MANAGEMENT SYSTEM FOR NATURAL RISK DISASTER ON INFRASTRUCTURE: REGIONAL APPROACH (GRDR)

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ABSTRACT

The South America integration considers an important impact in the sustainability of the infrastructure, especially in the international links road, due to critical commercial path between Atlantic Ocean and Pacific Ocean. For that reason, the roads, tunnels, bridges, ports and airport have to be in service and with a suitable performance.

In the last years, due to climate change and the integration of the region has initiated the development of several studies and programs related with the maintenance and emergency conditions. Some of them have the same goals, but with local issues, hazards and pathologies, providing a particular methodology for each case.

To standardize these methodologies, the project Cosiplan – IIRSA, has decided to focus on a regional level, in order to asses a Natural Risk Disaster Management, starting with a probabilistic methodology with specific structures.

Under this context, this paper presents a complementary methodology: Management System for Natural Risk Disaster on Infrastructure: Regional Approach (GRDR). This method seeks to standardize the methodology in South America and optimizing investment; being a preventive tool and improving the current maintenance plan.

Practical sheets with a high specialization are carried out and presented by following four levels of assessment: Phase I, II: Service level (Material and structure pathologies); Phase III, IV: Hazard level (individual and combination events). Finally, the GRDR includes concepts of decentralization, early detection of pathologies and training of local professionals.

Keywords: Management, Hazard, Disaster, Infrastructure

INTRODUCTION

The Deterministic Regional Method is elaborated under the South American Council of Infrastructure and Planning (COSIPLAN), related with the coordination manager of the state members of UNASUR in 2009. The agreements and status of COSIPLAN sets the goals and responsibilities for the several supporting activities of this council, in order to promote the integration and applied research. In specific, one of the projects related to this is the South American integration of regional infrastructure. (IIRSA, in Spanish).

The Action Plan defined for this project in 2012 specified six main research lines. One of these is the Management of Hazard on Infrastructure, with the aim that the member countries of the Council could develop and use some procedures and protocols in order to prevent, reduce and transfer the consequences of the hazards and disaster on the South American infrastructure i.e. earthquake, volcano eruptions, landslides, flood, etc. and set suitable plans to mitigates and develop robustness infrastructure (1). This methodology is called Disaster Risk Management (GRD in Spanish).

The GRD must be applied to a group of projects in order to define the optimal actions to prevent or reduce the natural hazards consequences. There are three ways to select the road infrastructure (2).

Infrastructure in one of the several project portfolios;

- To define the location and areas of influence of each project.
- To identify related hazards by each project.
- List of priority assessed hazards

Infrastructure in a pre-selected project portfolio;

- To define the location and areas of influence of a specific project.
- To identify related hazards by the specific project
- List of priority assessed hazards

Infrastructure due to a specific natural hazard source;

- To define the areas of influence of the hazard.
- To identify the infrastructure inside the area of influence
- To define the infrastructure to be assessed

CRITERION OF SELECTION

Project Portfolios

The GRD must be applied to several Projects Portfolios but it is not possible to assess all of them because of time, financial cost or external issues. For that reason, it is important to provide to technical teams a criterion of selection to define which infrastructure will be assessed. The following procedure is defined by COSIPLAN in order to optimize the cost and the efficiency of this decision. The structure has to assess when:

- It is located in a main international economic trade network.
- The design code of the structure has been modified.
- The authorities decide to know the current risk of a specific route.
- It is required a specific structure capacity.

Specific Structure

A project is composed by several structures. The road infrastructure project could include bridges, pavement roads and tunnels, among others. But, sometimes the assessment of the project does not imply that the technical team has to analyze all the structures. The following criteria are defined by COSIPLAN in order to decide when a specific structure has to be assessed:

- Detected damage of the structure due to different or a combination of extreme events.
- The design code of the structure has been modified.
- Singular (non-traditional) structures.

Specific Natural Hazard Source

The road infrastructure projects have an extensive area of influence (several kilometers) due to many natural and man-made hazards that can affect the structures. For that reason, it is important to prioritize which hazards have to be assessed. The following criteria are defined by COSIPLAN in order to decide which hazard has influence in the structures:

- Record of hazards or disasters in the area that had produced damage on the structures.
- Data of specific events that affected the structures (i.e. volcanic eruptions).

CHILEAN PROPOSAL GRDR

Currently the GRD methodology is developed by all the countries members of COSIPLAN (Argentina, Bolivia, Brazil, Peru, Colombia, Ecuador, Surinam, Venezuela y Uruguay), during its Technical meetings (GTE).

Chile is one of the first countries to implement this methodology as a startup stage, in order to improve the methodology and fit with the current maintenance programs.
From this start up, Chile has proposed a modification of the GRD method towards the local implementations defining the Local Hazard Disaster Management (GRDR in Spanish) (3).

