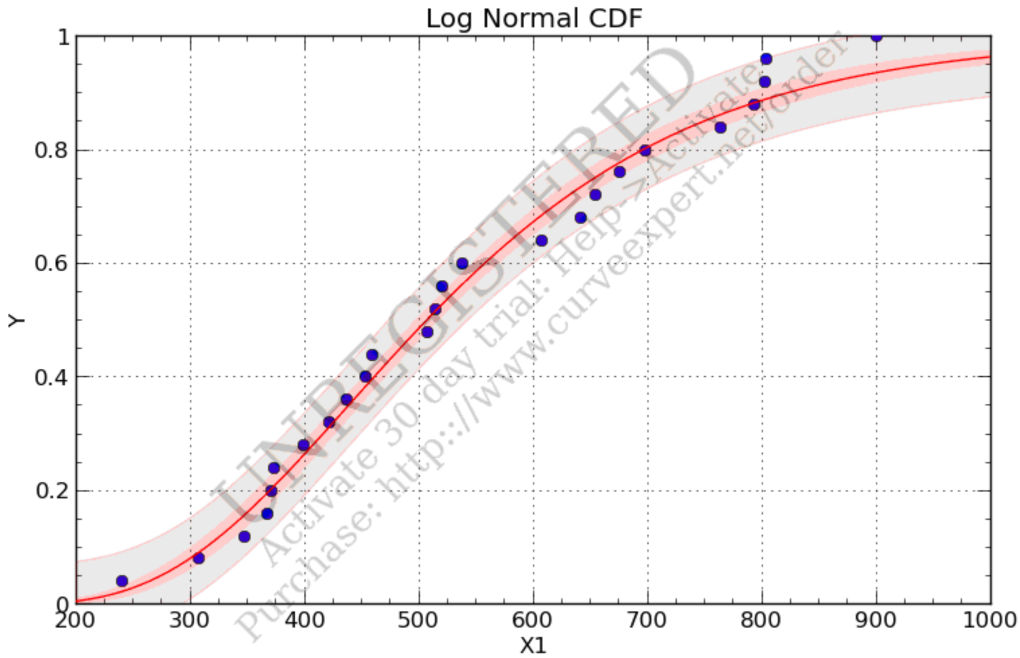
	Input	BetaGeneral	Triang	Weibull	Normal
Minimum	63,070.33	63,008.00	62,739.00	61,657.40	$-\infty$
Maximum	76,891.52	76,972.00	77,257.00	∞	∞
Mean	69,999.99	70,000.56	69,999.33	70,014.57	70,000.00
Mode	70,140.12	70,011.30	70,002.00	69,803.15	70,000.00
Median	69,999.30	70,002.50	70,000.00	69,930.71	70,000.00
Std Dev	3,130.82	3,132.80	2,963.47	3,075.45	3,130.80
Skewness	0	-0.0023	-0.0005	0.1818	0
Kurtosis	2.1433	2.1388	2.4	2.7346	3
Left X	64,895	64,895	64,895	64,895	64,895
Left P	5.00%	5.00%	4.40%	4.20%	5.10%
Right X	75,104	75,104	75,104	75,104	75,104
Right P	95.00%	95.00%	95.60%	94.60%	94.80%
Dif. X	10,209.61	10,209.61	10,209.61	10,209.61	10,209.61
Dif. P	90.00%	90.00%	91.20%	90.40%	89.70%
1%	63,817.07	63,822.81	63,765.86	63,635.38	62,716.67
5%	64,894.55	64,889.75	65,035.13	65,088.90	64,850.29
10%	65,741.08	65,735.78	65,986.22	66,034.11	65,987.72
15%	66,424.11	66,416.81	66,716.01	66,724.59	66,755.13
20%	67,019.92	67,016.05	67,331.26	67,297.71	67,365.05
25%	67,568.63	67,566.05	67,873.30	67,803.42	67,888.31
30%	68,086.44	68,083.83	68,363.35	68,266.60	68,358.21
35%	68,580.91	68,579.88	68,813.99	68,702.06	68,793.64
40%	69,060.83	69,061.47	69,233.44	69,119.77	69,206.82
45%	69,532.08	69,534.13	69,627.39	69,527.23	69,606.58
50%	69,999.30	70,002.50	70,000.00	69,930.71	70,000.00
55%	70,467.27	70,470.78	70,372.41	70,336.02	70,393.42
60%	70,940.66	70,943.21	70,766.14	70,749.15	70,793.18
65%	71,418.69	71,424.39	71,185.36	71,176.96	71,206.36
70%	71,915.82	71,919.84	71,635.75	71,628.16	71,641.79
75%	72,429.95	72,436.79	72,125.53	72,114.87	72,111.69
80%	72,979.68	72,985.66	72,667.27	72,655.95	72,634.95
85%	73,576.21	73,583.38	73,282.18	73,284.61	73,244.87
90%	74,258.03	74,262.23	74,011.57	74,071.29	74,012.28
95%	75,104.17	75,104.76	74,962.14	75,226.06	75,149.71
99%	76,168.26	76,165.49	76,230.71	77,348.58	77,283.33

