Project Risk Modelling Information and Management Framework

How to enhance risk management framework improve actor mutual understanding using BIM and Augmented reality tools

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The building industry is a field even more complex, characterized by different risks which can deeply influence the success of a building construction process. Aim of this paper is to demonstrate how the risk, declined in the main aspects that affects the construction industry, can be properly modelled and reduced thanks to the innovation of existing design methods and tools.The goal is to enhance the BIM models with AR (augmented reality), in order to intervene in the risk management process, increasing the level of knowledge exchanged between actors and, consequently, reduce defects related to misunderstandings. This can be possible using AR visualizations on site and/or Virtual Reality (VR) simulations, oriented to inform via the easier perceptive channel -the sight- actors involved in the process

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BUILDING THE ARCHITECTURE: A RISKY FIELD

In last years, the construction industry is becoming more and more complicated. This level of complexity is given, for example, from ever growing standards required from users and codes, and from the contemporary architectural morphogenesis, rich in innovative shapes and evolving materials. Actually, building a design concept mean critical involved factors like the project quality, an appropriate resources, an accurate definition of timing, goals and an effective very collaborating and scheduled construction phase.Considering these factors, is evident how the A/E/C domain is an highly risky field where, according to the Oxford English Dictionary, risk is descripted as "exposure to the possibility of loss, injury or other adverse or unwelcome circumstance". Among these, we most analyse the constructability, the financial and the Health and Safety risk, different for specific domain but strictly linked to the building process quality:

- Constructability risk, is the possibility that a building, or parts of it, can't be achieve or can be built in a different manner compared with the defined project. This risk is particularly dangerous for the aesthetic quality of the project, because often the solutions applied to solve this problem are not coherent (or totally opposite) with the building's design philosophy. In Italy, and particularly in Rome, this argument is very current and stimulate a hard debate;

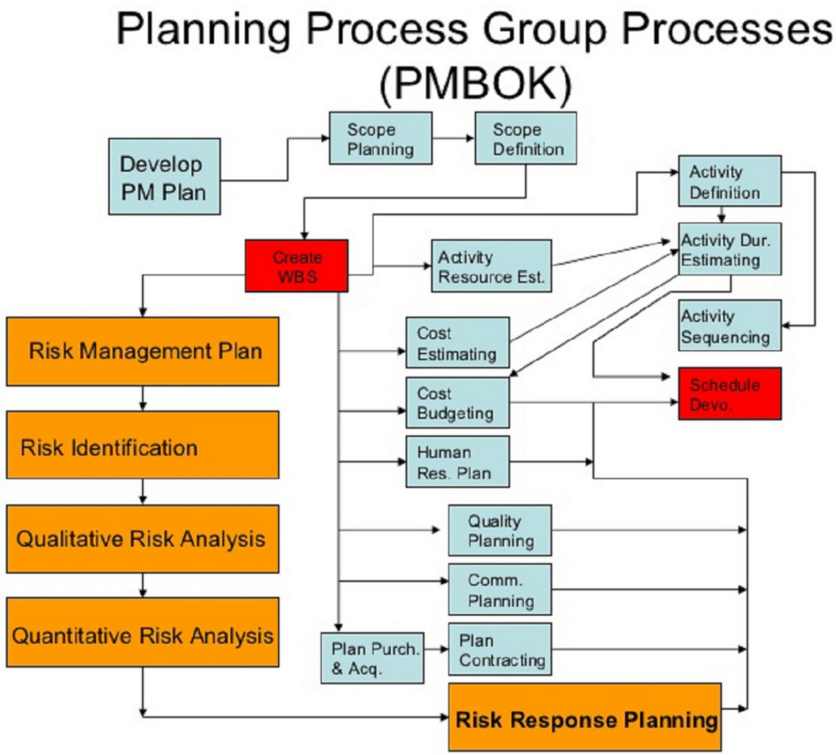
- Financial risk is the likelihood that the real expense exceed the preliminary budget. This is a very frequent condition for the A/E/C, and may occur when the execution plan is not well organized and also when the project management team has not expected some difficulties, predictable or not, that characterize every construction site;
- Health and Safety risk, according to OHSAS (Occupational Health and Safety Advisory Service) 18001:2007 "Risk is combination of the likelihood of an occurrence of a hazardous event or exposures and the severity of injury or ill health that can be caused by the event or exposure". For the building industry, this is a very important problem which causes a serious number of injuries and, at worst, dies. Furthermore, a bad safety-designed construction site is generally inefficient, more expensive in terms of time and workers are probably demotivate.

