4.3.3 Countermeasure Design and Costing Assistance using SIMS

Using a standardized list of countermeasure design elements and unit rates provided by JKR, this module will assists the selecting the appropriate countermeasures associated with the most likely failure type identified, and in determining the approximate cost of the Countermeasure as proposed.

Using information provided by persons trained in slope inspection and countermeasure design, information on countermeasure types and the approximate quantities are input for a slope feature using this module. Based on these quantities and the predefined unit costs, an approximate cost is calculated for the countermeasure design for the slope feature.

Under this application, only one set of information on the countermeasure design and its estimated cost can be associated with a slope feature. After a new inspection, a new countermeasure design can be generated along with the cost estimate and associated with this slope. This functionality will allow JKR to review present and historic countermeasure design data and cost for a specific slope.

Along with this countermeasure design and cost information, the application will also accommodate information that will assist JKR in managing countermeasure design, costing and execution information.

Based on field investigations within the Project Study Area, the list of countermeasures were revised from those originally provided to the application developer. Revisions to the application have been made to incorporate these changes.

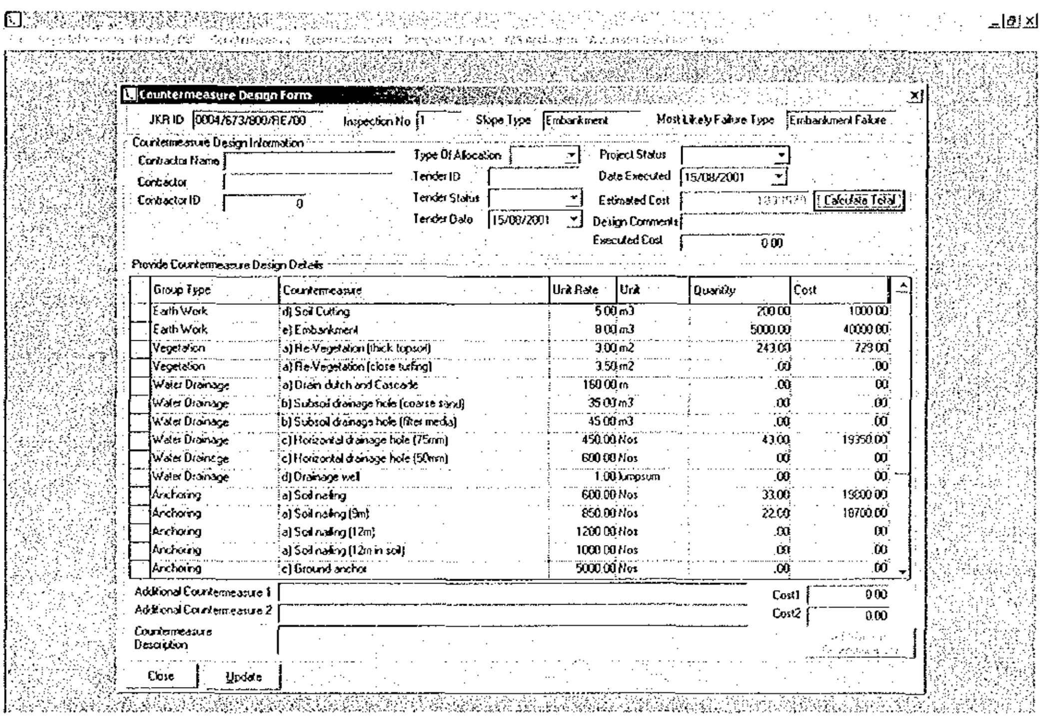

Figure 4.3.10 SIMS Countermeasure Design and Costing Module for Specific Slope Feature

4.3.4 Economic Analysis Functionality in SIMS

The economic analysis methodology has been adapted to better fit the data available. In this context, the simpler economic indicator will be calculated in the SIMS.

To generate the economic analysis for the slope feature, this module will use information from the "Consequence Form F" and the estimated cost of the designed countermeasure. This information along with a designated coefficient will compute the Economic Analysis Result for each specific slope feature and archive this information in the database.

The formula used is:

$$E = Vt / Cc$$

Where, *E:* *Ratio of Vt to Cc*

Vt: *AADT (Annual Average Daily Traffic of Each Route)*

Cc: *Cost for Countermeasures (RM)*

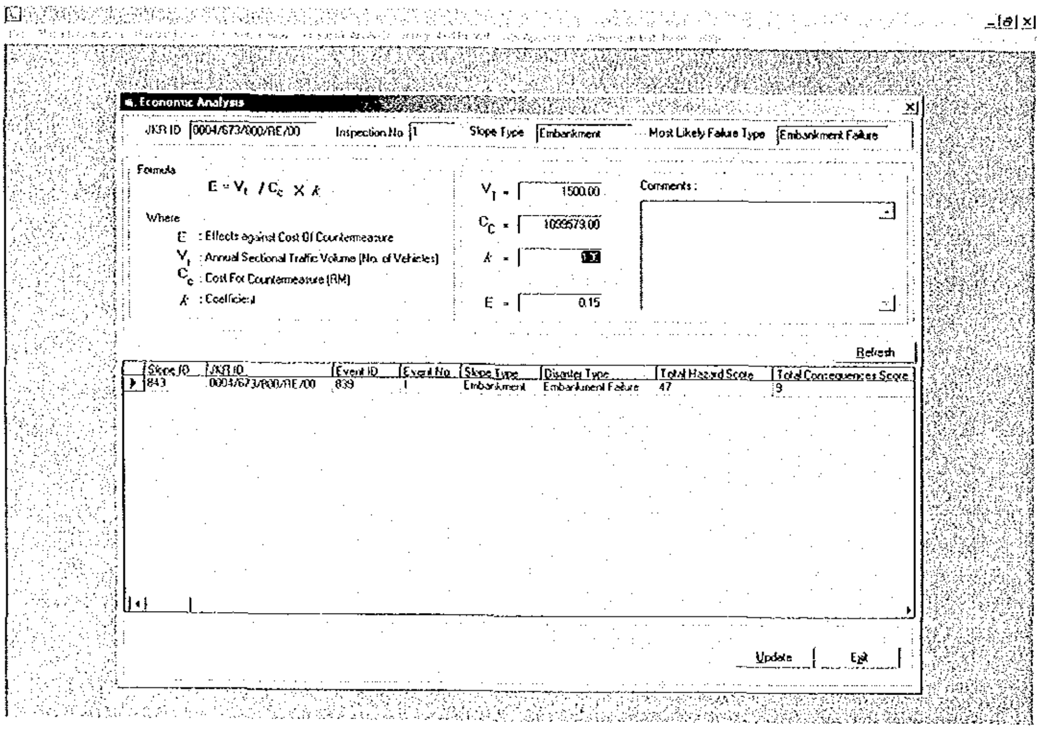

Figure 4.3.11 SIMS Economic Analysis Module for Specific Slope Feature

4.3.5 Integrated Report Generation Module

Although each module has its own specific report generation capability, it was considered to be more expedient to allow the user to access the report generation functionality from the main menu. This "Integrated Reports" menu will provide instant access to the user to the standard reports on Slope Information, Hazard/ Risk Rating, Countermeasures Selected and Associated Cost, Economic Analysis. These standard reports will now be made more readily accessible to the user. The ability to customize these report formats and create other custom reports will also be provided through this revised menu structure.

This module will provide the user with the ability to generate all pre-defined, standard reports from SIMS. It will also allow a more experienced user to create customized reports, selecting appropriate combination of the information from SIMS as required.

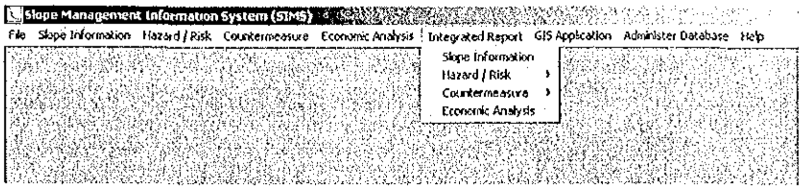

Figure 4.3.12 Menu Structure for Integrated Reporting Module

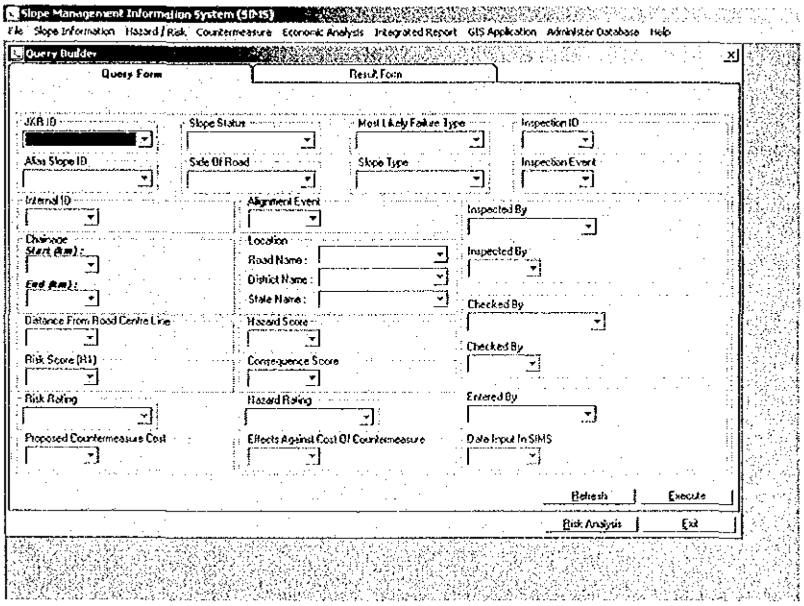

Figure 4.3.13 Standard Search Form Available through All SIMS modules

The standard reports will consist of:

- Individual Slope Inspection Report
- Slope Inspection Summary Report
- Risk Rating Report
- Individual Slope Countermeasure Report
- Summary Countermeasure Report
- Economic Analysis Report
- Overall Slope Prioritisation Report

(a) Individual Slope Inspection Report:

This is a detailed report that can be generated for each slope for which adequate information has been entered in the system. This report is structured along the lines of Form A through Form F as developed for the field investigation for slopes with some differences. The forms are individually described below.

(b) Form A:

Setup as a two page output, the first page provides a detail of the slope location information, as well as presents a summary of information from other modules to give the report reviewer an understanding of the hazard score, the economic analysis results, and a summary of the countermeasures identified appropriate for this slope as well as the estimated cost. The bottom of this page also provides a definitive space for the report to be signed and stamped after checking by the appropriate persons identified by JKR. The second page of this form provides a full-page map composed to automatically print the slope feature with standard background information, legend, scale, north arrow and date.

(c) Form B:

Sketches prepared by field investigators are archived as digital images. This form provides an output of one sketch to each page, with a maximum of two sketch images associated with each slope feature.

(d) Form C:

Photographs taken by field investigators are archived as digital images. This form provides an output of a maximum of 6 photographs to each page, the maximum number of images associated with each slope feature.

(e) Form D:

This output form reflects the slope inspection information details as entered in SIMS.

(f) Form E:

Associated with the slope failure type, this form provides the details for the hazard score for each slope.

(g) Form F:

This form summarizes the consequence score of each slope feature.

(h) Summary Slope Information Report:

This report presents a summary of essential slope inspection information for a group of selected slopes. The user is guided through the selection process to select slopes either by a particular highway, a state, or a district. This tabular output will include fields defined by JKR and the JICA Study team as appropriate for this report.

(i) Risk Rating Report:

Similar to the Summary Slope Information Report, this report will list the hazard score, the consequence score, the risk score, and the risk rating for the group of selected slopes.

(j) Individual Slope Countermeasure Report:

This report will be generated providing the details for the selected countermeasures, the defined quantities of materials, the rates used, and the total approximate cost of the countermeasures. Generated as a single page report for each slope, this report can be generated by specifically identifying a slope by the JKR Slope ID or for a group of selected slopes.

(k) Summary Countermeasure Report:

Similar to the Summary Slope Information Report, this report will briefly list the countermeasures selected for each slope with a summary total cost for each slope. This report will be generated for the group of selected slopes.

