Quantitative Hazard Analysis of Information Systems Using Probabilistic Risk Analysis Method

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Abstract

Hazard analysis identifies probability to hazard occurrence and its potential impact on business processes operated in organizations. This paper illustrates a quantitative approach of hazard analysis of information systems by measuring the degree of hazard to information systems using probabilistic risk analysis and activity based costing technique. Specifically the research model projects probability of occurrence by PRA and economic loss by ABC under each identified hazard. To verify the model, each computerized subsystem which is called a business process and hazards occurred on information systems are gathered through one private organization. The loss impact of a hazard occurrence is produced by multiplying probability by the economic loss.

Keywords : Hazard Analysis, Probabilistic Risk Analysis, Activity Based Costing, Business Process, Information Systems

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1. Introduction

Organizations have demanded hazard analysis and emergency preparedness about all hazards such as computer and communication breakdowns, and cyber terror as business activities dependency on information systems increased continuously. Hazard analysis identifies probability to hazard occurrence and its potential impact on business processes operated in organizations. This paper is focused on how hazard analysis manages quantitatively.

Crisis management and quantitative/qualitative hazard analysis about information systems were investigated. In addition, several case studies by the probabilistic risk analysis (PRA) method described other subjects such as nuclear, intelligent traffic system, and industrial engineering, etc. These subjects have involved in this research [US. DOT, 1996; Geun-Joong Yu and Seong-Ki Chae, 1987]. This paper illustrates a quantitative approach of hazard analysis of information systems using a case study.

2. Previous Study

Probabilistic Risk Analysis is a technique used to evaluate the failure and success rate of a system, and was mainly used to analyze/track the risk level of nuclear power plant accident event paths. Probabilistic Risk Analysis model assumes the probability distribution of the risk variable that causes business uncertainty and measures the level of the business's uncertainty through the resulting variable's probability distribution and cumulative probability distribution [US. DOT, 1996]. It generates What-IF scenarios using random numbers and computer simulation to analyze several frequently occurring risk situations and can be used in both quantitative/qualitative decision-making [US. DOT, 1996; Geun-Joong Yu, and Seong-Ki Chae, 1987].

Probabilistic Risk Analysis process closely examines the risk factors and tracks event paths, and depending on need, develops event path scenarios. Based on these, it creates risk analysis modeling and carries out the simulation. Such probabilistic risk analysis can proceed in two parts : the examination of the risk factors and risk analysis evaluation. In the examination of risk factors, data are collected through a preparatory investigation about the existence of risk factor's uncertainty, and based on these, scenarios that classify the risk are created. In the risk analysis evaluation, more precise data are collected to model risk factors and the Monte Carlo simulation is applied to evaluate the occurrence probability distribution. Impact assessment of the potential risk level is carried out with the result. Such probabilistic risk analysis may apply differently depending on the analysis situation and environment [Yong-Taek Lee, 2003].

3. Research Model

The research model is represented as following : [Hyonam Cho, 2001; [Jong-Sung Sunwoo, 1998]

$$f(Ri)=\Sigma(Pi \times Li) \quad (1)$$

- f(Ri) : The sum of risk loss impact from the beginning to "i"th event-path
- Pi : The probability of hazard occurrence of "i"th event-path
- Li : Loss amount of "i"th event-path

3.1 Probability of hazard occurrence (Pi)

The PRA is used to measure probability of the hazard occurrence (Pi) in this research. Specifically among the PRA methods, the Event Tree technique takes as modeling of the hazard analysis and the Monte Carlo Simulation (MCS) as a probabilistic analysis technique.

PRA means a model that allows the uncertainty of the business to be quantitative through the probability distribution of the resulted variables. Also, it is the accumulated probability distribution as taking the assumption that the probability distribution of the hazard variables is related to the business uncertainty [US. DOT, 1996].