The objective of this methodology is to incorporate aspects of decentralization in the acquisition of information with the participation of communal / sub-departmental technical entities, to allow the generation of early warnings in a preventive way, identification and updating of damage indexes of structures (complement to maintenance plans) and the use of reduced budgets, in the early stages.

This methodology includes the concept of local and regional management of the infrastructure until the vulnerability or hazard reaches a threshold limit predefined by high qualified experts or professionals in each field. Each local region is capable to manage its own infrastructure using the local budget in two main topics: Maintenance and Hazard. The local management is defined until certain alarm, for that reason a set of alarm is defined as it is shown in (Figure. 1).

Alarm Level	National level	Response Entity
Very Severe	Country	Central Level and experts
Severe	Region	Local Authorities and Experts
Moderate	Province	Local Authorities
Mild	Communal	Local Technical Team

FIGURE 1 Alarm level by GRDR.

The GRDR is directly applied only to Mild and Moderate level; then, a specific program of mitigation and assess has to be implemented, with probabilistic (4) and deterministic studies developed by experts and management from the Central Authorities.

DESCRIPTION OF THE METHODOLOGY

The methodology consists in the use of technical sheets for structural inspections (roads, ports, bridges, etc.) in order to identify the damage index, vulnerability index (location damage) and action recommendations.

The methodology is divided in two stages

A: Risk Assessment
B: Mitigation measures

The stage A is currently under develop and includes four phases:

- Phase 1: The identification of the element with material pathologies under service loads (damage index).
- Phase 2: Pathology analization over the concept of the overall structure under service loads (vulnerability – redundancy concepts). It analyzes the effects of the location of the damage in the structure, i.e. as shown in Figure 2, a damage in the top of the pier (red line) is less significant for the structure than a damage at bottom level (green line).
- Phase 3: The result of phase 2 is analyzed by one extreme event at a time.
- Phase 4: The structure is analyzed over extreme combinations of forces (earthquake and tsunami).

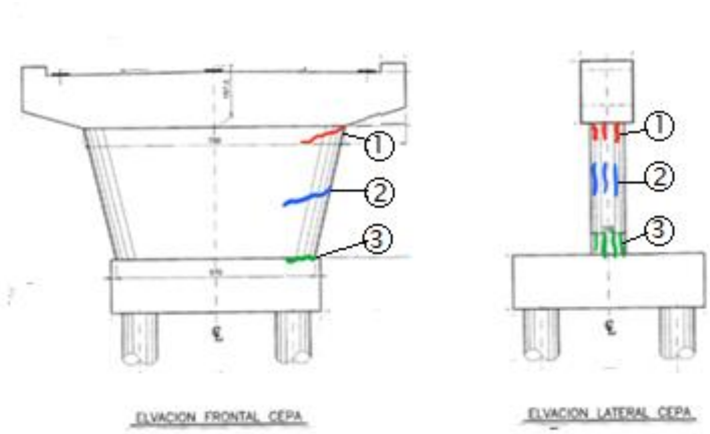

FIGURE 2 Location of damage in piers of a bridge.

The phase 1 and 2 are close related with the local maintenance program. In the phase 3 and 4, a specific sheet is developed to inspection, in order to include the performance index of the structure due to extreme events and hazard assessment. For that reason, two typologies of inspection are defined:

Micro-Inspection: Applied to phase 1 and 2, it has to identify the specific pathologies of the structure, following the same protocols of Maintenance program (routine inspections). The subjective inspection is reduced using a predefined catalog carried out by an expert. Following this procedure, the inspector could have a better accuracy of the damage index score. As shown in Figure 3 the catalog includes three columns for each element. The first column defines the level of damage (mild, moderate, severe and very severe); the second column provides a description of said damage. Column number 3 has a visual reference of the damage.

Patologias: Tipos de Deterioros			
Alteración Superficial			
Grado de deterioro		Descripcion	Ejemplo
1	Leve	Leve: Se considera leve si se trata de un deterioro muy superficial, como en los siguientes casos, • Metálicos, no hay perdida de la sección. • Hormigón armado o pretensado, perdida del recubrimiento. • Fábrica, perdida del volumen. • Madera u Otros, que no afecte a menos del 50% de la superficie del parámetro. • Juntas o pavimento, no hay riesgo de accidentes. Cuando el elemento no pierde las propiedades básicas de funcionalidad, durabilidad o de resistencia.	 
2	Moderado	Moderado: Se considera Moderado si se trata de un deterioro superficial, como en los siguientes casos, • Metálicos, existe una reducción de la sección. • Hormigón armado o pretensado, perdida del recubrimiento. • Fábrica, perdida del volumen. • Madera u Otros, que no afecte a más del 50% de la superficie del parámetro. • Juntas o pavimento, puede existir el riesgo de accidentes.	
3	Severo	Severo: no se puede asignar parámetros a este valor debido que ya no sería un deterioro superficial y pasaría a un deterioro más profundo.	✖
4	Critico	Crítico: no se puede asignar parámetros a este valor debido que ya no sería un deterioro superficial y pasaría a un deterioro más profundo.	✖

FIGURE 3 Example sheet of catalog.