(l) Economic Analysis Report:

Similar to the Summary Slope Information Report, this tabular report will list the defined parameters for economic analysis and the resultant calculated Economic Analysis Score for the group of selected slopes.

(m) Overall Slope Prioritisation Report:

Similar to the Summary Slope Information Report, this report will include the list the hazard score, the risk rating, countermeasure cost and the economic analysis score for the group of selected slopes. This report will allow the reviewer to sort and organize the report on any criteria, facilitating the evaluation of these multiple criteria in finally assigning a slope priority.

Report Output Generation

All the reports in SIMS will be output to multiple electronic formats. These are expected to be:

- Print directly to printer
- Print to Adobe Acrobat Reader PDF format. (The customized report will not be output to a PDF Format).
- Print to Excel File (Not available for the detailed slope inspection report)

This will allow the user to quickly review the reports, and then after determining them to be appropriate, generate a PDF format output for easy electronic distribution. The excel file format should be used only in the cases where the user wishes to make some evaluations by modifying the data/ using the data with alternative formulae etc. without affecting the data in SIMS.

4.3.6 GIS Functionality in SIMS

Using GIS functionality provided by the development environment of Map Objects, the SIMS application has a simple-to-use and an integrated GIS capability to perform all identified functions. The spatial data for the GIS functionality is managed in Arcview compatible format, in standards provided by JKR.

Through this module, the user can generate a standard Slope Map based for an identified JKR Slope ID. The map composition will automatically display at a standard defined scale, using data layers and symbologies most appropriate to a map at this viewing scale. This map is also composed to a standard map layout which will use an A-4 sheet, giving a main map window at 1:10,000 scale with the identified slope feature and standard background information, a location map window, map legend, north arrow, scale bar, and map title. This standard map composition for any JKR Slope ID makes it much easier for the SIMS user to interact with the GIS data and generate map output.

The user are assisted in their GIS review/ mapping activity by a selected set of functionality provided by icons on the GIS Mapping window. These icons provide viewing functions to enable the user to navigate the map window. An icon include in this set provides a "reset" functionality to take the user back to default settings should they at any time wish to revert to the pre-defined settings.

Through an advanced set of icons (which can be displayed/ hidden from display), the user can interact with the information available to add or remove data layers from the view, as well as perform functions of placing graphics or text labels in the map view.

The GIS window provides the user with constant feedback of the viewing sale, coordinate location, and the active data layer for which the display symbologies can be altered.

In addition to generating maps by individual JKR slope ID's, the application provides for two other map generation capabilities.

a. Generate maps based on thematic type for selected highway
b. Generate maps based on regional extent of district, state, national boundary

Thematic Maps

The thematic map types provided for by the main GIS menu are based on the results of the earlier analytical modules, i.e.:

- Based on Slope Information Module
    - Slope Type
    - Most Likely Failure Type
- Hazard/ Risk Module
    - Hazard Score
    - Risk Rating
- Countermeasure Module
    - Countermeasure Status (Executed/ Not Executed)
- Economic Analysis Module
    - Economic Analysis Result

Regional Extent Maps

Through a form-based interface, the user can select the geographic extent for which the slope information will be displayed. Once selected, the slope information for this defined extent can be thematically symbolized based on the types defined above. This functionality is provided through an icon displayed on the GIS window.

Providing this defined GIS functionality through the menu structure, query forms, and GIS window based icons, the users are provided adequate ability to use GIS for Slope Disaster Management activities. More extensive GIS functionality is available through the use of the other external GIS software like ArcView and other ESRI Software Solutions, easily using the GIS data used in SIMS.

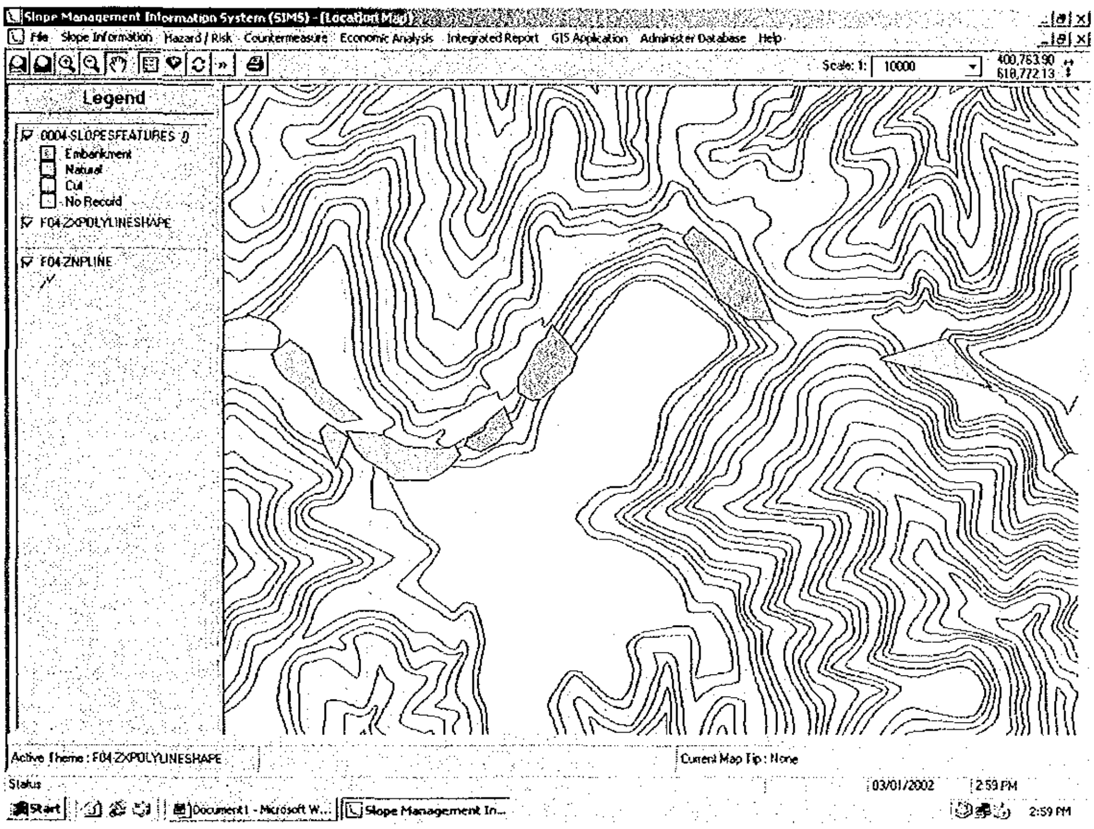

Figure 4.3.14 GIS Functionality for Map Generation on Screen

4.4 Technical and Technological Aspects of SIMS

4.4.1 Administrative and Operational Issues for SIMS

Administrative and Operational issues are an integral aspect of the application development efforts. Application and database administration functionalities are continuously being refined and integrated into the application development efforts.

In meetings with the JKR the necessary collective involvement of the Road Maintenance Unit, the GIS Unit, and the IT resources has been identified and discussed as being key to the successful use and deployment of this application.

JKR will also identify specific persons who will be provided with in-depth technical knowledge on the application to help address technical problems, application installation issues, database technology issues, as well as possible future development needs.

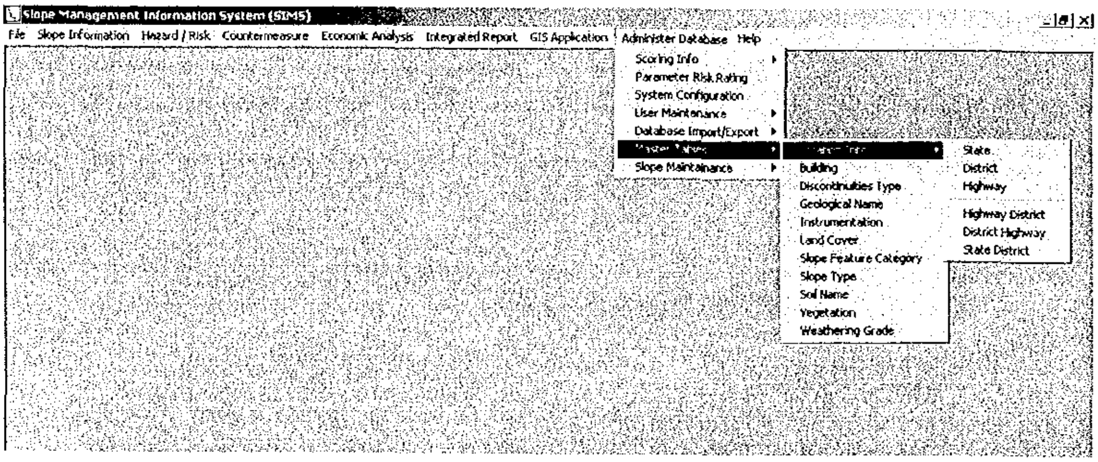

Figure 4.4.1 Administrative Functionality for SIMS

The administrative functions essential for the effective functioning of SIMS can be categorized as (a) administrative functions for managing standard data required in the application (scoring ranges, master tables, lookup tables), and (b) administrative function for defining and managing users of the application, managing the database installation, importing data from district/ zonal offices and integrating it into a master database at the headquarter installation, exporting relevant data for re-distribution to the district/ zonal offices.

These administrative functions need to be addressed by appropriately skilled and trained persons for the smooth and effective functioning of SIMS at the Headquarters, and at the district/ zonal offices.

4.4.2 Deployment and Integration Across Malaysia

The SIMS application has been designed with the intent of using it across all of Malaysia. Deploying one installation at the headquarters, a centralized SIMS database will be maintained that will support multiple, networked systems on which the SIMS application will be installed. This centralized database will house data for information for Slope Disaster Management for all federal highways in Malaysia. The administrative functions will also be handled at the headquarters, ensuring that a consistent set of standard information such as federal highway identification codes, categories for the data entry forms, hazard and risk scoring information, countermeasure unit rates, etc. are used by all application users.

SIMS will also be installed at multiple individual locations such as district/ zonal offices, as determined by JKR. The functionality of the SIMS application at these installations will be the same as at JKR headquarters, with the exception of the administrative functions that are addressed specifically by JKR Headquarters. Unlike the headquarter installations which will use a centralized database with multiple networked systems accessing the same database, these localized installations will be individually operational will the database and the application residing on the same computer system. The slope information assimilated into this local database will be periodically exported and delivered to headquarters for assimilation into the centralized database for all Malaysia.

The data handling procedures are structured for the headquarters database to receive information from the district/ zonal offices. Should updates and revisions be made to information for specific slope features at the centralized database, this information will be provided back to the district/ zonal office over-writing the local information. Should updates to existing slope feature information be provided from the district/ zonal offices to replace information in the central database, only slope features not updated by JKR headquarters will be replaced. This procedural control will ensure that the central database remains complete, most current, and that the decisions for revisions/ updates made by JKR HQ are not overwritten. As a result, JKR HQ based updates to the database supersede any revisions done at the local databases for the same slope feature.

4.4.3 Potential for Future Improvements and Refinements

The enhancements described below may be considered in the future as SIMS is used more intensely by JKR for managing slope disasters.

After extensive use of the application, in coordination with the field investigation procedures, it is likely that some revisions to nomenclature on the user interfaces, standardized information, and scoring systems may need to be revised.

With better infrastructure providing connectivity between offices, and with additional depth of expertise in technology at JKR, the workflow and functioning of the SIMS application may be enhanced to an internet based application. The benefits of this have already been stated earlier in this chapter.

To improve the coordination between the field inspection methods, data collection, and entry of information into the SIMS database, the paper-based forms may be substituted with more automation. Using devices like hand-held PC's or similar systems, user interfaces may be redeveloped to create electronic forms that can be used with these systems in the field, using similar pull-down selections, making the information collection process easier and more accurate.

4.5 Proposed Deployment Plan of SIMS

Working with the goal of using SIMS at a nation-wide level, its successful deployment at the JKR headquarters and at the district/ zonal locations identified, is dependent on institutional ownership and support, training of SIMS users, and its effective integration with the Slope Inspection and maintenance procedures.

