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Risk Assessment of ERP Implementation Using Generalized Stochastic Petri Net

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Abstract:

Risk and complete uncertainty can potentially have damaging consequences on the Enterprise Resource Planning (ERP) implementation projects. Risk management is also one of the ten knowledge areas propagated by the Project Management Institute which shows its importance. Risk management in the ERP system implementation context is a comprehensive and systematic way of identifying, analyzing and responding to risks to achieve the project objectives. This paper presents a risk modelling method using Generalized Stochastic Petri Nets (GSPN) along with simulation for risk estimation in ERP implementation. An overall risk management framework is also developed and the same is used to explore various risks, categorize them as per their sources, assesses those risks and their variability. This approach will help key project participants such as client, contractor or developer, consultant, and supplier – to meet their commitments and minimize negative impacts on ERP project performance in relation to cost, time and quality objectives. The methodology is demonstrated using a case study of ERP implementation project.

1. Introduction:

ERP is a suite of integrated software applications that allow seem-less integration of business processes and information by using a common database and standard procedures. They also automate many of the back-office functions as well as integrates all aspects of operations like product planning, product development, production, logistics and sales & marketing (Davide Aloini et al. (2012)). Generally, ERP packages used to have workflow engines which will help to automate workflows so that information and documents are passed to various users for transactions processing and to managers and directors for review and approval (Chuck et al. (2007), James et al. (2002)).

ERP system provides several advantages to the organization. Most of the operational difficulties such as meeting production schedules, reducing inventory, reducing operational costs, increasing productivity, providing better control over materials, improving quality etc. are minimized by ERP systems. ERP also helps to breakdown silos and enhances cooperation among various functions results in higher quality of product and service, reduced time to market, improved production with lower cost and finally improved market share with customer satisfaction (4).

Although there are several advantages are associated with ERP systems, many of the ERP systems failed to deliver results or ineffective (Xue et al. (2005)). Most of the failures are due to poor implementation of ERP systems. Generally, ERP system calls for massive change to reap the benefits. Critical issues should be addressed properly in ERP implementation. Selection of proper ERP package, management of consultant, commitment of top management, proper reengineering of existing business processes, integration with other information system software, proper training of employees place important role in success of ERP implementation.

Standish Group International (SGI) estimated that 90% of SAP R/3 ERP projects run late (Scott and Vessey (2002)). This group also studied more than 7400 IT projects and disclosed that 31% were abandoned after starting, 34% were running late or over budget and some of them were scaled down or modified. Only 24% were completed on time and on budget (Cunningham (1999)).

Since ERP system implementations is typically a massive project for an enterprise and their failures leads to wastages of money and time; it is essential for the companies to proactively identify and mitigate the various risks associated with the implementation process.

2. Literature review:

There are several research papers are available in the literature to outline the critical success factors of ERP implementation (Al-Mashari et al. (2003), Mabert et al. (2003), Mandal and Gunasekaran (2003), Umble et al. (2003), Woo (2007)).

Motwani et al. (2002) compared successful and unsuccessful ERP implementation using case study methods. Ineffective strategic planning, poor communication and insufficient project team skills are some of the reasons for failures. The authors reasoned out that proper change management practices, proper stakeholder relationships and cultural readiness of the organization are key success factors for ERP implementation.

Yusuf et al. (2004) highlighted business, technical and cultural issues of ERP implementation in Rolls Royce. It outlined the need for business process reengineering (BPR), proper communication and change management techniques. The importance of training both for senior and end training, matching processes to the software configuration are outlined.

Malhotra and Temponi (2009) suggested six factors which can lead to successful ERP implementation (1) project team structure, (2) implementation strategy, (3) database conversion strategy, (4) transition technique, (5) risk management strategy and (6) change management strategy.

Inadequate BPR, inappropriate software selection, low level of top management commitment, low quality consultancy services are some of the ERP risk factors (Ehie and Madsen (2005)).

The top five risk factors such as inadequate ERP selection, ineffective strategic thinking and planning, ineffective project management techniques, bad managerial conduct and inadequate change management are outlined by the authors Aloini et al. (2007).

Hakim and Hakim (2010) grouped the risks involved in ERP implementation from the perspectives of the client-organisation and that of the experts. They have given six categories of risks related to organisation, specialised skills, project management, system, user and technology.

There are several risk management processes are available in the literature. Some of them are PMI, Standards Australia 1999, SAFE methodology and Risk diagnosing methods. Most of them are too general for ERP applications.

