Proceedings of 7th Transport Research Arena TRA 2018, April 16-19, 2018, Vienna, Austria

RAGTIME Risk based approaches for Asset inteGrity multimodal Transport Infrastructure

María Zalbide a*, David García-Sánchez a, Jon Aurtenetxe a, Jose Luis Izkara a, Clemente Fuggini b, Federico Di Gennaro c, Maria Antonia Perez d, Claudia Pani e

[a]Fundación Tecnalia Research and Innovation (TECNALIA), Calle Geldo, Edificio 700, Parque Tecnológico de Bizkaia, Derio 48160, Spain
[b]Rina Consulting(RINA), Piazza Duca D'Aosta 14, Milan 20124, Italy
[c]AISCAT SERVIZI SRL (AISCAT), Via G Donizetti 10, Roma, Italy
[d]UNIVERSIDAD DE CANTABRIA, Avda. de los Castros sn, Santander 39005, Spain.
[e]AON, Via Ponti Andrea 8/10, Milano 20143, Italy

Abstract

The EU co-funded R&D project RAGTIME "Risk based approaches for Asset inteGrity multimodal Transport Infrastructure" aims at setting the basis for an efficient and innovative asset management (AM) across Evaluation/Planning, Procurement/Decision, Design/Project, Construction, Operation & Maintenance phases of Transport Infrastructure (TI). This paper discusses the RAGTIME approach to TIAM, which aims to establish a common framework for governance, management and finance in order to ensure the best possible return from limited investment funds. In line with this main goal, RAGTIME will lead to lay out a whole system planning software platform, based on standard multiscale data models, able to facilitate a holistic management throughout the entire lifecycle of the infrastructure, providing an integrated view of risk based approach, implementing risk based concepts, models and operative methods in order to optimize Return Of Investments (ROI), and guarantying at the same time the same or higher Level Of Service (LOS) through the whole lifecycle of the TI.

Keywords: risk-based approach; transport infrastructure asset management; resilience of Transport Infrastructure, governance, finance, decision support

* María Zalbide Tel.: +34-946-430-850.
E-mail address: maria.zalbide@tecnalia.com

1. Introduction

The new ISO 55000-1-2 suite of standards (ISO 55000 Asset Management—Overview, Principles, and Terminology; ISO 55001 Asset Management—Management System Requirements; ISO 55002 Asset Management—Application Guidelines) represents a significant advance on the Publicly Available Specification (PAS) 55 by applying the new ISO standard for a management system known as Guide 83 and providing improved opportunity for implementing an integrated management system including ISO 9001, 14001 and 18001. Longer-term benefits and return on investments (ROI) for plausible scenarios have to be considered now. This is usually conducted using life cycle risk assessment techniques to determine an optimal solution over a project's 'whole of life' or contract period plus handback. The current approach to asset management taken by most service providers can support a holistic framework that permits the integration of all aspects of any project.
However, Asset Management in Civil Engineering is by far less developed than in the industrial engineering field. Risk based approaches are not always integrated, and network resilience perspective is not implemented throughout the lifecycle.

Moreover, real time data is not incorporated in the asset management strategy as smart monitoring systems are not implemented in a large scale to provide data on condition assessment and alerts, in particular throughout the lifecycle of the infrastructure. In addition, there is not a harmonized approach for infrastructure asset management. Most widely used tools for assets management collect thousands of data from the assets (roads, bridges, signs, culverts, etc.) into a custom-made dashboard, from where engineers and managers can perform advanced calculations of the consequences of different approaches – the so-called "what-if scenarios." However, these tools, in most of the cases, do not include industrial and environmental inputs, do not have procurement stage and financial information, do not have risk-based approach and resilient concepts embodied accounting for mitigation and adaptation actions, and finally do not allow for the implementation of smart monitoring systems throughout the lifecycle of the multimodal infrastructures.

In this context, RAGTIME will develop a realistic, comprehensive and advanced management strategy on infrastructure projects which harmonizes the use of Information Technologies with different requirements in civil engineering, and it is based on the changing value of information during the life of any public work.

