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Reviewing of the Simulation Models in Cost Management of the Construction Projects

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Abstract

Simulation and computational techniques cover a variety of aspects also had proved its feasibility in construction management as whole, so it had adopted by a lot of researches during the last decades with rapid progress. The current study presents a focused review about construction cost simulation using, and provides an overview of such advancements achieved between 1990 and 2016 in construction management sector. This paper focuses specifically on many different topics including construction cost simulation, simulation modelling concept, steps of simulation conducting, simulation purposes, simulation advantages and disadvantages, etc. Major advances in construction cost simulation area are highlighted, as well as the trends for development and application. Over the selected study period, there has been a substantial increase in the use of high-fidelity simulation in construction cost management.

Keywords: Cost Management; Cost Simulation Modelling; Construction Projects; Simulation Purposes.

1. Introduction

Simulation concept is an expanding concept which is used in various fields such as economics and engineering. Simulation has been used extensively to study many complex decision problems that could not be effectively handled by other analytic methodologies. Simulation is a technique that uses computers to imitate the operations of various kinds of real-world systems and provides insights, support decisions, and prescribes policies about the system. In a construction project, many uncertain variables that may influence project objectives are productivities of crews and equipment, subsurface site conditions, weather, and so on. Therefore, in addition to traditional statistical methods, stochastic simulation methods are popularly used to deal with such random variables and to analyze their impact on project objectives, such as project completion time and costs [1].

2. Cost Management Techniques in Planning Phase of Construction Projects

The main advantage of cost management process is to provide direction for the project costs management during the project life. This process is the approach that presents the procedures, documentation, and policies, for planning, managing, expending, and controlling the construction costs. BMBOK set out a number of techniques that can be benefit in cost management process during planning phase of construction project, which they are [2]:

- Expert judgment: combines the expert judgment with previous historical data, and provides good insight to cost management plan.
- Analytical techniques: these techniques could consist of, internal rate of return, payback period, net present value; and return on investment,

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- Meetings: repeated meetings of project teams could help in developing a proper plan of cost management. The parties of these meetings could include the project manager, the project sponsor, some of project management team members, anyone who has a direct responsibility with project costs, selected stakeholders, and others as required.

3. Cost Control

This process is for monitoring the project status to be the project costs updated continuously and for managing changes on the cost baseline. The main advantage of control cost is to provide the proposals to distinguish the variance from the planned in order to be the corrective action taken to minimize the risk. Project cost control process includes the following actions [2]:

- Affecting the factors that generate variations to the cost baseline.
- Management of the actual variations when or before they occur.
- Conforming that the expenditures will not exceed the specified balance by time.
- Monitoring cost performance with time to avoid or at least understand the variances from the specified cost baseline.
- Preventing unacceptable changes from occurring.
- Informing the stakeholders about all approved changes with their associated cost.
- Making the cost overrun within acceptable limits.

4. Concept of Simulation Approach

There are a lot of authors who define simulation modelling, Taha [3] defined the simulation in a way, simulation may be considered as the next best thing to investigate the real system. In addition, simulation is flexible and can be used to analyse practically or mathematically the specified system. The same reference indicated some notions about the simulation; the use of simulation is not without drawbacks. The process of developing simulation model may be costly in both time and resources. Moreover, the execution of simulation models, even on the fastest computer, is usually slow. The art of modelling is defined as true representations of real situation. The model expresses in amenable manner the mathematical functions that represent the behaviour of real world.

Simulation modelling is the process of creating and experimenting with a computerized mathematical model for the system, a system is defined as (according to the same reference) a collection of interacting components that receives input and provides output for some purposes [4].

Simulation, according to Robert E. Shannon [5] (1975), is defined as "the process of designing a model of a real system and conducting experiments with this model for the purpose either of understanding of system disposal or of evaluating various strategies (within the limits imposed by a criterion or set of criteria) for the operation of the system".

A simulation can be a discrete-event simulation or Continuous-event simulation. The simulation model is actually a copy of the real system on which experiments (or scenarios) can be run to evaluate various strategies (such as how to respond to a drastic change in the forecast). Simulation can mimic the dynamic behaviour of a system. That is what it is built to do. Regardless of how complex a system may be, it is likely that a simulation expert will be able to create a model that will evaluate it. However, the more complex a system is, the longer it takes to model, run and evaluate. The modeller (or the person analysing the system) must have a good understanding of simulation statistics. It is important during the creation of the model so that input distributions are used properly. It is important during the analysis of the output statistics so that the output is not misinterpreted. Mistakes with either the inputs or the outputs will cause the simulation analysis to be invalid [6].

Simulation optimization is used to identify the optimal solution of a system, which is represented by a simulation model, through the manipulation of the systems' decision variables and the evaluation of the simulation model's output measures. Usually, simulation models are created to identify improvement opportunities; hence, generally, the simulation analyst is interested in using optimization to determine the optimal solution [7].

Simulation is a tool to evaluate the performance of a system, existing or proposed, under different configurations of interest and over long periods of real time. Simulation is used before an existing system is changed or a new system built, to reduce the chances of failure, to meet specifications, to eliminate unforeseen bottlenecks, to prevent under or over-utilization of resources, and to optimize system performance[8].

Al-zwainy [9], defined the simulation as a flexible tool to resolve the complex situations in order to gain the optimal results.

Simulation is an experimental technique, by using it, made it is easier to asses many different alternatives by comparing their impact on utilization of resources, cycle time, and cost. In other words, all simulation models produce important improvements without introducing complicated technologies or making huge changes to the system. In fact, the simulation model in construction, the only change is the rescheduling the activities sequence [10].

This study has defined simulation as the process by which, the simulator keeps up the actual system by making a number of experiments at the moment to predict the system behaviour in the future.

5. Purposes of Simulation

Displaying the models makes it possible to locate bottlenecks in construction operations, helps to reduce the untapped resources, re-sequence of process steps to influence positively the final product In addition to, the simulations are done economically on the computer with in shorten the time [11].

