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Analyzing the Risks in Highway Projects Using the Markov Chain Approach

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Abstract The issues associated to highway projects usually affect aspects like nature of the project, cost and time. Risk events that are not usual always give rise to positive or negative feedback and normally cause variations from project designs especially inclined to risk construction projects. However, more investigations have been done on risk management associated to highway projects, there is limited literature more so to the risk of the project. These projects can be overseen under some dubious condition by applying the risk management technique. The aim of this research was to demonstrate pertinence of the Markov Chain approaches in diminishing the risks of the highway projects by utilization of data from the projects. Other Commonly utilized procedures don't investigate potential risks successfully and subsequently the utilization of Markov chains. This project has made utilization of the Markov chain procedure to evaluate the short and long-term potential risks. This research project utilized risk data acquired from experts through questionnaires. The data was then analyzed utilizing the Octave software.

Keywords: *highway projects, Markov chain, risk, octave software*

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1. Introduction

This study investigates the possibilities of occurrence of events and the degree of impact of the risk in highway projects. The main challenge in connection with almost all the Highway projects is that cost has more weight on the completion delays. Adebayo (2002) asserted that the incompletion of projects is due to the limited number of good contractors, managerial skills, irreconcilable circumstance and defilement [1]. Many inquiries have been done especially on the quality of work and the functionality future of the most highway projects for the administration clients.

Highway projects risks can be defined as uncertain occasions that have both positive and negative results on the objectives. The objectives of these projects are; time, cost, degree, and quality according to Molenar and Robert (2010)) [2]. The procedure of risk management must be considered in the management of different risks. These procedures include such activities like project planning, project identification, analysis of the project, reaction rebuilding, project monitoring and control measures (Guide, A. (2001)) [3]. Legitimate control measures can be safely followed in the risk management criteria with the end goal to:

- Minimize negative impacts on the project's objectives.
- Maximize the opportunities in order to improve the objectivity by aiming at the reduced cost, short length programs, improved high degree, and high quality of the programs.

Analyzing the different risks associated with highway projects is one of the main aspects in risk management. The procedure of analyzing risks may be complicated due to complicated needs and the subjectivity nature of the data in highway projects. The complication nature of the risk analysis is not high since the benefits of the outcomes can be of highly importance.

The significance of the project can also be linked to the employment aspect. The Industry is said to be the mega employer of both the experienced and non-experienced workforce. The engineering company is categorized into smaller sub-firms that has < 1% of the engineering firms that are registered. Delays and cost aspects of the structural engineering works involving engineering has become the conspicuous and this has led to introduction of managerial skills to guarantee that these projects are completed within the stipulated time and within the budget constraints according to the projections.

Sujiao and Zhang (2009) proposed a Markov chain approach to study both short and long-term risks projects associated with development [4]. Qualitative risk analysis involves probabilities and the results are assessed qualitatively. The probabilities are then transformed to percentages and then into monetary terms. The scoring risk assessment matrix is utilized to transfer non-transparent arrangements of risks into a need rundown of risks. Quantitative risk analysis determines the impact of project risks on major cost and income places for financial or economic issues in highway projects.