4.5.1 Institutional Requirements

With software applications such as SIMS, multiple domains of expertise are required to manage its effective and continued use for Slope Disaster Management. The purpose of the application is to assist the Road Maintenance Unit and they best understand the functionality and inherent information in SIMS. Consequently, the application content, use and effective integration into the workflow falls under their domain, as well as providing them with tacit "ownership" of the SIMS software. Consequently it becomes imperative for the Road Maintenance Unit to be the focal point of contact for managing and deploying this application across the identified user base, as well as organizing the necessary resources of persons and financial support to ensure the SIMS users are identified, trained, and mentored in the continued use of SIMS. Adequate budgetary allocations will also be required to support the ongoing maintenance/ support/ enhancement of the application.

For the successful deployment of SIMS it is also essential to have IT and GIS support. Without the involvement of appropriate IT resources, important functions of installation and management of the application on computer systems as well as the user account management to provide appropriate levels of access to the application cannot be handled. Through participation of experienced IT persons, problems arising out of changes in computing technology, operating systems, and the computing infrastructure can be more effectively addressed and proactively managed.

The continued involvement and guidance of focal GIS resources from within JKR are essential to guide the Road Maintenance Unit on issues arising out of GIS technology options and changes, creation and management of GIS data, and integration of GIS activities in the Road Maintenance Unit with other institutional/ organization use of GIS. Since the current SIMS application will be delivered to JKR with data only for the project study area, additional and ongoing financial and technological support may also be required for the creation of appropriate GIS data.

Summarily, the effective use of SIMS can only be done by ensuring that:

1. Clear ownership and responsibility for all issues arising out of the use of SIMS are established with Road Maintenance Unit
2. Active and effective support is available to the RMU from appropriate IT and GIS resources within JKR
3. Financial allocations are set in place to address costs of continued use of SIMS

4. Users of the application are identified and provided the requisite training and support in using SIMS

4.5.2 Technical Requirements

SIMS has been designed to operate on a windows based operating environment using technologically current PC's. The preferred operating environment for the application is Windows 2000, installed preferably on Pentium (P-III/ P-4) computers with 128 MB of RAM. The application itself will occupy less than 50 MB of space after installation, however the additional space will be required for the SIMS Database, Slope Graphic Data (photographs and sketches), and GIS data.

The database functionality is provided by MS SQL/Server installed on the centralized database server at JKR Headquarters. MS Access 2000 will provide the database functionality for the stand-alone installations. GIS functionality is provided in SIMS through ESRI's MapObjects technology that has been embedded into the application.

For the centralize database, the size of the database for the slope information from the study area is approximately 12 MB (for approx 800 slopes). The GIS data of the slope features is less 5 MB for the study area slopes. The graphic data (photographs and sketches) associated with the study area is 2.0 GB approximately. Additional background GIS data for entire Malaysia is currently less than 1 GB and can be expected to increase be around 2 GB. For the data covering the project study area will currently occupy approximately 3 GB, with less than 10% of this space required by the database. In the future as slope information data and slope GIS data is assimilated in one location, the database for approximately 20,000 slopes could require up to 0.5 GB of space. The graphic data representing the more voluminous information can incrementally occupy approximately 50 GB of space.

For the local installations, the space requirements for the application and the database will be approximately 100 MB. Graphic data will require an additional 2.5 to 3 GB of storage space, depending on the number of slopes and associated image files.

For data exchange between the stand-alone installations and the JKR headquarters, the database files can be exported and incrementally delivered through e-mail or through media such as floppy disks. It would however be preferable to have CD writers available for all stand-alone installations and at JKR HQ for easy exchange of database information and graphic files.

4.5.3 Training and Integration Requirements

Different levels of users are anticipated to be trained for the effective deployment of SIMS. For most day-to-day operation of SIMS, the users will be given training in all modules of SIMS, expect for those addressed by administrative resource persons. An understanding of the purpose and the type of administrative functions included in the application will be communicated to all users, making them aware of the kind of instances where they would require administrative support.

For this reason, it is important that the day-to-day application users at the headquarters, as well as at the zonal/ district/ local offices, be identified, trained, and their working reviewed to determine the nature of supplemental/ refresher training that might be required. This is especially important since these individuals will be responsible for the collection of attribute information (geological, slope feature, inspection information) and its input into the database for the federal highways. Without this information, the SIMS application will not be effective in helping with slope disaster management activities.

A more advanced level of training will be imparted to the administrative users to sensitive them regarding the importance of the administrative functions in the application, as well as to make them familiar with the nature of administrative functions to be addressed. These administrative persons should include a key resource from JKR HQ, who will also serve as the point-of-contact for the all users at HQ and at stand-alone installations, ensuring that the data exchange keeps all databases upto date and synchronized.

After the training of the SIMS users, it is expected that it will take some time for the integration of the application into the workflow of JKR. It is essential that this investment of time and effort be made to ensure that the application is used as designed and intended. It is only after an initial period of adaptation and integration of the SIMS application into the normal work routine that the application will provide evident benefits in Slope Disaster Management.

4.5.4 Integration between SIMS and Field Investigations

SIMS is only a software application that has been developed based on the workflow and functional logic outlined by the JICA Study Team and by JKR. Unless the work processes of slope disaster management using the field inspection methodology developed by the JICA Study Team the information required by the application, from slope inspections, may not be correct or complete. Consequently, without appropriate and complete information, the application will not serve its designed intent.

The strong connectivity between the field investigation activities and SIMS must also be recognized. The SIMS application uses the field inspection forms as the basis of designing the database and the user interfaces. The synchronization between the Slope Inspection Forms, Field Inspection procedures (including taking photographs, making sketches, and assessing the possible countermeasures required), and SIMS is essential for the application to generate appropriate results. Changes to any of these activities would require a similar revision in the application and vice-versa.

CHAPTER 5 APPLICATION OF SLOPE INFORMATION MANAGEMENT SYSTEM (SIMS)

5.1 Application of SIMS to Case Study Route

After Slope Inspection work had been conducted, the inspection forms were reviewed and made ready for data entry. As a result of the conditions experienced in the field, revisions were required in SIMS to handle the data. These changes included reorganizing the input screens to make data entry easier and similar to the format of data collected from the field, providing multiple selections for some data fields, re-organize lookup tables for fields such as Geology, to provide easier organization of data.

The field inspections were conducted using Slope ID's designated in the field. As a result of the clearer definition of JKR's preferred approach to designate these slope ID's, the application and the data forms were revised. Since all data is essentially connected to the Slope ID, revisions to the data entry process and revision of the data already entered in the SIMS database was done.

On further re-examination by JKR, the slope ID naming conventions were further enhanced. Recognizing that the Slope ID would be dependent on the Highway ID, and also that the Highway ID's for all of Malaysia would be redefined as standardization of information is done by JKR, the application was re-structured to assign a system generated ID to the slope feature, linking the JKR Slope ID to this internally generated unique ID. The JKR Slope ID was also redesigned to be dynamically generated from a concatenation of the fields required.

As the application was revised and slope information entered into the application, additional modifications required of the application were identified and these changes have been initiated to make use of SIMS easier and more efficient for JKR.

Data for all the slope inspections carried out on the East West Highway have been entered using SIMS. The slope inspection information and hazard/ risk information are complete for this study section, and the hazard scores and risk ratings have been computed by SIMS. The countermeasure module is now available for data entry and design/ costing of countermeasures. Once this data is complete, the economic analysis results can also be be generated from the application.

To make the GIS module functional, the slope feature polygons have been created in the data format required (ArcView shape files). These features were originally created using the slope ID's assigned in the field. With the revisions to the conventions for assigning Slope ID's, the attributes of this data has been modified to use the unique system ID assigned to each JKR ID. This has been achieved by making a complex temporary table that captures all the different types of ID's that may have been used for a slope feature, correlating them with the JKR Slope ID and the System ID, and then editing the attribute tables of the GIS data to reflect the System ID and the JKR Slope ID. This process is expected to be simpler in future use of SIMS as a result of a better defined JKR Slope ID, and a closer correlation between the JKR Slope ID and the ID used by Slope Inspection persons.

The lessons learnt from the use of SIMS on the caser study have contributed to improving the application, better coordinating the Slope Inspection Forms with SIMS and vice-versa, and clearly defined processes for data entry, editing, and data creation. It has specifically contributed to a clearer definition of the process required for GIS data creation for the slope features.

5.2 Application to Penampang-Tambunan-Keningau Road

5.2.1 Background of the Work

The development of SIMS was based on slope analysis of the East – West Highway. As a verification exercise, the Study Team planned to apply a prototype of SIMS to the Penampang-Tambunan–Keningau Road with the intention of developing and improving its sub-systems through actual application.

Slope inspection is the most important component of SIMS because it provides fundamental information for slope management. The slope information was collected by inspectors on proformas called "Inspection Sheets" and the data were input to the SIMS.

A local contractor was engaged to perform the main inspection, namely "JW Geotechnical Consultant" located in Kota Kinabalu. At the beginning of the work, an engineer of the Study Team visited Kota Kinabaru to give the contractor suggestions on their work, and to select suitable slopes for the purpose of this work.

The contractor recorded observations on the inspection sheets and submitted the sheets to the Study Team in Kuala Lumpur. After the contractor's work was finished, engineers of the Study Team visited the site again to check and improve the results of the work done by the contractor. Finally, the data were revised and finalized based on the re-inspection performed by the Study Team and the contractor.

