Development and Evaluation of a Continuity Operation Plan Support System for an Information Technology System

Ichiro Matsunaga, Tokyo Denki University, Japan
5 Senju-Asahicho, Adachi-ku, Tokyo 120-8551, Japan
matsunaga@isl.im.dendai.ac.jp

Ryoichi Sasaki, Tokyo Denki University, Japan
5 Senju-Asahicho, Adachi-ku, Tokyo 120-8551, Japan
sasaki@im.dendai.ac.jp

ABSTRACT
Because organizations need to be able to deliver products and services at acceptable predefined levels, even in the wake of disruptive incidents, the number of enterprises implementing business continuity management (BCM) systems is increasing. However, during business continuity risk planning, difficulties are often encountered when attempting to determine the most appropriate BCM to implement. To solve this problem, we have developed a BCM implementation method for use in combination with event tree analysis (ETA), which is used to secure safety in engineering, and the program-evaluation-and-review-technique (PERT), which is used in operations research, and which also includes a function for showing analysis results in an easy-to-understand manner. We have also developed a system to support the above method and have confirmed the utility of the developed system by applying it to a small example.

KEYWORDS
Business continuity, Risk assessment, Information technology, ETA, PERT

1 INTRODUCTION
Because organizations need to be able to deliver products and services at acceptable predefined levels, even in the wake of disruptive incidents, the number of enterprises implementing business continuity management (BCM) is increasing recently [1] [2]. However, during business continuity risk planning, difficulties are often encountered when attempting to determine the most appropriate BCM measures to implement because the following characteristics need to be considered in order to determine the most optimal measures. Note that, hereinafter, the word “measure” refers to an action implemented to decrease a risk.

1. Measures need to consider both incident prevention and business continuity damage reduction should incidents occur.
2. There are numerous measures which are effective only in limited situations. The overall effect of a combination of measures will not be a simple summation of the effects of each measure.
3. Even if risk attenuation measures are taken, it may not be possible to completely remove risk.

To cope with 1, it is necessary to analyze changes in both the probability and downtime. To cope with 2, it is necessary to envision the various consequences that can result from an
incident. To cope with 3, it is necessary to estimate the effects of each measure combination. Finally, to cope with 4, it is necessary to discuss the residual risks which remain after taking measures.

To deal with these various characteristics we developed a BCM implementation method for use in combination with event tree analysis (ETA) [3], [10], which is used in safety engineering, and the program-evaluation-and-review-technique (PERT) [4], which is used in operations research, and which also includes a function to show the analysis result in an easy-to-understand manner (Fig. 1).

The proposed method makes it possible to analyze proposed changes in both the probability and downtime. In addition, by displaying the residual risk visually, it is possible to cope with the fourth characteristic mentioned above. In this paper, we report on the development of a system designed to support the above method and the result of a small example performed to confirm its efficacy.

2 RELATED WORKS

We found numerous studies related to the term “business continuity” by using the keyword search function of Google Scholar and the IEEE Xplore Digital Library, including the following:

(1) Studies on BCM frameworks. [5], [6]
(2) A study on methods for collecting business continuity information in order to implement a BCM framework [7]
(3) A study on effective measures in business continuity [8]
(4) A study on standards for prioritizing risks [9]

However, very few detailed studies have examined methods of determining appropriate incident response measures based on risk analysis. [5] In addition, no studies could be identified that examined the different response sequences which could result from initial incidents. Another novel aspect of our research is that it is the first risk analysis method to be used in combination with ETA and PERT.

3 APPLICATION PROCEDURES

For BCM, it is necessary to manage risks which can bring business to a standstill. As is noted in ISO22301 section 8.2.3 [2], this process can be carried out in compliance with ISO31000 [10]. Accordingly, our proposed method is applied in accordance with the risk-management process described in ISO31000. Use of the proposed method makes it easy to implement risk analysis, risk evaluation, and risk treatment. Figure 2 shows a flowchart of the application procedure in line with a risk management process that illustrates the scope of the proposed method. Explanations for the main processes are provided below:

1. Establishing context
The objective of this process is to determine, based on a business impact analysis, which critical systems have the highest priorities, the recovery time objective (RTO), and the minimum business continuity objective for an information system. The RTO is the elapsed time from the occurrence of an incident to the time when a product, service, and/or business activity is resumed, or when resources are recovered. In this paper, the RTO is used as the business continuity risk criteria.

2. Risk identification

The objective of this process is to identify risks by examining an event in relation to the critical system and the consequences that will result from such an event. Risks are not limited solely to natural disasters; they can also be the result of a device breakdown, wiring breaks, or some other such cause. Our proposed method uses these identified risks as ETA initiators.