Ebrahimnejad et al, 2009 proposed a fluffy decision-making model for assessing the risk assessment with applications to large projects [5]. They also came up with very important risks in build-operate-transfer projects and developed a multi-attribute analysis under a fluffy environment to manage the risks. Makui et al, 2010 and Mojtahedi et al, 2010 came up with the idea of simultaneous analysis of safety to the risk identification by basing on the safety, health, and the environment [6]. According to the literature a lot has been done on assessment of the risk and on issues involving management in highway projects. Palmer et al. (1996); Akinci and Fisher (1998) [7] have also done some work on phases, forms of risk and also the factors. Tah and Carr (2000) [8] carried out a study on classification of risk within projects utilizing the hierarchical risk breakdown structure (HRBS). The risk is classified into two: internal and external, where the internal risk is sub-divided into local and global. Moghaddam et al, 2011 suggested a statistical approach for identification and analysis of risks of the major projects simultaneously by fluffy collective choice analysis in mega projects [9]. Mousavi et al, 2011 also proposed a novice statistical approach which based on the technique of resampling with interval analysis for all the risks in projects involving engineering [10]. Mousavi et al, 2011, also assessed the risk in highway projects using the jackknife approach. They also developed a multi-attribute approach analysis under fluffy stochastic environment for determination of the risk problems in relation to highway projects [11]. Hashemi et al, 2011 applied the bootstrap approach for risk analysis employing interval numbers technique in developmental projects. Further, he presented a ranking approach with bootstrap confidence intervals for purposes of assessing risks in the port projects [12]. Due to enormous characteristics of the activities involving highway projects, they become subjective to myriad changes that happen now and then in some uncertain environment. The traditional methods that have been applied to assess project risks statistically have been criticized for not taking to account the sequential nature of the set norms in highway projects. In a conventional risk model, uncertainty of the stated projects should be modeled procedurally in respect dynamic states. A stochastic approach for example Markov chain is a robust analog for analyzing time-dependent behaviors of many dynamic systems. This paper study aims at providing another approach for the use of Markov chain analogy based on the project risk data collected from highway projects stakeholders.

Risk in highway projects is an important element because of the overall project cost hence the allocation of finance has a great impact on project budget this is according to Zaghoul and Hertman (2003). Molenaar, K (2005) also noted that developmental projects include an open system instead of a closed system, that outcomes to variability and riskiness of the highway projects [14]. Hashim, A. and Ku Hamid, K.H. (2007) explained that highway risk management highly depends heavily on contracts and it has bad reputations of involvement in disputes and claims [15]. Akintoye, A. and MacLeod, M. (1997) also stated that different studies have illuminated that highway structures are the major wellsprings of the lack of adaptability and hence they have a significant negative impact. According to Ashley, D., Diekmann, J., and Molenaar, K. 2006) [16,17], management of risk needs to be implemented; risks of contraction of other parties do not assume that they are managed because no much has been done to address these risks; rather an increase in the cost of the contract will be observed. Cost overruns and completion of the projects at late times in large infrastructures have been recognized as risks affecting project performance. P.M.I (2004) explained that barriers in management of highway risks are a drive for cost adequacy; management of the risk is just observed using a lot of assets and advantages are a complicated aspect to measure in financial dimension [18]. Due to lack of highway risk management systems and knowledge it makes it difficult for the utilization of risk management techniques. Studies have shown that various risks associated with highway projects have limited workforce to conduct the risk management process and that the risk management is just in the knowhow of few key individuals.

1.1. Statement of the Problem

Highway projects completion has undergone risk challenges worldwide for a long time now. Risk management within highway projects has been applauded as a very important tool to improve their performances and increase higher chances of completing these projects successfully without hasty.

1.2. Significance of the Study

In project risks management, proper measures are taken with the end goal to limit negative consequences for the projects targets and augment the probabilities of enhancing the destinations by thinking about the reduced cost, short time schedules, scope upgrading, high caliber and crisis management limitation. This paper will empower the management to realize the measures to put in each phase of the project in order to make the fulfillment successful.

2. Methodology

2.1. Data

In this stage, primary data on risks of parkway projects were extricated from 25 specialists through questionnaires. The specialists were randomly selected from various road construction companies and government multi-agencies, they included engineers, policy makers and even the general public. The development of the tables is completed by the assistance of the article on parkway chance data from International Scientific Publications with the end goal to give potential hazard, separate structure (PRBS) (Mojtahedi et al 2010, Gatti et al 2007, Moghaddam et al 2009) [19]. Various methodologies have been recommended in the writing for ordering project risks. According to Asbridge et al, 2012 [20], potential risks of the roadway projects are gathered with the main goal being the consideration of potential risks in various aspects of the highway project and scope of work involved. In this stage, the potential risks breakdown structure (PRBS) is characterized as a source-situated-gathering of potential risks inside expressway projects that arranges and characterizes the whole hazard presentation.