The formula to produce Pi refers to Cho's model [2001] and makes it by using the Event Tree technique as following.

$$Pi = P(Cn)(Ci \cdots k) \quad (2)$$
$$= P(Ti)P(E1)P(E2) \cdots P(Ek)$$

In this model, *P(Cn)* indicates the probability of an event to be the possible stirring (*Ti*). *P(Ci ⋯ k)* means that the probability of each event can be possibly occurred from *P(E1)* to *P(Ek)* on an event-path. In other words, an event that can be possibly occurred is caused by a stirring event. *Pi* produces a result by multiplying *P(Cn)* by *P(Ci ⋯ k)*.

The procedure to measure *Pi* is as followings : [Hyonam Cho, 2001]

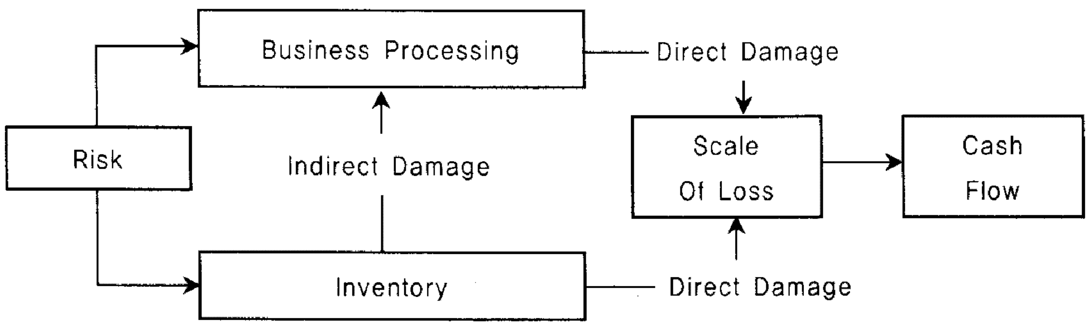
I) The classification between a stirring event and an event occurrence

ii) Build up the event tree scheme

iii) The calculation of probability of the event occurrence is related to each event-path using MCS

3.2 Loss Amount (Li)

The measurement of the loss impact is based on the Activity Based Costing (ABC) method. <Figure 1> shows the ABC model. If a crisis strikes an organization, business processes, assets, property, or a business image, they are damaged. Those elements affect the decrease of sales volume of the organization directly and indirectly, which produces bad cash flow as a result. The major concern is how business



⟨Figure 1⟩ ABC Model for Economic Loss Measurement [Jong-Sung Sunwoo, 1998] processes and inventories that are damaged by a business crisis, measure quantitatively in terms of information systems.

4. Research Model Analysis

The research model is verified through a case study that illustrates a big chemical engineering company being composed of the headquarter and a factory in the local area. It assumes that the hazard strikes the information systems in the organization.

4.1 Analysis of Information System Asset

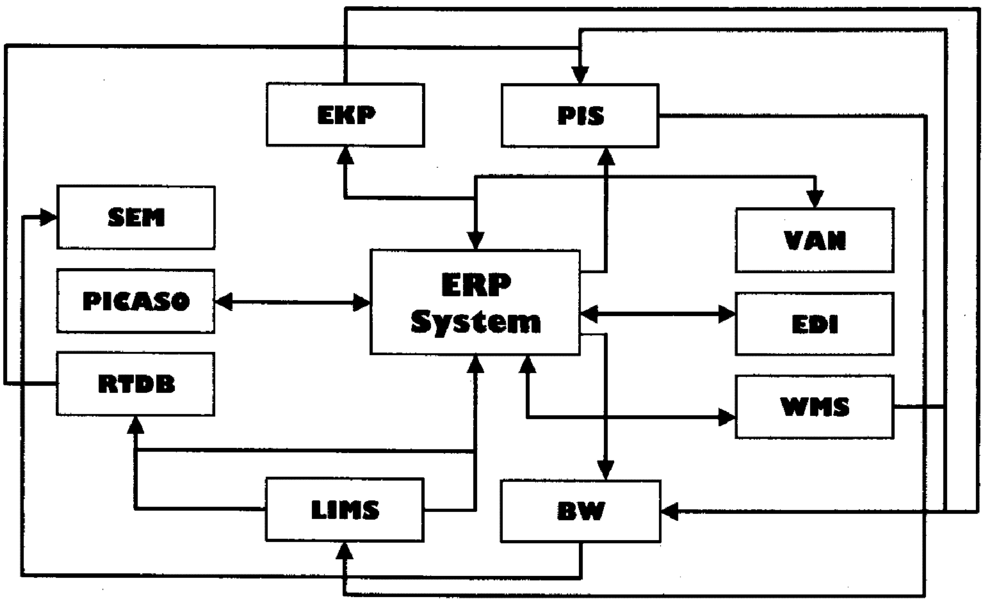
The information system includes ERP and 13 legacy systems, in which each system is consisted in detailed business processes. <Figure 2> shows a link among each system, which means that a linked system is affected if one system breaks down because the systems share the data. PICASO, RTDB, LIMS, PIS, and WMS subsystem supports the manufacturing process. SEM provides executive management based on data which are produced by the BW subsystem. EKP operated by a groupware system is a kind of knowledge management system.