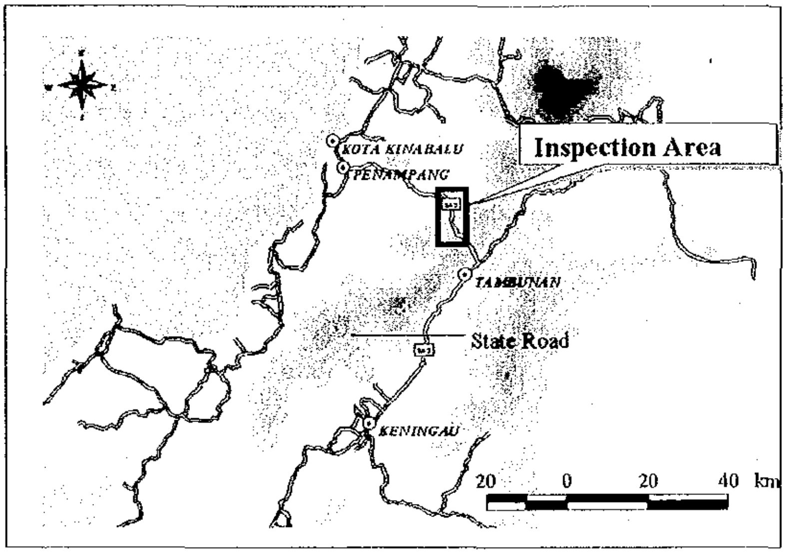

Figure 5.2.1 Location Map of the Inspection Area

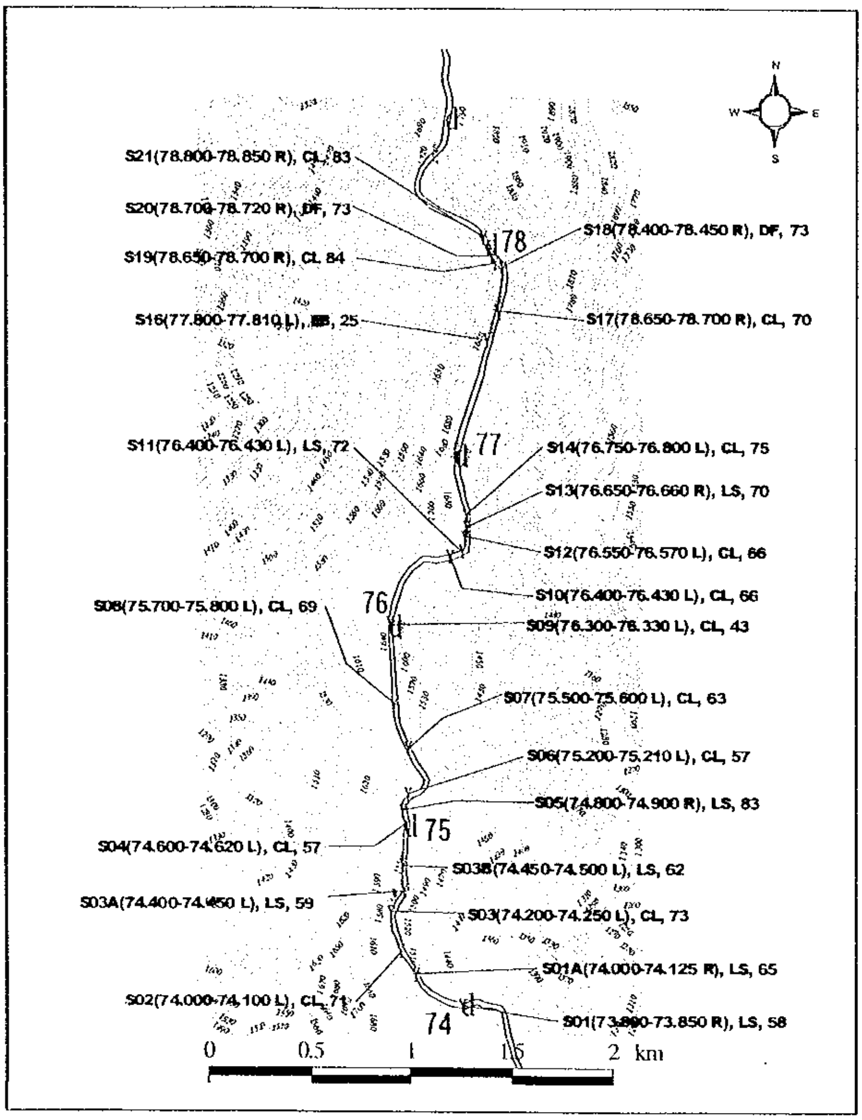

Figure 5.2.2 Location Map

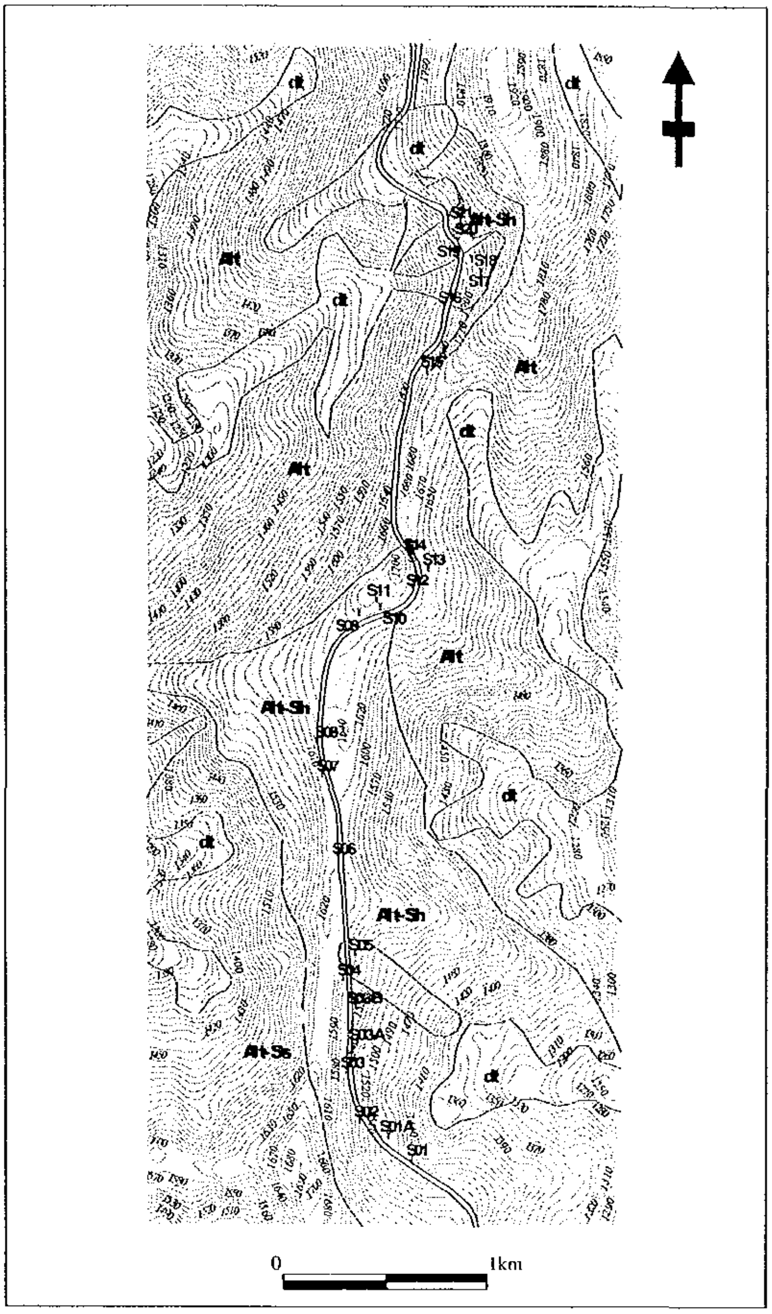

Figure 5.2.3 Geological Map

Ss : Sandstone

Sh : Shale

Alt : Alternate Layers

dt : detritus / talus deposit

5.2.2 Selection of Slopes

The road is a State Road of Sabah Province, extending 120 km from Penampang to Keningau via Tambunan. The trial inspection was carried out on 23 slopes of about 5km between CH74 and CH79, where typical slope failures were observed on both sides of the road.

5.2.3 General Condition

The 23 slopes are located in a mountainous area about 1,400 m to 1,700 m above mean sea level. The road has been built by cut-and-fill along a ridge extending from north to south. The area is covered with mixed vegetation, mostly of primary forest or secondary jungle.

Bedrock is Tertiary Crocker formation, composed mainly of an alternation of sandstone and shale and striking NW-SE. The thickness of the alternating beds is usually between 10 to 30 cm. The formation often shows slump-structures formed before lithification. Another Tertiary formation overlays the Crocker formation at higher elevations at the top of mountainous area. Quaternary sediments also overlay the Paleogene in the form of river deposits, talus deposits, and debris flow.

5.2.4 Results of Slope Inspection

Detailed results of the slope inspections are input to the SIMS and submitted as electric file.

(1) Classification of Slope Failure

Slope Failures in the area are divided into four types. They are, 1) Collapse / Rock Fall, 2) Landslide, 3) Debris Flow, and 4) Embankment Failure. Rock Mass Failure, one of the types of slope failure defined in the Guidelines prepared by the Study Team, was not found within the inspection area. Occurrences of this type may be found in future inspections.

(a) Collapse / Rock Fall

This type of slope failure is frequently found at the cut or natural slope along the road. Material forming slopes is usually alternating beds of intensely weathered sandstone and shale.

Massive or thick sandstone beds are continuously found along slopes between S17 and S21 where large collapses and Rock Falls are observed along the road. Slopes formed of sandstone tend to produce a larger scale of collapse and larger Rock Fall than that of alternating beds of shale and sandstone.

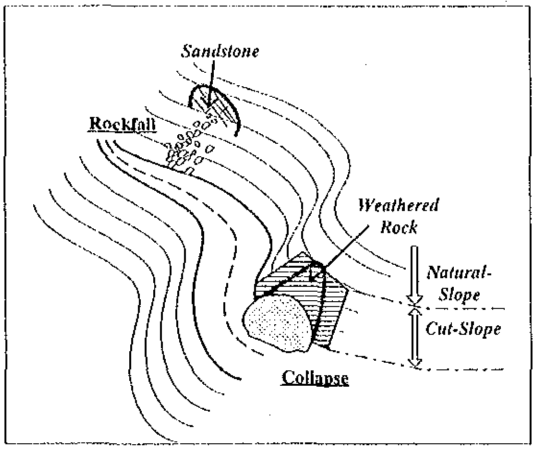

Figure 5.2.4 Schematic View of Rock Fall and Collapse

(b) Landslide

Landslides are usually found on natural slopes or embankments built over mountain streams. Most landslides are seen in embankments over mountain streams, as shown in Figure 5.2.5.

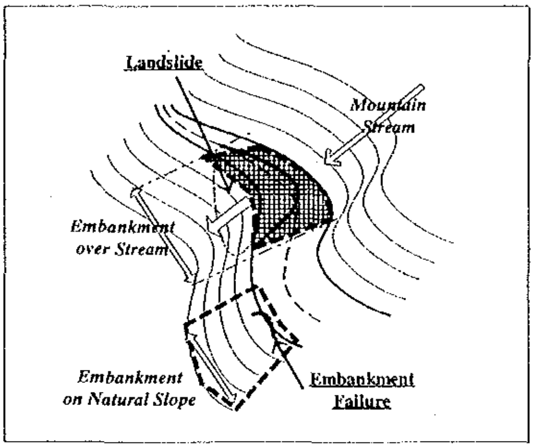

Figure 5.2.5 Schematic View of Landslide

There are a few landslides that occur on natural slopes. At S05, the pavement has been damaged and sunk because the road passes over weakened and disturbed material formed from a large landslide.

(c) Debris flow

This form of failure is restricted to mountain streams and its distribution and scale are usually confirmed through observation of aerial photographs and field reconnaissance. For example, the road has repeatedly suffered from debris flow at S18.

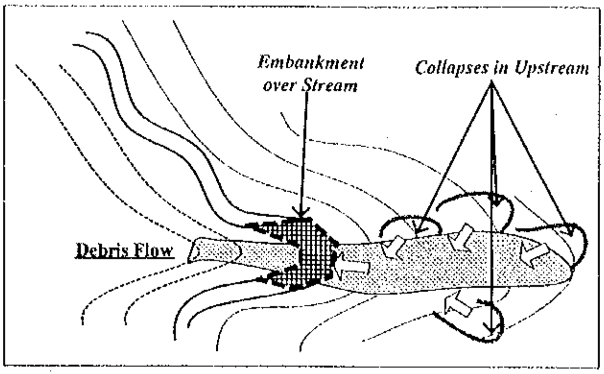

Figure 5.2.6 Schematic View of Debris Flow

(d) Embankment Failure

This appears as gully erosion, shoulder cracks or small collapse and can be due to heavy rainfall or lack of compaction of material forming the embankment.

(2) Risk Rating

The Risk Rating for each slope is read from a combination of the "Hazard Score" and "Consequence Score" and ranges from 25 to 84 for the 23 slopes. Details are shown in Table 5.2.1 and Table 5.2.2.

Table 5.2.1 Summary of the Inspection Results

Field ID	Chainage (km)	Side	Type of Failure	Hazard Score	Consequence Score	Risk Rating*
S01	73.975-74.025	R	Landslide	60	4	58
S01A	74.219-74.345	R	Landslide	69	3	65
S02	74.363-74.463	L	Collapse / Rock Fall	73	5	71
S03	74.567-74.617	L	Collapse / Rock Fall	76	5	73
S03A	74.687-74.737	R	Landslide	62	3	59
S03B	74.794-74.844	R	Landslide	65	3	62
S04	75.005-75.025	L	Collapse / Rock Fall	59	4	57
S05	75.024-75.124	R	Landslide	88	4	83
S06	75.144-75.154	L	Collapse / Rock Fall	59	4	57
S07	75.385-75.485	L	Collapse / Rock Fall	66	4	63
S08	75.589-75.689	L	Collapse / Rock Fall	72	4	69
S09	75.996-76.026	L	Collapse / Rock Fall	43	4	43
S10	76.484-76.504	L	Collapse / Rock Fall	69	4	66
S11	76.541-76.571	L	Landslide	76	4	72
S12	76.616-76.636	L	Collapse / Rock Fall	69	4	66
S13	76.662-76.672	R	Landslide	73	4	70
S14	76.699-76.749	L	Collapse / Rock Fall	79	4	75
S16	77.528-77.538	L	Embankment Failure	21	6	25
S17	77.620-77.720	R	Collapse / Rock Fall	73	4	70
S18	77.839-77.889	R	Debris Flow	75	5	73
S19	77.883-77.993	R	Collapse / Rock Fall	89	4	84
S20	77.935-77.955	R	Debris Flow	75	5	73
S21	78.010-78.060	R	Collapse / Rock Fall	86	5	83

* [Risk Rating]=[Hazard Score] * 0.9 + [Consequence Score]

Table 5.2.2 Risk Rating by Type of Slope Failure

Type of Disaster	Number of Slope	Risk Rating
Collapse / Rock Fall	13	43 –84
Rock Mass Failure	0	-
Landslide	7	60-83
Debris Flow	2	73
Embankment Failure	1	25

(3) Countermeasure

Countermeasures for each slope have been selected and summarized together with their estimated cost in Table 3.5.3. The total estimated cost for 22 slopes, i.e. excluding S05, is estimated to be RM1,800,365.