3. Risk analysis

The objective of this process is to determine the magnitude level of a particular risk. This level is expressed in terms of its combined likelihood and consequences. The likelihood is defined as the probability of the event occurring. The use of the proposed method makes it easy to carry out this process.

4. Risk evaluation

The objective of this process is to determine whether the risk magnitude is acceptable. The proposed method makes it easy to see the result of a risk analysis.

5. Risk treatment

The objective of this process is to evaluate both the risk being treated and the measure being implemented in order to achieve the RTO. By calculating the effects of a measure from the risk analysis result, it is easy to determine the risk treatment required.

4 PROPOSED METHOD

We have developed a BCM implementation method for use in combination with ETA and PERT. This method can consider changes in both the probability and downtime, and confirm residual risk. The remainder of this section will be as follows: Sections 4.1 to 4.4 describe the analysis method used for determining risk magnitude; Section 4.5 describes the calculation method used to determine the effect of measures achieved by using the analysis result; Section 4.6 describes the method used to confirm the residual risk.

4.1 Risk value

Hereinafter, risk is expressed by multiplying risk probability by risk magnitude. In the proposed method, the risk value is calculated using the following equation:

\[ R = P \times M \]  

R: Value of risk  
P: Occurrence probability  
M: Magnitude of damage

4.2 ETA
An ETA can be used to cover all sequences and can also easily calculate occurrence probability by setting branch probability, which represents the occurrence probability of the heading item. To calculate a risk via ETA, it is necessary to determine the following information:

1. Heading item
2. Heading item probability
3. Damage magnitude in each sequence

Here, the heading item is a factor of a branching sequence (Fig. 3). In the proposed method, the heading item is whether a device has broken down.

Total risk can be calculated using ETA as follows:

\[ R = \sum_{l=1}^{L} P[l] \times M[l] \]  \hspace{1cm} (2)

\[ P[l] = \prod_{h=1}^{H} P'[h] \]  \hspace{1cm} (3)

\[ P'[h] = ((1 - p[h])(1 - y[h]) + p[h] \times y[h]) \]  \hspace{1cm} (4)

\[ y[h] = \begin{cases} 1: h-th \text{ heading item unfolds in} & \text{horizontal direction} \\ 0: h-th \text{ heading item unfolds in} & \text{vertical direction} \end{cases} \]  \hspace{1cm} (5)

**4.3 PERT**

PERT is a method used to analyze the time needed to complete the total project (Fig. 4). In
the proposed method, the downtime of the \( l \)-th sequence calculated via PERT is introduced as a magnitude of damage for the \( l \)-th sequence. Here, the downtime, which also refers to the total recovery time for the \( l \)-th sequence of the ETA, can be calculated using equation 6.

\[
M[l] = \text{PERT}(S[l], D[l][q]) ; \quad q = 1, 2, \ldots, Q[l] \tag{6}
\]

**M\([l]\):** Downtime (total time required for recovery) used in \( l \)-th sequence of ETA

**PERT:** Function to calculate downtime using PERT chart [4]

**S\([l]\):** Structure of PERT chart used in \( l \)-th sequence of ETA

**D\([l][q]\):** Duration of \( q \)-th activity used in \( l \)-th sequence of ETA

**Q\([l]\):** Number of activities in PERT chart used in the \( l \)-th sequence of ETA
4.4 Risk evaluation via proposed method

The risk which is calculated in the above subsection is an expected downtime value. By comparing this with the RTO, we can determine whether that risk is acceptable. Specifically, if the calculated risk is less than the RTO, the risk is deemed acceptable.

4.5 Risk treatment via proposed method

In order to determine the optimal combination of measures, we must first identify the effectiveness of those measures. The effect of a measure is identified as the incremental difference in the calculated risk between the...
Here, \( \text{P}_0[l] \) is calculated as follows:

\[
\text{P}_0[l] = \prod_{h=1}^{H_i} \text{p}_i'[h]
\]  

(10)

\[
\text{p}_i'[h] = ((1 - \text{p}_i[h])(1 - y[h]) + \text{p}_i[h] \times y[h])
\]  

(11)

\[
\text{p}_i[h] = \text{p}_i'[h] \times \text{xp}_i[h]
\]  

(12)

\( H_i \): Number of heading item when adopting \( i \)-th measure combination

\( \text{p}_h \): Branch probability of \( h \)-th heading item when adopting \( i \)-th measure combination

\( y[h] = \{1: h \text{-th heading item unfolds in horizontal direction}
\]  

\( 0: h \text{-th heading item unfolds in vertical direction} \} \)  

(13)

Here, \( \text{M}_i[l] \) is calculated as follows:

\[
\text{M}_i[l] = \text{PERT}(\text{S}_i[l], \text{D}_i[l][q]; q = 1, 2, \ldots, Q_i[l])
\]  