Though there are several studies are available to manage risks in ERP project implementation, we still lack literatures on practically managing risks and uncertainties to effectively implement ERP project.

This paper provides an overall ERP life cycle model and the same is used to explore various risks, categorize them per their sources, assesses those risks and their variability. This paper also presents a Petri Net based risk modelling method and Monte Carlo simulation as an assessment method for ERP implementation.

3. ERP Implementation Life Cycle Model:

The process of implementing ERP in any organization has several phases. A seven phase model is presented to assess the risk involved in ERP implementation in its life cycle. It is starting with initiating the project, planning, development, Testing and Training, Review & Improve, Go-live and finally Sustain. The details of various phases are given below.

Phase 0: Initiate:
This phase is about the getting approval for the ERP project. The initial documents such as project charter must be created in the beginning. The documents should address the goals, objectives, and deliverables of the project, the business rationale for doing the project, initial project team, their roles and responsibilities, the investment details and the draft project plan. This project charter shall be approved by the project sponsor. The project manager can schedule a project kick-off meeting after approval.

Phase 1: Plan:
This is the crucial stage in ERP implementation. Proper study and research must be undertaken within the organization considering internal and external environment, the project team should select the right ERP package of the organization meeting the current and future requirements. The user requirements, Business Process Reengineering (BPR) requirements, best practices requirements are to be completely laid out. Gap analysis ought to be performed to understand the current situation and future position of the organization. The hardware and infra requirements are to be laid out. Finally, the detailed project plan shall be prepared with timelines and cash flows.

Phase 2: Develop:
This is the actual software development considering processes available in the organization. Some processes may require heavy customization and some may call for full adaptation of the software vendor modules. The great deal efforts are necessary to integrate existing application and databases to the new software and hardware systems. The entire development requires functionality testing to ensure adequacy of the ERP systems.

Phase 3: Testing and Training:
One of the major reason for ERP failure is that the installed products are not meeting the stakeholders' expectation and hence testing and training has been mentioned as separate phase to provide more focus. It is the process of checking the quality of the product. This provides enough confidence that developed products are meeting the stakeholders and end user requirements. Structured training shall be given to the end users so that their feedback will be useful for improvements.

Phase 4: Feedback and Review:
This phase is about collection of feedback from various users and reviewing their requirements and making changes if required. This phase will also helpful for evaluating the deployment plan and the project team can finalize deployment method.

Phase 5: Go-live:
The “big bang” and “phased methods” are used for introducing new system to the organization. Each of this method has their own pros and cons. The project team should select the best strategies for actual implementation. Post implementation review shall be undertaken after the go live. Subsequently, the project team can hand over the project to the support team. The project team can also initiate the actions for project closure.

Phase 6: Sustain:
Activities like bug fixing, maintenance and enhancements are to be carried out in this phase. Effort shall also be made to derive maximum values from the ERP system.

The complete ERP implementation life-cycle are mentioned the Figure 1. Figure 2 provides the details on efforts needed by the project team during various phases of ERP implementation life cycle.

Figure 1: ERP Implementation Life Cycle Framework

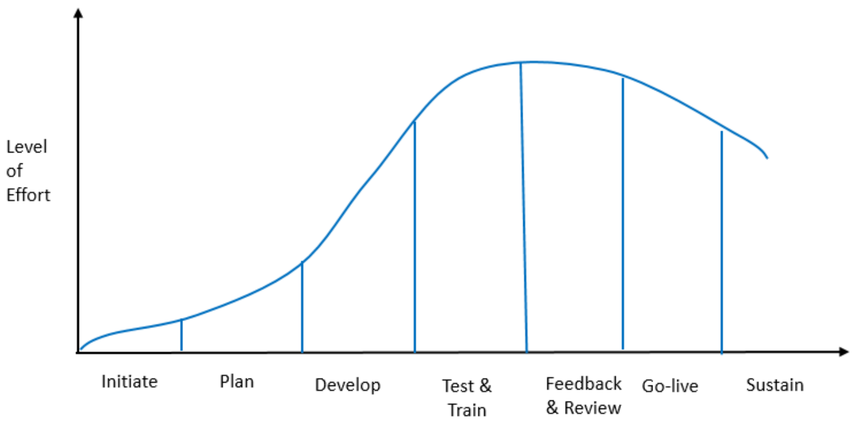

Figure 2: ERP Implementation Life Cycle – Effort Graph

4. Proposed Risk Assessment Methodology for ERP Implementation:

ERP implementation and risk are tightly linked; both are infinite in their variety and result that their combination usually defies accurate description. The environment in which the conception and development of ERP project takes place is complex and involves several phases as described in the project implementation life cycle (Figure 2). Hence, systematic risk assessment methodology is essential for any ERP implementation project. The proposed risk assessment method helps to identify risks associating in implementing ERP through all the seven phases of ERP. The companies could focus their effort in important delivery system aspects, so that the ERP value delivered as intended.