Table 5.2.3 Proposed Countermeasure and Cost

Slope ID	Type of Failure	Risk Rating	Proposed Countermeasure	Cost (RM)
S01	Landslide(E)	58	Gabion Wall + Drain Ditch + Horizontal Drain Hole +Pile Wall	229,200
S01A	Landslide(E)	65	Gabion Wall + Drain Ditch + Horizontal Drain Hole +Pile Wall	481,300
S02	Collapse / Rock Fall	71	Gabion Wall	25,350
S03	Collapse / Rock Fall	73	Removal + Retaining Wall + Cribwork	31,940
S03A	Landslide(E)	59	Gabion Wall + Drain Ditch + Horizontal Drain Hole +Pile Wall	322,500
S03B	Landslide(E)	62	Gabion Wall + Drain Ditch + Horizontal Drain Hole +Pile Wall	244,100
S04	Collapse / Rock Fall	57	Soil Cutting + Re-Vegetation	248
S05	Landslide(N)	83	(Further investigation is necessary)	-
S06	Collapse / Rock Fall	57	Soil Cutting + Re-Vegetation	223
S07	Collapse / Rock Fall	63	Retaining Wall + Rock Fall Fence	25,200
S08	Collapse / Rock Fall	69	Shotcrete (Mortal)	36,000
S09	Collapse / Rock Fall	43	Shotcrete (Mortal) + Rock Bolt	99,000
S10	Collapse / Rock Fall	66	Soil Cutting + Re-Vegetation	1,980
S11	Landslide(E)	72	Soil Cutting + Re-Vegetation + Gabion Wall	8,550
S12	Collapse / Rock Fall	66	Gabion Wall	6,240
S13	Landslide(E)	70	Horizontal Drain Hole + Pile Wall	42,000
S14	Collapse / Rock Fall	75	Soil Cutting + Re-Vegetation	6,750
S16	Embankment Failure	25	Re-Vegetation +Drain Ditch	17,400
S17	Collapse / Rock Fall	70	Soil Cutting + Re-Vegetation	3,630
S18	Debris Flow	73	Ground Anchor + Gabion Wall + Pile Wall	174,300
S19	Collapse / Rock Fall	84	(Further investigation is necessary)	-
S20	Debris Flow	73	Gabion Wall	4,875
S21	Collapse / Rock Fall	83	Removal + Soil Cutting + Re-Vegetation + Drain Ditch +Gabion Wall	21,260
			Total	1,782,046

Table 5.2.4 summarizes the basic countermeasure work for each type of slope failure.

Table 5.2.4 Proposed Basic Items of Countermeasure

Type of Failure	Patterns of Countermeasure	Number of Slope
Collapse/Rock Fall	1) Gabion Wall	2
	2) Gabion Wall + Soil Cutting	1
	3) Removal + Retaining Wall + Cribwork	1
	4) Removal + Soil Cutting + Re-Vegetation + Gabion Wall +	2
	Drain Ditch	4
	5) Soil Cutting + Re-Vegetation	1
	6) Retaining Wall + Rock Fall Fence	2
	7) Shotcrete (+ Rock Bolt)	
Landslide	1) Gabion Wall + Drain Ditch + Horizontal Drain Hole (+ Pile	4
	Wall)	1
	2) Horizontal Drain Hole (+ Pile Wall)	1
	3) Gabion Wall + Soil Cutting + Re-Vegetation	
Debris Flow	1) Gabion Wall + Ground Anchor	1
	2) Gabion Wall	1
Embankment Failure	1) Re-Vegetation + Drain Ditch	1

(a) Countermeasure for S05 and S19

The large landslide at S05 is about 70 to 100 m in width, 10 m thick, and 250 m in length and is still partially active at present. The pavement has been broken and is clearly sunken at present because the road passes over unconsolidated material that has been disturbed intermittently by mass movement. It is likely to cause more serious problems for the road in the future. Countermeasures for S05 are proposed with estimated costs as shown in Figure 5.2.7 (not yet prepared).

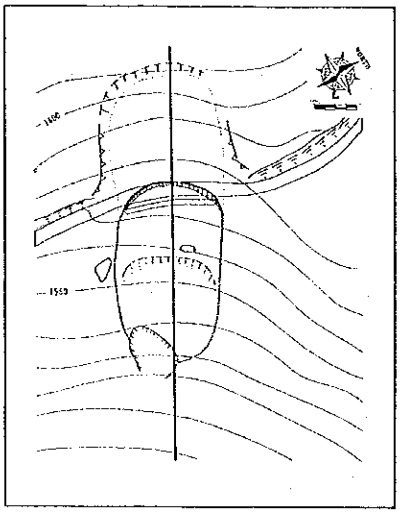

Figure 5.2.7 Schematic View of Landslide at S05

5.2.5 Commentary on the Slope Inspection in Penampang – Tambunan Road

The Study Team previously prioritised the slopes of the E-W Highway for the application of countermeasures, mainly based on the Risk Rating Score (H). The priorities for the Penampang–Tambunan Road were also determined and divided into four categories as shown in Table 5.2.5.

Table 5.2.5 Priority Category with Risk Rating Score

Priority Category	Range of Risk Rating Score	Number of Slope in the Area
Very High	H≥75	4
High	65≤H<75	11
Moderate	50≤H<65	6
Low	H<50	2

Four slopes are categorized as very high priority, these being S05, S14, S19, and S20. Eleven slopes are categorized as high priority. The four very high priority slopes require application of countermeasures as soon as possible. The 11 high priority slopes also need countermeasures to be applied, but some re-prioritisation within this category is possible depending on their slope condition, or countermeasure costs, etc.

The road relocation that has been completed at S02 seems to be effective. Accordingly, the priority of S02 shall become lower than that of the others.

Countermeasures can be delayed in the case of moderate and low priority slopes.

5.2.6 Commentary on Improvement of Data Quality

Slope data collected through inspection was ultimately input to the SIMS database. Data entry was finished smoothly, although there are some points that could improve the data quality as follows.

(1) General Matters

Text and number characters on the inspection sheet must be legible and should be typed and printed.

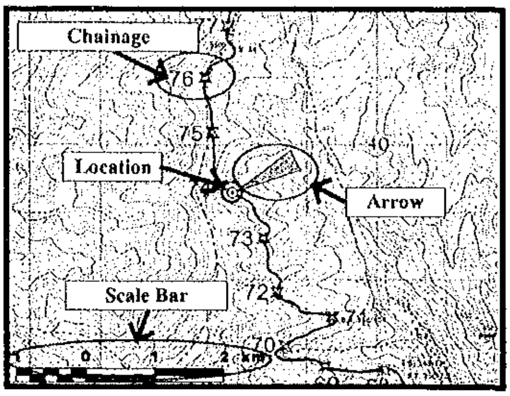

Figure 5.2.8 An Example of Location Map in Form A

(2) Location Map in Form A

The location of slopes should be indicated by a circle and arrow on 1:50,000 topographic map published by JUPEM. The map needs to be copied and pasted firmly on the map section provided on FORM A (e.g. Figure 5.2.8).

(3) Sketch in Form B

The sketch to be drawn on FORM B should present basic information for slope disaster management. It is necessary to show the locations of photographs, cross sections, horizontal and vertical scale bars, angles of slopes, information on existing countermeasures, comments by the inspector, and so on, as shown in Figure 5.2.9.

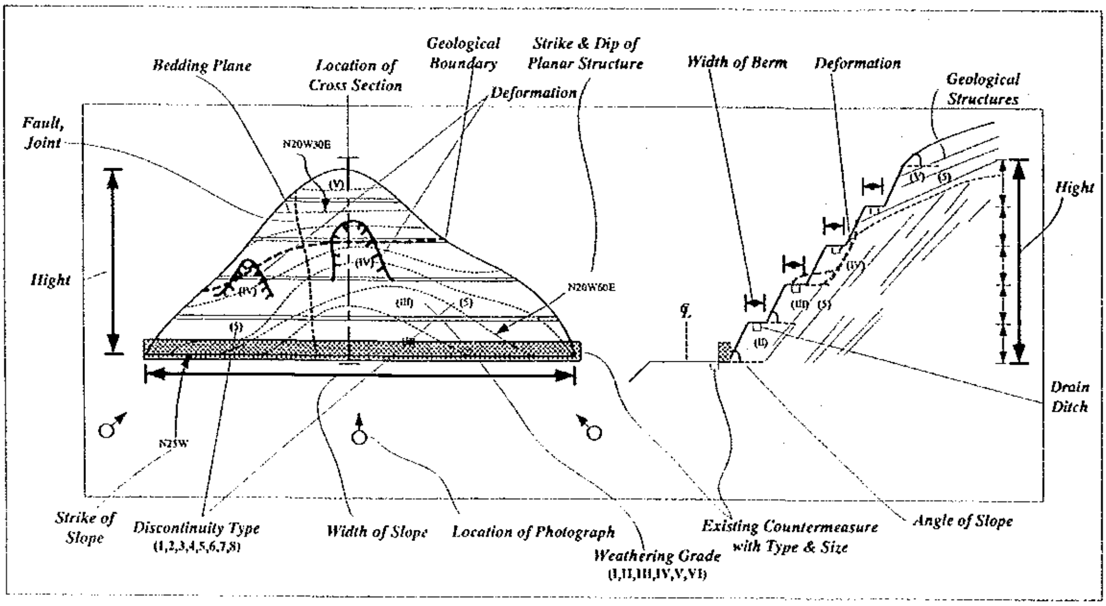

Figure 5.2.9 An Example of Sketch assigned in Form B

The sketches must be readable by anyone. They should be drawn in clear and visible black lines because they are displayed as monochrome JPEG images in SIMS.

If the contractor uses a pencil to draw or write on the Inspection Sheets, the lines and lettering should later be traced using a black pen onto a clean sheet.

(4) Photograph in Form C

It is preferable to take pictures with a digital camera. If a digital camera is not available, printed photographs should be scanned by an image scanner and saved in JPEG format on digital media. File names are better to be simple, imaginable, and distinctive to distinguish the slopes from each other. The recommended file-size for each photograph is around 100 KB.

(5) Hazard Score in Form E

The contractor should re-examine the Hazard Score of the slope. Slopes of similar condition should be adjusted to have a similar score if necessary.

(6) Countermeasure Selection in Form F

Countermeasures should be selected from the list provided in the Guideline for Inspection. The section for countermeasures on Form F must be filled in with a description as shown in the example of Figure 5.2.10.

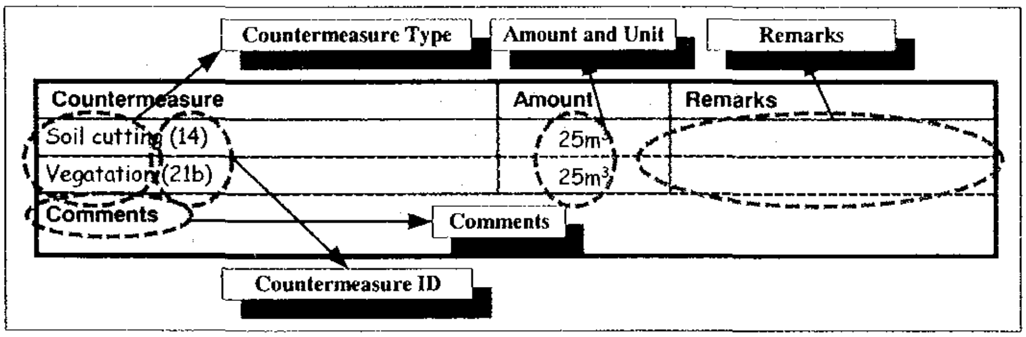

Figure 5.2.10 An Example of Proposed Countermeasure

The points mentioned above have been reflected in the Guideline for Slope Inspection prepared by the Study Team.