FIT TEST CHI SQUARE

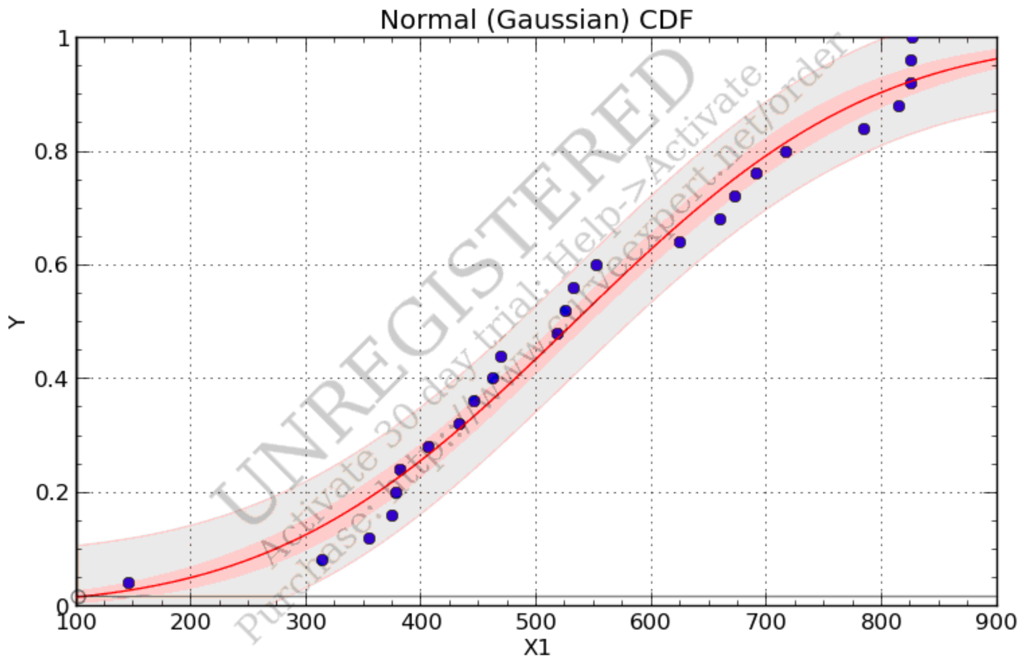
	Input	BetaGeneral
Minimum	14,865.87	14,846.90
Maximum	18,131.71	18,146.60
Mean	16,500.42	16,500.38
Mode	16,446.24	16,504.02
Median	16,500.77	16,501.04
Std Dev	737.52	738.04
Skewness	-0.0036	-0.0033
Kurtosis	2.1482	2.1425
Left X	15,296	15,296
Left P	5.00%	5.00%
Right X	17,702	17,702
Right P	95.00%	95.00%
Dif. X	2,406.14	2,406.14
Dif. P	90.00%	90.00%
1%	15,040.59	15,042.47
5%	15,295.98	15,295.71
10%	15,496.30	15,495.78
15%	15,658.07	15,656.55
20%	15,799.26	15,797.87
25%	15,928.60	15,927.48
30%	16,050.99	16,049.44
35%	16,167.21	16,166.24
40%	16,280.10	16,279.60
45%	16,390.81	16,390.83
50%	16,500.77	16,501.04
55%	16,610.84	16,611.23
60%	16,722.14	16,722.38
65%	16,834.82	16,835.60
70%	16,951.25	16,952.19
75%	17,072.34	17,073.87
80%	17,201.40	17,203.10
85%	17,342.01	17,343.90
90%	17,502.58	17,503.92
95%	17,702.12	17,702.80
99%	17,955.23	17,953.91

