A METHODOLOGY FOR THE DEVELOPMENT OF A EUROPEAN APPROACH CONCERNING PERFORMANCE AND RISKS OF BUILT SYSTEMS

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The built environment is expected to face major renewal and development across the wider Europe and especially in the new member states of the European Union. The increasing societal demands for an environmentally friendly urban development as well as a variety of global issues, such as lifecycle sustainability and climate change impacts, require an integrative planning, design and construction of built systems based on lifecycle performance management. The vehicle to achieve these goals may be a European virtual knowledge and information framework for performance and risks associated with built systems. The major needs for establishing such a framework, the objectives and benefits, and the anticipated scientific deliverables are presented here. The collaboration with ongoing research projects with similar orientation is discussed. This paper accentuates the importance of and contributes towards a European approach for the development of built systems, based on shared understanding and treatment of performance and risks issues.

Keywords: Built environment; Information management; Knowledge management; Performance; Risks.

INTRODUCTION

The recent expansion of the European Community (EU) from the EU-15 to EU-25 has shifted the need, i.e., west-east vs. north-south, for infrastructure network systems (e.g. highways, railways) to ensure fast development and promote social cohesion with the new member states. These networks represent a major part of the built environment and to a large extent ensure Europe’s competitiveness and economic growth potential. Most of this growth is expected from new member states of the European Union in the form of transport infrastructure, urban development, housing construction, and other civil engineering projects (Copenhagen Institute for Future Studies 2003).

In order to address the above issues, the European construction industry must deliver infrastructure solutions which will satisfy: (a) the increasing societal demands for an environmentally friendly urban development, (b) the needs of the newcomers in the European Union, and (c) global issues such as life-cycle sustainability, the greenhouse effect and the overall climate change impacts.

The ability of new and renovated buildings to satisfy various demands (e.g. a combination of residence and office work space) and to support flexibility in use while achieving a defined performance requires an integrated planning, design and construction approach (Altgeld and Mahler 2003). At the same time the built environment has to ensure safety against an ever-increasing risk from natural hazards and other types of risks such as terrorism. In this paper the accumulated knowledge

concerning: (a) the deficiencies of the European construction industry and (b) the current practices in managing performance and risks are used in combination to identify the steps towards a framework for risk-based performance management of built systems. The formation of this framework as presented hereunder is the result of joint work among experts of several disciplines that formed a core group to investigate the appropriate steps mentioned above. This work involved: (a) meetings for exchanging knowledge and information and discussing methodologies and potential approaches, and (b) individual work by each participant of the core group based on review of the state-of-the-art and original research on specific aspects of the framework. The core group introduced each individual work to the suggested framework through an iterative screening process of each proposal among its members until it reached the framework suggested in this paper.

THE TRANSFORMATION OF THE CONSTRUCTION INDUSTRY

The Challenges

In the new European framework, the challenges for the construction industry are distinctive from the past ones in the following ways:

- Construction projects are now considered in a much broader societal and environmental context than before. They comprise integral parts of the environment that, during the lifecycle, affect and are affected by interrelating environmental parameters such as the climate, the built environment, the infrastructure, the human activities, etc. The material and methods used for the construction and their impact on the environment, the operation of the project and the maintenance activities are features that render any built artefact a dynamic link in the environmental chain (E-CORE 2004).

- The scope of the infrastructure is trans-national. Infrastructure programmes such as the Transeuropean Networks Ten-T (http://europa.eu.int/comm/ten/transport/index_en.htm) are increasingly initiated and planned on a European level. Transportation networks serve the needs of the European commerce and the movement of European citizens all across Europe with profound societal impacts (Ouzký 2004). In many cases the financing of infrastructure projects in Europe largely depends on European funds. Therefore, the infrastructure is a shared concern between European nations. This, in turn, demands harmonisation of practices and processes, as well as technical standards, across Europe.

- The construction industry assumes increased responsibility over the whole life of the constructed artefact. There is a transformation from traditional construction companies to construction related service providers, who are not just designing and building but also financing and operating the infrastructures, e.g. highways, airports, office buildings, urban city development, schools and hospitals, being the lifeblood of today’s fast-changing mobile society (Arendt 2002).

These challenges require the transformation of the conventional construction industry from driven by rule based (code of practice) procedures to a performance-based driven one. It is essential to design and construct the built environment to satisfy not only today’s needs by providing ‘standard solutions’, but also to provide future-compatible and future-proof solutions, which address all the stakeholders of the construction industry and are dependent on the life-cycle performance management of the project.
The importance of this issue is stressed in two major reports (Latham 1994 and DTI 1998) concerning the UK construction industry, where the inadequate attention paid to the stakeholder requirements is criticised. Owners and operators of any network infrastructure system are legally responsible for its correct, continuous and safe functioning, and owe a duty of care to the public and the user community. This means that owners, builders and operators must consider performance criteria such as user satisfaction, safety and security, congestion/availability of service, maintaining asset value, sustainability and accessibility. Furthermore, in the Privately Financed Infrastructure, PFI, schemes, the concessionaires need to view their principal purpose as effectively supporting primary services for example teaching and health care, in case of schools and hospitals respectively, through the building-related services they provide, i.e. new-construction, renovation and operation/maintenance of the facility.

