Safety Hazard Control in the Workplace: a Dynamic Model

INTRODUCTION

The work described in this paper was carried out as part of a study into occupational health and safety information systems, and the simulation package used was Powersim. Systems thinking and practice are tools which can contribute greatly to better safety management (Waring 1990). The paper presents a generic model to illustrate the ***life cycle*** of a workplace hazard, from its conception to its final control. The greater the number of uncontrolled hazards in a working environment at any one time, the greater the likelihood of accidents being generated. The rate at which hazards can be identified and controlled will have a great bearing on the overall safety of the workplace. The exclusive use of a reactive approach to hazard control in the following system models proves not to be sufficient in substantially controlling hazards.

JUSTIFICATION FOR THE IMPORTANCE OF HAZARD CONTROL WITHIN THE WORKPLACE

According to the Health and Safety Executive (HSE) in 1986 over £300 million was paid out in employers' liability insurance claims for injury and ill health (HSE 1990). They estimated that accidents were costing the United Kingdom up to £15 billion per annum, almost 3% of Gross Domestic Product.

The number of successful prosecutions brought by the HSE has increased in recent years, showing a rise of 9% in 1992, with average fines rising to £877 (RoSPA 1993). Substantial new Health and Safety at Work Regulations came into force on 1st of January 1993. The onus of responsibility for health and safety has been placed firmly on the shoulders of the organisation. It is the employers duty to interpret the new guide-lines and to make provision for full compliance with legal minimum requirements. This includes assessment of the risks associated with workplace hazards (HSE 1992b).

The employer is required to carry out "effective planning, organisation, control, monitoring and review of the preventative and protective measures"(HSE 1992b). Many features of effective health and safety management are not distinguishable from competent management practice (HSE 1991a).

The Reporting of Injuries, Diseases and Dangerous Occurrences Regulations (HSE 1992a) requires employers to keep records of accidents and report them to the HSE. Reportable Accidents include injuries classified as fatal, major injuries and injuries that cause incapacity to work for more than three days; and ***near misses*** (HSE 1991b).

Hazard, Risk and Accident Definition

The Royal Society for the prevention of accidents defines an accident as "an unplanned and uncontrolled event which has led to or could have caused injury to persons, damage to plant or other loss" (Stranks 1992).

A hazard is something with the potential to cause harm, this can include substances or machines, methods of work and other aspects of work organisation (HSE 1992a).

Risk has a number of definitions such as "a chance of bad consequences" or "the probability of harm, damage or injury" (Stranks 1992). The most appropriate definition of risk for the work under review is "the probability of a hazard leading to personal injury and the severity of that injury".

ACCIDENT REPORTING AND INVESTIGATION, AND SAFETY MONITORING

The traditional approach to hazard identification and control is reactive, requiring an accident and often a string of accident repeaters to be reported, then consequently investigated before a hazard can be controlled. Reactive systems monitor accidents, ill health and incidents. They require the reporting of:-

- injuries and ill health;
- other loss events, such as damage to property;
- near miss incidents (where the potential to cause injury, ill health or loss is present);
- hazards; and
- weakness or omission in performance standards (HSE 1991a).

Safety monitoring in its widest sense can be adopted using a variety of techniques. It is concerned with the measurement and evaluation of safety performance (Stranks 1992). It may take the following forms.-

- Safety surveys: Consisting of a detailed examination of critical activities, or a study of all safety related workplace activities;
- Safety tours: Unscheduled examinations of a work environment carried out as a group exercise with the aim of assessing general compliance with safety requirements;
- Safety audits: Systematic critical examination is used to examine wide ranging factors which concern health and safety;
- Safety inspections: Scheduled inspections of the workplace, usually conducted by the company safety specialists and trade union representatives, in order to determine the level of legal compliance and adherence to company safety procedures;
- Safety sampling: Measurement of the accident potential of a workplace, through the use of random sampling to identify defects in safety performance or omissions;
- Hazard and operability studies: The use of formal critical examination to assess the hazard potential resulting from incorrect operation of equipment, and its effects on the facility.

REACTIVE DRIVEN HAZARD LIFE CYCLE

Description of Reactive Accident Policy

Accidents are generated in the workplace intermittently over time. In the event of an accident, a report is generated, often along with an investigation. This follow-up assists the management with hazard identification, and subsequent control. The hazard is pushed through its ***life cycle*** as a consequence of accident generation. The system is always reacting to accidents.

Model Description

Figure 1 schematically represents an overview of the leverage that reactive safety exerts upon workplace hazard control. The causal diagram in figure 1 contains two feedback loops, one is a balancing loop B(1) which is the driving loop for the system, and the reinforcing loop R(1) being the consequential loop. B(1) is driven by accidents, which are dependent for their existence upon the

hazards. A total of 226 accidents are generated in the model where only a reactive approach to hazard control is pursued.

Archetype in the Model

The **Fix that Fails** generic archetype structure (figure 5) contains a balancing loop intended to control a problem, but the reaction is the generation of a reinforcing loop (Senge 1992).

