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# A fuzzy approach to construction project risk assessment and analysis: construction project risk management system

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**Abstract**

The construction industry is plagued by risk, and poor performance has often been the result. Although risk management techniques have been applied, the lack of a formalised approach has produced inconsistent results. In this paper, a hierarchical risk breakdown structure is described to represent a formal model for qualitative risk assessment. The relationships between risk factors, risks, and their consequences are represented on case and effect diagrams. Risk descriptions and their consequences can be defined using descriptive linguistic variables. Using fuzzy approximation and composition, the relationships between risk sources and the consequences on project performance measures can be identified and quantified consistently. © 2001 Civil-Comp Ltd and Elsevier Science Ltd. All rights reserved.

*Keywords*: Qualitative risk assessment and management; Fuzzy logic; Linguistic variables

## 1. Introduction

The construction industry, perhaps more than others, has been plagued by risk [1,2] and this has not always been dealt with adequately, often resulting in poor performance with increasing costs and time delays. With the need for improved performance in the construction industry [3] and increasing contractual obligations [4], the requirement of an effective risk management approach has never been more necessary. There are a proliferation of risk management software tools on the market, and while the facilities offered by these packages vary widely, their underlying methodologies are often founded on the principles and techniques developed for operational research in the 1950s and 60s. Hence, the use of statistical techniques is commonplace and little else is considered. Construction projects are becoming increasingly complex and dynamic in their nature, and the introduction of new procurement methods means that contractors have to rethink their approach to the way risks are treated within their projects and organisations.

Risk assessment is a complex subject shrouded in vagueness and uncertainty. Vague terms are unavoidable since individuals often find it easier to describe risks in qualitative linguistic terms. The work presented here is part of a much larger project, which aims towards a different approach to risk management, one which will hopefully grow with individual organisations and increase their chances of success in project management. In this paper, a scheme for classifying risks and remedial actions in a consistent way is described. Fuzzy set theory is introduced to enable qualitative risk assessment descriptions to be modelled mathematically. Relationships between risk factors, risks, and their consequences are represented on cause and effect diagrams. Using fuzzy association and composition, the relationships between risk sources and the consequences on project performance measures can be identified. A methodology for representing the risk exposures in terms of time, cost, quality, and safety changes is presented.

## 2. Overview of the risk management process

To overcome the lack of formality in construction risk management, the development of formal risk management processes has been the subject of much interest recently. The Association of Project Managers (APM) have developed Project Risk Analysis and Management (PRAM), as described by Chapman [5]. Following the pattern typical of many risk management systems, PRAM defines a number of phases of risk process description. In this case there are nine phases: define, focus, identify, structure, ownership, estimate, evaluate, plan, and manage. Similarly, Kähkönen [6] defines a risk and project

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management process, but with fewer phases: organisation and scope, risk identification, risk analysis, risk strategy, response planning, and continuous control and feedback. Though there are fewer phases, they tend to cover the same scope as those used in PRAM. A more recent approach by the Institution of Civil Engineers and the Faculty and Institute of Actuaries [7] has resulted in a more comprehensive process of Risk Analysis and Management for Projects (RAMP), designed to cover the complete project lifecycle. The architecture for RAMP follows a more complex multi-level breakdown structure. The top-level processes within this structure are: process launch, risk review, risk management, and process closedown. The lower-level processes break these top-level processes down further.

The PRAM and RAMP approaches attempt to overcome the informality of most risk management efforts. PRAM and RAMP are essentially process models, albeit ones which have been well thought out with a considered approach to the risk management process. As such they exist as methodologies rather than as implemented software systems. One of the aims of the current work is to build on the foundations of systems such as PRAM and RAMP, using a common language as the underlying basis for risk description, and to develop a software prototype in which the risk methodology can be tested.

## 3. Risk classification and underlying system logic

Many approaches have been suggested in the literature for classifying risks. Perry and Hayes [8] give an extensive list of factors assembled from several sources, and classified in terms of risks retainable by contractors, consultants, and clients. Cooper and Chapman [9] classify risks according to their nature and magnitude, grouping risks into the two major groupings of primary and secondary risks. Tah et al. [10] use a risk-breakdown structure to classify risks according to their origin and to the location of their impact in the project. Wirba et al. [11] adopt a synergistic combination of the approach of Tah et al. and that of Cooper and Chapman, where the former is used to exhaustively classify all risks and the later is used to segregate risks into primary and secondary risks. In this paper, risks are classified using the hierarchical risk-breakdown structure of Tah et al. with minor modifications to the structure to provide a more enriched content.

A hierarchical risk breakdown structure (HRBS) has been developed, and the structure of this provides the basis for a stratified classification of risks and the development of a nomenclature for describing project risks. The HRBS allows risks to be separated into those that are related to the management of internal resources, which are relatively controllable, and those that are prevalent in the external environment, which are relatively uncontrollable. Internal risks may affect individual tasks or work packages or may affect the project itself, and as such are defined as local and global respectively. Risks are defined by the centre they affect within a project, and are themselves affected by risk factors. Risk factors do not affect projects or activities directly but do so through risks. This classification allows us to view the existence of risks as dependent on the presence of one or more risk factors. This is because the risk factors are more concrete abstractions of the risk and define situations that can be individually assessed with a limited amount of vague information or facts. The key attributes of risks and risk factors are likelihood, severity, and timing.

The risk catalogue is a collection of risks which have been defined using the common language and the HRBS. It is completely generic in nature, all the items contained in it are potential risks which have been identified. An example of part of the risk catalogue is shown in Table 1. The items within the risk catalogue are used as the basis for defining project specific risks. Each item within the catalogue is defined by risk type, scope, centre, risk, and risk factor. Given the use of risk factors within the system, risks can be defined as either a risk or a risk factor. An action catalogue has also been developed. This is similar in design to the risk catalogue — it has type, scope, and centre, but has action and action factor instead of the risk equivalents.

Table 1
A small section of the risk catalogue

| HRBS Code | Type | Scope | Risk centre | Risk | Risk factor |
|---|---|---|---|---|---|
| R.1.1.01.03.01 | Internal | Local | Labour | Productivity | Fatigue |
| R.1.1.01.03.02 | Internal | Local | Labour | Productivity | Safety |
| R.1.1.02.01.00 | Internal | Local | Plant | Suitability | Suitability |
| R.1.1.02.01.01 | Internal | Local | Plant | Suitability | Breakdown |
| R.1.1.03.01.00 | Internal | Local | Material | Suitability | Suitability |
| R.1.1.03.02.00 | Internal | Local | Material | Availability | Availability |
| R.1.1.04.01.01 | Internal | Local | Sub-contractor | Quality | Quality |
| R.1.1.04.02.01 | Internal | Local | Sub-contractor | Availability | Availability |
| R.1.1.05.01.00 | Internal | Local | Site | Weather | Weather |
| R.1.1.05.01.01 | Internal | Local | Site | Weather | Temperature |
| R.1.1.05.02.00 | Internal | Local | Site | Ground conditions | Ground conditions |
| R.1.1.05.02.01 | Internal | Local | Site | Ground conditions | Site investigation |