The expenses element with the amount gathered as the following : IT expense ($1,919,629), IT property ($1,919,629), Salary ($47,009,496), department expense used by employees ($24,263,771), external project ($322,099), and business profit ($162,685,177).

4.2 Hazard Analysis of Information Systems

The Incident/Accident history with the interview to the system director is gathered to analyze the hazards related to the information systems.

<Table 1> shows hazards that were controlled orderly within a specific time period during one year [2003]. This research is focused on the technological hazards such as human er-



〈Figure 2〉 A Link Diagram among Information Systems (business processes) [H. Chemical, 2004]

<Table 1> Accidents that occurred on Computer and Information Systems [H. Chemical, 2004]

Category	Accident	Number	Rate(%)	Acc. No.
Operation Defect	Virus	9	30.0	T1
	Data deletion on PC	1	3.3	T2
	Operator error on servers	1	3.3	T3
	Lack of DB management	1	3.3	T4
	Defect of computer devices	1	3.3	T5
System Defect	Server breakdown	2	6.7	T6
	Network down and defect	3	10.0	T7
	Defect of Web service	1	3.3	T8
	Data transmission delay	1	3.3	T9
	Server disk error	2	6.7	T10
	DB defect	1	3.3	T11
Infrastructure Defect	Air conditioner trouble	4	13.3	T12
	UPS defect and trouble	3	10.0	T13
Total		30	100.0	

ror, and equipment failure (except natural hazards and civil hazards). The organization was faced with cyber terror, and the virus had the highest rate among the hazards.

4.3 Scenario Development of Hazard Analysis

(1) Event on Hazard Analysis

The PRA measures probability of the event occurrence with the event tree model, which is developed by a predefined scenario. There are two kinds of scenarios. One is for stirring event and the other is for the event that can possibly occur. The stirring event promotes an event that is possible to occurrence, which may be a series of events. The accident that shows in <Table 1> indicates a stirring accident. A breakdown of business process (such as ERP system that shows in <Figure 2>) is affected by a stirring event, which refers to an event that is possible to occur [Hyonam Cho, 2001; Hyun-Ho Choi, 1998; Young-Bin Park, 1997; Gwang-Seop Kim, 1997].

Accordingly, we called that the process breakdown of ERP, EKP, BW, SEM, PICASO, LIMS, RTDB, WMS, VAN, EDI, PIS into E1, E2, E3, E4, E5, E6, E7, E8, E9, E10, E11 sequentially.

(2) Scenario Development of Accident Occurrence

The purpose to develop the scenario related to the accident occurrence is due to the lack of historical data in the organization. The scenario was created based upon a few historical data [K. Bank, 2005; Jeong-Hwa Hahn, 2004]. <Table 2> shows the total number and the rate of each