5.2.7 Conclusion of the Trial Inspection

The Study Team and its contractor carried out a slope inspection of the Penampang–Tambunan Road as a part of a trial application of SIMS. It was confirmed that SIMS would be applicable not only to the E-W Highway but also to the Penampang–Tambunan Road. It is believed that SIMS is also applicable to other roads in Malaysia.

The work for the Penmanpang – Tambunan Road presents the data from only 23 slopes. There are still many slopes that have not been inspected with the SIMS inspection method.

Further inspection is necessary for the total slope management of the Penampang – Tambunan Road and other roads in Malaysia.

5.3 Consideration of Economic Analysis

5.3.1 Economic Indicator in SIMS

The Study Team has made much effort to introduce the economic analysis into the SIMS. But it was found that some of the necessary data was not easy to collect and that some assumption in the economic analysis was not accurate enough from the viewpoint of practical use of the economic analysis.

In these situations, thinking of importance of economic analysis to evaluate the feasibility of the road disaster prevention work, a simpler economic indicator was studied and applied to the SIMS as below, while the basic concept, methodology and result of the economic analysis are presented in 5.3.2 – 5.3.4.

$$E = V_T/C$$

Where,

E : Rate of V_T to C
V_T: AADT (Annual Average Traffic Volume (No. of Vehicles of Each Route)
C : Cost for Countermeasures (RM 1,000)

"V_T" could be interpreted as a substitute of "benefits" tentatively. Because "V_T" as traffic volume of the route in the number of vehicles is assumed to represent the socio-economic activities of the regions as the beneficiaries of countermeasure works for slopes along side the route. The data of "V_T" in this calculation is ADT Annual Daily Traffic of the East-West Highways. The data of AADT is adjusted with regard to seasonal fluctuation but not yet available. This rate (E) was tentatively calculated for all slopes of which countermeasures works are necessary (317 slopes) for the comparison with the total score of risk rating. The result of calculation for slopes of which risk priority ranking is "Very High" and "High" is shown in Table 5.3.1. The result of B/C is included in this table for convenience for comparison with V_T/C.

The values of "V_T/C" are larger than the ones of B/C but change proportionately with them. The histograms of the total score of risk rating and "V_T/C", and the relation between total score and "V_T/C" are shown in Appendix 5.3.1 to 5.3.3 respectively. It proves that the degree of co-relation between the total score of risk rating and "V_T/C" is low. This means that the risk priority ranking does not coincide with the rank of the rate of "V_T/C".

In other words, the slope ranked as high risk is not always highly effective from the viewpoint of economy.

Table 5.3.1 Result of Calculation of V_T/C for the East-West Highways (Case Study)

Priority Ranking	No.	JKR Slope ID No.	Total Score (Risk Rating)	Type of Slope Disaster		B/C	V_T/C *1)
Very High	1	F04/071.50RC	85	4	1	1.1	0.8
	2	F04/081.15LC	84	4	1	1.6	2.6
	3	F04/031.46RC	81	1	2	2.4	5.2
	4	F04/032.08RG	78	1	2	1.4	1.9
	5	F04/033.30RC	77	1	2	5.1	15.5
	6	F04/072.68LC	77	4	1	1.7	2.8
	7	F04/069.52LC	76	1	-	1.2	0.9
	8	F04/031.92RC	76	1	2	2.6	6.0
	9	F04/050.90RE	76	6	-	3.4	9.0
High	10	F04/035.53LR	73	3	-	1.1	1.4
	11	F04/036.14LC	70	4	-	1.1	1.1
	12	F04/027.35RC	70	3	-	2.3	9.6
	13	F04/027.91RC	70	1	2	2.1	8.7
	14	F04/038.80RC	70	1	-	1.9	7.1
	15	F04/032.95RC	69	1	2	2.6	12.3
	16	F04/038.53LE	68	6	-	1.5	4.4
	17	F04/042.38LC	68	1	-	2.9	14.4
	18	F04/080.70RE	68	6	-	3.1	16.1
	19	F04/028.24RC	67	1	2	1.7	5.2
	20	F04/049.68RE	66	6	-	3.6	19.6
	21	F04/076.10LE	66	6	-	1.1	1.7
	22	F04/072.41LC	65	1	-	2.0	7.8
	23	F04/027.68RC	65	1	2	8.2	25.3
	24	F04/035.86LR	65	3	-	5.5	32.6
	25	F04/036.83LC	65	3	-	1.3	2.9
	26	F04/038.31RC	65	1	2	2.0	7.5
	27	F04/042.71LC	65	1	-	3.0	7.2
	28	F04/061.60LE	65	6	-	9.3	62.1
Route Total (317 Slopes)						1.6	14.3 *2

Note: *1) " V_T " means the sectional daily traffic volume of the route. V_T = 1,808 vehicles/day. " C " means the cost of countermeasures.
*2) was derived from dividing " V_T "(1,808) by the average cost of countermeasures of all slopes in the route (126.4 RM 1,000)

5.3.2 Purpose and Significance of Economic Analysis

The ordinary economic analysis was conducted outside of the system of SIMS.

(1) Purpose of Economic Analysis

The priority ranking for implementation of countermeasures against slope failure should be basically decided by risk rating on the basis of "Hazard Rating" and "Consequence Attributes" by slope inspection.

Then purpose of this economic analysis is not to make decision for the priority ranking of different slopes or routes for countermeasures against slope failure, but to provide the decision makers the materials to judge the justification of the countermeasure works against the individual slope failure and to decide the implementation of countermeasure works.

Then the comparison of importance for countermeasure works against slope failure will be conducted not by the economic analysis but by the traffic volume and road standard.

(2) Significance of Economic Analysis

The SPRS is the existing application for slope disaster management application in JKR. This application does not include the viewpoint of economic analysis, which makes possible the economic effectiveness of the countermeasures by comparison of cost and benefit. The significance of the economic analysis is found out in the following advantages.

1) Accountability to the People

The countermeasures have been executed for the slope with high-risk disaster on the basis of risk rating by the SPRS. The cost for the countermeasures is calculated mainly from viewpoint of engineering although the benefit by countermeasures is informed by the influence to the roadside area as "Consequence Attributes" in slope inspection. But the benefits are not quantified by money terms. The cost for countermeasures will generate the benefits to the inhabitants alongside the roads with slopes.

The source of countermeasures cost comes from the budget of the Government. The most of the budget are composed of the taxes collected from the income earned by the people of Malaysia. Then the countermeasures should be accountable not only to the Government but also to the people of Malaysia. The economic analysis will contribute to accountability of the countermeasures because it can evaluate the cost and benefit simultaneously.

2) Improvement of Effectiveness of Countermeasures

The priority of countermeasures should be judged on the basis of comparison with the cost and effects. The effects have been judged mainly on the basis of comparison between the cost and physical effectiveness of the countermeasure to protect the slope disaster. But the effects must be measured not only by engineering viewpoint but the economic viewpoint as the benefits. The benefits have been indirectly informed by the score of "Consequence Attributes" in slope inspection sheet of the SPRS. But the score is not the quantitative evaluation but only useful for the ordering of the degree of impact on the alongside of road with slope. In this context, the SPRS cannot evaluate directly the effects of the countermeasures in same dimension with the cost. The effects of countermeasures are the benefits brought to the users and suppliers of transportation services, the people inhabiting alongside roads with slopes and the industries and business in the area to be influenced by transportation.

Then the effectiveness or validity of countermeasures will be improved by the direct quantitative comparison of the cost and the benefits.

3) Reinforcement of Objectivity of Judgement for Priority Ranking

The one sided evaluation tends to mislead to the non-suitable judgement. Especially the cost of countermeasures is expended from the Government budget to be sourced by the tax collected from the income earned by the peoples' economic activity. Then to preserve the objectivity of judgement or decision making for the prioritising and the expenditure for countermeasures to mitigate the slope disaster, the diversified study and analysis are indispensable.

Under the SPRS, the priority ranking is decided only based on the score of the inspection sheets and the cost for the countermeasures was calculated for the high-risky slope. But in the economic analysis, the cost will be compared with the benefits and the more objective decision-making is expected. In this context, the economic analysis will strengthen the objectivity of justification for priority ranking for the countermeasures.

5.3.3 Methodology of Economic Analysis

(1) "With- Without" Method

The "With- Without" methodology is applied. This method is known as the most standard methodology. In this methodology, the benefits between the case of "With-The-Project" and the one of "Without-The-Project" are compared each other and the difference of the benefits between them are considered to be the benefits of the project.

"With-The-Project" means that the countermeasure works will be implemented while "Without-The-Project" means that the countermeasure works will not be implemented. The items of benefits are as shown in Table 5.3.2.

(2) Assumptions

The assumptions for the economic analysis are as follows.

1) The Period for Economic Evaluation

The period for economic evaluation is assumed to be twenty one years including the years for countermeasure works (one year) and twenty years of the project life. This is based on the condition that the countermeasures will be able to protect the slope failure at least for twenty years at maximum.

Table 5.3.2 Items of Benefits

1. Damages for Human Bodies	(1) In Vehicles (Injures and Death)
	(2) In Building Alongside Roads (Injury and Death)
2. Damages for Assets	(1) Vehicle by Type
	(2) Buildings Alongside Roads
	(3) Agricultural Products Alongside Roads
3. Cost for Recovery Works	
4. Loss of Time and Cost of Passenger and Freights by Vehicle Type for Alternative Roads	
5. Construction Cost of By-Pass Road	
6. Loss Time during Road Closure	
7. Damages for Business Income and Others	

2) Probability of Occurrence of Slope Failure (Return Period)

The slope failure and its damages will happen on some specified time. But in economic analysis, the damages (the benefits in with-the-project) are evaluated as the cash flow during the evaluation period by averaging the benefits. The averaging the benefits is estimated on the basis of the probability of occurrence of slope failure (the return period, in other word). Then the return period is better to be analysed by statistical method on the basis of time series data for the amounts of failed materials and the date of occurrence of sloped failure. But there is not enough data to analyse for the case study route.

The alternative method was selected by using the data with regard to total score of "Hazard Score" and "Consequence Attributes" in the slope inspection sheets for the case study route. The return period is set up for the probability of occurrence year of slope disaster by the risk ranking on the basis of the data with regard to the frequency of occurrence of slope failure during the latest three years (1998-2001). In the past three years, about 150 slope failures have happened in the Federal Roads. Then one slope failure is assumed to have happened in 10 km interval of slope during three years in average (1/10≒150 slopes/1,600 km). If this rate is applied to the East-West Highways, six slopes will fail within three years and ten slopes will fail within five years approximately.

In this study, there are nine slopes, which are ranked as "Very High" by risk rating. Then these slopes are assumed to fail within five years and the return period of slopes with risk priority ranking of "Very High" is assumed to be five year. Other slopes of priority ranking are set up on the basis of total score of risk rating as shown in Table 5.3.3.

By application of this classification, the benefits are averaged per year. For example, if the total score between 65 and 75, the probability of occurrence year is assumed to be 10 years, then probability of occurrence of slope disaster is considered to be one tenth (1/10). The annual average benefits are derived from dividing the amounts of damages by ten.

Table 5.3.3 Classification of Return Period of Slope by Risk Ranking

Classification of Score	Risk Ranking	Probability of Occurrence Year
$S \geq 75$	Very High	5
$65 \leq S < 75$	High	10
$55 \leq S < 65$	Moderate	20
$S < 55$	Low	30

3) Cost of Recovery Works

The cost recovery works is composed of (i) cost for removal of failed materials on the roads and (ii) cost for repairs of failed slope. The repair works will not conducted for external life but for short life (simple works). The repair works is assumed to occur according to probability of occurrence of slope failure on the basis of return period, which was classified by risk priority ranking, mentioned above. In case study, the cost of repairs is assumed to be two times of cost for countermeasures with the project. This cost of repair works is distributed equally in twenty years of economic life according to the return period.

4) Loss Time During Road Closure

The loss time during road closure by slope failure is composed of the time for responding time until starting clearing road to make traffic and the time for clearing road. The time for clearing road depends on the failure volume. In this study, the relation between failure volume and loss time during road closure is assumed as shown in Table 5.3.4.

