

# Judgemental Risk Analysis Process Development in Construction Projects

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**Abstract:** Every Software project by its inherent nature and contains significant numbers of uncertainty from various perspectives such as time to market, budget and schedule estimation, product maintenance . if failing to the control these un certainties it imposes potential risk not only during the developing phases but also throughout the life cycle of the product. Software Risk Management is an effective tool to control these risks and project success .The risk Management practice is not always possible due resource problems, more emphasize on budget and schedule constrains and difficulties to concretely estimate the benefits of Risk management. Various risks and uncertainties exist in construction projects. These may not only prevent the projects to be completed within budget and time limit, but also threaten the quality, safety and operational needs. In this context, risk analysis processes are the systematic methods to analyze the potential project risks and develop risk response strategies in order to cope with risks and achieve the desired objectives. This study proposes a new schedule risk analysis method named as Judgmental Risk Analysis Process (JRAP) and offers a different project duration equation through JRAP. The process (JRAP) can be defined as a pessimistic risk analysis methodology or a hypothesis based on Monte Carlo simulation that is effective in uncertain conditions due to its capability of converting uncertainty to risk judgmentally in construction projects. A case study has also been developed to show how the proposed process is applied on a construction project and to prove its validity.

**Keywords:** Risk, Risk Analysis, Project risk analysis and project scope, JRAP methodology

## I. INTRODUCTION

Risk analysis is the systematic study of uncertainties and risks we encounter in business, engineering, public policy, and many other areas. [1] Risk analysts seek to identify the risks faced by an institution or business unit, understand how and when they arise, and estimate the impact of adverse outcomes. Risk managers start with Risk analysis, then seek to take actions that will hedge these risks. Risk is inevitable in a business organization when undertaking projects. Risk can be mainly divided into two types ie, 1.Negative impact risk 2.positive impact risk these are the two types of risk in risk analysis .not all the time project managers facing negative impact risks too .once the risk has been identified ,project managers need to come up with a plan or any other solution to counter attack the risk. Each construction project has unique features that differentiate it from even resembling projects. [2] Construction techniques, design, contract types, liabilities, weather, soil conditions, politic-economic environment and many other aspects may be different for every new commitment. This fuzzy atmosphere has been represented with the terms ‘uncertainty’ or ‘risk’ by construction managers and researchers, and they tried to control this systematically through risk management and analysis methods since the early 1990s . Some researchers like Flanagan et al. and Pilcher put differentiation between these two terms.

## II. DEALING WITH RISK

[1] **Risk analysis** is the systematic study of **uncertainties** and **risks** we encounter in business, engineering, public policy, and many other areas. **Risk analysts** seek to identify the risks faced by an institution or business unit, understand how and when they arise, and estimate the impact (financial or otherwise) of adverse outcomes. **Risk managers** start with risk analysis, then seek to take actions that will **mitigate** or **hedge** these risks. Some institutions, such as banks and investment management firms, are in the business of taking risks every day. [3] Risk analysis and management is clearly crucial for these institutions. One of the roles of risk management in these firms is to quantify the financial risks involved in each investment, trading, or other business activity, and allocate a risk budget across these activities. Banks in particular are required by their regulators to identify and quantify their risks, often computing measures such as Value at Risk (VaR), and ensure that they have adequate capital to maintain solvency should the worst (or near-worst) outcomes occur.

- Quantitative risk analysis
- Models and simulation
- Monte carlo simulation

#### A. Quantitative Risk Analysis

[1] **Quantitative risk analysis** is the practice of creating a **mathematical model** of a project or process that explicitly includes uncertain parameters that we cannot control, and also *decision variables* or parameters that we *can* control. A quantitative **risk model** calculates the impact of the uncertain parameters and the decisions we make on outcomes that we care about -- such as profit and loss, investment returns, environmental consequences, and the like. Such a model can help business decision makers and public policy makers understand the **impact of uncertainty** and the consequences of different decisions.

#### B. Models and Simulation

One way to learn how to deal with uncertainty is to perform an experiment. But often, it is too dangerous or expensive to perform an experiment in the "real world" so we resort to using **models** -- such as a scale model of an airplane in a wind tunnel. With a model, we can perform many **experiments to simulate** what could happen in the real world. For example, subjecting our model airplane to various air currents and forces, we might learn how an actual aircraft design is likely to behave in the real world. We can introduce **uncertainty** into our experiments by allowing some conditions to vary randomly. A single experiment that involves a randomly generated condition might not tell us very much, but if we perform a **simulation** that consists of *many* such experiments (or **random trials**), and collect **statistics** about the results, we can learn quite a lot.