2. Methodology

2.1 Lean and agile procurement processes

Current procurement procedures in public administration for infrastructure management are quite obsolete in content and form. Procurement procedures are not meaningfully risk-based but are, essentially, value-based with a basic purchase mind set "purchase price only". There is also a lack of tools for comparing / testing particular technical solutions according to relevant aspects such as resilience, cost-effectiveness or environmental impact. Moreover, tenders form different administrations and different countries apply different evaluation methodologies.

RAGTIME proposes the definition a new procurement strategy focusing on the identification and assessment of innovation, from the view of a long term whole life cycle investment return approach. Key innovative aspects in lean and innovative procurement processes are related to project finance, including a financial risk evaluation during all the phases of the project. The project will promotes a standard methodology for common evaluating evaluation of the tenders from different administrations and different countries, by defining key evaluation parameters and their weighting factors for a multicriteria proposal selection. RAGTIME will incorporate the concept of labeling of technical solutions coming from ongoing EU projects for proper identification of best option in the selection process.

2.2 Risk-based approach processes throughout the life cycle

Risk-based approaches are nowadays well known and used to analyse the inner and outer risk a structure/system is subjected to. A common methodology for the quantification of the risk related to the failure of a component/element is the one that makes use of the calculation of a Risk Priority Number (RPN) that accounts for the severity of a failure, the occurrence of that failure and the detection of the failure. The RPN is calculated as output of a Failure Mode and Effects Analysis (FMEA). Therefore, this index allows quantifying the risk associated to a failure of a component/element being part of a structural system. In addition a Fault Tree Analysis (FTA) is used to display the state of a system (top event) in terms of the states of its components (basic events). This allow "mapping" for complex systems the dependencies of states and components in case of undesirable events. Moving further, when dealing with complex systems such as transport infrastructure systems, made of various sets of components and elements, providing various functions, the integration of an FTA with an FMEA is used this approach can be used in an effective way to understand failures in the system and interdependencies among states and components across the lifetime of the TI, since it gives given the capability of decomposing the system into sub-systems and providing a certain level of importance or weight to the different system components, that can take the form of a node or of a structure in the form of an asset(a bridge, tunnel), etc..

2.3 Mitigation actions and Countermeasures in multimodal infrastructure networks

As outcomes of a risk-based approach, most relevant issues are identified that requires proper mitigation measures and the adoption of countermeasures to minimize the risks and the impact it can have in case of adverse events. Therefore, potential countermeasures and mitigation actions need to be as well considered and identified within a life-cycle management of the transport infrastructure. In this sense, strategies for moving from a pure risk-based management approach to the introduction of resilience concepts that accounts for mitigation actions and countermeasures need to be investigated. RAGTIME defines resilience guidelines to be considered as potential applicable solutions to be addressed / implemented in the procurement, design and construction, operation and maintenance process of an infrastructure network by the infrastructure manager.

In this context, RAGTIME progress is due to the adoption and implementation of an Operational Risk Strategy (ORS) that allows considering the "risk-related" aspects/contribution in all phases of the process from the planning and design, to the delivery, deployment and management of the infrastructure. This allows introducing the following aspects that together with the methodological approach represents the key innovations of RAGTIME:

- Raise the awareness on the operational risks of the infrastructure by providing suitable instruments for addressing and managing risks.
- Increment the cost saving on the operational losses through the implementation of a more effective analysis of the risky processes.
- Identify a strategy to mitigate risk through the underlying of ad hoc solutions.

Moreover, RAGTIME does not only provide an evaluation of the risk and associated mitigation actions and elements, but also accounts for the effects of the response and mitigation actions. This complements the Operational Risk Strategy (ORS), by adding a quantification of mitigation actions and countermeasure in terms of costs and insurance solutions. Here, the best insurance placement structures, identified in the risk evaluation process, are adopted. Eventual risk transfer approach, taking into consideration either the investments to mitigate and reduce the impact of any physical adverse event, as well as the effectiveness of a substantial and sustainable retention of the risk is identified and implemented.