This bulleted list partially describe how the construction project is complicated, dynamic and interactive. In order to govern and mitigate these risks, Project Managers are constantly required to speed up reflective decision-makings on time (Kanapeckiene et al. 2010).Actually, to rule all of these aspects, a valid project team is normally composed by various specialist, developing their field of interest sometimes in conflict, other times collaborating with others specialists. To have the possibility to govern effectively a complex project, Project Managers have to use tools able to collect information properly, linked to a building's virtual model, in order to have a wide view over the consistence of the project, of its working phases, of the overall time and cost necessary to realize the architectural idea. Aim of this paper is to explain a possible implementation model for risk management, argument especially heard in the construction's industry, which is matched by the urgency to find appropriate and effective solutions since the design phase, because safe construction requires care and planning throughout the project lifecycle, from design through construction planning [...] and extending into operations and maintenance (Zhang et al. 2013). The proposed framework consist in the implementation of the current risk management workflow (fig. 01), using existing methodology like BIM (Building Information Modelling) and instruments like smart-phone, tablet, ultra-book, which have the capability to take and store up information, directly on construction site, and to share them in real time.

CRITICAL ASPECTS: EVALUATION, COMMUNICATION, KNOWLEDGE EXCHANGE

Currently, the first critical aspect is related to evaluation process, spring out by specialist's choices: these, in effect, are guided mainly from personal experience (implicit knowledge) that is difficult to share and formalise. This aspect implies also a evident lack of communication: the building sector should be a collaborative space, but companies using several methodologies to collect data and share them; the result is a poor knowledge data level, which limits the possibility for the Risk Manager to have an overall view over the project and its risks, and start a proficient dialogue among colleagues. Another strong limit is the difficulty to have a proficient level of communication: referring to construction site, for example, information about work in progress are strongly filtered by objective evaluations of the site inspector, which is personally present in site. Communication via images-transmission is also dangerous, because a static photo loses the main part of context information, and not talk about details, notes and other information that should be forwarded with a proper level of knowledge. The same problem, obviously, is present in the design phase, where are different misunderstandings between project team and client, be-

Figure 1
From: A Guide to the Project Management Body of Knowledge (PMBOK Guide), pp.44



cause rendering and design papers not describes at all every aesthetic detail. But the spreading of the use of Virtual Reality, video-presentations and virtual walkable building models, partially solve the client's need to foresee the final result in terms of architectural quality. Conversely, referring to BIM, a big problem is the interoperability among software. This is a strong limit for the diffusion of related tools, despite the constant work done by the BuildingSMART association, that promote the adoption of the international standard ISO IFC, that currently suffers of a limited use. At present we need to consider that, in relation to aspects of management, construction, safety, etc., the established practices of the operators, often erroneous, refer to the current BIM technologies and ICT tools as if they were traditional CAD tools, resulting in under-used and ineffective to deal with the problems exposed.

RISK MANAGEMENT WORKFLOW IN CURRENT PRACTISE: STATE OF THE ART

There are very different methodology to approach risk (fig. 02), because it is typical of every human activity. Therefore, we have many methodology to mitigate the likelihood that an event occurs. In A/E/C sector, when risk is evident in every meaning, we can recap as follow:

Context analysis: first of all, is essential to know deeply the environment when we are moving to

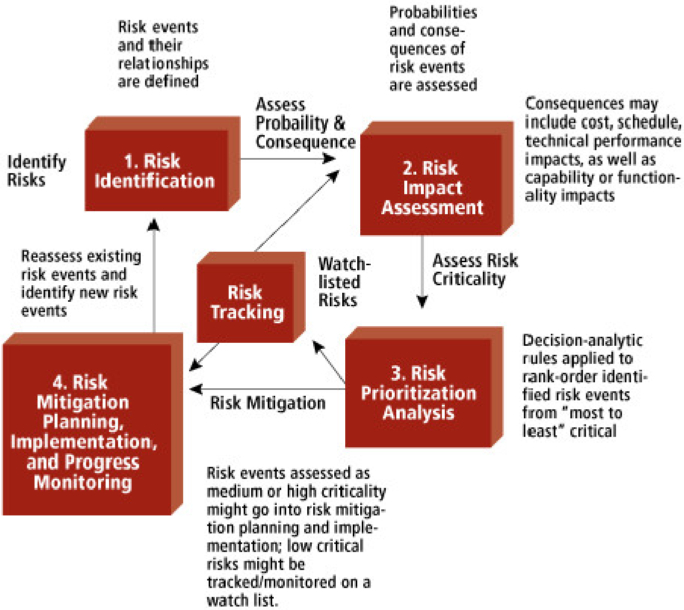


Figure 2
Risk Management foundamental steps (from MITRE's Systems Engineering Guide)

work. Social conditions, typical methodologies, cultural factors, organizational structure, and environmental features determines condition every different. Moreover, this analysis includes working activity, because these activities are the environment where risk is present and, if not opportunely mitigate, grows. In the overall process, this is the phase that has the most important number of random likelihood.