(14)

PERT: Function used to calculate downtime using PERT chart

\( \text{S}_i[l] \): Structure of PERT chart used in \( l \)-th sequence of ETA when adopting \( i \)-th measure combination

\( \text{D}_i[l][q] \): Duration of \( q \)-th activity used in \( l \)-th sequence of ETA when adopting \( i \)-th measure combination

\( Q_i[l] \): Number of activities in PERT chart used in \( l \)-th sequence of ETA when adopting \( i \)-th measure combination

4.6 Cumulative probability distribution graph

The cumulative probability distribution graph

Since it is often impossible to completely remove a risk, it is necessary to discuss the
remaining residual risk after the implementation of a measure. To facilitate this, we developed a graph for presenting the relationship between the downtime and the occurrence probability (hereinafter referred to as the cumulative probability distribution graph) (Fig. 5). The use of this graph makes it possible to visually express residual risk. The process used to create this graph is as follows (see Fig. 6):

1. The sequences in ETA for the $i$-th measure combination and without measures are sorted according to the small order of the downtime value
2. The cumulative probability is calculated by adding the occurrence probability with its relation to total downtime
3. A graph is made from the relationship between the downtime and the cumulative probability

**5 TRIAL APPLICATION**

The proposed method was applied to a small example. To apply the method effectively, we developed a support system by adding a function to Excel. Table 1 shows the support system development and operating environments.

In this trial application, we calculated the values of $R_i$ and $E_i$ shown in Eqs. (10) and (11). In addition, we obtained the cumulative probability distribution graph for when the $i$-th measure combination was adopted.

**Table 1. Development environment and movement environment**

<table>
<thead>
<tr>
<th>OS for development</th>
<th>Microsoft Windows 7 Professional Service Pack 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Development language</td>
<td>Microsoft Visual Basic for Applications 7.1</td>
</tr>
<tr>
<td>Operating environment</td>
<td>Microsoft Excel 2013 (15.0.4641.1000) 64 bit</td>
</tr>
</tbody>
</table>

**5.1 Evaluation model**

In this trial application, we applied the proposed method to a Web-service system, a mail system, and a business-support system. These systems were assumed to be installed in the same room of a municipal city hall. The Web service system is designed to support a help line that deals with various application forms. It is very important and its RTO is assumed to be 50 hours.

The mail and business support systems must be operational for the employees to perform their duties. Their RTO is assumed to be 100 hours. Table 2 shows the structure of the examined systems and the RTO. Figure 7 shows the system configuration of the application model. The implemented measures that are already in place and operating are shown in Table 3.

As the initiator of a BCM-related incident, the business continuity planning guidelines published by the Japanese government recommends assuming the occurrence of an earthquake measuring six on the seven-point Japanese scale [11], [12]. Accordingly, each data set was set up based on those guidelines. Table 4 shows the index used for setting the time required for recovery tasks. Table 5 shows
the index for setting failure probability. The application process is as follows:

First, we calculate the current downtime. Second, we list an alternative measure for a system that has a high treatment priority. Third, we estimate the values of \( R_i \) and \( E_i \) and obtain the cumulative probability distribution graph for when the \( i \)-th measure combination is adopted using the proposed method. Finally, we decide the correct measure combination taking into consideration not only the values of \( R_i \) and \( E_i \), by which we obtain the cumulative probability distribution graph, but also the cost and the derivative risk.

**Table 2. Structure of treated systems and RTO**

<table>
<thead>
<tr>
<th>ID</th>
<th>System</th>
<th>RTO (hours)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Web-service system</td>
<td>50</td>
</tr>
<tr>
<td>B</td>
<td>Mail system</td>
<td>100</td>
</tr>
<tr>
<td>C</td>
<td>Business-support system</td>
<td>100</td>
</tr>
</tbody>
</table>

**Table 3. Implemented measure**

<table>
<thead>
<tr>
<th>ID</th>
<th>Measure</th>
<th>Time required (hours)</th>
<th>Failure probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Y 1</td>
<td>Preserving data backup</td>
<td>1</td>
<td>0.01</td>
</tr>
<tr>
<td>Y 2</td>
<td>Obtaining middleware via Internet</td>
<td>14</td>
<td>-</td>
</tr>
<tr>
<td>Y 3</td>
<td>Setting reference of network device</td>
<td>1</td>
<td>0.01</td>
</tr>
<tr>
<td>Y 4</td>
<td>Clustering device</td>
<td>-</td>
<td>0.8</td>
</tr>
<tr>
<td>Y 5</td>
<td>Load balancer</td>
<td>-</td>
<td>0.8</td>
</tr>
</tbody>
</table>