Simulation models consist of the following components: system entities, input variables, performance measures, and functional relationships [8].

A good designed model should be [8]:

- A close approximation to the real system and incorporate most of its salient features;
- On the other hand, it should not be so complex that it is impossible to understand and experiment with it; and
- A good model is a judicious tradeoff between realism and simplicity.

Amongst the numerous people who are potentially relevant to include in a modeling investigation are [38]:

- Decision maker(s): those who will base decisions, at least partly, on model output.
- Stakeholders: those who will potentially be affected by judgments formulated by the decision makers.
- Technical experts: those who will provide information during the modeling process. These people may have expertise regarding individual components of a system, the entire system or a similar system.
- Analysts: those who carry out the modeling exercise.

Simulation modeling with different types of systems is conducted for the purposes of:

- Gaining insight into the operation of a system:

  Some systems are so complex that it is difficult to understand the operation of and interactions within the system without a dynamic model. A typical example of this would be to try to understand how manufacturing process bottlenecks occur [4].

- Developing operating or resource policies to improve system performance:

  There are many existing systems that are understandable but wish to improve. Two fundamental ways of doing this are to change operating or resource policies. Changes in operating policies could include different scheduling priorities for work orders. Changes in resource policies could include staffing levels for example [4].

- Testing new concepts and/or systems before implementation:

  If a system does not yet exist, a simulation model can help give the simulator an idea of how well the proposed system will perform. The cost of modeling a new system can be very small in comparison to the capital investment involved in installing any significant manufacturing process. The effects of different levels and expenses of equipment can be evaluated by the simulation model [4].

- Gaining information without disturbing the actual system:

  Simulation models are possibly the only method available for experimentation with systems that cannot be disturbed. Some systems are so critical or sensitive that it is not possible to make any types of operating or resource policy changes to analyze the system. The security checkpoint at airport is an example of this type of systems [4].

- It is impossible or extremely expensive to observe certain processes in the real world, e.g., the effect of Internet advertising on a company’s sales. So, the simulation can be a suitable solution [8].
- By changing the inputs to observe the outputs during run the simulation, the important variables that can affect the actual system may be indicated by the simulation [13].
- Problems in which mathematical model can be formulated but analytic solutions are either impossible (e.g., high order difference equations) or too complicated (e.g., complex systems like the stock market) [7].
- It is impossible or extremely expensive to validate the mathematical model describing the system, e.g., due to insufficient data [8].

Although simulation has many advantages, there are also some considerations of which the simulation practitioner should be aware. These considerations are not really directly associated with the analysis of a system but rather with the expectations associated with simulation projects [8], some of them are:

- Simulation cannot give accurate results when the input data are inaccurate: no matter how good a model is developed, if the model does not have accurate input data, the practitioner cannot reasonably expect to obtain accurate output data. Unfortunately, data collection is considered the most difficult part of the simulation process
- Simulation cannot provide easy answers to complex problems: some analysts may believe that a simulation analysis will provide simple answers to complex problems. But, In fact, it is more likely that complex answers are required for complex problems.
- Simulation alone cannot solve problems: some managers, on the other hand, may believe that conducting a simulation model and analysis, project will solve the problem. Simulation by itself does not actually solve the problem. It provides the management with potential solutions to solve the problem.

6. Types of Simulation Models

Simulation models are divides into many types, according to the varying pattern of the system variable. The study had joined these types name in Figure 1:

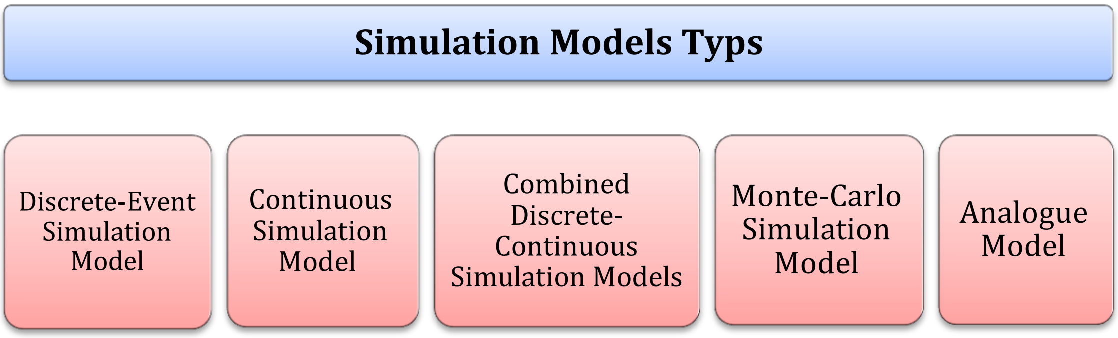

Figure 1. Simulation models types

6.1. Discrete-Event Simulation Model

The power of discrete-event simulation is the ability to mimic the dynamics of a real system. Many models, including high-powered optimization models, cannot take into account the dynamics of a real system. This property gives discrete-event simulation its structure, its function, and its unique way to analyse results [6].

In this type of simulation models, changes in its state occur at discrete points of time. For instance, in brickwork activity, the events included in this activity are, carrying bricks, mixing mortar, and so on. The time depends on starting and stopping time of these events so it jumps from one event to another. The most popular simulation model used by management scientists is Discrete-event simulation model in comparing with other types [11].

6.2. Continuous Simulation Model

In this type of models, the variables of the system under study change with time. For instance, the water level in a dam changed continuously with passing the time. Usually, this type of simulation models uses the differential equations. Management scientist, rarely depend on continuous simulation model [11].

6.3. Combined Discrete-Continuous Simulation Models

As the indication referred to by the name, this type of simulation model involves the occurrence of both continuous and discrete changes. This type of simulation model is useful in construction planning. In a way, the effects of varying the weather conditions on the activity durations or project productivity are simulated by using continuous simulation models. Then, these effects are incorporated with discrete simulation model that simulates the activities network of the project [14].

