



## An expert system for strategic control of accidents and insurers' risks in building construction projects

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### ABSTRACT

Building construction projects appear to have higher accident rates. Contractors procure workers' compensation insurance (WCI) to transfer these risks to insurance companies. The commitment of insurers under WCI is extremely broad; there are no exclusions and ceilings on their liabilities. They must quote adequate premiums to cover future risks. Yet, the prices should be low enough to penetrate the market. Thus, accomplishing rigorous risk and market assessments to decide optimal premiums for building projects is crucial. Traditionally, experience rating approach has been adopted for WCI premium-rating. However, this approach has been found ineffective for construction. Hence, the purpose of this study is to develop an effective WCI premium-rating model for building projects, and to automate the model as an expert system. A new WCI premium-rating model was developed based on the findings of a literature review and a questionnaire survey. A hybrid of interviews and past workers' compensation claims data analysis was pursued to develop the conceptual model of a fuzzy expert system to automate the proposed model. It was then prototyped and verified with Turing tests. The proposed expert system advocates real-time assessments of project hazards, safety, market conditions and insurers' internal factors for premium-rating. It also establishes an effective risk control strategy via a well-structured incentive system for contractors and clients. Its implementation in the insurance industry can curtail accidents in the construction industry, thereby minimising insurers' financial risks.

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### 1. Introduction

Construction is one of the most dangerous and risky businesses; insurance is a keystone to eliminate most of the financial risks in construction (Clough, Sears, & Sears, 2005). Bunni (2003) identified five types of insurance that are available for contractors for different risk natures; contractors' all risk insurance, general liability insurance, workers' compensation insurance (WCI), motor insurance and marine transport insurance. Out of these five classes of insurance, the significance of the WCI in construction is immeasurable because the construction industry appears to have higher injury and fatality rates globally. Conversely, insurance companies who issue the WCI for construction projects are forced to assume abundant financial risks, which imply that the construction WCI is a critical class of insurance for them. Hence, the utilisation of an effective premium-rating technique is essential for insurers to perform rigorous risk assessments for construction WCI.

Traditionally, there are three basic approaches of premium-rating; exposure rating, experience rating and retrospective rating. The exposure rating uses the claims experience with a broad group

of policyholders to estimate the expected claims of an individual. Insurance companies accumulate data over many years, involving many policyholders, to gain a broad knowledge-base. Under the experience rating approach, the premium charged to a policyholder is based on the claims experience with that policyholder. The retrospective rating approach is a self-rated program under which the actual losses during the policy period determine the final premium for the coverage, subject to a maximum and a minimum. A deposit premium is charged at the inception of the policy and then adjusted after the policy period has expired, to reflect actual losses incurred (Booth, Chadburn, Cooper, Haberman, & James, 1999; Vaughan & Vaughan, 1996). Among these three approaches, the experience rating is an established technique for WCI premium-rating (Hoonakker et al., 2005). However, many researchers have criticised that this approach is ineffective for construction applications as summarised in Table 1. The exposure rating approach is common in health and motor insurance where the risk exposure is similar across policyholders unlike construction projects where each project is unique. The retrospective rating is less appreciated by contractors and clients as it does not provide a price certainty, which is crucial for tender decisions. A combination of a benchmark and heuristics is applied for premium-rating in the Singapore insurance industry. WCI premiums are

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**Table 1**  
Shortcomings of the EMR

Author(s)	Criticism
1. Everett and Thompson (1995)	<ul style="list-style-type: none"> <li>• The EMR is a complex approach</li> <li>• The EMR cannot fairly compare the safety records of different contractors</li> <li>• New contractors are forced to pay more premiums since they are not experience-rated</li> <li>• The premium is more biased towards the ownership of the company</li> </ul>
2. Hinze, Bren, and Piepho (1995)	<ul style="list-style-type: none"> <li>• The EMR value is decreased as the project size increased</li> <li>• Highly paying contractors will have lower EMR values</li> </ul>
3. Coble and Sims (1996)	<p>The EMR can be vulnerable to fraud by contractors to obtain low premiums in three ways:</p> <ul style="list-style-type: none"> <li>• Manipulating the payroll of workers</li> <li>• Misrepresenting work classification</li> <li>• Manipulating company ownership</li> </ul>
4. Hoonakker et al. (2005)	<ul style="list-style-type: none"> <li>• The EMR is a lagging indicator</li> <li>• The EMR is based on worker classifications and not on jobs, which impedes the interpretation of the results</li> </ul>