Macro-Inspection: Applied to phase 3 and 4, it has to identify the general hazards and the location of the structure. In this case the inspector has to review not only the structure but to include studies of the cliff, river, sea, forest, etc. (special inspection plus environmental inspection).

The local inspection has to include a good judgment of the damage of the structure and the hazards parameters that could affect the structure. For that reason, for each structure typology and hazard a comprehensive catalog is developed, including:

- Description of the damage.
- Causes of the damage.
- Measurements of the damage.
- Damage index explanation.
- Photo and sketch in order to justify the damage index value.
- Location index. It is defined a modification score of the pathology related with the impact of that damage in the structural integrity (for service and extreme event scenario).

The implementation of the methodology is carried out by the professional and technical teams at local level, whom are trained by the Central Level in order to use the sheets and follow the protocol of inspections.

After the first trained course, the inspector carries out the micro and macro inspection of the local road network and filled up the sheets with the support of the catalog. The damage index is defined in 4 levels from 1 to 4 (mild to severe level).

In phase 1, the damage index is defined by each element of the structure, composed by an algorithm of each pathology of the element. In the same way, the damage index of the structure is defined by an algorithm that includes all the damage index of each element. This is the damage index of the structure due to service loads.

The location damage index is included in phase 2, and also weights the damage index from phase 1, recalculating the damage index of the structure.

All of this data has to be updated continuously per each structure. For that reason, the Road Department of Chile started a maintenance program during 2016, in order to get a state of arts of the bridges conditions and provide a baseline for this program (5).

Once completed the inspection and applied the sheets, the damage index is included in a software (under develop) in order to update the background data. A meta-heuristic algorithm is proposed in order to assess the final damage level at phase 3 and 4, and modify the weights of the algorithm including the local status of each structure.

The methodology via algorithms is based on expert experience and the dynamic update of the baseline knowledge providing the final indexes following achromatic.

All of that experience is considered in order to reduce the subjectivity of methodology due to include in it's sheets and software platform some detailed explanations of every pathology as well as tables of orientation, with photos and schemes.

Under this condition and following the visual inspections, the sheets will automatically provide the conditions of the structure, which will allow the teams to make suitable decisions for action. As an example, once structure is qualified in yellow, this information would allow the local teams to take the decisions to implement minor actions (reduced costs); in case of red indication, it would allow the technical team to request to Central Level an action of major prevention that mitigates potential risks.

This methodology is in continuous update in order to provide reliable data and indexes, customizing the review via adjustment on the decision-making algorithms. This procedure includes major and relevant structures, but also minor ones (network concept).

Below is presented the software architecture proposed:

- The software analyzes the inspection sheet by element and provides a value of vulnerability. Every pathology has its own sheet.
- Study of natural and man-made hazards. It develops a general hazard sheet with a generic (baseline) algorithm which includes a feedback of each technical inspection. It is possible to give recommendations of the actions prior to the event to decrease the infrastructural risk, (Figure 4). This provides the vulnerability index of the structure affected by N hazard.