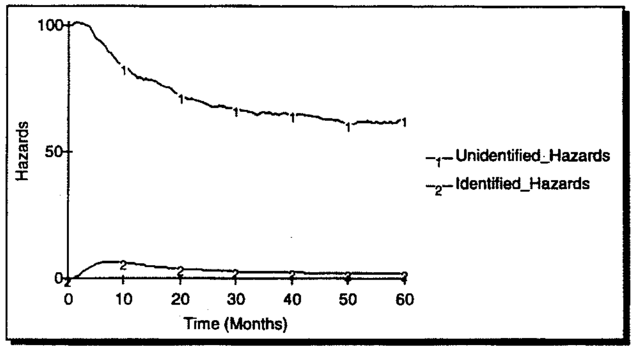

Figure 2 Stock of unidentified hazards versus identified hazards in the workplace

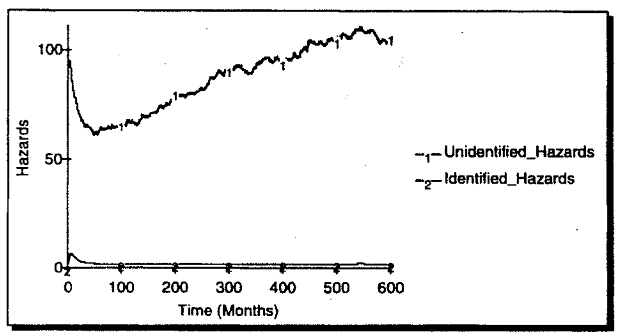

Figure 3 Stock of unidentified hazards versus identified hazards in the workplace over an extended simulation

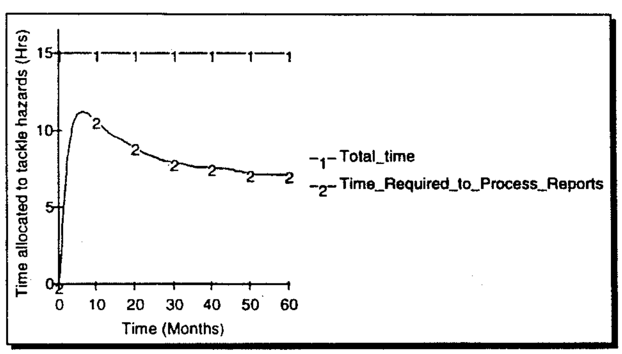

Figure 4 Total time resource available for safety versus actual time required to process accident reports

The consequence being a potential heightening of the problem (Senge 1992, Wolstenholme and Corben 1993). A fix effective in the short-term has unanticipated long-term consequences which could require greater use of the fix (Senge 1992).

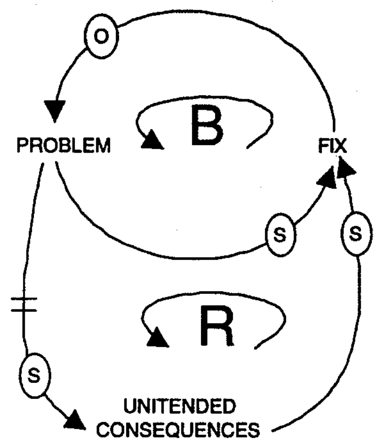

Figure 5 Fixes that fail archetypes

Let a comparison be made between the **Fix that Fails** archetype and the causal diagram. The quick fix is the reactive accident reporting and investigation, the problem being accidents and the unintended consequences are the unidentified hazards. The reporting manages to keep pace with the accidents generated from the stock of unidentified hazards in the short term (balancing loop). Time is bought until a longer term solution can be effected. If the system is left unchecked the stock of unidentified hazards eventually grows exacerbating the accident problem (reinforcing loop).

Consequences of the Reactive Safety System

The consequences of reactive accident reporting is a failure to control hazards, therefore, contributing to greater accident generation. Control is intended, but the reality is unwanted growth being achieved (Wolstenholme and Corben 1993). The system dynamics model for th simulation can be found in Appendix A of the paper.

PROACTIVE DRIVEN HAZARD LIFE CYCLE

Description of Proactive Accident Policy

There is a legal requirement for all types of accidents to be reported and logged, and often an investigation is necessary. When adapting a proactive policy towards safety, reactivity must still take priority, although this does not mean that proactivity can not take the lions share of safety time resource. Safety monitoring techniques are able to identify and subsequently control hazards prior to accidents becoming generated.