Table 5.3.4 Relation between Failure Volume and Loss Time

Failure Volume (Q: M3)	Loss Time [hour (day)]
Q < 200	6 (0.25)
200 < Q < 5,000	24 (1.0)
Q > 5,000	48 (2.0)

5) Economic Cost

(a) Economic Pricing

The project cost, as evaluated by financial prices, will be converted into the economic prices by deducing the transfer items such as local taxes and custom duties and be adjusted by avoiding any economy distortion such as inflation and controlled prices. Then shadow prices have to be applied in economic evaluation instead of such distorted prices. The project cost in financial price is considered to be the local currency portion. Then the standard conversion factor (SCF) for shadow pricing is applied to the economic pricing of the project costs. The costs for unskilled labor (being a part e.g. of the construction cost and to some extent of the cargo handling cost, which is subject to minimum wage regulations), does not usually reflect the real market prices. Then, the shadow price is applied to the economic pricing as cost for unskilled labour.

(b) Operation and Maintenance Cost

Only the cost for countermeasures is considered as the economic cost. Because the operation and maintenance cost after countermeasures will not differ from the one of without countermeasures. The economic analysis is conducted by the comparison between "with-the-project" and "without- the-project". Then this cost will not be taken account of for the economic evaluation.

6) Opportunity Cost of Capital

The key indicators for the economic evaluation are as follows;

- EIRR (Economic Internal Rate of Return)
- B/C Ratio (Benefit Cost Ratio)
- NPV (Net Present Value)

These indicators or criteria are related to the adopted economic discount rate, which is also often referred to as **'cut-off ratio'** or 'target rate'. Although the economic discount rate is more or less clearly defined in the economic theory (equal to the "opportunity cost of capital"), there is a wide range of definitions in practice. The opportunity cost of capital as the cut-off-ratio in this Study is assumed to be 10 % by taking account of the opportunity cost of capital for project of road safety in Malaysia.

7) Evaluation by Type of Slope Disaster

The failed materials and quantity are different from the type of slope disaster. Then the damages of slope failure are quite different from the type of slope disaster. In this context, the result of economic evaluation will reflect the type of disaster and benefits as follows.

Table 5.3.5 Contents of Economic Evaluation

Type of Slope Disaster	Amounts of Failed Materials in General	Indicators for Economic Evaluation
1. Landslide	Large Scale	B/C, B-C (NPV), EIRR
2. Mud and Debris	Large Scale	
3. Rock fall and Rock Mass	Large Scale	
4. Slope Collapse (1) Cut slope (2) Embankment	 Small Scale Small/Medium Scale	

The general flowchart of economic evaluation is shown in Figure 5.3.1.

8) Assumption of Alternative Roads

Setting up of alternative roads is very important factors for the damages for the users and supplier of transport service. In the case study, the alternative road is considered to be the southern part of roads far from the existing road. The distance of alternative road will be very long distance and it is unrealistic that the road transport users will use the alternative roads. Then the benefit for alternative roads was not accounted in this study.

The details for methodology including input data, calculation formulas and assumptions are shown in Appendix 5.3 respectively.

5.3.4 Result of Economic Analysis

The result of economic analysis is figured out as the indicators such as EIRR (Economic Internal Rate of Return), B/C (Benefit Cost Ratio) and NPV (Net Present Value: B-C). The criteria of judgment for these indicators are defined as shown in Table 5.3.6. NPV is the difference between benefit and cost. Then even when B/C or EIRR is equal among projects (slopes), benefit and cost are different by project (slope). Therefore NPV is useful to decide the priority ranking of projects of which B/C or EIRR is equal each other.

Table 5.3.6 The Definition of Judgment for Indicators

Judgment for Project	EIRR	B/C
Good (Highly Feasible)	> 18%	>2.0
Fair (Feasible)	10-18%	1.0 – 2.0
Poor (Non-Feasible)	< 10%	<1.0

The economic analysis was conducted by the methodology mentioned above on the basis of the total score of "Hazard Rating" and "Consequence Attributes" recorded on inspection sheet for the East-West Highways in case study and other socio-economic data. The result is shown in Table 5.3.7.

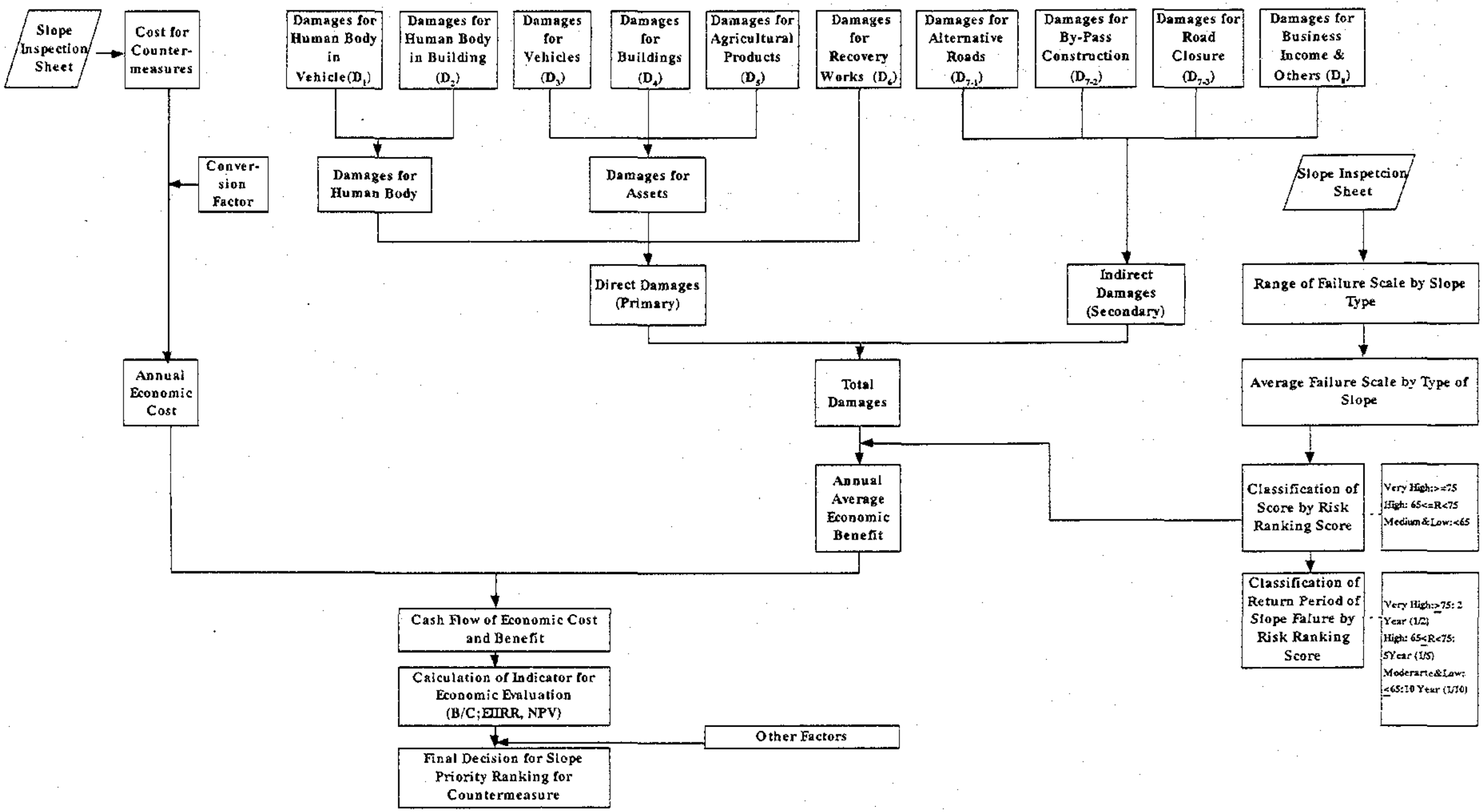

Figure 5.3.1 General Flow Chart of Economic Evaluation for Countermeasure of Slope Disaster

Table 5.3.7 Result of Economic Analysis for the East-West Highways (Case Study)

Priority Ranking	No.	JKR Slope ID	Total Score (Risk Rating)	Type of Slope Disaster		EIRR (%)	Benefit (RM 1,000)	Cost (RM 1,000)	B/C	NPV (B-C) (RM 1,000)
Very High	1	0004/071/50RC	85	4	1	11.7	2,407.4	2,136.5	1.1	271
	2	0004/081/15LC	84	4	1	17.3	1,047.8	639.9	1.6	408
	3	0004/031/46RC	81	1	2	23.7	742.7	314.2	2.4	429
	4	0004/032/08RC	78	1	2	15.4	1,264.8	875.7	1.4	389
	5	0004/033/30RC	77	1	2	43.3	541.1	106.3	5.1	435
	6	0004/072/68LC	77	4	1	17.9	1,004.9	593.7	1.7	411
	7	0004/069.52LC	76	1	-	12.1	2,154.2	1,855.6	1.2	299
	8	0004/031/92RC	76	1	2	25.4	703.1	272.7	2.6	430
	9	0004/050/90RE	76	6	-	31.7	620.5	182.2	3.4	438
High	10	0004/035/53LC	73	3	-	11.6	1,292.5	1,155.0	1.1	137
	11	0004/036/14LC	70	4	-	10.9	1,581.2	1,488.1	1.1	93
	12	0004/027/35RC	70	3	-	23.4	395.4	171.1	2.3	224
	13	0004/027/91RC	70	1	2	21.7	401.7	189.1	2.1	213
	14	0004/038/80RC	70	1	-	19.8	442.6	232.6	1.9	210
	15	0004/032/95RC	69	1	2	25.6	349.3	134.0	2.6	215
	16	0004/038/53LE	68	6	-	16.4	574.1	371.9	1.5	202
	17	0004/042/38LC	68	1	-	27.8	330.5	114.4	2.9	216
	18	0004/080/70RE	68	6	-	29.8	320.8	101.9	3.1	219
	19	0004/028/24RC	67	1	2	17.5	518.0	313.5	1.7	204
	20	0004/049/68RE	66	6	-	33.2	303.2	83.9	3.6	219
	21	0004/076/10LE	66	6	-	12.0	1,136.3	991.0	1.1	145
	22	0004/072/41LC	65	1	-	20.7	421.4	210.0	2.0	211
	23	0004/027/68RC	65	1	2	65.1	534.3	65.0	8.2	469
	24	0004/035/86LC	65	3	-	46.7	278.6	50.3	5.5	228
	25	0004/036/83LC	65	3	-	14.2	769.3	576.2	1.3	193
	26	0004/038/31RC	65	1	2	20.4	428.8	217.9	2.0	211
	27	0004/042/71LC	65	1	-	29.2	695.1	228.7	3.0	466
	28	0004/061/60LE	65	6	-	71.2	246.3	26.5	9.3	220
Route Total (317 Slopes)						17.0	65,079	40,124.5	1.6	24,955

Note: The number of slopes of Route Total stands for the number of slopes necessary to be implemented their counter measure works.

The order of risk rating for each slope does not coincide with the one of B/C. The projects for countermeasures of slopes to be ranked as "Very High" and "High" could be judged as "Good" and "Highly Feasible". Then the countermeasure works for these slopes are justified from the viewpoint of national economy. The B/C of integrated economic analysis for countermeasure works of all slopes of the route was derived as 1.6. Then this route as a whole can be concluded as fair and feasible for its countermeasure works.

The histogram of frequency of B/C and the relations (i) between total score and B/C and (ii) B/C and V_T/C are shown in Appendix 5.3 respectively.

Judging from the result of economic analysis mentioned above, the indicators such as the ranks of B/C, EIRR, and NPV of the slopes do not coincide with the ones of the total score for risk rating. Then the economic analysis is utilized only for the justification of countermeasure works against the slope failure from the economic viewpoint.

5.3.5 Effective and Sustainable Management of Economic Analysis

To maintain and sustain the economic analysis in the road slope disaster management, the following efforts are indispensable.