**Table 4. Index of setting time required for recovery**

<table>
<thead>
<tr>
<th>Recovery task</th>
<th>Time required (hours)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Procuring common device</td>
<td>24</td>
</tr>
<tr>
<td>Procuring technical device</td>
<td>92</td>
</tr>
<tr>
<td>Procuring legacy device</td>
<td>2160</td>
</tr>
<tr>
<td>Installation</td>
<td>2</td>
</tr>
<tr>
<td>Device or measure</td>
<td>Failure probability</td>
</tr>
<tr>
<td>---------------------------</td>
<td>---------------------</td>
</tr>
<tr>
<td>Constitution device</td>
<td>0.6</td>
</tr>
<tr>
<td>Clustering device or load balancer</td>
<td>0.8</td>
</tr>
<tr>
<td>Fixing device</td>
<td>0.5</td>
</tr>
</tbody>
</table>

Table 5. Index of setting failure probability

5.3 First Experiment

The objective of our first experiment was to calculate the risk for each system in order to determine whether the risk magnitude is acceptable. In addition, the achievement rate of RTO was confirmed via the cumulative probability distribution graph.

Table 6. Calculated risk for each system

<table>
<thead>
<tr>
<th>I</th>
<th>System</th>
<th>Calculated risk $R_0$ (Hours)</th>
<th>RTO (hours)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Web-service system</td>
<td>119.13</td>
<td>50</td>
</tr>
<tr>
<td>B</td>
<td>Mail system</td>
<td>95.61</td>
<td>100</td>
</tr>
<tr>
<td>C</td>
<td>Business-support system</td>
<td>73.52</td>
<td>100</td>
</tr>
</tbody>
</table>

Table 6. Calculated risk for each system

5.4 First Experiment Result

Table 6 shows the calculated risk $R_0$ calculated in Eq. 9 for the three systems. Figs. 8-10 show the cumulative probability distribution for the three systems. As can be seen in the table, the value of $R_0$ for all systems is more than the RTO. The mail and business-support systems could obtain sufficient effects by introducing small-scale measures because the RTO is exceeded by a very small amount. However, the Web-service system must consider the adoption of large-scale measures because the RTO is exceeded by a very large amount.

5.5 Second Experiment

The objective of the second experiment was to consider a measure that would reduce risks for the Web-service system. Two measure alternatives were created, as shown in Table 7. X1 indicates a measure in which spare devices

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5.5 Second Experiment

The objective of the second experiment was to consider a measure that would reduce risks for the Web-service system. Two measure alternatives were created, as shown in Table 7. X1 indicates a measure in which spare devices
are prepared (without setup) in a remote location. X2 indicates a measure in which those spare devices are prepared in a local location. X3 indicates a measure in which the device is fixed in place with bolts, screws, etc.

X1 and X2 are the measures implemented to reduce the downtime, and X3 is the measure implemented to prevent incident occurrence. This measure changes the occurrence probability.

Table 7. Measure alternatives

<table>
<thead>
<tr>
<th>ID</th>
<th>Measure alternatives</th>
<th>Time required (hours)</th>
<th>Failure probability</th>
<th>Cost ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>X1</td>
<td>Preparing a spares in remote location.</td>
<td>48</td>
<td>0.01</td>
<td>6,250</td>
</tr>
<tr>
<td>X2</td>
<td>Preparing spares in nearby location.</td>
<td>1</td>
<td>0.01</td>
<td>2,500</td>
</tr>
<tr>
<td>X3</td>
<td>Fixing the device in place</td>
<td>-</td>
<td>0.5</td>
<td>500</td>
</tr>
</tbody>
</table>

5.6 Result of Second Experiment

Table 8 shows the measure effects and the calculated risk when a measure is implemented. Fig. 11 shows the cumulative probability distribution.

Even though the summation of the X1 and X3 effects gives 92.81, the effect of X1+X3 can be calculated as 82.07. Conversely, even though the summation of the X2 and X3 effects is 57.26, the effect of X2+X3 can be calculated as 66.73.

Table 8 shows that although the most effective individual measure is X1, the most effective combination of measures is the selection of all three. In addition, when the cost constraints are $7,000, for example, we can understand that the optimal combination is X1+X3 (see Fig. 12).

From these results, we confirmed the basic effectiveness of the proposed method.
6 Conclusions

In this paper, we proposed a BCM implementation method for use in combination with ETA and PERT that considers changes in both the probability and downtime. In addition, we provide an intuitively understandable display of analysis results and the residual risks.

Furthermore, we have also developed a system to support the above method and confirmed its usefulness by applying the BCM implementation method to a small example.

From these results, we confirmed the basic effectiveness of the proposed method.

However, since the number of applied cases is very limited, it will be necessary to apply the proposed method to other cases as future work.

REFERENCES