Identify risks: this operation allow to identify and analytically characterize every risk. It's a very difficult stage because the factors in game are various and not easy to globally determine. Usually, this identification happens filtering the existing databases with a specialist judgement (tacit knowledge).

Risk evaluation: in this stage appears the reporting activity about risk; according with the introduction of this paper, we control the constructability of an intervention and, accurately, where and when the building construction shows critical aspects. After that, the evaluation shift toward the financial issues, underlining critical aspects and the determination of a fitting budget. Finally, when the stakeholder decides to start building, the attention move to Health and Safety aspects, evaluating risks connected to every expected activity. Each evaluation is composed by two level of analysis: qualitative and quantitative one. The qualitative evaluation is a subjective analysis of risks that produces a risk ranking, usually in the order of high, medium low or an a ordinary scale. The quantitative evaluation is a numerical analysis of the probability and impact of risks on the project.

Risk-response planning: is a formal tool that allow to know and strategically use a sequence of action necessaries to deal with risks, in order to mitigate the dangerous impact or solve the risky situations.

Risk monitoring and controlling: during the construction phase, it's necessary to constantly monitoring and controlling the state of context, its changes, the - possible - appearance of others risk's factors, that eventually modify the risk evaluation and the risk response planning.

But risk is not intended only as a bad condition: in the risk science, the risk is neutral in its nature and it is subjective. When an event happens, it may be understood as positive or negative, based on the risk owner and risk recipient perspectives (Tomek and Matejka, 2014). Effectively there's another methodology to approach risk that considers every condition, known as the SWOT (Strength, Weakness, Opportunity and Treat) analysis. This method is composed by a Matrix that, in every condition of risk, declines different points of view: for example, in a construction site, a hole on a floor could be at same time a threat for the likelihood to fall into it; but also an opportunity to use this opening like a passage for tall beams from a floor to others. In structural means, this hole could be a point to completely analyse the composition of structural element, but also a point of weakness for the structural behaviour of the same floor. In this methodology, the context is formalised in "internal factors" and "external factors", as described in (fig. 03). *This confirm that risk management is an iterative process*.

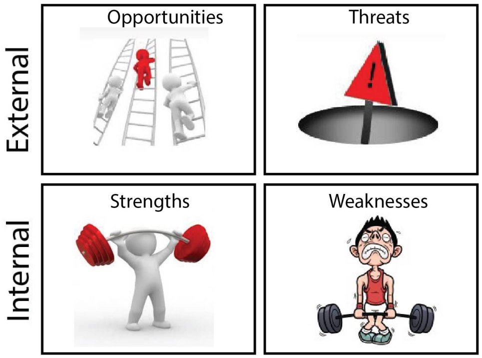


Figure 3
SWOT analysis Matrix: an easy template

TOOLS TO OVERCOME CURRENT LACKS: THE IMPACT OF BIM METHODOLOGY ON RISK MANAGEMENT

The term BIM Building Information Modelling, has now entered in common language, although in Italy is still not widespread, to indicate a methodology which, as Eastman said "integrates all of the geometric model information, the functional requirements and capabilities, and piece behaviour information into a single interrelated description of a building project over its life cycle. It also includes process information dealing with construction schedules and fabrication processes." In effect, BIM, founded on a scientific basis developed over more than twenty years of research on a data model for general construction (Björk, 1989; Eastman et al. 2008), uses information technology to model and manage data throughout the building life cycle (Lee et al. 2006). Currently, BIM tools are able to hold and connect to external databases a considerable amount of project-related information, such as sheets of materials and components, papers, drawings represented with different scales, 3D views, renderings, quantities take off, schedules, timing (PERT, GANTT, CPM) etc. In risk management, this capabilities are essential to have a more complete scenario in which analyse and evaluate risk and then strategically mitigate them. The big benefit done by BIM tools is to give a building virtual model in which are linked 3D views, 4D timing (with tri-dimensional animation about construction development), 5D estimation cost, every linked to specified property such as technical papers, documents, material's specifications and so on. This allow to have a high number of information about spaces, interferences, activities to do, activities done, costs, quantity and other aspects which are the core of Risk management. With a real time access to the building information database, these tools improve the chance to share and update information among stakeholders, reducing mistakes due to misunderstanding, not useful copy of information and a more efficient visual to compare how is designed with how is built. Several experience made in more BIM-oriented countries like

Norway, Sweden, Finland, Malaysia, Singapore, USA, United Kingdom demonstrate that "BIM creates significant opportunity " "reduce the financial risk" "reduce schedule-related risk" and "decrease the risk for errors and omissions" (Eastman et al. 2011). An important chance is done by the clash and/or rule detection, which allows the identification, during the design phase, of possible geometrical problems or, moreover, the violation of rules imposed by the designer to accord with codes or others requirements. Another important innovation, come from the development of tools able to make construction phases animation: this permit to analyse with an augmented perception of reality to optimize the allocation of resources and, essentials for workers' safety, to mitigate the exposition to risk factors.