The Problems
Addressing the previously stated challenges strongly depends on the shared understanding of performance and its constituents at a European level. However, the current European construction industry is not equipped with a harmonised approach towards performance in practice. Current efforts in the EU for defining a European Construction Technology Platform (http://www.ectp.org) pinpoint the need for a focus on the whole lifecycle performance of construction artefacts to which all stakeholders must contribute. The current European construction industry is a fragmented organization with poorly developed supply networks involving many Small and Medium Enterprises (SMEs). According to the Annual Report 2004 of the European Construction Industry Federation (FIEC) there are 1.8 million enterprises (EU15), of which 97% are SMEs with fewer than 20 and 93% with fewer than 10 operatives. The total number of operatives in the construction industry is 11.7 million, which represents 7.1% of Europe’s total employment and renders construction the biggest industrial employer in Europe (28.5% of industrial employment - 26 million workers in the EU depend, directly or indirectly, on the construction sector). Other reports raise the number of employees in the construction industry to 30 million people and the enterprises to 2.7 million in the EU with an amount of 10 – 12% of GDP of all manufacturing sector of Europe (http://europa.eu.int/comm/energy_transport/atlas/html/boverview.html).

With a few exceptions, current construction practice adopts known and tested technical solutions. Incompatible traditional and local procurement and project delivery practices along the construction industry’s value chain (http://europa.eu.int/comm/energy_transport/atlas/html/bomarbarr.html) are major roadblocks to realizing the full potential of an integrated plan, build, operation & maintenance approach. This stifles innovation by preventing those involved in the process (particularly SMEs) from developing, evaluating, proposing and adopting alternative optimal solutions. Basic notions such as performance, life cycle and risks are not commonly understood in the industry (E-CORE 2004, Tecklenburg 2003a, and Tecklenburg 2003b) and are not adequately incorporated in decision-making processes due to different cultures, methodologies, expertise and practices. All the above characteristics mean that the current built environment industry cannot effectively satisfy the (new) European societal demand for a comprehensive approach to plan, finance, build, operate and maintain built systems (inclusive of all components that constitute and support a city, i.e. buildings, utilities, transportation systems, life-line systems, plants, etc.).
The Solution
The solution to this complex problem requires the ongoing extension, retention and dissemination of the underpinning knowledge base through an active learning process that is embedded within the construction industry. Through this process, the stakeholders (from the designer to the end user) of a built system will be able to integrate different attitudes, diverse knowledge and concerns over societal, environmental, technical, and economical issues related to the life cycle of the built system. This integration will result in inclusion of sustainability principles into the built environment and is expected to significantly improve life cycle performance of the system.

Information technology provides the means for this process (Bloomfield and Amor 2001). For example, the rapid development of Industry Foundation Classes (IFC) based standards for digital object oriented models of building products, enabling Building Information Models (BIM) to be exchanged between the stakeholders of the building process, provide tools for the achievement of the defined goals (Wix et al., 2005). The implementation base and output of such an effort could have the form of a virtual repository of knowledge, best practice, standard processes and supporting tools in Performance-based Engineering and Risk Management that all stakeholders involved with the creation and renewal of built systems can access, contribute to and collaborate through, in the long term (Taylor 2003). The objectives and benefits obtained from the development of this virtual knowledge and information framework are presented below.

OBJECTIVES AND BENEFITS
The main objective set forward in this paper is the designing of a universal, risk-based, performance management system for the European construction industry. This system will be the enabling technology to significantly advance the project delivery standards for the development of more sustainable built systems, facilitated by a new knowledge base framework.

This objective is fully justified by the major issue discussed in the previous section that the European construction industry primarily needs efficient management and supporting tools for performance-based production processes.

The above objective will be achieved by establishing a new, innovative framework for risk-based performance management of built systems following a two-fold direction:

1. To establish a uniform process-driven approach to risk-based performance management that will enhance the European construction industry in new development, renovation and operation of construction artefacts. This uniform process will extend from understanding to active management and control, and will initially focus on specific European conditions. The long-term aim is to affect the European construction industry in order to become more efficient, more competitive, environmentally aware and societally responsive.

2. To establish an approach that will identify and control performance and risk indicators in sustainable built systems. These indicators will represent the economical, ecological and societal demands of the European environment after the enlargement in order to improve the quality of life in Europe in the long term.