〈Table 2〉 Stirring Events by Scenario

Category	Accident	Acc. No.	Time(Month)																								Number	Rate
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24		
Operation Defect	Virus	T1	0	0	1	1	0	1	1	0	0	1	1	1	0	0	2	1	0	0	1	0	0	1	1	0	13	0.29
	Data deletion on PC	T2	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	00	0	0	0	2	0.04
	Operator error on servers	T3	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0.04
	Lack of DB management	T4	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	2	0.04
	Defect of computer devices	T5	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	2	0.04
System Defect	Server breakdown	T6	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0.07
	Network down and defect	T7	0	1	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	4	0.09
	Defect of Web service	T8	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	2	0.04
	Data transmission delay	T9	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	2	0.04
	Server disk error	T10	1	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	3	0.07
	DB defect	T11	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0.02
Infrastructure Defect	Air conditioner trouble	T12	1	0	0	1	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	5	0.11
	UPS defect and trouble	T13	1	0	0	0	1	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	4	0.09
Total																											45	1.00

stirring event that explains accident occurrence, which is derived from a scenario during two years. Virus (29%) is the most and DB defect is the least (2%) among the stirring events [K. Bank, 2005; Jeong-Hwa Hahn, 2004].

<Table 3> refers to the total number and the rate of breakdown of each business process that indicates an event occurrence, which is derived from a scenario during two years. ERP breakdown (24%) is the most among event occurrences.

(3) Scenario Development of Event-Path

An event-path scenario that is shown in <Table 4> develops on the basis of the link among the business processes like <Figure 2>.

In the case of scenario number 1, for example, T1 (stirring event, virus) affects E1 (event occurrence, ERP) breakdown. E1 induces E2 (EKP) breakdown, and E2 brings about E3 (BW) breakdown, and E3 causes E4 (SEM) breakdown. Scenario 1 refers to an event-path. <Table 4> includes 11 event paths stirred by a virus ac-

〈Table 3〉 Events Occurrence by Scenario

Process	Acc. No.	Time(Month)																								Num-ber	Rate
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24		
ERP	T1	1	0	0	1	0	0	1	0	0	1	1	0	1	0	1	1	0	1	1	0	1	0	0	0	11	0.24
EKP	T2	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	1	0	1	0	1	6	0.13
BW	T3	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	3	0.07
SEM	T4	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	2	0.04
PICASO	T5	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	5	0.11
IIMS	T6	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	3	0.07
RTDB	T7	0	0	0	0	2	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	5	0.09
WMS	T8	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	3	0.07
WAN	T9	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0		0	0	0	3	0.07
EDI	T10	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	3	0.07
PIS	T11	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	2	0.04
Total																										45	1.00

cident (T1). Accordingly, event paths can be created by each stirring event, that is, overall accidents in the organization [Yong-Taek Lee, 2003].