6.4. Monte-Carlo Simulation Model

Monte Carlo simulation is a type of simulation that relies on repeated random sampling and statistical analysis to compute the results. This method of simulation is very closely related to random experiments, experiments for which the specific result is not known in advance. In this context, Monte-Carlo simulation can be considered as a methodical way of doing so-called what-if analysis [15].

6.5. Analogue Model

Analogue model represents the original system in a way, which is simple to perform the mathematical operations and to treat, to obtain the desired results. Another definition for this type, is a representation of the mechanical system with a simple electrical system, since the treatment with the latter is simpler than treating the former [9]. These models can simulate different types of physical models in order to obtain the close results of complex integral-differential equations. This model can be done by connecting the variables of system with a set of differential equations and then, solving itself by using analogue program [16].

7. Results and Discussion

This section provides more information regarding each step in the simulation modelling process which they listed in Figure 2. below:

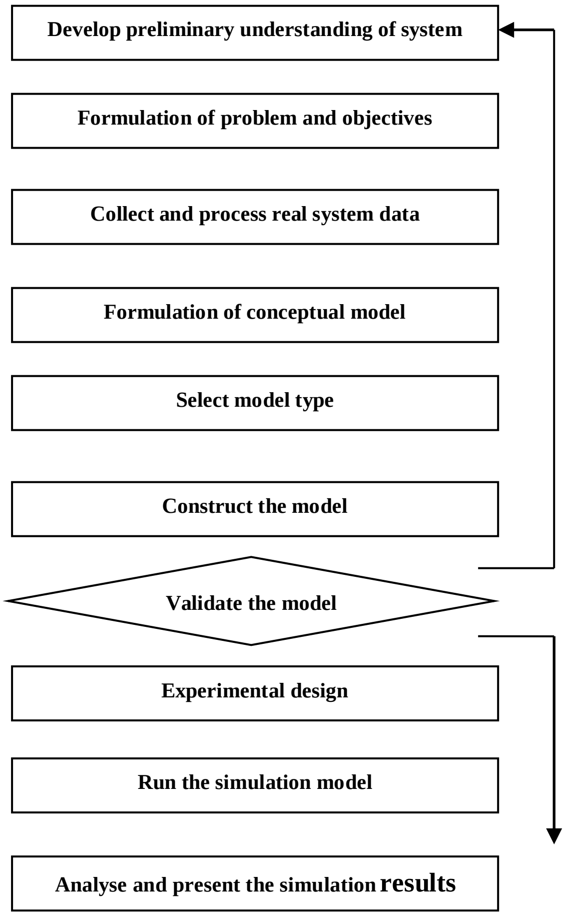

Figure 2. Simulation modelling procedures [12]

7.1. Develop Preliminary Understanding of System

Motivation to begin a modelling study may begin from personal interest or through a request by others. In any case, to be relevant, the analysis requires an in-depth understanding of the system under study. This is a key goal of the modelling process overall, but some preliminary knowledge is necessary to provide context to problem and objective formulation (Formulation of problem and objectives) and guide the development or selection of appropriate conceptual and simulation models. This step can involve literature reviewing, participation in the system or personal discussions [12].

7.2. Formulation of Problem and Objectives

Problem definition is a critical part of a modelling investigation. It increases awareness of the key focus of the analysis and its scope. Formulation of a problem statement and a problem structure allows an analyst to appreciate the different facets of the problem. Problem structure requires identification of the decision maker(s), their objectives, their decision criteria, their decision variables, the relationship between decisions and outcomes, constraints on decisions, and the person who benefits from decisions. A structured problem definition allows the statement of concise objectives that state the proposed, practical outcomes that the modelling study seeks to achieve. Objectives should also be specific, measurable, achievable, relevant and time-bound. This ensures that [12]:

- The scale and scope of the project are defined.
- The precision of model output is explicitly outlined.
- The intended outcomes of the analysis can be rigorously stated such that the degree to which these are achieved can be ascertained.
- Objectives are directly focused at the alleviation of the issue defined by the problem statement.
- The project plan is feasible in terms of methods and time.

7.3. Collect and Process Real System Data

Data collection is a primary component of many modelling studies and can exhaust more than half of the time available for an analysis. Compilation, analysis and evaluation of existing data are undertaken to provide suitable input values and provide for satisfactory model validation. Interaction with system experts is a key opportunity to review the quality of these data [12].

This step involves collect data on system specifications, input variables, as well as performance of the existing system. Identify sources of randomness in the system, i.e., the stochastic input variables. Select an appropriate input probability distribution for each stochastic input variable and estimate corresponding parameter(s) [8].

7.4. Formulation of Conceptual Model

Formulating a concise description of the structure or framework of the simulation model prior to its construction provides some a priori insight into whether the simulation models will [12]:

- Adequately address the objectives of the analysis
- Be completed subject to any expected resource constraints (Define and collate resources)
- Possess any potential limitations that may be needed to be addressed.

Develop schematics and network diagrams of the system (How do entities flow through the system?). To be ready these conceptual models to be translated to simulation software in acceptable form and verify that the simulation model executes as intended [35]. Formulation of the conceptual model requires analysts to make explicit preliminary descriptions of the problem boundary (i.e. which system factors are included/excluded), the main components of the problem, the characteristics of those components, relationships between components, how components will be represented in the simulation model, the resolution with which each component will be described, the nature of inputs, the nature of outputs, key data sources, and key assumptions [17].

7.5. Select Model Type

An understanding of the strengths and limitations of a method in the context of a given problem ensures that the solution method is appropriate and that its limitations have been minimized through appropriate procedures. The suitability of a method is determined by its capacity to describe important features of the problem structure, the type of inputs available, the type of outputs required and proposed level of abstraction [12].

7.6. Model Construction

Model construction is a stage that is visited often in the modelling process. The gradual evolution of a model from a small, simple framework to a larger, more complex framework allows efficient identification of limitations of the model structure and its coding. Systematic and deliberate expansion of the model helps to identify apparent errors. Indeed, rapid extension can delay model development considerably by complicating the identification of errors [9].