2.2. Research Methodology

This study made use of the Markov chain to see how we can use it to intensively reduce the highway project risks. The method is as discussed below;

2.2.1. Markov Chain

A Markov chain approach employs a stochastic analogical process that works in a sequential manner for example it involves states that are not permanent (e.g. temporally), transitioning starting with one state then onto the next within an allowed set of states (Brooks et al, 2011) [21]

$$x^{(0)} \to x^{(1)} \to x^{(2)} \dots \to x^{(t)}.$$

A Markov chain technique is expressed by three elements:

1. A state space, which is represented by a set of values that the chain is allowed to take
2. P $(\boldsymbol{x}^{(t+1)}|\boldsymbol{x}^{(t)})$ which is a transition operator that expresses the probability of a state moving from state $\boldsymbol{x}^{(t)}$ to$\boldsymbol{x}^{(t+1)}$.
3. An initial condition distribution $\boldsymbol{\pi}^{(0)}$ which defines the Probability of being in any of the possible states at the initial cycle t=0.

The Markov chain starts at some state, which is sampled from $\boldsymbol{\pi}^{(0)}$, then transitions starting with one state then onto the next according to the transition operator P $(\boldsymbol{x}^{(t+1)}|\boldsymbol{x}^{(t)})$. A Markov chain is called memory less if the following state only relies upon the current state and not on any of the state's past to the current:

$$P\left(x^{(t+1)} \mid x^{(t)}, x^{(t-1)}, x^{(0)}\right) = P\left(x^{(t+1)} \mid x^{(t)}\right) \qquad (1)$$

(The memoryless property is known as the Markov property). At the point when transition operators in a Markov chain don't change crosswise over transitions, the Markov chain is alluded as time-homogenous. A pleasant property of time-homogenous Markov chains is that as the chain runs for a long time and t→∞, the chain will achieve an equilibrium that is called the chain's stationary distribution:

$$P\left(x^{(t+1)} \mid x^{(t)}\right) = P\left(x^{(t)} \mid x^{(t-1)}\right). \qquad (2)$$

One of the reasons for a Markov chain is to foresee the future. Given a vector of state probabilities $\boldsymbol{R_0} = [\boldsymbol{P_{11}} \quad \boldsymbol{P_{12}} \dots . \boldsymbol{P_{1m}}]$ and the matrix of a transition probability at time period n=0, we can determine the state probabilities at a future time. For accommodation let $\mathbf{R_1}$ speak to the state probabilities at a time (state) n=1. After one execution of the experiment, it very well may be composed as far as a crude matrix as $\mathbf{R_1} = \mathbf{R_0} \times$ P, to figure the vector of state probabilities at the time (state) 2,3,… ..n, multiply the framework state at time 0 with transition matrix (P) that is:

$$\mathrm{R}_2 = \mathrm{R}_1 \times \mathrm{P} = \left(\mathrm{R}_0 \times \mathrm{P}\right) \times \mathrm{P} = \mathrm{R}_0 \times \mathrm{P}^2$$

$$\mathrm{R}_3 = \mathrm{R}_2 \times \mathrm{P} = \mathrm{R}_0 \times \mathrm{P}^3$$
$$\vdots$$
$$\mathrm{R}_n = \mathrm{R}_{n-1} \times \mathrm{P} = \mathrm{R}_0 \times \mathrm{P}^n.$$

The elements of the n state transition matrix $\boldsymbol{P_n} = [\boldsymbol{P_{ij}^n}]_{m*m}$ are obtained by repeatedly multiplying a transition matrix P independent from anyone else. In general $\boldsymbol{P^n} = \boldsymbol{P^{n-1}} \times$ P where each column $\boldsymbol{P^n}$ speaks to the state probability distribution after n transitions given that the process begins in a state $\boldsymbol{i}$.