The proposed method consists of two stages. The Stage A is about development of GSPN model for various risk sources associated with ERP implementation and Stage B is about simulation to handle uncertainties in risk sources.

Stage A: Development of GSPN Model for Risk Sources:

The following steps are adopted for developing GSPN model.

1. **Determine Risk Sources:** Identification of risk sources provides a basis for systematically examining the situation and ability of ERP project to meets its objectives. The risk sources are both

internal and external to the project. Establishing categories for risk sources provides a mechanism for collecting and organizing risk.

2. **Identify potential risk events and actions:** Brainstorm with the team and create a list of every possible risk event and opportunity you can think of. If you only focus on the threats, you could miss out the chance to deliver unexpected value to the customer or client. Also the project team need to get in touch with experts and lead users on various risk events. The project should be in a position to capture almost 99% of risk events in the planning stage itself.
3. **Determine causes:** By asking several "whys" (Five Whys) repeatedly will lead to root causes (deficiency or sources of variability) of risk events/actions.
4. Determine the Effects (consequences) of each risk event if it happens.
5. **Determine likelihood:** What is the rate at which a risk event will occur? Estimate it with past data or use expert opinion.
6. **Determine Response:** What are the response mechanisms in place to minimize the impact of risk if it happens? Estimate the rate at which response will takes place.
7. **Determine impact on project value (%):** What would happen if each risk occurred? Would your final delivery date get pushed back? Would you go over budget? Identify which risks have the biggest effect on your ERP project's outcomes, and estimate them in terms of monitory value and calculate percentage value affecting.
8. **Calculate Value @ Risk:** It is the multiplication of likelihood, impact of project value to bring project to risk free.
9. **Develop GSPN model:** This step is about development of GSPN model for the risk sources.
10. **Generate Reachability Markings and Graph:** Develop a set of reachable markings and reachability graph to understand the various possible states of the system in ERP implementation.

Stage B: GSPN Simulation:

Discrete event simulation (DES) is a method of simulating the behaviour and performance of ERP implementation process. Each event occurs at a particular instant in time and marks a change of state in the system (Stewart Robinson (2004)). Between consecutive events, no change in the system is assumed to occur; thus the simulation can directly jump in time from one event to the next.

5. Case Study: ERP Implementation in a Home Appliances Manufacturing Company:

This case study was prepared keeping in mind a mid-sized company manufacturing home appliances. The company has manufacturing plants in 3 locations and has sales and marketing offices almost in all major cities. The company plans to implement ERP systems for seem-less operations. The risk assessment was carried out using the methodology described in Section 4. The details are provided in the following subsections.

5.1 Sources of Risks and failure initiating events/actions/conditions

The various sources of risks and their failure initiating events/actions are given in Table 1. These failures initiating events are grouped into seven risk sources which are identified as:

1. Strategic
2. Organizational & Managerial
3. Technology
4. Processes
5. Project Management
6. People (internal)
7. People (external)

The construction of functional block diagram for various risk sources are given in Figure 1.