Another key benefit of systematic model development is that preliminary results provide a general indication of the nature of model output that will be obtained in the final version of the model. Results will change as the model becomes more sophisticated, but this preliminary information allows tactical decisions to be made regarding the sufficiency of model type, structure and inputs. Early results may motivate the use of another method, thus reducing the investment of resources in a flawed system description. Alternatively, they may reveal a simpler model specification to be sufficient [12].

7.7. Model Validation

Once the model has been constructed it is necessary to test and validate the constructed model. Several kinds of validity are provided can be made. One involves checking the program of computer to verify that it works as the model builder intended. By running the program with historical data, this can be determined whether the model performs as the real system or not during the specified historical period [9].

The validation compares the model's performance under known conditions with the performance of the real system. Perform statistical inference tests and get the model examined by system experts. Assess the confidence that the end user places on the model and address problems if any. For major simulation studies, experienced consultants advocate a structured presentation of the model by the simulation analyst(s) before an audience of management and system experts. This not only ensures that the model assumptions are correct, complete and consistent, but also enhances confidence in the model [8].

7.8. Experimental Design

Once the model has been constructed and validated, the next step is to establish carefully the experiments that are to be achieved with the model. This process include ,Selection appropriate experimental design, Select a performance measure, a few input variables that are likely to influence it, and the levels of each input variable [8].

The choice of experimental design alternatives is dependent on the original simulation project objectives developed during the problem formulation phase. In experimental design terminology, factors are the different variables thought to have an effect on the output performance of the system. These variables are controllable in that the practitioner can vary the levels in both the actual system and the simulation models. These may include as examples, Workers who perform specific functions, Machines that perform specific operations, Machine capacities, Priority sequencing policies, Worker schedules, and Stocking levels [4].

7.9. Simulation Run

Perform simulation runs according to the selected experimental design as explained in step eight [8].

7.10. Analyze and Present Simulation Results

The last step of the simulation model producing process is to analyse the simulation and present the results. This step may involve some statistics criteria (mean standard deviation, minimum value, and maximum value) on the performance measures. To present data this may include the following alternatives such as, Test hypotheses about system performance, Construct graphical displays (e.g., pie charts, histograms) of the output data, and Document results and conclusions [8].

8. Obstacles of Using Simulation Modeling in Construction Sector

The major causes which emerged against using simulation in the construction industry are lack of data; current simulation software; poor skills; nature of construction; and lack of methodology, as explained in the following Figure 3.

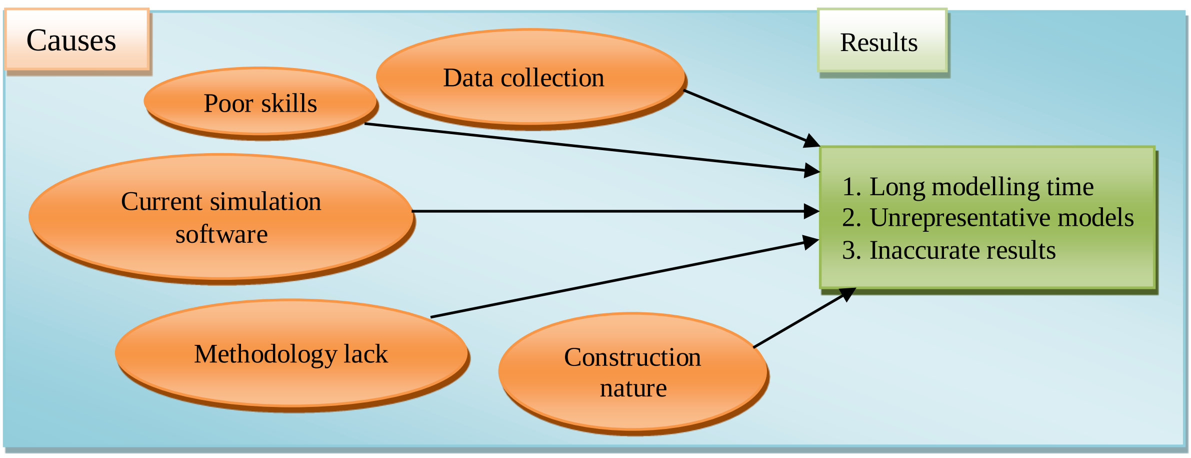

Figure 3. Drawbacks of using simulation in construction [18]

8.1. Data Collection

Data collection, which encompasses gathering and validating data, is typically a major activity in any simulation project, occupying up to forty percent of the total duration in manufacturing simulation project. Typical pitfalls when collecting data include:

System complexity leads the modeller to collect data in ad hoc manner; difficult to identify the available data sources; and poor quality of data available [18].

8.2. Poor Skills

There has been a lack of awareness about process simulation in construction, leading to construction managers without the necessary skills to be simulation. Those skills include the ability to translate an operational logic into a form which the computer understands, to be a competent statistician, and have the ability to draw valid conclusions and make recommendations based upon simulation experiments. Unskilled simulation can lead to the actual simulation projects over-running in duration, and models being incorrect [18].

8.3. Current Simulation Software

Inadequacies of previous simulation systems were cited as reasons why simulation has not been adopted by the construction industry. Recognized manufacturing standard simulation packages such as ARENA tend not to have been used in construction because of the fundamental differences between construction and manufacturing. The CYCLONE modelling methodology, developed primarily or construction, have been more widely accepted, mainly because they are easy to implement, and cost less. However, the amount of detail which can be modelled using these simpler packages is limited, which can lead to unrepresentative models [18].

8.4. Methodology Lack

Good modelling techniques and methods are left to the practitioner to develop intuitively, with no framework to follow. Inexperienced simulators take too long to build model and model critical factors incorrectly, thus invalidating the model [18].