The scientific and technological steps towards achievement of the establishment of this framework are listed in more detail below:
Step 1: Foster networking, communication and interaction of stakeholders towards improved performance of built systems
In this step there are certain objectives that need to be pursued. First of all, there is a need to systematize the stakeholders groups (including general public, end-users and SMEs), which are related to the development of built systems of different kinds, according to their main roles, requirements, tasks and responsibilities. This can be achieved through establishment of an ongoing process to create and maintain a comprehensive and detailed structure of identifiable classes of stakeholders in built systems problems. This list will indicate, at the very first stages, all interested parties who should contribute to the optimised planning of a built system and ensure that sufficient representatives of these stakeholder classes will be engaged with the overall effort to conceptualise the framework to be developed.

Consequently, it is significant to identify the components and attributes that will describe performance and risk in the new framework. The identification of these features will be based on current industry practices and exchange of scientific knowledge at the European scale, as well as recording of components and attributes of high-level performance criteria as appreciated by the society, business and scientific community, and government agencies. This input will then be elaborated to generate a new, generic, comprehensive and adaptable list of components and attributes of performance and risk that will assist the understanding of performance and risk by the various stakeholders.

Once this framework is set, the next stage is the creation of a knowledge community that will expose results of a thorough review of the state-of-the-art and case studies concerning current industry practices and scientific knowledge in terms of risk and performance management. The unique and innovative feature of this knowledge community is that it will integrate the different views of the stakeholders in a built system concerning performance and risks; it will also provide with consistent performance criteria in a systematic, integrative way, covering a wide variety of built systems and corresponding, interdependent risk catalogues. The knowledge community will be the interface for an extensive discussion among interested stakeholders concerning the performance criteria and the risk catalogues that should be adopted during a system’s life cycle. This discussion will contribute to increased transparency amongst the stakeholders and lead to the adoption of consistent and uniformly accepted performance criteria and risk catalogues for built systems.

Step 2: Development of an approach for risk-based performance
The new, integrated performance and risk management approach discussed here is the result of the main assumption that performance and risks are inherent features of processes involved during the whole life cycle of built systems. Therefore, this approach should incorporate a continuous process of performance and risks control and active management. This continuous process can be achieved by investigating incentives to optimise performance by sharing and balancing risks; developing risk catalogues for built systems (in hard copies as well as over the Internet for the common use of the construction industry – internationally) and providing explicit knowledge from case study analyses. The approach should also improve transparency in risk-related information and collaboration amongst the stakeholders involved during the life cycle of a built system. This objective can be achieved by setting-up an information and knowledge management framework that will use the Internet as a deployment platform. Such a platform would facilitate the transparent co-operation of
stakeholders within the life cycle phases by integrating the methods of risk awareness, risk communication and minimization of the overall risk exposure of the parties.

**Step 3: Establishment of a new knowledge management framework for life cycle risk-based performance management of built systems**

The radical changes in the fields of performance and risk management can be assisted by the incorporation of modern information technology tools in risk-based performance. Such tools render the foundation for integrated data management, analysis and processing. A multi-dimensional information management framework that can support data management in different granularities, flexible data representation in various dimensions, and data mining in complex and extensive data sets can enable homogeneous, integrated management of data, information and knowledge from different, inhomogeneous, incomplete data sources as well as its re-structuring and consolidation. This support can be achieved through the development of appropriate data mining algorithms that will explore new interdependencies between specific data sets and thus the identification of the need for new knowledge.

The extracted knowledge can then be shared and reused by the development of respective, universally accepted ontologies that will describe the area of performance-driven risk management. Ontologies are a powerful and promising technology to support integration efforts of data management and communication and provide an important step towards radical changes in the fields of performance and risk management.

These information technology tools will be integrated in a visual knowledge and information framework that could reside on the web and constitute, among other things, a nucleus and information source for further joint activities on European scale.

Realization of the above steps will promote competitiveness and incorporate innovation in the near and long term future of the European construction industry and contribute to specific achievements like:

- **Significant impact on the identification of the performance criteria of built systems.** The new generation of performance criteria of built systems will ensure increased effectiveness in meeting user needs (delivery time, quality, health & safety, comfort etc.) and will lead to a reduction of construction costs and risk liabilities.

- **Value increase of all stakeholders, by affecting significantly the fragmented supply chain.** This will result by focusing on overall performance of built systems and fostering synergies among all stakeholders involved in the development of built systems.

- **Movement of the construction industry towards a knowledge-based industry.** This will result in a construction industry that will rationalize performance and risk perception and related information, and it will consequently increase recognition of risk and save costs.

- **Societal and economical impact leading to a more sustainable development of built systems and refurbishment of infrastructure and lifeline systems i.e. optimised to the real needs and demands and accepted by end-user.**

- **A sociological impact on the industry by improving stakeholder relationships through balanced sharing of risk and managing performance.**
REALIZATION FRAMEWORK

The objectives and benefits set above can be realized through the process presented in Figure 1. As can be deduced from this figure, the process has a twofold direction.