2.4 Interoperability and Multiscale data model

In infrastructure management micro and macro levels are uncoupled worlds. Analysis, users and supporting tools for each level are different in scope and they do not share data and conclusions. Infrastructure design and simulation tools consider the asset as an isolated element without considering the surrounding elements (buildings, landscape, other infrastructures, etc.). As a consequence, impact of the infrastructure on the environment (erosion, risk of flooding, pollution, biodiversity loss, etc.) and vice-versa (capacity, land use, maintenance, etc.) are not properly evaluated. There is an increasing demand on bridging the gap between the micro- and macro-scale. Relevant advances are being achieved regarding data standards definition at different levels. The most developed and used one is IFC (Industry Foundation Classes), data model used in Building Information Modelling (BIM) processes promoted by BuildingSMART Alliance, at building level and accelerating its adoption for infrastructures. At city level the OGC (Open Geospatial Consortium) has specified the CityGML standard data model for storing and exchanging virtual 3D city models. Currently, the OGC is working on the InfraGML standard definition. InfraGML aims to link the Geospatial and BIM worlds and influence the conditions and requirements for infrastructure projects and the contractors.

At the same time, BuildingSMART announced the IFC Alignment project, which prepares the specification to enhance the current IFC data standard for Infrastructure. It is clear that the definition of a standard data model for the representation of infrastructures in the environment is a key challenge of the near future. This challenge is the key issue for interoperability. The current approach for interoperability between existing simulation tools in infrastructure asset management is very poor and relies on proprietary file format transformations and one-to-one tools coupling. Each domain addresses its topic separately without any or poor integration. At different scales several tools exist but the current support for interoperability between them is not sufficient.

RAGTIME proposes to overcome the current limitations for information flow and system interoperability by the need of harmonizing data dictionaries through a linked data model between standards defined at different scales (IFC Alignment, CityGML and InfraGML) extended with domain specific information not included in the data models. RAGTIME is developing a software platform based on the extension of existing simulation components and a multiscale data model that provides the capability for multimodal simulations during all stages of the life cycle of the infrastructure. Finally, realistic high-detailed 3D visualization of the model will be based on the point-cloud representation allowing a realistic and detailed model of the asset without the need of developing a 3D model, which is time consuming and not cost-effective.

2.5 Smart Monitoring Systems embedded into the infrastructure along the whole life cycle

Today, there is a need to keep track of the status of the infrastructures throughout its entire life cycle at real time, in order to anticipate problems and manage the risks and the impacts of climate change and any other external extreme event. In line with this approach, currently several solutions are dedicated to public transportation management, traffic control, quality control of the infrastructure and structural health monitoring, but they are isolated subsystems which can significantly benefit from cooperation. Therefore, it is necessary the development of a complete solution able to: firstly, immediately detect any risk or problem in the infrastructure or in the environment, react quickly and transmit the information to other management tools and control systems in order to mitigate effectively the possible consequences. The solution shall be able to manage all the measurements, environmental parameters and location coordinates of the elements involved such as: traffic, effects produced by climate change, structural parameters, etc. and support the response to different events or problems that may arise. RAGTIME is developing solutions for connectivity and interoperability, supporting the implementation of smart monitoring systems capable of integrating data coming from multipurpose ICT systems (for structural health monitoring, weather monitoring, traffic surveillance, etc.) embedded into the infrastructure, and enhancing the capabilities of the communication services in the transport infrastructures. Thus, the deployment of RAGTIME technology contributes to decrease incidents, increase the safety of users and the services offered (i.e. emergency responses through collective scheduling across subsystems in the context of transport projects.), and increase resilience against man-made hazards (i.e. traffic incidents) and natural hazards (i.e. climate change), in the whole lifecycle of transport projects in terms of time, operation and maintenance costs of the equipment and facilities.

3. Results and analysis

3.1 Lean and agile procurement processes

A risk-based decision management study of infrastructure projects has been carried out, according to the demands of society and the commitment of European public authorities to promote a leadership based governance.