8.5. Construction Nature

The construction site is a highly dynamic system, involving many interactions between different resources and activities, and is also far less controllable than its manufacturing equivalent, i.e. the factory floor. The factory floor is static (i.e. it does not alter significantly over time) which is in contrast to the construction site which alters daily as the building is constructed, foundations are laid, etc. Likewise, environmental factors such as weather may have to be incorporated into the model to make it representative of the system, adding complications to the modelling process. These complex factors make it difficult to model certain construction activities using present software [18].

9. Simulation Modeling Packages

Main reasons for the weakness of the spread of simulation software in the field of the construction sector generally and in the field of project management particularly belong to the following [19]:

- The absence of strong programs that have the ability to display the simulation operations;
- The difficulty of using these software;
- The complexity of the methods of preparing the model;
- The scope of use part of these software is very narrow Where they do not process construction problems in a comprehensive manner;
- In addition to the economic factor where the cost of this software is very high because they serve large construction sector firms, studies at universities, and scientific institutions.

Table 1. Includes the most popular simulation software which had gathered by the current study:

Table 1. Most Popular simulation software in construction sector

Package	Description
GPSS	Is the first simulation software that was produced by IBM company in the year of 1960 which is multifunctional [20].
PETRI NETS(PNs)	Developed by C. A. Petri in the year of 1962 which is use to model communication system, safety analysis and construction management [21].
VEHSIM	Produced by Caterpillar Company in the year of 1963 which explains the movement of equipment in different working conditions to choose the best alternative and thus achieve economic [20].
CYCLONE	It is an acronym of “CYCLic Operation Network” developed by D. W. Haplin in the year of 1976 to model and analyse construction operations, also it has a pure graphical nature that makes it easy to use [24].

STROBOSCOPE	It is an acronym for "State and Resource based simulation of Construction Processes". It was implemented by Julio Martinez as a part of his Ph.D dissertation research. Is a general-purpose simulation programming language which is used to model construction operations [11].
3DSIM	It is a recent simulation tool that supports the combine between risks and accuracy in activities Achievement time [22].
SIM PROD, SILK, AND JSIM	This more recent software, their building depends on VAJA programming language. Also it depends on internet so it allows the user handling the model and treats it anywhere in the world [23].

10. Applications of Cost Simulation in Project Management

Many researchers in construction sector had adopted simulation method in their studies. The following subsections are talking about local and international studies (which adopted simulation method) in an attempt to investigate the development in utilizing the simulation in construction sector generally and in project management particularly and in an attempt to highlight the difference among the previous studies and the current study.

10.1. Local applications of simulation in project management

Simulation approach was adopted in local researches for many different years in all engineering disciplines, in particular electrical engineering and computer engineering, but the study focused on researches done in the field of project management sector which adopted simulation method. The following sub-sections are a reviewing for some researches in the field of project management in Iraq:

In 1990, Yunis [13] built a simulation model, which is used as a game to train engineers in the field of the projects management in the construction sites. The model connects the network diagram information with the bill of quantities in such a way that permits the calculation cost of the project. In addition, the players take project manager role for the project planning.

In 1994, Al-Aanee [25] made a study to search for the effect of variations ratio in total project execution period by using a system similar to PERT technique but with little differences. This process was conducted by using computer simulation in the light of the following:

- The effect of different amounts of time variations in increasing according to contract conditions.
- The change effect on the project key resources which are limited to manpower needed by the project.

One of the research outputs is finding the effect of uncertainty on the completion date by determining the standard deviation criteria.

In 2000, Al-zwainy [9], had suggested a simulation model which involves on studying the possible alternatives to perform the maintenance of highway by checking and evaluating these alternatives on computer, so the benefit obtained by the model is to shortcut time, effort, and cost if the alternatives was selected in situ, as well as this model could analyze the impact of different factors on the maintenance management process, before the commencement of the execution process. The model was named (PMMSIM), its work is summarized by representing the trucks movement from the manufacture to site, asphalt loading, asphalt discharging.

In the same year 2000, Khaleel, T. A. [26] presented a simulation model to schedule the project activities, combine between critical path method and time-site method to capitalize each method benefits. Many of probability distributions are dependent by the researcher. To find out the completion rate for each major activity in the project, the researcher developed a new method called triangulation scheme. To be the project scheduled, by checking the impact of resources restricting, the researcher adopted new method for resources allocation which differs from the conventional methods adopted at that time, as this technique depends on the recalculations after each step of resources allocation thereby changing the preference among the project activities depending on the degree of its embarrassment.

In 2001, Al-najjar [11] investigated the lean production theory principles if it has a benefit in construction domain by using the simulation modelling tool. Among many simulation systems, Al-najjar has used STROBOSCOPE system to perform the research aims to model the complicated construction operations. Nine construction activities had been developed for a housing project by using STROBOSCOPE system. Then the model was programmed, verified and validated. Finally, the researcher obtained a result, that the developed model showed a high level of efficiency in dealing with construction site problems.

In 2006, Najee, H., A., [27] tried to highlight the importance of risk management in the construction sector through the adoption of the analytical hierarchy techniques (AHP), sensitivity analysis, simulation, the effect scheme and impact of the intersection, and then highlight the role of value engineering as a tool to test the responses to the risk. After that have been identified the most risks surrounding the construction project, have been the administrative system building for qualitative risks assessment and then simulate this assessment by using AHP. A second administrative system was built by the researcher for quantitative risks assessment through measure the impact of risks on project cost also by using AHP simulation

10.2. International applications of cost simulation in project management

On the other hand, there were a good number of international research-based simulation methods. The following subsection is a review of some these studies. With respect to the use of Monte-Carlo simulation in project management, researchers outlined how simulation is used in both project cost (budget) management and how these processes are integrated with risk management to produce reasonable project budget reserves. It is worth mentioning that the adopted period for international studies extends from 2000 up to 2015:

In 2000, Alkeajer [28] presented a new method for cost estimation. The innovative idea for this method is to combine the conventional calculation method of stochastic simulation with basic facets of the successive principle. This method named as Stochastic Budget Simulation (SBS). The SBS can be applied to the projects that have a simple cost structure at the initial stages where the concept of uncertainty plays a significant role in estimating the cost. The most likely users for the provided model are planners, project managers and consultants. He had use Monte-Carlo simulation as a tool to represent distributions of the possible costs. So that the players have analytical tool which can be used by them to predict the most likely total cost.