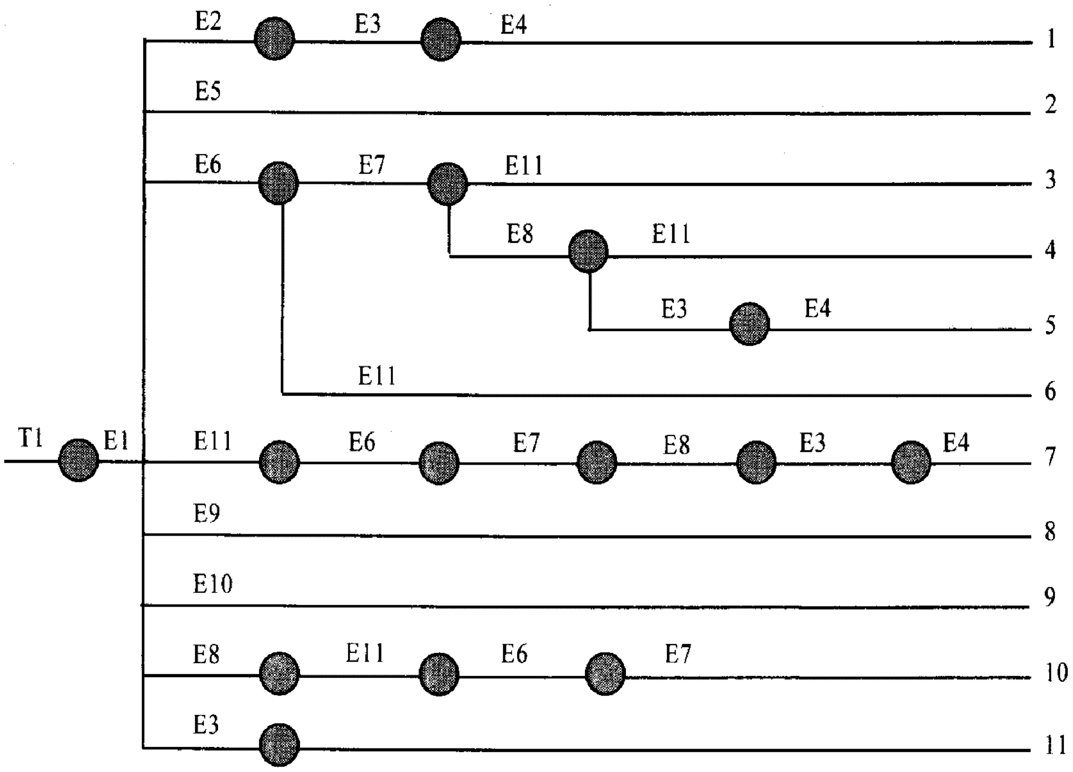
4.4 Event Tree Modeling

The event-paths can be transformed to an event tree that represents the relationship between a stirring event and event occurrences. The Event Tree that comes from the event paths in <Table 4> shows a causal relation between E1 (ERP) and the other Legacy system, induced by T1 (virus stirring event)<Figure 3> [Hyonam Cho, 2001].

〈Table 4〉 Event Path Scenario of ERP Business Process

Scenario No	T	P1	P2	P3	P4	P5	P6	P7
1	T1	E1	E2	E3	E4			
2	T1	E1	E5					
3	T1	E1	E6	E7	E11			
4	T1	E1	E6	E7	E8	E11		
5	T1	E1	E6	E7	E8	E3	E4	
6	T1	E1	E6	E11				
7	T1	E1	E11	E6	E7	E8	E3	E4
8	T1	E1	E9					
9	T1	E1	E10					
10	T1	E1	E8	E11	E6	E7		
11	T1	E1	E3	E4				

T : stirring event, P : business process.



〈Figure 3〉 Event Tree Induced by a Stirring Event T1

〈Table 5〉 Average and Standard Dev. of Stirring Events

Category	Accident	Acc.No	Occurred Number	Standard deviation
Operation Defect	Virus	T1	0.541666667	0.588229966
	Data deletion on PC	T2	0.083333333	0.282329851
	Operator error on servers	T3	0.125000000	0.337831962
	Lack of DB management	T4	0.083333333	0.282325851
	Defect of computer devices	T5	0.125000000	0.337831962
System Defect	Server breakdown	T6	0.166666667	0.380693494
	Network down and defect	T7	0.250000000	0.442325868
	Defect of Web service	T8	0.083333333	0.282329851
	Data transmission delay	T9	0.083333333	0.282329851
	Server disk error	T10	0.166666667	0.380693494
	DB defect	T11	0.083333333	0.282329851
Infrastructure Defect	Air conditioner trouble	T12	0.291666667	0.464305621
	UPS defect and trouble	T13	0.208333333	0.414851117

4.5 Monte Carlo Simulation

@RISK 4.5.2 simulation software for the Monte Carlo simulation selects a P method among several probabilistic distributions. P distribution requires the average and standard deviation of

<Table 6> Average and Standard Dev. of Events Occurrence

Process	No	Occurred Number	Standard deviation
ERP	E1	0.458333333	0.508977378
EKP	E2	0.25	0.442325868
BW	E3	0.125	0.337831962
SEM	E4	0.083333333	0.282329851
PICASO	E5	0.208333333	0.414851117
LIMS	E6	0.125	0.337831962
RTDB	E7	0.166666667	0.481543412
WMS	E8	0.125	0.337831962
VAN	E9	0.125	0.337831962
EDI	E10	0.125	0.337831962
PIS	E11	0.083333333	0.282329851

each stirring event that shows in <Table 5>, and the average and standard deviation of each event occurrence that shows in <Table 6>, <Table 5> and <Table 6> make on the basis of <Table 2> and <Table 3> [Ki-Ju Moon, 1994; Palisade Corporation, 2002].

Each result that is operated by 10000 simulations shows in <Table 7> and in <Table 8>.