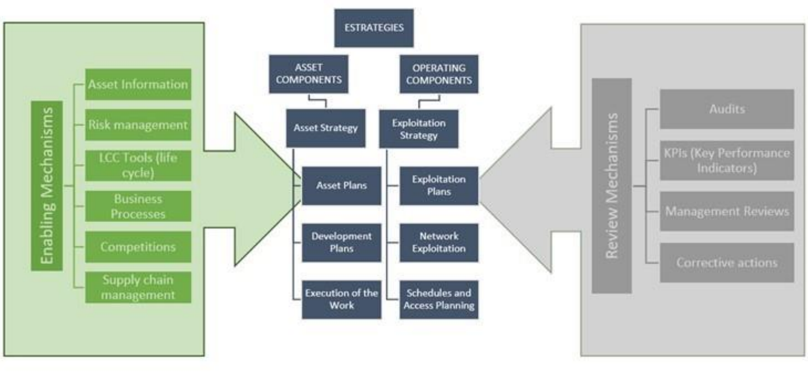

Fig. 1 Infrastructure Asset Management: enabling and review mechanisms

The holistic analysis carried out includes the description of the lifecycle of the works, the role of each stakeholder and the current legal framework on any kind of infrastructure projects. To conclude risks have been identified and classified, according to: the project lifecycle stages, the stakeholders and the legal framework.

3.2 Risk-based approach processes throughout the life cycle

The main objective of the work in this section has been to define the existing framework in the risk analysis in transport infrastructure projects by investigating best practices, regulations & standards, main studies and researchers in this field.

Transport infrastructure projects are exposed to a high number of technical, operational and governance risks which can affect the various stages of the infrastructure life-cycle and which may have severe impacts. Moreover, the problem approach is complex considering the number of heterogeneous stakeholders involved.

The study has been conducted in the following main areas:

- Introduction and context;
- General risk assessment framework;
- Best practices in the risk assessment of transport infrastructure projects;
- Main Regulations and Standards at a European level in the risk assessment of transport infrastructure sector;
- Main studies and projects, developed by collaborative partners of, in the main field of risk assessment in transport infrastructure projects.

The main results which can be drawn from this study are summarized below.

Firstly, from the state of the art emerged the lack of a unified and comprehensive risk-based approach to enable decision supports during the whole life-cycle of a transport infrastructure project (from design to operation&maintenance) able to assist Infrastructure Managers and Infrastructure Operators to have the adequate knowledge and resources to react to potential risks that might arise.

Moreover, a number of best practices to be followed in transport infrastructure projects are detailed, based on the analysis of recognised guidelines and of some real case studies analysed in the specific field. In particular, the suggested best practices consist in the following main steps recommended when approaching a transport infrastructure project:

- Common and proper definition of risk;
- Complexity assessment;
- Capabilities assessment;
- Define and create a complete project management tool;
- Ensure a proper communication and information system;
- Assess cost and risk estimates side-by-side;
- Provide quantitative risk estimation to promote more informed decisions and communications;
- Review main risk sources;
- Ensure proper risk mitigation;
- Use of reference-class forecasting and risk analysis;
- Employment of well informed and rapid contingency processes.

Although it is a recognized problem, to date there is not a clear framework of specific legislative provisions which regulates risk assessment in transport infrastructure projects at a European level. From the research work emerges that legislation in this area is rather fragmented and most of the regulations and standards related to the risks assessment in transport projects are partial and sector specific. At a National level, each country has its own internal legislation in native language. In all the analyzed countries emerged that the national transpositions of the EU Directives are not exhaustive and no country seems to have developed a fully complementary internal regulation, providing a perception that the issue is fully disciplined.

Finally, a number of research and design/construction projects developed by collaborative *partners* have been analyzed and summarized with specific focus on the type of risks addressed, on the faced hurdles and on adopted control and mitigation measures.

3.3 Technical management risks

This aspect focuses on identifying the most impactful threats that affect every day technical management, hindering the management of transport infrastructures, deteriorating the infrastructure performance, especially during the exploitation phase.

Hence a comprehensive identification and quantification of technical risk sources has been undertaken: climate related risk sources, risk factors and hazards taking into account the different stakeholders points of view and degree of exposure of infrastructures and its components along the whole lifecycle, as the example shown in Table 1.