(1) Training of Staffs

The economic analysis is composed of many assumptions and formulas on the basis of economic theory. Then it is necessary to have the basic and minimum knowledge of contents with regard to economic analysis. The specialty of staffs of the Slope Maintenance Section of the Head Quarter and the Road Maintenance Divisions of the State and District Offices are mostly engineers and technicians. But it is requested to acquire the basic knowledge of the economic evaluation. Main items of contents of economic analysis are as follows:

- Necessity and purpose of economic analysis
- Period of economic evaluation (Project life)
- Conversion from financial cost to economic cost
- Benefits
  - Classification of damages
  - Return period of slope failure
  - Estimate of time value for transportation
  - Estimate of assets of buildings alongside of roads with slope
  - Estimate of products alongside of roads with slope
  - Estimate of value of human life and injuries in the accidents by slope failure
  - Gross national income (GNI) or Gross National Product (GNP)
  - Average annual benefits
- Cash flow stream of cost and benefits
- Criteria of viability of the countermeasures
  - Economic Internal Rate of Return (EIRR)

  - B/C (Benefit cost ratio)
  - NPV (Net present value)
- Opportunity Cost of Capital

The knowledge mentioned above could be basically acquired by tracing the formulas and explanations in Appendix 5.3.

(2) Recording of Slope Disaster

It proved that there is no systematic database with regard to the records of slope disaster in almost all routes including the East-West Highways. The records are indispensable to estimate the return period of slope disaster. Figure 5.3.2 shows the hypothetical relation between the quantity of failed materials and the return period if there are available data. The estimation of the return period of slope disaster is usually conducted by the statistical analysis of relationship of the amounts of rainfall, scale of slope disaster and their frequency on the basis of the historical data. In this study, the return period is estimated on the basis of total score of "Hazard Score" and "Consequence Score" of the slope inspection sheets for the East-West Highways. But if the data base system would be established, the more sophisticated and scientific estimate could be possible for estimation of the return period of slope disaster.

Maintenance Section of the Head Quarter and the Road Maintenance Divisions of the State and District Offices are mostly engineers and technicians. But it is requested to acquire the basic knowledge of the economic evaluation. Main items of contents of economic analysis are as follows:

- Necessity and purpose of economic analysis
- Period of economic evaluation (Project life)
- Cost
  - Financial cost
  - Economic cost

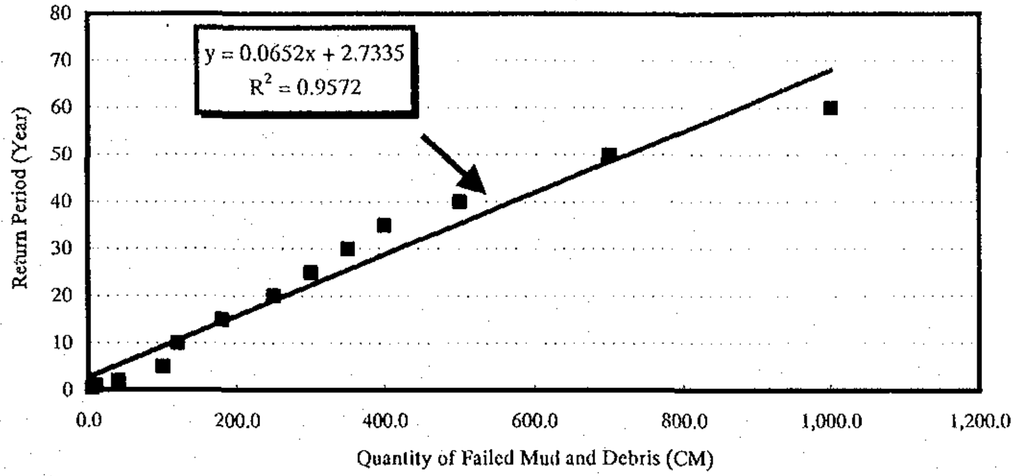

Figure 5.3.2 Hypothetical Relation Between Quantity of Failed Materials and Return Period

(3) Data Updating

To preserve the credibility of the economic analysis and the consistency between the economic analysis and the risk ranking survey by slope inspection sheet, it is also indispensable to update the input data for the economic analysis. The major data to be updated are as follows:

- Score of Hazard and Consequence Attributes by Slope
  The slope stability will be checked by recoding on the slope inspection sheets. Total score of inspection sheet is basic data for estimating the return period of slope disaster. Then the record on inspection sheets should reflect the latest slope conditions.

- Traffic Volume by Type of Vehicle by Route
  The traffic volume by type of vehicle is acquired by the "ROAD TARFFIC VOLUME MALAYSIA" surveyed and reported by Highway Planning Unit of the Ministry of Works. The latest report was published on July 1999 for data of 1998. The traffic volume to be used is based on this report. Then the traffic volume by route is necessary to be updated according to the latest report.

- Growth Factor of Per Capita GNI
  The period for economic evaluation of the countermeasures is twenty-one years including the one-year of countermeasure works. Then the benefits for the future must be forecasted. The value of lives and loss by injuries caused traffic accidents by slope disaster is assumed to be decided by the level of per capita GNI. The per capita GNI will usually increase in the future and necessary to be forecasted for estimation of the future value of lives and loss

of injuries. Then per capita GNI is forecasted by setting up the growth factor on the basis of the latest data with regard to the GNI and population.

- Growth Factor of Traffic Volume
  The traffic volume will also usually increase in the future and the damages will increase when the slope disaster would happen. Then the traffic volume must be forecasted by setting up the growth factor on the basis of the latest data of traffic volume and its time series data.

(4) Pursuit of Practicality (Easy Accessibility)

The some of formulas and assumptions are tentatively. All calculations of the economic application are conducted on the worksheets of the Excel application and very easy to access to it. The economic analysis application is composed of three files as follows;

- ♦ Benefits (Present) with two work sheets
- ♦ Benefits (Future) with two work sheets
- ♦ EIRR with one work sheets

The economic analysis application is not directly connected with the other SIMS applications. Only the final results of indicator for economic evaluation (EIRR, B/C and NPV) will be transferred to the SIMS. Then it has the high flexibility to be revised its formulas and assumptions to be suitable to the characters of each route if necessary. To pursuit the practicality of the economic application, the users in JKR could revise the formulas and assumptions according to their needs to reflect the actual conditions as much as possible.

5.3.6 Tasks for Improvement of Economic Analysis

The major tasks to be tackled to improve the economic analysis for future works are considered as follow;(1) Simplification of Calculation Procedure

The benefits for the economic analysis in this study include the most of items to be possible to be quantified as possible. In this context, the benefits are comprehensive. But some benefits could be roughly calculated or their formulas could be revised to more simple forms if the data collection is difficult or the assumptions would not reflect the actual situation.

(1) Reflection of Professional Opinion for Countermeasures

If the plans for countermeasures are not appropriate, their costs will not be estimated properly. The cost of countermeasures as well as benefits will dominantly influence to the economic analysis. Then the professional opinion of the experienced engineer is necessary to be reflected on designing the countermeasures.

(2) Review of the Relationship Between the Failure Volume and Loss Time

The relationship between the failure volume and loss time during the road closure assumed in this study is still tentative. Then this relationship should be reviewed and would be more accurate on the basis of accumulation of data. (4) Relationship Between the Failure Volume and the Return Period

As already mentioned, there is not enough data for the analysis of the relationship between the quantity of failed materials and the return period of occurrence of slope failure, and between the quantity of rainfall and the quantity of failed materials. Then as the alternative method, the return period is estimated on the basis of classification of risk priority ranking according to total score from slope inspection sheet in this case study. If the recording system for quantity of rainfall and failure volume, and frequency of slope failure (return period) would be established, and data could be accumulated, the more objective and scientific relationship could be established. As the result, the estimation of the benefits could be more accurate.

(3) Estimation of Damages for Building and Agricultural Product

The data of agricultural production and assets of buildings was planned to acquire from the slope inspection sheet. In slope inspection sheet, the kinds of agricultural crops by kinds and the kinds of buildings were marked alongside the roads within area of the two times of height of slope. But it was found out that it is difficult to get accurate data with regard to agricultural area and number of buildings by type. Then the rough estimates were conducted in the case study. To acquire more accurate data, other kinds of survey must be conducted.

(4) Assumption of Alternative Roads

The data with regard to the benefit from alternative roads, the road length by slope is basic data. Then it is necessary to collect data and information from the districts on the base of the road network map.

5.4 Future Deployment of SIMS

The design and development intent of SIMS is for universal use across Malaysia. Beyond the project study areas, SIMS is expected to be deployed and used by JKR at its Headquarters and at multiple district/ local / zonal offices. This future deployment of SIMS to these multiple locations to cover all of Malaysia will require a more extensive slope information database, possible expansion of the standard information tables in the application, extensive GIS data covering additional federal highways and all of Malaysia providing more information than presently included as an example of the kind of information possible.

5.4.1 Regional Scope

Expanding the scope of the use of SIMS from the project study area to a larger regional extent will require additional information to be collected through detailed slope inspection procedures as provided for by this study. While the current standard information in SIMS may be adequate to assist in the data entry of information on new slopes, it is possible that this standard data may have to be enhanced.

Using administrative functions provided for in SIMS, the underlying design and database provides for flexibility in adding/ changing the standard information and scoring systems, which drive the data assimilation, risk rating, and other calculation functions in the application. As SIMS is more extensively used, these standard tables can be expanded to address conditions not experienced in the Project Study Areas.

To define the slope features and generate GIS data for them, new slope polygons will have to be defined and created. For initial identification of slope feature boundaries, the field investigation teams will require current aerial photography of the additional areas under consideration and detailed contour maps of the same areas. The aerial photographs and contours will need to be added to the background GIS data in SIMS.

Slope features drawn-up on the contour maps (at possibly 1:5000 scale) will be digitised and entered into the GIS dataset as ArcView shape files, with attributes for each slope feature mapped relating it to the SIMS Slope Information database. Through the GIS Module, these new slope feature polygons and the database information can be inter-linked, making the entire functionality of SIMS applicable for an expanded regional applicability.

5.4.2 Institutional Aspects

In its expanded regional scope of use, the SIMS application will require the institutional support for the additional data collection and integration of information. This may be handled internally through additional expertise and additional staff at JKR or through well defined external contracts that are possibly assigned and managed for information collection at a district of highway level.

In addition to the resources and support required for data collection, the data input into SIMS, training of additional SIMS users, and technical support (for system maintenance and user support for problem solving) on SIMS will be required for its effective regional deployment.

It would enhance the effective use of SIMS if the desirability of technological awareness at JKR was further encouraged by growing the awareness of GIS, Software Applications, and Databases technologies at varying levels of professional expertise. Recognizing the benefit of these technologies in more effective departmental functioning, administration, and governance, professionals with domain expertise in technology and an understanding of departmental activities and functions are equally important to the more effective use and deployment of SIMS and other similar systems at JKR.

5.4.3 Technological Aspects

The application of designed software solutions like SIMS are intended to assist JKR in more effectively addressing work activities such as Slope Disaster Management. This system brings together the **technology** of Database Systems, Geographic Information Systems, and Custom Designed Software integrating **expertise** of members of the JIA Study Team and that of JKR Road Maintenance Unit.

The current system is designed using Visual Basic, a relational database (SQLServer for HQ and MS Access 2000 for individual installations), and ESRI's MapObjects for GIS Functionality, for operation on a Windows 2000 based operating system. This technology and the current design of SIMS will be equally effective to address a larger regional deployment of SIMS to all of Malaysia. Limitations in its use may arise from the need for additional software licenses of MapObjects if the total number of installations exceeds 20, and from the need of additional storage capacity should the slope data increase beyond projected expectations.

The awareness and expertise in the professional domain of technology such Databases, GIS, and Software Applications will however require increased in-house resources and the participation of the private sector, or a combination of both. Additional training, more extensive use, and active participation of a larger number of uses will increase the understanding of SIMS and of the related technologies. Specific training and exposure to GIS technologies, outside of the SIMS application, will facilitate a better understanding and application of GIS by JKR for Slope Disaster Management, as well as other functional activities of the Road Maintenance Unit.

Future changes in the computing technology, operating systems, and supporting infrastructure can have possible implications on the continued and effective use of SIMS. It is not feasible to predict these technological changes and the efforts required to address them, however it must be recognized that with informed expertise and continued participation of JKR in the continuous use, maintenance, and possible enhancement of SIMS will be required.