<Table 8> Simulation Result of Event Occurrence

Process	No	Result
ERP	E1	0.4583
EKP	E2	0.2499
BW	E3	0.125
SEM	E4	0.0834
PICASO	E5	0.0833
LIMS	E6	0.125
RTDB	E7	0.1667
WMS	E8	0.125
VAN	E9	0.125
EDI	E10	0.125
PIS	E11	0.0833

4.6 Economic Loss Measurement by ABC

The Economic value of each process includes the following elements : salary, department expense, IT expense, IT property, external project, and business profit. Salary is divided by activity volumes (business hours) of employees that are involved in business process. The de-

<Table 7> Simulation Result of Stirring Event

Category	Accident	Acc.No.	Result
Operation Defect	Virus	T1	0.5417
	Data deletion on PC	T2	0.0833
	Operator error on servers	T3	0.1251
	Lack of DB management	T4	0.0834
	Defect of computer devices	T5	0.125
System Defect	Server breakdown	T6	0.1665
	Network down and defect	T7	0.2502
	Defect of Web service	T8	0.0833
	Data transmission delay	T9	0.0833
	Server disk error	T10	0.1667
	DB defect	T11	0.0832
Infrastructure Defect	Air conditioner trouble	T12	0.2915
	UPS defect and trouble	T13	0.2083

〈Table 9〉 Expense of Each Business Process

Process	Process expense(₩)	monthly expense(₩)
ERP	211,670,158,636	17,639,179,886
RTDB	5,769,834,780	480,819,565
PIS	1,396,831,319	116,402,610
PICASO	4,221,155,247	351,762,937
EKPEKP	2,132,444,341	177,703,695
SEM	2,634,597,246	219,549,771
BW	28,470,304	2,372,525
EDI	239,414,097	19,951,175
VAN	119,358,195	9,946,516
LIMS	15,181,420,053	1,265,118,338
WMS	10,080,703,923	840,058,660
Total	253,474,388,141	21,122,865,678

partment expense, external project expense, and the IT expense are divided into the business process according to a rate of salary allocated to the business process. The IT property is divided by the power of influence of the business process. Activity volumes of the employee and the influencing power are investigated through interviews and survey in the organization. As a result, <Table 9> shows economic value of each business process.

4.7 Result

In order to verify the proposed research mod-

〈Table 10〉 Probability of Event Occurrence on Each Event-Path

No	T	P1	P2	P3	P4	P5	P6	P7
1		E1	E2	E3	E4			
		0.4583	0.2499	0.125	0.0834			
2		E1	E5					
		0.4583	0.0833					
3		E1	E6	E7	E11			
		0.4583	0.125	0.1667	0.0833			
4		E1	E6	E7	E8	E11		
		0.4583	0.125	0.1667	0.125	0.0833		
5		E1	E6	E7	E8	E3	E4	
		0.4583	0.125	0.1667	0.125	0.125	0.0834	
6	T1	E1	E6	E11				
	0.5417	0.4583	0.125	0.0833				
7		E1	E11	E6	E7	E8	E3	E4
		0.4583	0.0833	0.125	0.1667	0.125	0.125	0.0834
8		E1	E9					
		0.4583	0.125					
9		E1	E10					
		0.4583	0.125					
10		E1	E8	E11	E6	E7		
		0.4583	0.125	0.083	0.125	0.1667		
11		E1	E3	E4				
		0.4583	0.125	0.0834				

〈Table 11〉 Risk Amount of Each Event-Path_

Event path	Occurrence Prob.	Loss amount($)	Risk amount($)
1	0.005174174	18,588,164	96,178
2	0.02068015	17,816,883	368,455
3	0.000430923	18,701,160	8,058
4	5.38653E-05	18,721,112	1,008
5	6.74125E-06	18,349,218	123
6	0.002585019	18,698,788	48,336
7	2.69488E-05	19,189,277	517
8	0.031032639	17,649,126	547,698
9	0.031032639	18,904,298	586,650
10	5.36713E-05	18,721,112	1,004
11	0.002588122	18,107,345	46,864
Average Amount			$165,803

el, probability of the event occurrence and economic loss are produced according to each event path. <Table 10> refers to probability of event occurrence on each event path.