Table 1. Assets risks and components with associated KPIs

Asset type Id	Risk Id	Components Id	Damage Id	Set of thresholds, alarms and pre-alarms for damage (Ache, 2016; US Army Corps of Engineers, 1992, Infrarisk, 2016)				KPI
				SLIGHT	MODERATE	SEVERE	CRITICAL	
Bridge 01	92	Bridge foundations 1	Flood level and stability 92.01.1.01	The top face of foundation is seen	The bottom face of foundation is seen	Scour depth is equal to the estimated one in project	Scour depth is equal to about twice the pile diameter	2 5 5 7 3 3 8 8 9
		Bridge foundations 1	Channel modification 92.01.1.02			Downcutting of streambed affecting piers or abutments		2 5 5 7 3 3 8 8 9
		Bridge. Deck 4	Overtopping 92.01.4.01			Shifting of bridge deck due to pressure of rising floodwater		2 5 5 7 3 3 8 8 9
		…						

The identified technical risks and thresholds are specified for different risk levels in the diagnosis process (see Fig 2)

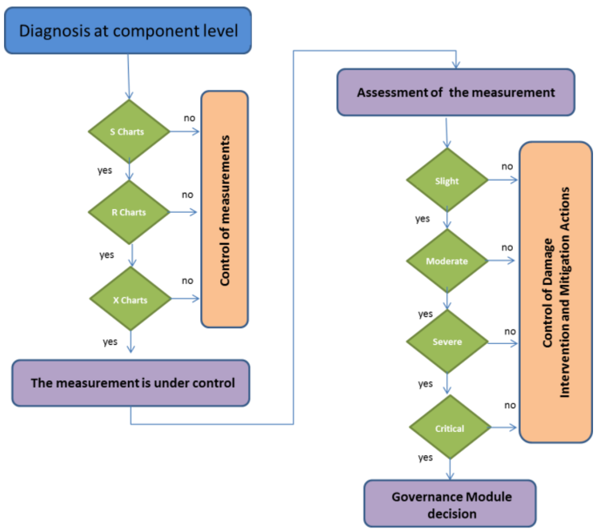

Fig. 2 Diagnosis process at component level

The basis for the methodology followed has been an extensive review and analysis of historical records, and future projections

4. Conclusions

There are some important conclusions that arise from the study developed. With respect to the governance risks analysed for transport infrastructures:

- The risks identified in the Governance process are due to the decision-making process, the profitability study, the financing methods, the technical capacity of the property technicians, and the transparency of the entire management process.
- The proposed evaluation of Governance risks can be done through the experience of the property experts (administration divisions and related entities), by valuing from 0 to 1 the perceived risk. The values not exceeding 0.25 represent a low risk as far as its intrinsic value, while the values closer to 1 represent higher risks with values of the order of the infrastructure costs or higher (millions of euros).
- The legal framework significantly affects the governance risk and is considered as the main risk mitigation method to apply.
- The greater risks of governance according to the legal framework can occur in the concession contracts, where the concessionaire is involved in the planning phase of the infrastructure.
- The governance risk is greater during the decision-making and planning phase, and coincides with the legal framework of the concession.

Regarding operational risks, the state of the art performed in these months laid the foundation for the next steps of the projects. In order to fill in the gap in the literature, one of the main objective of RAGTIME is to implement a new risk-based approach on the transport infrastructure field. The specific Risk Strategy approach will be able to consider the "risk-related" aspects from planning and design, to the delivery, deployment and management of a generic transport infrastructure. This strategy will raise the awareness of the risks of the infrastructure by providing suitable instruments for addressing and managing risks. Potential cost savings on the operational losses through the implementation of a more effective analysis of the risk processes and an identification of the best measures to mitigate risk will be also studied through specific and dedicated solutions.

Finally, for the technical management of risks a proper identification of risks is crucial, as one of the first steps to be subsequently managed based on interpreted information that provides value and supports decisions of action and prioritization, is the basis of an advanced asset management system as RAGTIME intends to achieve.

The full infrastructure lifecycle perspective makes it necessary to reflect on the participating actors as well as the different phases that take place in the infrastructure, as well as the potential risks or causes of technical risks, which in a direct or indirect way affect the level of service with the social and economic consequences. Therefore, it is necessary to keep in mind at all times the triangle formed by: stakeholders, life cycle and typology of risks such as technical, which are also classified according to type and class, to ensure the level of service, whose objectives defined generally in green, cost-efficient, social / inclusive, resilient and safe / secure have their implication.

After analyzing the different considerations that are taken into account today, in the life cycle of the transport infrastructure, as well as the analysis of events collected in the past in the four transport modes, 104 causes of risks or technical risks have been identified, which has been grouped into 5 clusters depending on their nature: contractual; data; design and calculations; building and civil works and, unintentional hazards; natural disasters and intentional threats.