2.2.1.1. Formulation of Transition Kernel from the Probabilities of States

According to Trahlar et al 1996 and Tierney, L. (1998)) [22]; in a stochastic processes, $\{\boldsymbol{x_n}$, n=0, 1…….} that goes up against a finite number of possible values if $\boldsymbol{X_n} = \boldsymbol{i}$, at that point the process is said to be in state I at time n. Whenever the process is in a state I, there is settled probability $\boldsymbol{P_{ij}}$ that will next be in state j. i.e., we guess that

$$\begin{aligned}&\mathrm{P}\left\{X_{n+1} = j \mid X_n = i, X_{n-1} = i_{n-1}, \dots X_1 = i_1, X_0 = i_0\right\} \\ &= \mathrm{P}\left\{X_{n+1} = j \mid X_n = i\right\} = \mathrm{P}_{ij}.\end{aligned} \qquad (4)$$

For the states, $\boldsymbol{i_0}, \boldsymbol{i_1}, \dots, \boldsymbol{i_{n-1}}$, I, j and all n>=0. Such a stochastic process is known as Markov Chain, and the conditional distribution of any next future state $\boldsymbol{X_{n+1}}$ given the past states $\boldsymbol{X_0}, \boldsymbol{X_1} \dots . \boldsymbol{X_{n-1}}$ and the present state $\boldsymbol{X_n}$, is independent of the past states and only depends on the present state. The matrix of one stage transition is denoted by P=initial state

$$\begin{bmatrix} P_{00} & P_{01} \dots & P_{i1} \\ P_{10} & P_{11} \dots & P_{1j} \\ P_{i0} & P_{i1} \dots & P_{ij} \end{bmatrix}$$

Where P_{ij}>=0, i, j>=0; $\sum_{j=0}^{\infty} P_{ij} = 1$,i=0,1……

2.2.1.2. Ergodicity

If any state I is a recurrent state, then at that point we say that the state is positively recurrent iff starting in I, it is expected that the time expected until it returns back to state I is finite. Since there some recurrent states that are not recurrently positively, it can be easily demonstrated that infinite Markov Chain states which are all recurrent are simply positive recurrent. Some recurrent states are not positive recurrent and they can be well expressed that in a finite state Markov chain all the states that are recurrent are sure recurrent. If a state is a periodic and positively recurrent then the state is said to be ergodic.

Theorem: For every irreducible and ergodic Markov chain lim n→∞ $\boldsymbol{P_{ijn}}$ exists, and is independent of $\boldsymbol{i}$. Moreover, letting

$$\prod j = \lim_{n \sim \infty} P_{ij}^n, \; j \geq 0 \qquad (5)$$

then πj is the unique nonnegative solution of

$$\prod j = \sum \prod P_{ij}^{n},\ j \geq 0, \sum_{j=0}^{\infty} \prod j = 1 \quad (6)$$

iff the Markov chain is positive recurrent. If a solution exists then it will be unique, and $\prod$j will equal the long-run proportion of time that the Markov chain is in state j. If the chain is aperiodic, then πj is also the limiting probability that the chain is in state j.