![Diagram of the realization process for the virtual knowledge and information framework]

Figure 1. The realization process for the virtual knowledge and information framework

First, establish an approach that will beneficially affect the way of life in the long term for European citizens. Second, provide the tools, so the European construction industry will become efficient and competitive, by establishing a uniform process-driven approach to risks and performance, from understanding through to their control. The vision is to provide the basis for a European construction industry, which will be guided by uniform, risk-based, performance management and project delivery standards. In the context of this framework, innovative performance monitoring and control methods, systems, devices and instruments, and supporting organizational structures for the construction industry can also be achieved. The outcome of this process essentially will provide the framework to upgrade significantly the quality of built systems and advance the knowledge and capacity of all stakeholders in the related industries. This outcome must include:

- Documentation of stakeholders and their requirements.
- Evaluation of perceptions, existing practices and technologies in risk-, performance- and life cycle assessment and management.
- Establishment of consistent risk definitions.
- Categorization of risk/chance attributes for selected types of artefacts and their interrelation with performance criteria. Criteria and demands to facilitate risk communication amongst stakeholders.
• An initial framework to identify performance requirements, define performance, and generate understanding amongst the stakeholders, as well as to generate high-level key performance indicators (KPIs) and a breakdown of KPIs amongst the stakeholders.

• A prototype maintainable knowledge database of stakeholders and stakeholder requirements, case studies, and best practices.

• Conclusions and trends derived by the use of specific case study solutions to be used for the development of a generic risk and performance framework.

• A framework for a generic performance and risk modelling and management tailored to inter-European needs.

• A prototype of a virtual knowledge and information centre.

The realization of this system should be based on the collaborative work of participants from the fields of academia, industry, research institutes and public agencies. It is a multi-disciplinary approach that involves a wide range of expertise, such as engineers (civil, structural / geotechnical / hydro dynamics, mechanical, etc.), architects, economists, sociologists, managers and specialists (management, communication, information technology). These participants may transfer their experience but, also, their knowledge acquired inside the framework of several other programs, which are related to some extend with the problem in hand. The need of integrating existing knowledge and information for generating new one is very well served by incorporating the findings of programs such those, which are referred to the Appendix.

CONCLUSIONS

The construction industry in the European Union faces new opportunities and challenges created by the increasing societal concern for environmental safety and planned built systems development. The transnational character of major construction projects and the international consortia formed to realize such projects but also the smaller and medium enterprises that are connected in one or another way to the construction industry need to operate in a new framework, where risk-based performance management will replace the standard rules and procedures for construction products.

The need for such a framework is thoroughly explained in this paper. Moreover, a new framework for the systemization and management of knowledge and information concerning construction risk and performance issues is discussed in terms of objectives to achieve, benefits to gain, and architecture to implement for it. A large motivation of human resources from the industry, the academia, and the pubic domain is required for the implementation of this framework. It is envisaged that the final outcome will, significantly, assist the society to acquire better knowledge and information about the large infrastructure projects that serve it, achieving in this way:

• Improvement of the dialogue between science and the society.

• Presentation of the industrial research conducted and of the current developments to render them more accessible and comprehensible.

• Shaping and consolidating the ideas and needs for further related actions on a European Scale.
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REFERENCES


APPENDIX

The projects and networks below may act in collaboration on the development of the new proposed framework and approach for performance and risk of built systems:
• European Thematic Network on Performance Based Building (PeBBu, http://www.pebbu.nl)
• Joint Committee on Structural Safety, (JCSS, http://www.jcss.ethz.ch)
• European Construction Technology Platform (ECTP, http://www.ectp.org)
• European Construction Research Network (E-CORE, http://www.e-core.org)
• Impact of wind and storm on city life and built environment (COST action C14, http://www.costc14.bham.ac.uk)
• International Alliance for Interoperability (IAI, http://www.iai-international.org)
• European Network of Construction Companies for Research and Development (ENCORD, http://www.encord.org)
• LESSLOSS: Development of advanced methods for risk assessment, methods of appraising environmental quality and relevant pre-normative research (http://www.lessloss.org/main/index.php)
• IuK-System Bau: Design, development and evaluation of an information and communication system for the controlling and monitoring of construction progress in small and medium-sized enterprises (SMEs). (http://www.iuk-systembau.de)
• ArKoS: Development of an architecture for the management of collaborative scenarios consisting of methods, a tool support and an integration platform (http://www.arkos.info)
• Life Cycle Management of Concrete Infrastructures for Improved Sustainability (LMS, http://www.vtt.fi/rte/strat/projects/lifecon/index.htm)