If we have the skills and **software tools** needed to create a mathematical model of a project or process on a computer, we can perform a simulation with many trials in a **very short time**, and at **very low cost**. With such advantages over experiments in the real world, it's no wonder that computer-based simulation has become so popular. For business models, Microsoft Excel is an ideal tool for creating such a model -- and simulation software such as Frontline Systems' **Risk slover** can be used to get maximum insight from the model.

#### C. Monte Carlo Simulation

**Monte Carlo simulation** -- named after the city in Monaco famed for its casinos and games of chance -- is a powerful mathematical method for conducting quantitative risk analysis. **Monte Carlo methods** rely on **random sampling** -- the computer-based equivalent of a coin toss, dice roll, or roulette wheel. The numbers from random sampling are "plugged into" a mathematical model and used to calculate outcomes of interest. This process is repeated many hundreds or thousands of times. With the aid of software, we can obtain statistics and view charts and graphs of the results.

Monte Carlo simulation is especially helpful when there are several **different sources of uncertainty** that interact to produce an outcome. For example, if we're dealing with uncertain market demand, competitors' pricing, and variable production and raw materials costs **at the same time**, it can be very difficult to estimate the impacts of these factors -- in combination -- on Net Profit. Monte Carlo simulation can **quickly analyze thousands** of 'what-if' scenarios, often yielding surprising insights into what can go right, what can go wrong, and what we can do about it.

### III. THE PROCESS OF RISK ANALYSIS

The process of risk analysis includes identifying and quantifying uncertainties, estimating their impact on outcomes that we care about, building a risk analysis model that expresses these elements in quantitative form, exploring the model through simulation and sensitivity analysis, and making risk management decisions that can help us avoid, mitigate, or otherwise deal with risk.

- Identify and Quantify Uncertainty
- Compute the Impact of Uncertainty
- Complete a risk analysis model
- Explore the model with simulation
- Analyze the model results
- Make decisions to better manage risk

#### A. Identify and Quantify Uncertainty

In risk analysis, our goal is to **identify** each important source of uncertainty, and **quantify its magnitude** as well as we can. For example, we may not know our competitor's exact price, but we can place bounds on it, based on known production and marketing costs. While we can't predict the exact number of people shopping at a store each day, we can examine past data for the **frequency** of days when (say) 10, 20, 30, ..., 100 people shopped, and use this to estimate

a **distribution** of shoppers on future days. This process of identifying and quantifying uncertainties is a **key step** in risk analysis.

**B. Compute the Impact of Uncertainty**

Our next step is to accurately estimate the **impact** of the uncertainties on the outcomes we care about. For example, we may not be able to predict demand for our product exactly; but given a number for demand, since we know our costs and margins, we can often calculate the impact on our Net Profit. We may not know the exact number of shoppers on any future day; but given a number of shoppers, we can calculate how many store salespeople we need to service them, and estimate the sales we're likely to generate. In doing this, we **build a model** that allows us to compute "outputs" -- outcomes such as Net Profit -- for any given "inputs".

**C. Complete a Risk Analysis Model**

If we can complete these steps, we'll have a **risk analysis model** (or simply **risk model**). The model has **inputs** which are uncertain -- these may be called uncertain variables, random variables, assumptions, or simply inputs. For any given set of input values, the model calculates **outputs** -- outcomes such as Net Profit. Unlike other kinds of models, a risk analysis model requires us to **think in ranges**: Because the **inputs are uncertain** and may take on many different values, the **outputs are also uncertain** and may take on a **range of values**. If management asks, "Give me a number for next year's sales", a risk analyst must respond that a single number is not going to be meaningful -- it will defeat the purpose of risk analysis.

**D. Explore the Model with Simulation**

We can use our **risk model** in several ways -- but one effective way is to explore the possible outcomes using **simulation**. For a model in Excel, we can use software, such as Frontline's Risk Solver, to perform a **Monte Carlo simulation** on our model. Simulation performs many (thousands of) experiments or **trials** -- each one **samples** possible values for the uncertain inputs, and calculates the corresponding output values for that trial. The first run of a simulation model can often yield results that are surprising to the modelers or to management -- especially when there are several different **sources of uncertainty** that interact to produce an outcome. Even before an in-depth analysis of the results, simply seeing the **range of outcomes** -- for example, how low and how high Net Profit can be, given our model and sources of uncertainty -- can encourage a re-thinking of the risks we face, and the actions we can take.