AN IMPLEMENTATION MODEL FOR RISK MANAGEMENT USING BIM AND AUGMENTED REALITY

AR is a computer technology that combines, in real time, virtual objects and real images in order to give a more wide spectrum of information to user. The typical process for implementing AR technology is as follows (Park et al. 2013):

1. Objects are detected and the camera position information is estimated through the detected objects;
2. The locations where virtual objects will be registered are predicted using the estimated information;
3. The real world images are combined with the virtual images. The key element in this process is calculating the camera position information using the images captured from a camera and synthesizing virtual objects using the position information;

Linking AR information to a BIM model allow to have related 2D drawings, 3D dynamic images, and materials and schedule included in the project can be transformed to a maker, that plays as an instrument of augmenting the information of a real element in the site. Using these AR techniques, managers and workers could automatically confirm the results of their tasks by augmenting virtual shapes and dimensions onto the real objects or actual photos (Park et al. 2013).Starting by this considerations, a possible framework to implement the project-risk management workflow could be:

Context analysis: after the BIM modelling, a camera take several picture in order to have a "starting-point" which represent a first data-set, valuable to analyse potential risk factors or opportunities. A very important task is to assign comments and tags to remarkable elements

Identify risks: proactive identification of the potentially elements by using augmented views of these or, more correctly, the combination of events that could determine an accident. We can produce augmented reality frames that describes dynamically risks and, most important and difficulty, the possible combinations among these. An interesting develop can be represented by using human behaviour simulator, capable to predict the risk global rate of interference between workers, activities and working site

Risk evaluation: in this phase is important to analyse the possibility that an event occur and the related damage procured. The damages related can be obtainable by the existing database, produced by public institution that, every year, publish statistic studies about effective building costs, related timing and accidents and injuries happened. In this project phase, the AR can be useful to best represent the condition evaluated as "highly risky". An interesting perspective in research about computational design is to better define the likelihood, using for example statistical predictive methods like Bayesian networks.

Risk-response planning: in this fundamental phase for the real approach of the construction site, the AR is a very strong tool to verify the effectiveness of the risk mitigation programs. In preliminary project meetings, aimed to organise the actions required to every process actor, the use of AR view could be an immediate way to explicit the construction-site organisation, the workers' team management, correct construction modes and risk mitigation program. Moreover, AR views are able to show to workers how manage emergencies.

Risk monitoring and controlling: this is the time when the AR technology can find an immediate and proficient application. Consequently, a possible risk mitigation workflow, applicated by AR monitring and controlling, could be described as follows: the manager extracts the necessary BIM information including virtual 3D geometry, materials, and schedule of the targeted element from the BIM model, and the virtual 3D shape information is transformed into a maker via the maker generator program. Then, the maker is delivered to site inspector or trade workers and is attached in a designated location. After that, BIM information in the marker is read and augmented real work place through mobile devices such as smart-phone or tablet PC, which could be used not only for workers to confirm their tasks but also for inspector to check the worker's job performance during the work process, and the coherence between project and building. The manager could ask workers to transmit AR screenshots at the time of performing critical activity and/or would go out to the job place at critical check time during the work, in order to make sure whether the job is going well or not. The transmitted AR image is checked and reviewed by the site inspector and/or manager. If it is not right, the manager could give immediate warning and order rework to trade managers and/or workers proactively (Park et al. 2013).

CONCLUSIONS AND FUTURE WORK

The current economic condition of building industry require new tools and methods to optimize production monitoring and mitigate risks. The immediate need is to find an innovative way of change current risk management practices, which includes constructability, cost estimation, Health and Safety preservation, from reactive to proactive, using AR technology to inform about risks and implement inspection methods. Another aim is to implement the knowledge exchange, using the principal path of human cognition: the sight. Furthermore, BIM and AR applications permit to field experts not only to have a building virtual model that includes a risk knowledge linked database, but also to have an easy search tool for the retrieval of the work-specific risk information. Another important issue on proactive risk management is to find a way to overcome the manual inspection practices in the construction site. It requires that managers and/or inspectors know the key control points and measures for the frequently occurred defect work. However, due to the limited time and heavy work load, it is almost impossible to check and inspect all of the work procedures in the site. With the development of mobile application, it is certain that managers and workers not only remotely interact with each other but proactively exchange the right information at the right time during the work procedure (Park et al. 2013). Furthermore, collecting the BIM - AR applied views allow to store the knowledge acquired during the building phase and to gradually share with other stakeholders in order to implement more and more the workflow model. The future work related to this paper include an experiment on a real case-study, where we propose to try the real practical applicability of the proposed system in the construction field, in order to measure in terms of the efficiency and the effectiveness the real benefit that this framework should give to building industry and linked stakeholders.

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