Table 1: Sources of Risks and their Failures Modes

Risk Sources	Failure initating Events/Actions/Conditions	Effect(s)
Strategic	No clear goals and objectives	Loosing competive advantage, Hampered growth, No integrated info, Poor quality reporting, Poor data quality, Poor CRM, Reduced business analytics, Poor supply chain, Ineffective regularotory compliance, Inefficient workflow, Higher cost of operation, Poor visibility on organization performance, Redundancy in work, Poor customer satisfaction.
	Poor ERP implementation strategy	
	Wrong team formation (Client, vendor etc.)	
	Lack of champion	
Organizational/Management	Poor cultural readiness	
	Poor organizational maturity	
	Retension of key employees	
	Inadquate communication system	
	Inadequate training	
	Failure to convince key users	
	Lack of coordination	
	Bad managerial conduct	
	Poor planning	
Technology	Not good technical infrastructure	
	Issues of data migration and analysis	
	Wrong package selection	
	Poor system architecture	
	Poor legacy system management	
Processes	No change management process	
	No risk management process	
	Inadequate communication	
	Inadequate new process education and training	
	Poorly implemented BPR	
	Lack of process streamlining	
Project Management	Inadequate budget	
	Inadequate timing	
	Poor project creep management	
	Inadquate risk management	
	Cash flow issues	
	No proper investment analysis	
	Ineffective PM techniques	
People (internal)	Commitment issues with leadership team	
	Poor leadership	
	Lack of internal experts both in internal processes and technology	
	Failure to mix both internal and external experts	
	Workforce resistance to change	
	User insecurity	
People (external)	Ineffective consulting services	
	Lack of comittment	
	Incomplete development	
	Poor capture of "as-is" process	
	Lack of technical expertise	
	Poor post-implementation support	
	Poor understanding of needs and wants	
	Development errors	
	Too many contractors/subcontractors	

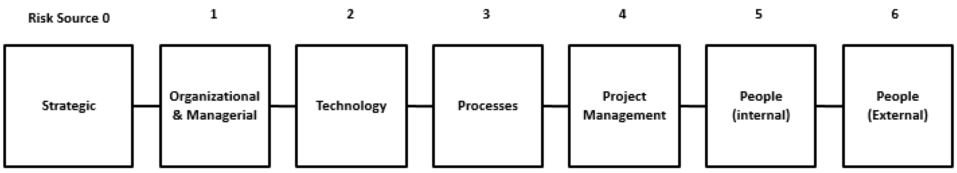

Figure 1. Various risk sources of ERP implementation

5.2 Petri Nets

As per (T. Agerwala (1979), T. Murata (1989, J. L. Peterson (1981), and C. A. Petri (1962)), Petri Nets have, over the last five decades, attracted the attention of researchers in several areas ranging from computer science to social sciences. PN can be introduced either algebraically or graphically. They are defined algebraically in terms of the following elements.

A PN is a 5-tuple, $PN = (P, T, A, W, M_0)$, where
$P = \{P_1, P_2 ..., P_m\}$ *is a finite set of places*
$T = \{t_1, t_2, ..., t_n\}$ *is a finite set of transitions*
$A \subseteq (P\ X\ T)\ U\ (T\ X\ P)$ *is a set of arcs,*
W is a weight function that takes values 1,2,3... and
M_0 *is the initial marking.*

A standard PN consists of a set of *"places" P* drawn as circles, a set of *"transitions" T* drawn as bars and a set of directed arcs *A*. An arc connects a transition to a place or a place to a transition. Place may contain *"tokens"*, which are shown as dots. The *"marking"* or the state of a PN is defined by the number of tokens contained in each place and is denoted by *M*. The construction of a PN model requires the specification of the *"initial marking"* M_0.

A place is called an *"input place"* to a transition if an arc exists from it to the transition. A place is an *"output place"* if an arc exists from a transition to the place. A transition is said to be *"enabled"* when all its input places contain at least one token. If the enabled transition is *"fired"*, it removes one token from each input place and deposits one token in each output place. The firing of a transition modifies the distribution of tokens in places and thus produces a new marking for the PN.

For a given initial marking M_0, the *"reachability set" S* is defined as the set of all markings that can be reached from M_0 by a sequence of transition firings. As per reference (G. Florin et.al. (1991), and M. K. Molloy (1995)), in a Stochastic Petri Net (SPN), the firing time is an exponentially distributed random variable. Thus, the marking sequence in a SPN obtained from the firings, is isomorphic to a continuous time Markov Chain. As per (M. A. Marsan et.al. (1991)), in a Generalized Stochastic Petri Net (GSPN), the transition firing rates can be instantaneous or random firing time based on some distribution. Therefore, the set of transitions can be partitioned into a set of random timed transitions (with finite firing rate) and a set of immediate transitions. However, for any marking at which there are several enabled immediate transitions, a probability distribution must be specified, according to which firing of the transitions are selected.