2.3 Proposed Approach

Risks associated with highway projects have been posing the question of consideration in light of time and cost impact related with these mega projects. A venture in highway projects is isolated into three noteworthy stages: planning, engineering and development. The risks transform continuously in the cycle of the projects. Subsequently, these highway projects venture risks can be modelled stochastically. Besides, on the grounds that the advancement of highway projects mainly relies upon the venture circumstances, the risks within highway projects have the qualities of the stochastic phenomenon. It tends to be modeled by Markov chains analogy. There are two phases of the proposed approach for the risk analysis in highway projects which dependent on Markov chain approach are given as. Mane and Pimplikar (2013) listed the different risk looked in projects into three kinds as Financial Risk, Political Risk and Technical Risk [23]. Shirking, Transference, Mitigation and Acceptance are the Risk reaction systems followed in India. Delays in project approval, Change in legal advice, Cost impact overrun, Land acquisition, and remuneration, Enforceability of agreements, Construction schedule, financial closing, Tariff improvisation and Environmental risk are the key critical risks in projects. Maintaining great relationship with government specialists help to stay away from the risk of delay in approval, obtaining government's assurances by means of adjusting tariff or extending concession period help to evade the risk because of progress in law, choosing quality and trust commendable consultants with knowledge of how to handle ordinary development issues help to dodge risk of delay in development schedule, etc., Sato et al, 2005 examined about the risk looked by street projects at different task arrange [24].

3. Results and Discussion

In this section, the categories of risk data were given as follows:

3.1. Project Potential Risk Analysis

The potential risks of the project were grouped into five subgroups in order to improve the precision of the risk assessment approach. These groups were (Very Low (VL), Low (L), Medium (M), High (H), and Very High (VH)) are depicted in Table 2. Twenty-five experts with high qualification regarding this subject gave the following information. The assessment results in the planning phase of the highway project were illustrated in Table 1. A primary data that involved questionnaires was used.

Table 2 shows the number of experts who perceived that there is either a possibility of potential risk moving from one level to another or remaining in the same level during phase transitions. For example, 3 experts said that their possibility of very low potential risk remaining in very low level of potential risk in the 2nd phase. Also none of the experts suggested that potential risk will move from very high to medium level in the 2nd phase.

Table 1. Potential risk structure for the highway project

Highway project phase	Risks Involved	
Engineering	Changes in design Defective and erroneous design, errors, and rework Deficiency in drawing prototype of projects	Documents not issued on time Unforeseen adverse ground conditions
Procurement	Delays in material delivery due to procurement regulations Delays in data dissemination to vendors Quality issues of material	Associated challenges with equipment availability. Inadequate manpower.
Construction	scope of work Delay in equipment delivery to site Delay in honoring paying subcontractors invoices Health, Safety, and Environment (HSE) Matters	Shortage of experienced workers Interferences from subcontractors Ad hoc site conditions
Management	Corruptions & bribes Delay in processing of payments and receiving project's invoices Failure of planning. Communication failure	changePolitical policies Project funding Project manager disabilities Necessary documents for project permits & Approvals

Table 2. Risk Analysis

	Phase 2 analysis						
	Level of risk	VL	L	M	H	VH	Totals
Phase 1 analysis	VL	3	2	2	0	0	7
	L	3	4	2	0	0	9
	M	3	2	4	2	0	11
	H	0	2	2	3	2	9
	VH	0	2	0	2	2	6
	Totals	9	12	10	7	4	42

3.1.1. Initial Potential Risk Distribution

Initial potential risk distribution is as follows $S^{(0)}=$ (0.17, 0.21, 0.26, 0.21, and 0.14) i.e. {4/25=0.16… 3/25=0.12}. The initial potential risks, represents the potential risk associated at each level. The one-step transition matrix is as follows:

P= [3/7=0. 43…………….,2/6=0.33] i.e. divide each element of each row by its corresponding row totals. The transition probability matrix describes the associated probability of risk from one level to the next level.

$$P=\begin{bmatrix} 0.43 & 0.29 & 0.29 & 0.00 & 0.00 \\ 0.33 & 0.44 & 0.22 & 0.00 & 0.00 \\ 0.27 & 0.18 & 0.36 & 0.18 & 0.00 \\ 0.00 & 0.22 & 0.22 & 0.33 & 0.22 \\ 0.00 & 0.33 & 0.00 & 0.33 & 0.33 \end{bmatrix}$$

$$>> S^{(0)}=\begin{bmatrix} 0.17 & 0.21 & 0.26 & 0.21 & 0.14 \end{bmatrix}.$$

3.1.2 Potential Risk Distribution in Second Phase

>> $S^{(0)}$ * P= [0.2126 0.2788 0.2353 0.1623 0.0924].