In 2002, Isaksson [29] developed a model for cost and time estimation which was applied to tunnels projects only. Since the estimations of project time and cost are usually made in a deterministic manner, the justification for this model takes in consideration of the variation in cost and time variables. The developed estimation model gave particular attention to the quantification of risks using different tunnelling methods. As each underground project is unique in purpose, requirements, location and surrounding environment, each project must therefore be subject to risk analysis specific to the given circumstances. In order to makes the best choice of the best execution method.

In the same year 2002, Wang [30] proposed a model for determining a reasonable project price. The model, called SIM-UTILITY, is based on a utility theory and enhanced by cost simulation approach. The utility theory is applied to reflect the owner's preferences regarding the determination criteria, while the simulation approach is used to generate more objective project cost to support execution of the utility theory. The proposed model can be useful for the owner, where the owner should determine a project ceiling price or cost estimate to use as a reference point for evaluating the bids, before considering bids submitted.

In the same year 2002, Wang [31] developed a simulation-facilitated factor based model, called COSTCOR, that allows correlation between cost items to be considered in cost analysis. The proposed model can decrease the uncertainty of achieving the construction project within the target budget. The uncertainty in the total cost distribution of an item according to this model is transferred to several factors with cost distributions according to qualitative estimates of the sensitivity of each cost item to each factor. Each cost distribution is then decomposed into a family of distributions. Correlations are retrieved by sampling from the minor distributions with the same condition for a given iteration of the simulation.

In 2005, Yang [32] proposed a general method based on the simulation to predict total project cost by incorporating the correlations between cost elements. The proposed method is more general than previous approaches because:

- It can treat different types of marginal distributions (discrete or continuous, different minor distributions) for cost elements in one framework; and
- It can directly adjust the correlation matrix into a close and feasible one which it is very efficiently.

Yang indicates that the impact of correlations between cost elements is significant and may cause serious of problems if neglected.

In 2006, Amaratunga et al [33] developed a computer based-simulation model to simulate construction cost overruns in building projects. The simulation model has been developed in visual basic based on the Monte Carlo analysis which provides the client with a range of possible cost overruns. The calculations of the model are joined with the cost overruns factors which searched by the developer. The model simulates possibilities of cost overruns represented in terms of probability distribution where the probability distribution for the factors that affect the cost overrun was objectively derived from the records collected through detail survey.

In 2008, Wang [34] et al, presented procedures for determining construction project budgets. The proposed procedures integrate an analytical hierarchy process (AHP) (which incorporate a multi-criteria) evaluation model with a simulation-based cost model. The AHP reflects owner evaluations with regard to budget determination criteria. The cost model generates a cumulative cost distribution for establishing project budget ranges. The proposed simulation model (by integrating it with AHP) can serve the following benefits:

- Generate a project budget that includes many principal parts: owner overhead costs, construction costs (direct and indirect costs), engineering costs, and other costs.
- Conduct simulation analysis that includes cost uncertainties, and then generate a cumulative distribution of the project budget.

- Identify the maximum budget and minimum budget for the project.

In 2009, Pena [35] set out simulation-based optimization model to optimize the project time-cost tradeoff. Activities that comprise a project may have several alternatives to accomplish it, each with an associated cost and stochastic duration. The goal of the model is to select the suitable alternative from among project activity alternatives under uncertainty. Where the final project cost is a result of the time and cost required to complete each activity and lateness penalties that may be occur if the project is not completed within the specified completion time. The model minimizes the expected project cost due to lateness penalties and the activity alternatives selected.

In the same year 2009, Yang et al [36] developed a probabilistic simulation approach for analyzing construction project cost estimation and correlation effects of incorporated risk. The developed approach is an alternative that aids decision makers in terms of probability and confidence level. The proposed procedures comprise heuristic and simulation models by using Monte-Carlo that can be employed to calculate the probabilistic costs of highway and bridges projects by using data from previous projects. The proposed approach sheds light on assisting estimators who are attempting to enhance the accuracy of engineering project cost in the preliminary stage. Cumulative distribution functions (CDFs) are then developed as a user-friendly chart for decision makers and these CDFs can be used to assess project risks where the computer simulation generates CDF graphs that offer alternative valuable information shedding lights on the probability of executing a construction alternative at or below a specific budget. This approach can be applied to other projects when similar project cost data are available.

In the same year 2009, Kwak and Ingall [37] presented a study explored the implementation of Monte-Carlo simulation in project management sector, particularly risks and uncertainties. This study included a review of this simulation concept type in detail with discussion their advantages and disadvantages, their applications in the field of construction project management, their cons and pros, their applications in other disciplines, constraints or limitations of its applying in the field of project management.

In 2011, Chou [38] set out comprehensive stochastic processes involving the examination of a series of simulation building blocks for conceptual cost range estimates. By introducing streamlining Monte Carlo simulation procedures with evaluation of stochastic processes and input probability distribution selection via hypothesis testing, and specification of correlations between simulated varieties. The main contribution of this stochastic process is that project management team can apply it to make rational decisions regarding cost estimation and quantify its likelihood of success in situations with specific degrees of simulation precision.

In 2012, Malmquist [39] proposed a project cost estimation model that called Project Pricing Program (PPP). Base on two methods, Monte-Carlo simulation and Hierarchy Probability Cost Analysis and provides a structured way to assess the projects. It can be used in the tender phase. The comparison between Company's costs and competitors' costs can give indication of whether it is worth bidding at all on a project. In this case, the model provides guidance on which price interval will be reasonable for Company in order to have a decent chance of winning the project. After projects have been won or lost, they can be analyzed.