By Formula (2) of the research model, for instance, probability of event path 1 is 0.5%, which means 0.005 frequencies during one month happened. Also, the probability of event path 2 makes 2% although the other paths have very low frequencies.

The economic loss of each event path sums up the loss of each business process on the event path. For example, in the case of event path 1, the total economic loss adds up loss of E1, E2, E3, and E4. The total amount of event path 1 becomes the value of $18,588.00 that is shown in <Table 11>. Thus, the risked amount of event path 1 has a result ($96,178) by multiplying the occurrence probability by the loss amount. <Table 11> shows the risked amount of each event path affected by the event occurrence (E1, ERP) and the stirring event (T1, virus).

Cho [2001] researched that the average value (economic loss) of the total event paths per a stirring event refers to the level of a hazard. Therefore, the average of 11 event paths tells $165,803.00, which indicates that the economic value of the ERP process can be affected by the virus hazard in this case study.

5. Summary and Conclusion

This paper illustrates a quantitative approach of hazard analysis of information systems through a case study. The research model projects probability of occurrence by PRA and economic loss by ABC under each identified hazard.

To verify the model, first, each computerized subsystem which is called a business process and hazards occurred on information systems are gathered through one private organization.

Second, scenarios of an event-path, which means a relationship among business processes, are developed on the basis of gathered data. The probability of hazard occurrence and the probability of business process breakdown are extracted from the scenarios. Third, event-paths, which are affected by a hazard, are represented by an event tree technique. The operation of the event tree was conducted by Monte Carlo simulation using the @RISK4.5.2 simulation program. Fourth, economic loss of a business process is measured by the ABC method, in which the cost includes salary, direct and indirect expenses, IT property value, business profit, etc. Finally, the loss impact of an event-path is produced by multiplying probability by the economic loss. The quantitative degree of a hazard occurrence results in average economic loss impact of all event-paths.

It concludes that the possibility to measure the level of hazard quantitatively can show in spite of the limitation to the simulation operation and the scenario development process. The quantified level of the identified hazard is provided (can be helped) so that the senior management can make his decision effectively about hazard mitigation implementation.

Reference

[1] US. DOT, "Probabilistic Risk Analysis for Turnkey Construction : A Case Study", 1996.

[2] Geun-Joong Yu, and Seong-Ki Chae, "Probabilistic Stability Analysis Technique", Korea Institute of Energy Research, 1987

[3] Hyonam Cho, Probabilistic Risk Analysis for Construction Using Fudge Uncertainty Modeling, Korean Civil Engineering, Vol. 21, No. 3-D, 2001.

[4] Jong-Sung Sunwoo, Research on the Establishment of Emergency Planning and Disaster Relief Planning for Public Information Systems, Korean National Computerization Agency, 1998.

[5] Dongguk University Disaster Prevention Research Center, H Chemical Risk Evaluation and Work Impact Analysis Report, H Chemical, 2004.

[6] Hyun-Ho Choi, Probabilistic Risk Analysis Evaluation Model for Subway Construction, Hanyang University, 1998.

[7] Young-Bin Park, Probabilistic Risk Evaluation for the Risk Analysis of Building Construction, Hanyang University, 1997.

[8] Gwang-Seop Kim, Building Construction's Probabilistic Risk Analysis Evaluation Using Fudge Technique, Han-Yang University, 1997.

[9] K. Bank, Constructing Operation Risk Prediction System, 2005.

[10] Jeong-Hwa Hahn, Uncertainty and Strategic Scenario Management, Han-Yang University, 2004.

[11] Yong-Taek Lee, Developing ITS Business's Economical Efficiency Evaluation Model Using Probabilistic Risk Analysis, Seoul National University, 2003.

[12] Ki-Ju Moon, Industry Simulation, Saeng-Nung Books, 1994.

[13] "@RISK 4.5.2 Guide to Using", Palisade Corporation, 2002.

[14] Geun-Joong Yu, and Seong-Ki Chae, "Probabilistic Stability Analysis Technique", Korea Institute of Energy Research, 1987.

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