traditionally computed by applying a rate on wage rolls of construction projects. There has been a collective agreement among the insurers that the preferable WCI premium rate for building projects is 1% of the wage roll. This rate, however, is merely a yardstick. Individual insurers set competitive rates heuristically around the yardstick. However, no strong theory or analysis supports this benchmark norm. In the face of keen competition in the Singapore insurance market, underwriters tend to compromise the technical factors such as risk profile of the project and contractors' safety management systems, due to the lack of a well-balanced framework. This brings about risky projects being insured at lower premiums, causing adverse loss-ratios. Insurance companies who issue the WCI are forced to assume abundant financial risks. Many such insurers in Singapore have been experiencing detrimental loss-ratios and some have given up issuing the WCI altogether. Hence, there is an intense need for developing a new methodology for WCI premium-rating of construction projects. Based on the findings of a literature review and an interview questionnaire survey, a new WCI premium-rating model was developed by the author for building projects. The details of its development process and testing were discussed in Imriyas, Low, and Teo (2007).

Expert systems are a class of computer programs that can advise, analyse, categorise, communicate, consult, design, diagnose, explain, explore, forecast, form concepts, identify, interpret, justify, learn, manage, monitor, plan, present, retrieve, schedule, test and tutor. They address problems that normally require human specialists for their solutions (Brown & O'Leary, 1995). They mimic human experts' ability of heuristic reasoning from the knowledge and experience gained from years of practice in solving problems. Since expert systems are developed by acquiring the knowledge and experience of many experts in the industry, they provide effective and efficient solutions for problems in a specific domain and produce benefit/cost results well above a human expert. Due to this high quality, expert systems have had a great commercial acceptance throughout the world; for example, in Great Britain, the Department of Commerce and Industry reported 2000 commercial expert systems in operation, without considering expert systems working in universities and academic environments (Guardati, 1998). It is therefore convinced that developing an expert system for WCI premium-rating would enhance the potential benefits of the new model that has been developed by the author. It can also facilitate the implementation of the model in the practical sense. Durkin (2002) and Negnevitsky (2002) categorised expert systems into seven types, viz: (1) rule-based systems; (2) frame-based systems; (3) case-based reasoning systems; (4) fuzzy systems; (5) evolutionary computation systems; (6) neural network systems; and (7) hybrid systems, which combines more than one of the above systems. The selection of an appropriate type of expert system depends on the problem domain and its characteristics. Shapiro (2005) quoted that fuzzy logic applications in

insurance and related areas should be a fruitful area for exploration for the foreseeable future. There are many insurance problems that could be resolved by using fuzzy systems. These include classification, underwriting, project liabilities, future and present values estimation, asset allocations and cash flows, and investments. Young (1997) claimed that: (1) fuzzy logic provides a uniform way to handle factors that influence insurance pricing decisions; and (2) it allows one to combine conflicting goals and constraints. Bell and Badiru (1996) noted that the development of predictive models for occupational injuries is often hampered by the variability associated with human abilities and performance; fuzzy set theory provides a tool to address this variability. Moreover, WCI premium-rating involves subjective assessments of numerous hazard and safety factors in construction projects, and rating them using an objective scale like the Likert-scale. However, the ratings given by experts may not be precise as they are quantitative expressions of qualitative assessments. Thus, there is a need for accommodating this imprecision in premium-rating. Si, Ruxton, and Wang (2001) reported that fuzzy logic gives a more flexible structure for combining qualitative and quantitative information over conventional or other subjective methods. Hence, the objectives of this paper are to:

- Develop the conceptual model of a fuzzy expert system to automate the premium-rating model above; and
- Prototype and verify the fuzzy expert system.

## 2. A new model for WCI premium-rating of building projects

As per the new WCI premium-rating model, it is proposed that (Imriyas et al., 2007):

1. The net optimal WCI premium for a building project would have three components as shown in formula (1).

$$\text{WCI net premium} = \text{Risk fee} - \text{CCI}_{\text{Contractor}} - \text{SMD}_{\text{Client}} \quad (1)$$

where Risk fee is the gross price of the risk covered by the insurer and it has to be paid by the contractor at the underwriting stage and subsequently reimbursed by the client via interim payments,  $\text{CCI}_{\text{Contractor}}$  is a claim control incentive for the contractor, which is to be furnished at the policy expiry stage for controlling the actual claims below the predicted amount and  $\text{SMD}_{\text{Client}}$  is a safety monitoring discount for the client, which is to be furnished at the policy expiry stage for monitoring the contractor's safety management, which minimised claims in the project.

2. The computation of the net premium would be performed in two stages, viz:

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