In the same year 2012, Mavridis [40] proposed a model which simulates the possible risk of failure for all possible building pit construction sequences. In a way, the cost profile for every possible construction sequence is generated, which incorporates the probable risk of failure and its impact on cost. The model overcomes the limitations of traditional construction sequence selection by providing managers with enhanced information about the risks regarding the time, cost and quality of prospective projects. The potential risk of failure and subsequent failure costs varies depending on the construction sequence selected, and the methods which comprise that sequence. So there is a need to build a model which can simulate the constructive sequences for the prospective project to obtain the suitable sequence which affects the final cost positively.

In 2013, Hajji [41] used CYCLONE simulation model to compare the direct pipe technology with traditional trenchless technology by incorporating real costs and duration into the model, where the direct pipe technology is one of new technology that has been invented by German's Herrenknecht Inc. Recently. It claims that the technology is economical, fast, and has a single step installation procedure more than other techniques of trenchless technologies. So, the study had conducted to analyze and evaluate this claim.

In 2014, Deidda et al [42], set out a reliable and correctly justified cost function attribution for the water in multi-source and multi-centre supply systems, to define the optimal economic level in leakage reduction when reaching equilibrium between marginal costs of saved water and marginal costs of achieving additional reduction in leakage. Finally, the achieved target is to decide the optimal decisions considering complex multi-centre (or multi-district) supply systems, subject to reduced water resources and reduced funds.

In 2015, Perez [43] designed a simulation-based optimization approach to solve the resource constrained project scheduling problem (RCPSP) under uncertainty. Two methods proposed: the Total Cost Resource Constrained Method (TCRCM) and the Earned Value Resource Constrained Method (EVRCM). The TCRCM minimize the total project cost, while considering the RCPSP with stochastic activity times and costs in terms of resource alternatives as well as precedence relationships for activities sharing resources. Both methods can be implemented in two phases, the first phase could be implemented prior the starting of the project to determine the total cost while the second phase can be implemented as the project progresses to determine the optimal resource configuration for the remaining activities of the project.

In the same year 2015, Hyunjoo et al [44], proposed a 3D STEP to simplify the process of defining the optimum alternative of highway alignment alternative among the provided alternatives. The motivation for building this mode from view point of developers is the limitations of the currently approaches, one example of these approaches is LandXML, which was compared and founded that it could not define the characteristics and details of structures such as bridges and tunnels. After the system had been finished, it was applied to a highway project in Korea, and it was found that this system was able to identify the QTO values, costs of earthworks, and the schedule of a construction highway project. The quantity comparison showed a 3.95% accuracy variance between the proposed 3D STEP system and the real project.

In 2016, Amir et al [45], conducted a comparison of both types of green roofs (intensive green roofs and extensive green roofs) to find any type is feasible economically by computing two indicators which are net present value and bay back period for each type. The study places an emphasis on all the private factors affecting cost-benefit analysis. Installation, operation and maintenance costs are compared with the benefits such as energy saving, the increase in property value, and the acoustic effect in order to determine the two required indicators (net present value and pay-back period) by using Monte-Carlo simulation. Net present value for intensive green roofs is found to be higher than extensive ones, whereas the payback period for installing extensive green roofs is lower than intensive green roofs.

The comparisons among the international studies only had conducted by the current study and given in Table 2. Also the comparison between the current study and the previous studies has been conducted and given in Table 3.

Table 2. Comparisons among the previous applications in construction cost simulation

	Researcher Name	Year	Research Place	Study Tools	Statistical Methods	Constructed Model
1	Martin alkeajer [28]	2000	Denmark	Historical data	Measures of central tendency	Monte-Carlo simulation model
	Research Objectives: To develop a new estimation method named Stochastic Budget Simulation (SBS) which can be used in the early stages of the project where uncertainties play a significant role. **Research Description:** The researcher identified the cost items and generic risks, a triple estimate for each item is calculated, and then generic risks are estimated in percentage then added to the estimated cost as a final sum to be ready to enter to the model. **Study Population:** construction project with a simple cost structure (there is no signal to its type).					
2	Therese Isaksson [29]	2002	Sweden	Historical data	Measures of central tendency	Monte-Carlo simulation model
	Research Objectives: To develop a model for cost and time estimation, where the model takes in consideration variations in cost and time variables during the estimation. **Research Description:** The researcher made a quantification of risks for each different tunnelling method, the tunnel project divided into geotechnical zones according to the proposed methodology to find finally the time and cost by the model. **Study Population:** Tunnels projects					
3	Wei-Chih Wang [30]	2002	Taiwan	Historical data	____	SIM-UTILITY model
	Research Objectives: proposed a model for determining a reasonable project ceiling price **Research Description:** The research based on a utility theory and facilitated by a cost simulation approach. The utility theory is applied to reflect the owner's preferences regarding the determination criteria, while the simulation approach is used to generate more objective project cost data to support execution of the utility theory **Study Population:** Residential building, educational building, and office building					
4	Wang [31]	2002	Taiwan	Historical data	____	COSTCOR
	Research Objectives: to develop a simulation-facilitated factor based model **Research Description:** The developed model allows correlation between cost items to be considered in cost analysis to decrease the uncertainty of achieving the construction project within the target budget. **Study Population:** General construction project.					
5	I.-T.Yang [32]	2005	Taiwan	Historical data	Coefficient of correlation and Pearson matrix	____
	Research Objectives: to develop a general method to incorporate correlations between cost elements in the process of cost estimation. **Research Description:** the researcher first checked the feasibility of the correlation (by Pearson matrix), to adjust it if					