**E. Analyze the Model Results**

Because a simulation yields many possible values for the outcomes we care about -- from Net Profit to environmental impact -- some work is needed to **analyze the results**. For instance, we can summarize the range of outcomes using various kinds of **statistics**, such as the mean or median, the standard deviation and variance, or the 5th and 95th percentile or Value at Risk. It is also very useful to create charts to help us visualize the results -- such as **frequency charts** and **cumulative frequency charts**

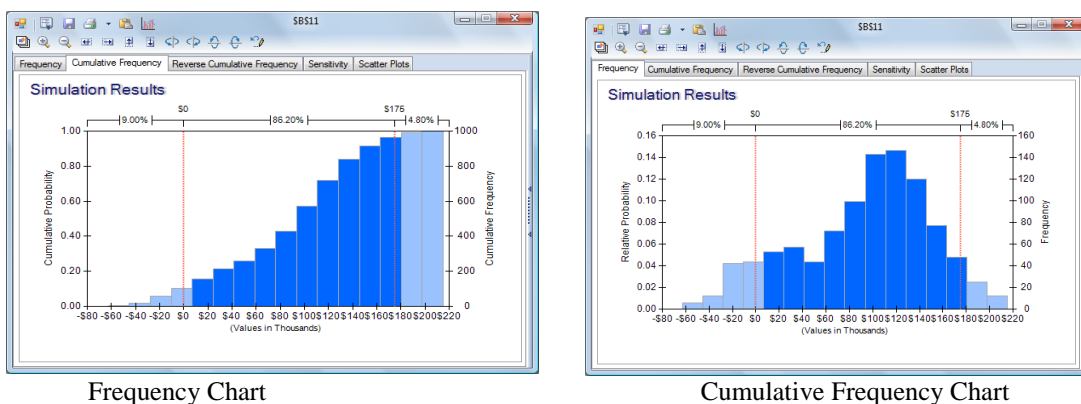


Fig:1

Another powerful tool for assessing model results is **sensitivity analysis**, which can help us identify the uncertain inputs with the biggest impact on our key outcomes. Using software, we can also run **multiple simulations**, with an input we choose taking a different value on each simulation, and assess the results. Analyzing the model can give us more information, but also **insight** about our real-world problem. For example, a **tornado chart** can give us a quick visual summary of the uncertainties with the greatest positive and negative impact on Net Profit.

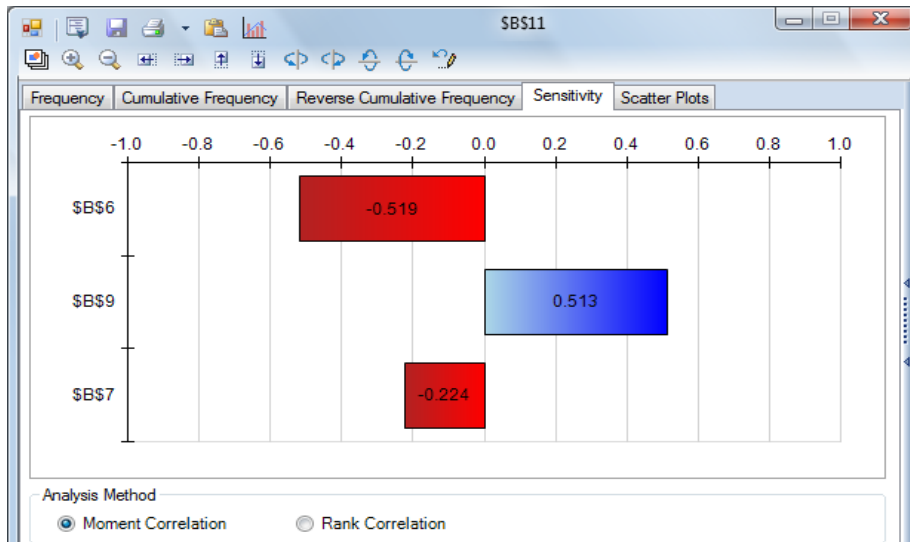


Fig: 2 uncertainties with the greatest positive and negative impact on Net Profit.

**F. Make Decisions to Better Manage Risk**

The payoff comes when we use our risk analysis model and simulation results to make choices or decisions, that may help us avoid or mitigate risk -- or perhaps earn greater returns that help compensate us for taking these risks. We can also compare the risk and return of different projects or investments, and we can seek to diversify our position so that no single risk can do too much harm. [5] By doing this, we can practice risk management While we can't avoid uncertainty and risk altogether, there are often many steps we can take to better cope with risk. Risk analysis helps us determine the right steps to take. Our next step in this Tutorial is to take a closer look at a risk analysis model.