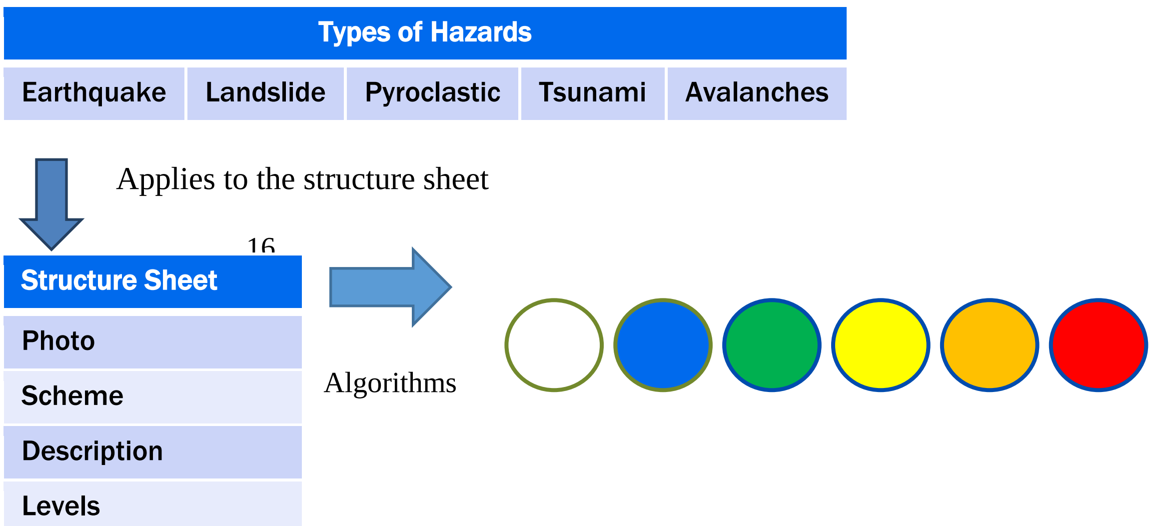

FIGURE 4. Scheme of input data to software

- The flow-chart (Figure 5) shows an example of the general software procedure:

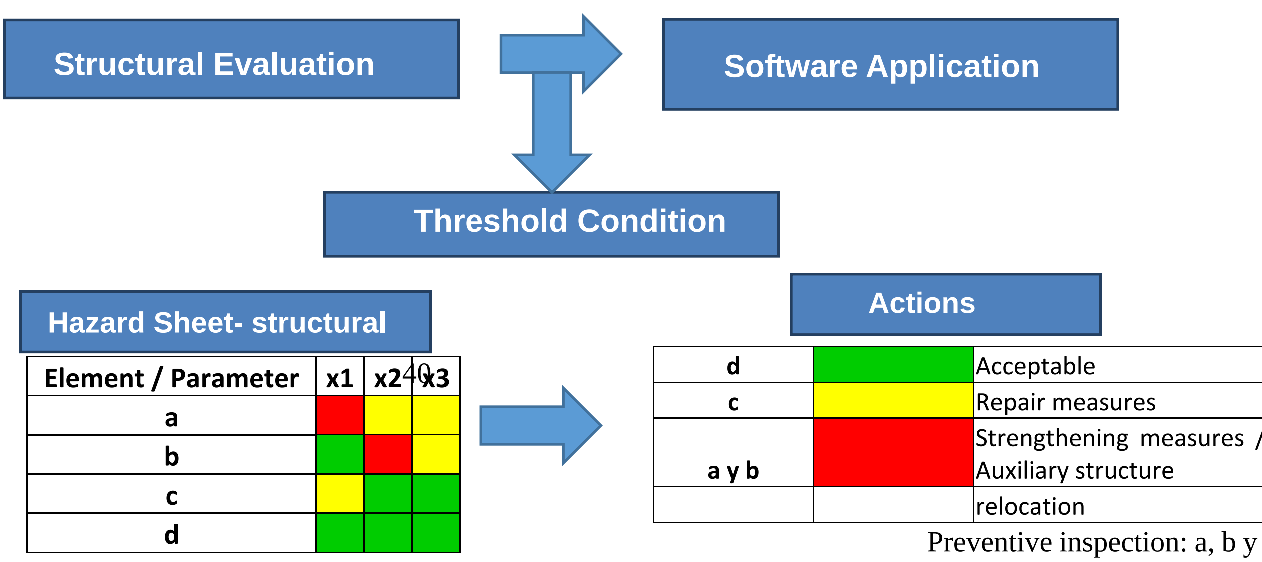

FIGURE 5. Scheme of outputs of software assessment

Currently, the GRDR has been applied twice in Chile by the Ministry of Public Works with the support of PUCV and PUC (Universities). The first one was carried out at Route 11Ch (north of Chile) including road, bridge and port considering floods, earthquakes and tsunami hazards. The second one was carried out in the Route 7, Patagonia region including roads and bridges with volcanic and landslide hazards (6).

CONCLUSIONS

The structures have been subjected to different types of service and accidental loads. Due to the climate change these structures have been subjected to hazards which were not anticipated in it's design. The GRDR method is intended to predict the damage of a structure under different types of hazards and prevent future damage.

The GRDR method is updated by inspections using local technical teams, in order to reduce costs of management and provide preventive alerts/warning to Central Level and experts. A great number of data will be obtained with this method, allowing to develop a dynamic methodology and specific per each local areas.

The next steps for the GRDR development are:

- Integrate the fragility and vulnerability studies from PUC and Universidad de Concepcion to GRDR.
- Start up: Valparaiso Region (Tsunami, Earthquake, Landslides and Fires)
- Update Maintenance Sheet for phase 1 and 2.
- Update Hazard Sheet and Catalog of Pathologies of GRDR
- To develop optimization algorithm and software solutions

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