	necessary, then uses the correlations to generate correlated multivariate random vectors, which are employed to model possible outcomes of the cost elements. **Study Population:** Office buildings.					
6	R.D.G.Amaratunga et al. [33]	2006	Sri-Lank	Historical data	Measures of central tendency	Monte-Carlo simulation
	Research Objectives: To set out a model to simulate the cost overruns **Research Description:** The theoretical part of the study is investigated the factors which cause the cost overruns then, to include the specified factors into simulation model as practical part. **Study Population:** Office building					
7	Han-Hsiang Wang et al.	2008	Taiwan	Historical data	____	Computer simulation model by using stroboscope simulation language
	Research Objectives: to develop a computer simulation model for determining construction project budgets. **Research Description**: The research integrated two methods; the analytical hierarchy process (AHP) reflects officer evaluations with respect to budget determination criteria and simulation model to determine the budgets. **Study Population:** Public building construction projects.					
8	Radhamés A. Tolentino Pena [35]	2009	USA	Historical data	____	Simulation-based optimization model was created in the C++ programming language
	Research Objectives: to present model to optimize the project time-cost trade off by using simulation based optimization. **Research Description**: The researcher implemented 3 experimental cases (with different number of critical paths and different number of activities) to find the optimum cost and time. **Study Population:** Construction project (there is no signal to its type).					
9	Yang et al. [36]	2009	Taiwan	Historical data	Measures of central tendency	Monte-Carlo simulation model
	Research Objectives: to develop a probabilistic simulation approach for analysing project cost estimation procedures and correlation effects of incorporated risk. **Research Description**: The research provided approach, which is an alternative that aids decision makers in terms of probability. The model generates cumulative distribution functions graphs that offer information shed lights on the probability of executing alternative at or below a specific budget. **Study Population:** Highway projects.					
10	Jui-Sheng Chou [38]	2011	Taiwan	Historical data	Measures of central tendency	Monte-Carlo simulation model
	Research Objectives: to present comprehensive stochastic processes involving the examination of a series of simulation building blocks for conceptual cost range estimates **Research Description**: This study examined experimental simulation of alternative mathematical equations using different testing methods and techniques of handling correlation random variables. **Study Population:** Highway projects					
11	Daniel Malmquist [39]	2012	Sweden	Historical data	Measures of central tendency	Project Pricing Program(PPP) implemented by MATLAB
	Research Objectives: to develop a model for project cost estimation. **Research Description**: The research based on the theoretical one (Hierarchy Probability Cost Analysis) to the extent possible, project costs were broken down in sub costs which were included in Monte-Carlo simulation. **Study Population:** construction projects (there is no signal to its type).					
12	A. Mavridis [40]	2012	Holland	Historical data	Measures of central tendency	Monte-Carlo simulation model
	Research Objectives: To propose a model which simulate the potential risk of failure, for the purpose of assessing the variation in risk and their impact on cost. **Research Description**: The researcher checked the sequencing impact of project activities (with its inherent failure and risks) on final cost of project. **Study Population:** Geotechnical Construction Projects.					
	Hajji [41]	2013	Indonesia	Historical data	____	CYCLONE simulation model
	Research Objectives: to compare the direct pipe technology with traditional trenchless technology.					

13	**Research Description:** economically comparison between two installation pipes technologies had conducted. **Study Population:** underground infrastructure.					
14	Deidda et al. [42]	2014	Italy	Historical data	Measures of central tendency	WARGI-SIM simulation model
	Research Objectives: set out a reliable and correctly justified cost function. **Research Description**: the optimal economic level in leakage reduction for the water in multi-source and multi-centre supply systems is obtained. **Study Population:** water supply systems.					
15	Maribel Perez [43]	2015	USA	Historical data	Earned value management	Simulation-based optimization model by using MS EXCEL
	Research Objectives: to resent simulation-based optimization approach that focuses on identifying the optimal scheduling scheme that minimizes the cost of the project. **Research Description**: the researcher implemented approach in two phases: the static phase, which is executed before the project begins and the dynamic phase, which is implemented during project execution. **Study Population:** construction project (there is no signal to its type)					
16	Hyunjoo et al. [44]	2015	Korea	Historical data	LandXML, and QTO estimation method.	3D STEP model
	Research Objectives: to propose a 3D STEP model. **Research Description**: This research came to simplify the process of defining the optimum alternative of highway alignment alternative among the provided alternatives. **Study Population:** highway construction project.					
17	Amir et al. [45]	2016	Malaysia	Historical data	Measures of central tendency	Monte-Carlo simulation model
	Research Objectives: to conduct a comparison of both types of green roofs (intensive green roofs and extensive green roofs). **Research Description**: economically comparison between the two types had conducted by computing two indicators (net present value and bay back period). **Study Population:** green roof construction material components.					

Table 3. below shows the comparison between the current study and the previous studies:

Table 3. Comparison between the current study and previous studies

Current study	
Research location	Iraq
Research aim	Keeping up of using simulation concept in construction management sector.
Research population	Highway construction projects in Iraq.
Research tools	Previous literature, documented data, survey questionnaire, and semi-structured interviews.
Statistical means	Knowledge that was gathered from the literature review.
Research case study	Ministry of housing and construction in Iraq/General Authority of Roads and Bridges.
Previous studies	
Research locations	Denmark, Sweden, Taiwan, Sri-Lank, USA, Holland, Italy, Indonesia and Korea
Research aims	As a whole, building a simulation model for cost predicting. It is important to say that each research has a different pattern which recognized it from other.
Research population	Different construction projects.
Research tools	Knowledge that was gathered from the literature review.
Statistical means	Different of statistical analysis.
Research case study	Different organizations.

11. Conclusion

Study findings are:

- Over the selected study period, there has been a substantial increase in the use of high-fidelity simulation in construction cost management.
- Simulation approach had proved as a feasible approach in construction management especially in cost management topic.

- The study found that Monte-Carlo simulation is the most popular type in construction cost treatments among other simulation types.
- Simulation is a methodologically approach that translates their outcomes to future performance and practice.
- In the actual implementation of construction projects, there is no embarking over simulation concept, since simulation implementation suffers from many challenges including a lack of knowledge, and a lack of simulation training for staff.

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