5.3 GSPN Model of ERP implementation

The risk event initiation (from a risk source) mechanism and risk response activities of the ERP implementation are given in Figure 2. The initial marking of the net contains tokens in the places P_0 to P_{14} and P_{15}. This indicates that the risk sources *0* to 6 are available in the ERP project and are ready to initiate any risk event. The token in the place P_{15} indicates that the ERP implementation is going on normally without any risks. Tokens in the places P_0 and P_{15} may enable the transition t_0, which corresponds to the initiation of any risk event from risk source called strategic (source *0).* If the transition t_0 is fired, then it removes a token each from places P_0 and P_{15} and deposits a token each in the places P_7 and P_{14}. The token in the place P_7 indicates the source *0* is in the state of initiated risk event and the one in the place P_{14} indicates the project is experiencing the risk. The token at P_7 can enable the transition t_7. The transition t_7

corresponds to the risk response by the management so that the effect of risk event is nullified or minimized. If the transition t_7 fires then it removes a token each from the places P_7 and P_{14} and deposits a token each in the places P_0 and P_{15}. This means that corrective actions are completed and the risk from source *0* are removed and now the ERP implementation is working normally without any risks. The same description is also applicable to other types of risk sources with their places and transitions.

In this model, the presence of a token in the place P_{15} indicates that the ERP implementation is in good state. The project under risk is indicated by the presence of a token in the place P_{14}.

If,
T_o – is the mean time of a token is available in the places $P_{15.}$
T_f – is the mean time of a token is available in the places P_{14}

Then, the success of the ERP implementation is given by,

$$PID\,\text{ProcessSucess} = \frac{T_o}{T_o + T_f}$$

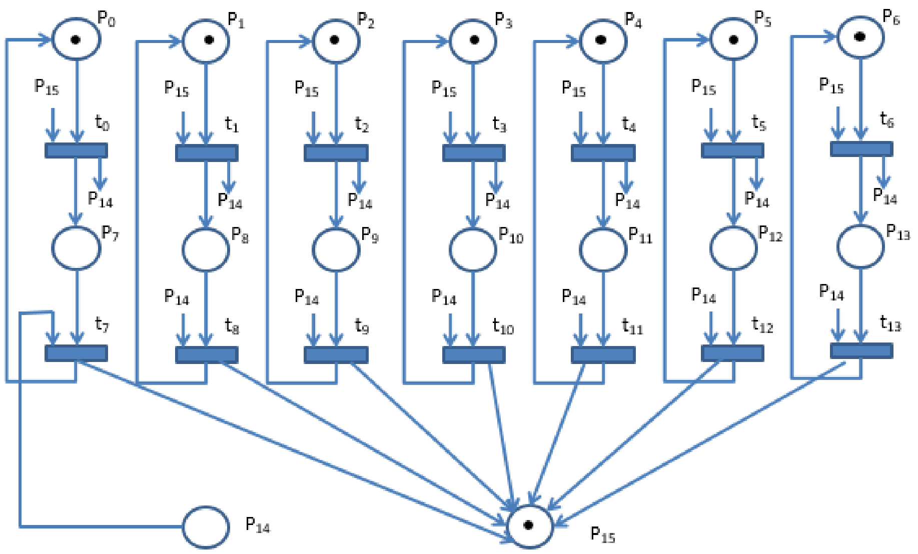

Figure 2. GSPN specification of risk model of ERP implementation

5.4 Generation of reachability tree

The first step in the analysis of PNs is the generation of the reachability tree. This is a set of markings that are possible from the initial marking. The nodes of the reachability tree represent the markings of the net, the root representing the initial marking. The directed edge from one marking to another indicates the firing of the corresponding transition. The analysis of the reachability tree will generate a lot of information about the system and a close examination enables verification of PN as a valid representation of the system being modeled. Thus, it is used for checking whether the model is a good representation of the system. The reachability tree is generated as follows.

Beginning with the initial marking, transitions which are enabled by this marking are identified and new markings that result from the firing of each of the enabled transitions are generated. Each new marking is added to the tree and the directed edges from the markings are drawn. The algorithm for generating the reachability tree was developed. The set of reachable markings along with its arc sets and reachability graph generated using the algorithm for the ERP implementation system are provided in Table 2, 3 and Figure 3.