CHI-SUARE TEST FOR VARIABLE KL

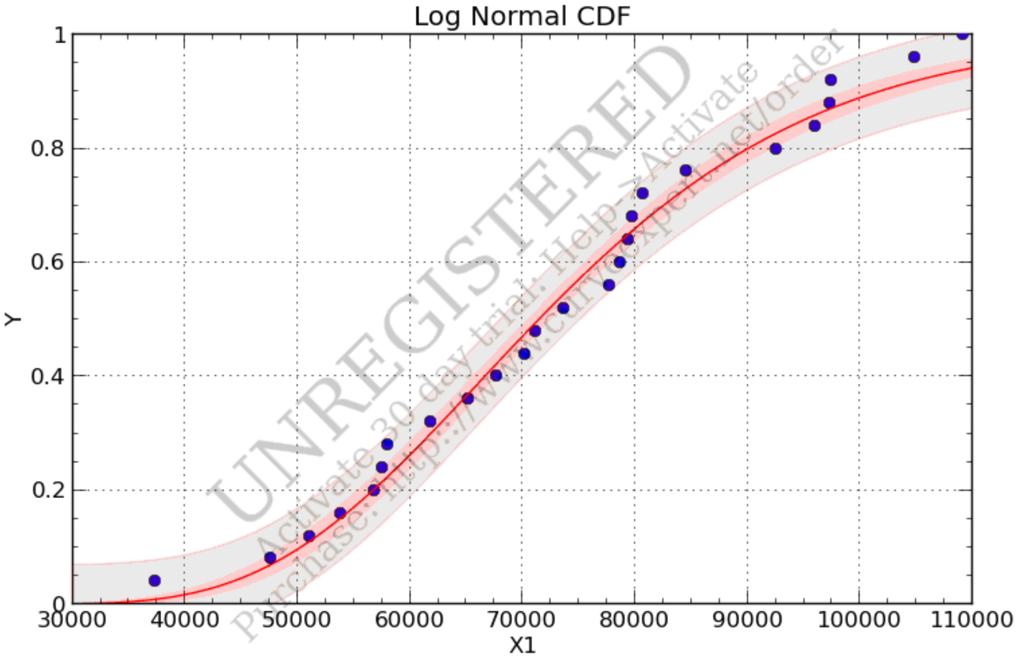
Variable	Input	BetaGeneral
Minimum	49,559.48	49,504.00
Maximum	60,479.49	60,515.00
Mean	54,999.99	54,997.83
Mode	≈54.669,50	54,986.23
Median	54,998.82	54,995.72
Std Dev	2,459.94	2,459.40
Skewness	0	0.0032
Kurtosis	2.1433	2.1442
Left X	50,986	50,986
Left P	5.00%	5.00%
Right X	59,010	59,010
Right P	95.00%	95.00%
Dif. X	8,023.84	8,023.84
Dif. P	90.00%	90.00%
1%	50,142.46	50,151.09
5%	50,985.72	50,990.39
10%	51,652.33	51,654.05
15%	52,188.47	52,187.68
20%	52,658.36	52,656.99
25%	53,088.23	53,087.63
30%	53,496.55	53,493.02
35%	53,885.96	53,881.41
40%	54,261.49	54,258.53
45%	54,632.31	54,628.75
50%	54,998.82	54,995.72
55%	55,366.52	55,362.77
60%	55,738.88	55,733.25
65%	56,114.04	56,110.82
70%	56,505.53	56,499.86
75%	56,909.94	56,906.15
80%	57,341.35	57,338.02
85%	57,810.55	57,809.00
90%	58,345.47	58,345.01
95%	59,009.56	59,012.49
99%	59,849.75	59,858.62



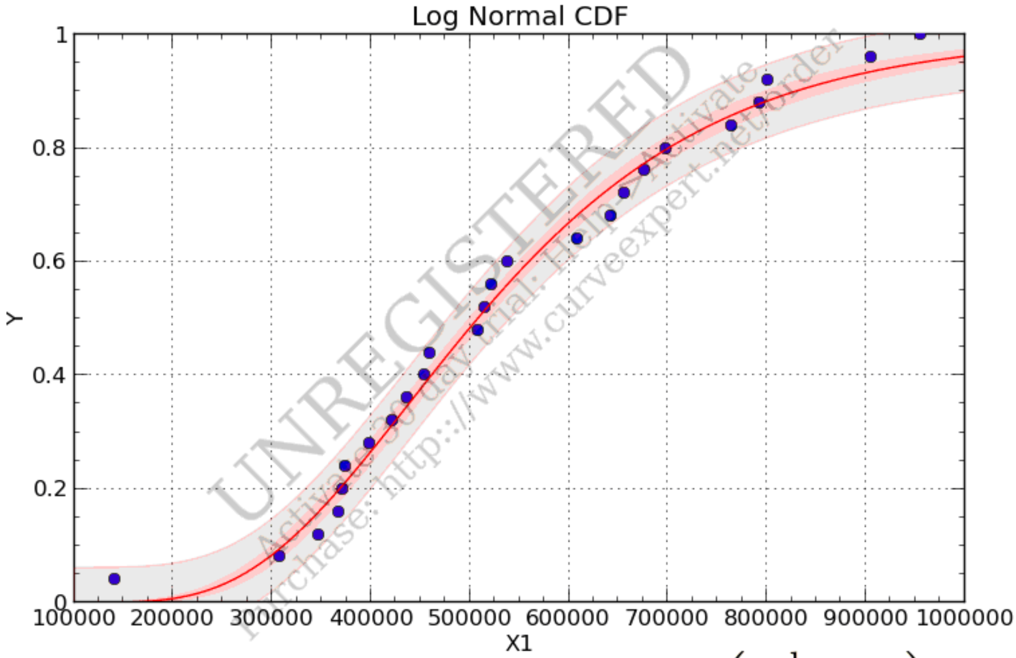
Concrete $$y=\frac{1}{2}\operatorname{erfc}\left(-\frac{\ln x-\mu}{\sigma\sqrt{2}}\right)$$



Reinforcement $$y=\frac{1}{2}\left[1+\operatorname{erf}\left(\frac{x-\mu}{\sigma\sqrt{2}}\right)\right]$$



Formwork $y = \frac{1}{2}\operatorname{erfc}\left(-\frac{\ln x - \mu}{\sigma\sqrt{2}}\right)$



Formwork 1 $y = \frac{1}{2}\operatorname{erfc}\left(-\frac{\ln x - \mu}{\sigma\sqrt{2}}\right)$