From the second phase above, it is clear that the very low risk level probability has increased to 0.2126 making it more effective. The risk for the very high level has decreased from 0.14 to 0.0924, which means that after one transitional period the probability of having very high risks is reduced to a reasonable condition.

3.1.3. Potential Risk Distribution in Third Phase

$$>> P^2=\begin{bmatrix} 0.3589 & 0.3045 & 0.2929 & 0.0522 & 0.0000 \\ 0.3465 & 0.3289 & 0.2717 & 0.0396 & 0.0000 \\ 0.2727 & 0.2619 & 0.2871 & 0.1242 & 0.0396 \\ 0.1320 & 0.2816 & 0.2002 & 0.2211 & 0.1452 \\ 0.1089 & 0.3267 & 0.1452 & 0.2178 & 0.1815 \end{bmatrix}$$

>> $Q=P^2$

>> S * Q= [0.2476 0.2938 0.2439 0.1264 0.0662]

From this phase, the probability of having very high risks is still reducing. This confirms the effectiveness of the Markov chains in reducing the highway project risks.

3.1.4. Potential Risk Distribution in 16th Phase

>> P^{15}

$$P^{15}=\begin{bmatrix} 0.2945 & 0.2893 & 0.2638 & 0.0852 & 0.0281 \\ 0.2882 & 0.2831 & 0.2581 & 0.0834 & 0.0275 \\ 0.2867 & 0.2817 & 0.2568 & 0.0830 & 0.0274 \\ 0.2833 & 0.2784 & 0.2538 & 0.0820 & 0.0271 \\ 0.2831 & 0.2782 & 0.2536 & 0.0820 & 0.0271 \end{bmatrix}$$

>> S * P^{15}= [0.2842 0.2793 0.2546 0.0823 0.0272].

After 15 transition periods, the probabilities for high risks are reducing so fast compared to the previous phases.

3.1.5. Potential Risk Distribution in Kth Phase

>> S × P^k= [0.2942 0.2693 0.2246 0.0723 0.0172].

The distribution of risk after *k*-steps transitions from the first phase is $S^{(K)}=S^{(0)}\times P^{(K)}$ whereby k is the transitions.

When the factors affecting the projects reach stable state, then the level of risks remains constant. After k transitions we obtain potential risk probabilities stable state as follows;

[0.2942 0.2693 0.2246 0.0723 0.0172].

These results illustrate that after the k transitions, the probabilities of the risks in highway projects for the five categories (levels) are 29.4%, 26.9%, 22.5%, 7.2%, and 1.7% respectively.

Through comparison we find out that between these levels of risks in the planning phase of the projects and after these transitions, the severity of these potential risks has been minimized throughout the period of the highway projects, especially for the risks in medium, high, and very high levels. The Markov Chain, through the application of the transition states, is then seen so effective in risk management.

3.2. Conclusion

The paper has drawn the following conclusions: Project completion has been intensively affected by risks which are a threat for a long time now. Handling these uncertainties, identification of risks and its' analysis are the key steps in highway projects. The key aim of this study was to analyze the evolution of different risks in the highway projects by using a Markov chain approach. Henceforth, the Markov chain which is a stochastic process is illustrated and presented. The other aim of the paper was to show the applicability of Markov chain approach in these projects using risk data. The Markov chain can be used effectively in management of the risks to reduce the corresponding levels of risks at different phases. This can be effective when the appropriate measures are put in every phase according to the probabilities of occurring.

3.3. Recommendations

The following recommendations are hereby presented:

- Research should be done to connect Markov chain with the cost functions in optimization models.
- Since uncertainties in highway projects can result to inexact and subjective risk data presence making the assessment of risk process complicated, then more research should be done on the topic which considers the Markov chain approach vague environment.

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Competing Interests

The authors have declared that no competing interest exists.

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