**1) Using Models for Risk Analysis**

[6] A risk analysis model could be a physical scale model, but it is most often a mathematical model. The model can be created by writing code in a programming language, statements in a simulation modeling language, or formulas in a Microsoft Excel spreadsheet. Regardless of how it is expressed, a risk analysis model will include:

- Model inputs that are uncertain numbers -- we'll call these uncertain variables
- Intermediate calculations as required
- Model outputs that depend on the inputs -- we'll call these uncertain functions

It is essential to realize that model outputs that depend on uncertain inputs are uncertain themselves -- hence we talk about uncertain variables and uncertain functions. To make use of a risk analysis model, we will test many different numeric values for the uncertain input variables, and we'll obtain many different numeric values for the uncertain output functions. We'll use statistics to analyze and summarize all the values for the uncertain functions (and, if we wish, the uncertain variables).

- a• Creating the Model
- b• Model Simplification

a. Creating the Model

	A	B	C	D	E	F	G
1							
2	<b>Financial Results</b>			<b>Market Scenarios</b>			
3					Low Demand	High Demand	Average
4	Sales in units	60,000		Sales units	60,000	100,000	80,000
5	Price per unit	\$10.00		Price per unit	\$10.00	\$8.00	
6	Unit cost	\$7.07					
7	Fixed costs	\$30,000			<b>Unit Cost Scenarios</b>		
8					Low	High	Average
9	Net Profit	\$146,070			\$6.00	\$9.00	\$7.50
10	True Average	\$69,517					
11							

Since a risk analysis model will be subject to intensive computations, you'll generally want to create the model using available risk analysis tools. An Excel spreadsheet can be a simple, yet powerful tool for creating your model --

especially when paired with Monte Carlo simulation software such as Risk Solver. If your model is written in a programming language, Monte Carlo simulation toolkits like the one in Frontline's Solver SDK Platform provide powerful aids.

An example model in Excel might look like this, where cell B6 contains a formula =PsiTriangular(E9,G9,F9) to sample values for the uncertain variable Unit cost, and cell B10 contains a formula =PsiMean(B9) to obtain the mean value of Net Profit across all trials of the simulation.

### Model Simplification

Like all models, a risk analysis model is a **simplification** and **approximation** of reality. The art of modeling involves choices of what **essential factors** must be included, and what factors may be ignored or safely excluded from the model. As Albert Einstein suggested, a model should be "as simple as possible, but no simpler."

We must also choose what **sample values** to test for the uncertain variables. Simulation software such as Risk Solver lets us draw sample values from scores of different probability distributions. While we should do our best to choose the right sample values, we derive a great benefit simply by moving from **fixed values** to almost any reasonable **sample** of values for an uncertain quantity.

Dr. Sam Savage likes to use the analogy of **shaking a ladder** before you use it to climb up on a roof. When you do this, you subject the ladder to a random set of forces, to see how it behaves. Even though the forces when you are shaking are not distributed in the same way as the forces when you are climbing, shaking a ladder is still a good "stress test" in advance.

## IV. RISK ANALYSIS SOFTWARE

[2] **Risk analysis software** covers a wide spectrum of capabilities and price points, from under-\$1,000 general-purpose packages to \$100,000 and much higher priced packages tailored for banks, insurance companies and enterprise risk managers in large corporations. Our focus here is on lower-cost general-purpose packages that offer great flexibility, but require that you "roll your own" **risk analysis model**. The most popular packages perform Monte Carlo simulation of models created in Microsoft Excel, with a surprising range of technical capabilities.

### Some capabilities to look for in a general-purpose package:

- High-quality (long-period and well-equidistributed) **random number** generation
- **Latin Hypercube** and/or **Quasi Monte Carlo** based sampling for variance reduction
- A wide range of analytic **probability distributions** -- leading packages have 40 or more
- Flexible creation of **custom distributions**, both continuous and discrete
- Ability to **correlate** dissimilar distributions, typically via **rank order correlation**
- Ability to **fit analytic distributions** to user-supplied data or to simulation results
- **Statistics** to measure central tendency and variation, **quantile measures**, and **confidence intervals**
- Easily created but customizable **charts and graphs** of PDFs, CDFs, frequencies and cumulative frequencies
- **Sensitivity analysis** of outputs against uncertain inputs
- Ability to run **multiple simulations**, varying parameters across the simulations