After the identification of the technical risks, a final analysis has been made taking into account the transport mode, life cycle phases and stakeholders as criterion, setting two and leaving one as a variable. Thus, the objective of this analysis is to evaluate and preview the relative weight of each technical risk on each of the criteria. This first approach aims to identify the risks of higher index and to be able to guide in the WP4 the management of these technical risks.

Acknowledgements

Authors would like to acknowledge the financial support of the European Commission under the H2020 programme.

5. References

Ambrasaite, I., Barfod, M. B., & Salling, K. B., 2011. MCDA and risk analysis in transport infrastructure appraisals: The rail baltica case. Procedia-Social and Behavioral Sciences, 20, 944-953.

Beckers, F., Chiara, N., Flesch, A., Maly, J., Silva, E., & Stegemann, U., 2013. A risk-management approach to a successful infrastructure project. McKinsey & Company. Berrado, A., El-Koursi, E., Cherkaoui, A., & Khaddour, M. (2010). A framework for risk management in railway sector: application to road-rail level crossings. Open Transportation Journal, 19p.

Cerema, 'Plan National d'Adaptation au Changement Climatique, volet infrastructures et systèmes de transport, action 1', Cerema, Jul., 2015.

Clarke, J., & Obrien, E., 2016. A multi-hazard risk assessment methodology, stress test framework and decision support tool for transport infrastructure networks. Transportation Research Procedia, 14, 1355-1363.

EC, 2017. Web site of European Commission for Mobility and Transport, 25.3.2017, https://ec.europa.eu/transport/home_en

El, M. S. B. A. A., El Nawawy, O. A. M., & Abdel-Alim, A. M., 2015. Identification and assessment of risk factors affecting construction projects. HBRC Journal.

Her Majesty's Treasury, 2013. Infrastructure procurement routemap: a guide to improving delivery capability.

Infrastructure and Projects Authority, and Infrastructure Client Group, 2016. Improving Infrastructure Delivery: Project Initiation Routemap. Handbook.

Infrastructure Risk Group, 2013. Managing Cost Risk & Uncertainty in Infrastructure Projects. Leading Practice and Improvement: Report from the Infrastructure Risk Group 2013.

Institution of Civil Engineers and Institute and Faculty of Actuaries, 2014. Risk Analysis and Management for Projects. Default Book Series. January 2014

Legifrance, 2017. Décret n° 2017-439 du 30 mars 2017 relatif à la sécurité des circulations ferroviaires sur certaines voies ferrées locales supportant du transport de marchandises | Legifrance.

Legifrance, 2011. Arrêté du 26 octobre 2011 relatif à la classification et aux règles de construction parasismique applicables aux ponts de la classe dite « à risque normal » | Legifrance. 2011.

Legifrance, 2016. Décret n° 2016-522 du 27 avril 2016 relatif à la mission d'appui au financement des infrastructures.

Miller, M. and Szimba, E., 2013. How to Reflect the Issue of Risk in Transport Infrastructure Appraisal: Synthesis of Methods and Best Practice, Selected Proceedings of the 13th World Conference on Transport Research, Rio de Janeiro.

OECD, 2002. Impact of Transport Infrastructure Investment on Regional Development.

OxeBridge, 2014. DIS of ISO 9001 Introduces ISO's 40th Definition of "Risk". http://www.oxebridge.com/emma/dis-of-iso-9001introduces-a-fifth-definition-of-risk/

PIARC, World Road Association, 2010. Towards Development of a Risk Management Approach. PIARC Technical Committee 3.2 Risk management for roads.

Project Management Institute, 2013. A guide to the project management body of knowledge (PMBOK® guide). Fifth edition.

Salling, K. B. and S. Leleur, 2012. Modelling of Transport Project Uncertainties: Feasibility Risk Assessment and Scenario Analysis. EJTIR, 12(1), 21-38.

RAGTIME, 2016. Grant Agreement (GA)

RAGTIME, 2016. Consortium Agreement (CA)

DIRECTIVA 9 2014/24/UE del Parlamento Europeo y del Consejo de 26 de febrero de 2014 sobre contratación pública y por la que se deroga la Directiva 2004/18/CE