Table 2. Set of Reachable of Markings

	Places															
Markings	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
0	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	1
1	0	1	1	1	1	1	1	1	0	0	0	0	0	0	1	0
2	1	0	1	1	1	1	1	0	1	0	0	0	0	0	1	0
3	1	1	0	1	1	1	1	0	0	1	0	0	0	0	1	0
4	1	1	1	0	1	1	1	0	0	0	1	0	0	0	1	0
5	1	1	1	1	0	1	1	0	0	0	0	1	0	0	1	0
6	1	1	1	1	1	0	1	0	0	0	0	0	1	0	1	0
7	1	1	1	1	1	1	0	0	0	0	0	0	0	1	1	0

Table 3. Set of Markings

Start Marking	End Marking	Fired Transition
0	1	0
0	2	1
0	3	2
0	4	3
0	5	4
0	6	5
0	7	6
1	0	7
2	0	8
3	0	9
4	0	10
5	0	11
6	0	12
7	0	13

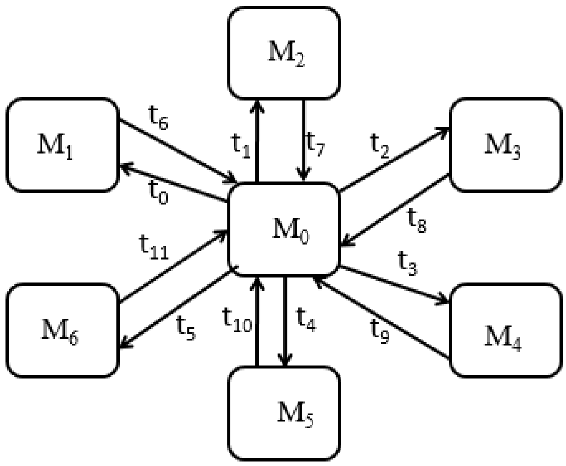

Figure 3. Reachability Graph

5.5 GSPN simulation

At the beginning of the simulation run, the algorithm identifies all the enabled transitions from the initial marking. The firing time for each transition is determined by sampling from exponentially distributed firing intervals. The minimum firing time is selected and the corresponding transition is fired. The system moves to the next marking. The state of the system (good or complete failure) is ascertained. Initiated risk events from a source, if any, will undergo corrective response actions. After response completion, the ERP project implementation process will become risk free. These events are simulated for 2 years (it is assumed that the approved ERP project duration is 2 years). To reduce the standard deviation of the estimates of system down time and up time, a Variance Reduction Technique (VRT), *viz.*, antithetic variate is used. The simulation is replicated in sufficient number of times to achieve convergent results. The risk occurrence rate and response rate data used in the simulation experimentation is given in the Table 4. The entire program is written using GPSS/H. The algorithm for the simulation is given below:

marking = initial marking
for j = 1 to t do
  firing_time(j) = -1
while (simulation run not ended) do
  for j = 1 to t do
    if transition j is enabled, then
      if firing_time(j) < 0 then
        generate firing_interval
        firing_time(j) = clock + firing_interval
      endif
    else (if not enabled)
      firing_time(j) = -1
    endif
  endfor
  find minimum firing_time(t)
  fire transition t
  reset firing_time(t) = -1
endwhile

Table 4. Risk occurrence rate and Response rate data

#	Risk Sources	Risk Occurence Rate (events/year)	Response rate (actions/year)
1	Strategic	0.36	0.29
2	Organizational/Management	0.69	0.80
3	Technology	0.92	1.05
4	Processes	0.51	0.92
5	Project Management	0.80	0.69
6	People (internal)	0.92	1.05
7	People (External)	1.05	0.69

THE PORTIONS BELOW REQUIRE WORKING WITH SIMULATION (NEED MODIFICATION)

6. Results and Discussion (Similar results are given below – need modifications)

The results concerned with process is under risk, obtained from the simulation experiments are given in the Table 5. The first column is the replication number. The second column corresponds to simulation results using thetic random numbers and third column corresponds to simulation results using antithetic random number. The average value given in the 4th column is finally considered as the simulation result of replication 1. Like this, 30 replications are carried out to get steady state. The system with risk-freeness graph is provided in the Figure 5. The percentage of time the ERP implementation is risk free was found to be very high as ……….

Table 5. The thetic and anti-thetic simulation results (need modification)

Replication #	Thetic down time (Hrs)	Anti-thetic down time (Hrs)	Average down time (Hrs)
1	465.1	298.5	381.8
2	304.3	223.7	264
3	395.7	617.7	506.7
4	244.2	207.5	225.85
5	260.9	294.1	277.5
6	252.5	277.6	265.05
7	292.9	278.7	285.8
8	634	305.6	469.8
9	277.8	297.4	287.6
10	230.1	331.2	280.65

7. Conclusion:

Risk assessment study conducted for the ERP implementation project generates proactive solutions for managing different sources of risks associated with ERP project effectively. Any company can also use these methodologies to find out their weaknesses in their ERP project implementation. This will help organizations to develop necessary learning and increase their capabilities, which lead to project success.

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