### Some advanced capabilities available in the best packages:

- **Shifting and truncation** of analytic distributions
- Independent **streams of random numbers** for different distributions
- Ability to run "**trace simulations**" using pre-generated simulation trials
- Ability to model **conditional distributions** in simulation results
- Ability to find optimal or near-optimal decisions using **simulation optimization**
- Ability to **create** (analytic or custom) distributions and **share** them among modelers
- Ability to create **custom risk analysis applications**, and distribute them to end users
- And of course, the **fastest possible** execution of simulation trials

## V. JRAP METHODOLOGY

The JRAP proposed in this research consists of a number of managerial steps to be carried out and an equation that offers the variation in each activity's duration in the schedule network. The characteristics of JRAP make this methodology effective in uncertain conditions of which there is no or little previous data and increases its applicability for converting high level of uncertainty to risk judgmentally. Since, judgmental decisions based on experience and intuition would insert additional risks to the project network model, a pessimistic way has been followed in analyzing the overall project duration. In other words, the pessimistic characteristic of JRAP decreases the effect of planning



engineer's making inaccurate data estimation during risk modelling. This pessimism is created through the computing characteristics of the proposed equation that is introduced within JRAP.

Another important point that should be mentioned about JRAP is that it is not a whole risk management system, rather it is considered as an analysis stage that is performed during the configuration of a risk management system. JRAP can be defined as a pessimistic risk analysis methodology or a hypothesis that is effective in schedule risk modelling of even the most uncertain situations in construction projects.

of risks that are effective on critical activities explored during the critical path analysis (refer to Fig. 1). The critical risks of the project are determined as: defective design, design changes, subcontractors' default, fluctuation in labor productivity, delay in resolving disputes, difficulties/delays in availability of materials, equipment and labor, inadequate quality of work and need for correction, promoter delays (unable to get approvals, lack of payment, etc.), and changes in quantity/scope of work ..

Three different computer package programs namely MS Project, MS Excel and Crystal Ball have been used during this JRAP application. Before producing the spreadsheet risk model, activity-risk factor matrix has been formed. Table 2 presents activity-risk factor matrix of the bank decoration project. Afterwards, the remaining steps of JRAP, which are 'assigning probability distributions and maximum–minimum durations', and 'modelling and simulating' have been carried out subsequently

The cell at the bottom of the 'late finish time' column gives the total project duration and it is related

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## VI. CONCLUSION

The aim of this paper was to propose a time schedule risk analysis methodology that is applicable on construction projects. This methodology, which is named as Judgmental Risk Analysis Process (JRAP), can be considered as a different approach to the analysis stage of risk management systems. Judgmental Risk Analysis Process is comprised of a number of steps as shown in

The methodology is mainly based on MCS and an equation that is proposed in the preceding sections. This equation (Eq. (1)) enables the planner to observe the variation in activity durations during MCS. These simulated values regarding the activity durations are then utilized in the spreadsheet risk model through arithmetic formulas that are produced according to the logical relationships between the activities of the time schedule network.

The reason for the proposed risk analysis method to be qualified as 'judgmental' is that the lack of historical data related to the activities of the time schedule network does not interfere with performing risk analysis on the network, i.e. engineering judgment, experience and intuition of the planner have all been utilized through JRAP. Obviously, such an analysis strategy would create additional risks due to the subjective data used. Nevertheless, the pessimistic character of the proposed activity duration equation (Eq. (1)) and skewness in probability distributions assigned to critical risks compensate this undesired situation.

The other objective of the present research was to illustrate the application of JRAP using a construction project data. For this, JRAP was applied on a bank decoration project using the computer package programs, which are MS Project, MS Excel and Crystal Ball. The results of the case study have shown that JRAP has been capable of answering the questions such as:

In how many days and with how much probability it is possible to complete the project?

Which activities are the most critical activities?

Which risk elements are more effective on project duration?

The answers to such questions are obviously useful to make sound decisions prior to the contracting. As in the case study, the project completion duration specified in the contract, which is 57 days, came out to be only a big mistake because the results of JRAP has shown that the total project duration is 114.6 days with 90% and 124.8 days with 100% probability. The commissioning documents of the project have already supported this result because the construction has been completed in exactly 122 days, i.e. 65 days after the negotiated contract deadline.

As a general concluding remark, JRAP stands as a practical schedule risk analysis methodology in the overall risk management framework and it also contributes to the dynamism of the risk management system through its stochastic characteristics. However, it is open to development through its application over more complex construction projects of longer durations from different categories. Furthermore, the methodology can be modified and converted into a more

data (past record)-dependent characteristic by adaptation of modern techniques Igenetic algorithms, artificial neural networks and expert systems.

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