Model Description

The causal diagram showing hazard control is a development of figure 1 (figure 6). The reinforcing loop R(2) is the driver for the system, with the balancing loop B(1) acting as the limitation to growth, and R(2) is consequential to both loops. Loop B(1) is driven by accidents, which are dependent for their existence on unidentified hazards. Accidents generate accident reports which must be processed,

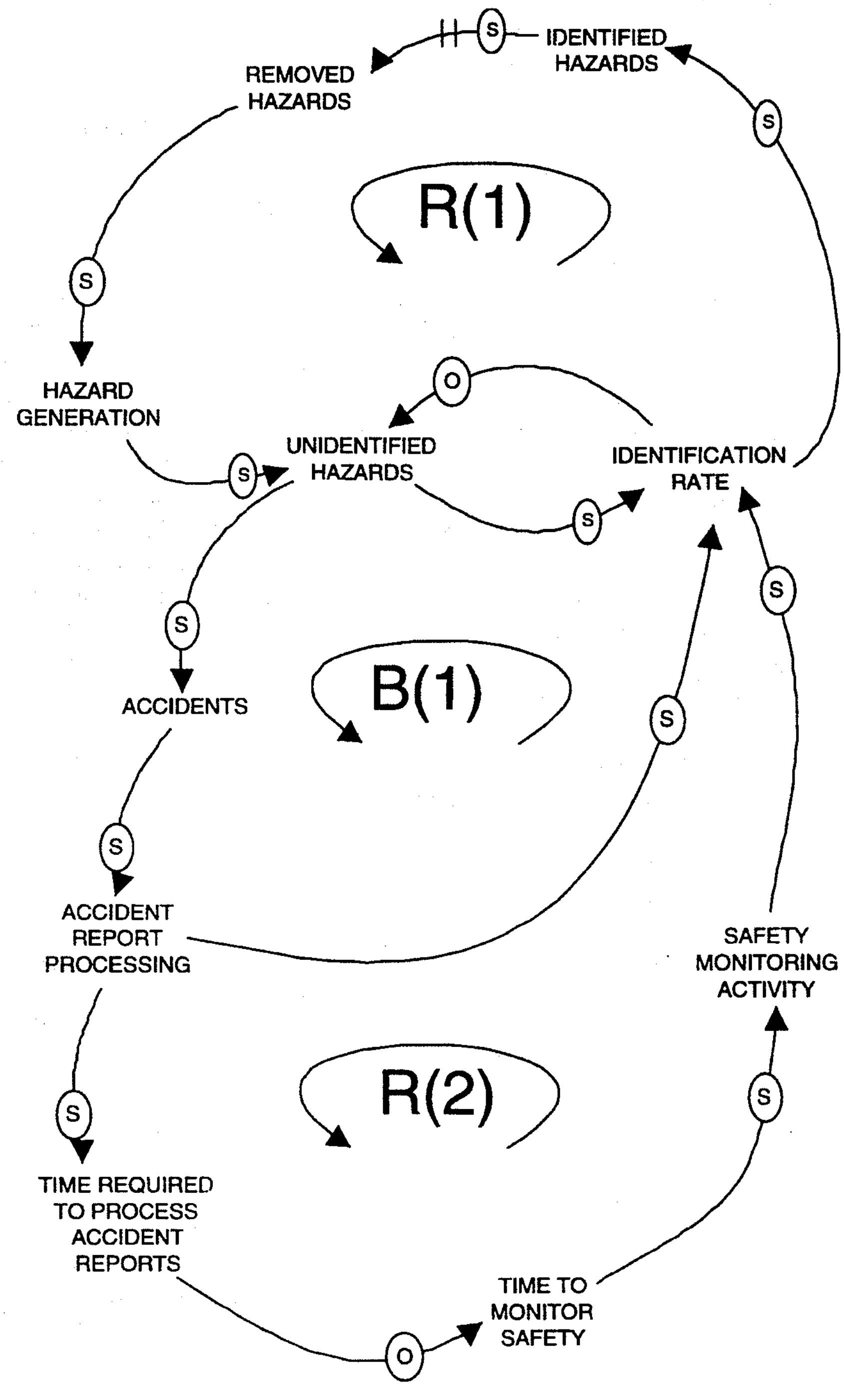

Figure 6 Reactive and proactive hazard control feedback loops

leading to identification of hazards, thus, reducing the stock of unidentified hazards. This is the reactive side of hazard identification. Proactive safety monitoring is proceeding simultaneously. Time is required to process accident reports. Safety time remaining after report processing can then be dedicated to safety monitoring. This also results in hazard identification, and ultimately control.

Loops B(1) and R(2) both contribute to hazard identification. Accident reporting and safety monitoring concurrently drive hazard identification, which results eventually in hazard removal then subsequent replacement.

Model Behaviour

Figure 6 schematically represents an overview of the leverage that concurrent reactive and proactive safety exerts upon workplace hazard control. Three feedback loops exist in the causal diagram, two reactive and one balancing. The driver being R(2), B(1) the limitation, and R(1) the consequential loop.

Figures 7-9 illustrate the effects of concurrent accident reporting and safety monitoring. Over the 60 month simulation the stock of unidentified hazards declines sharply and approaches zero within a 10 month period. Thereafter the unidentified hazards *bounce along the bottom* of the graph (figure 7). A sharp rise in identified hazards is evident in the initial stages of the simulation. This is a consequence of the rapid decline in unidentified hazards. The identified hazard stock remained near to zero through the remaining stages of the simulation. Figure 8 reveals that when simulating over a 120 month period the unidentified hazards never lift off the base of the graph following the initial 10 month period. Figure 9 reveals the answer to the improved hazard control. The same ceiling has been placed on the safety time resource as in the solely reactive system, but 100% of the time is utilised for safety work, unlike when only using the accident reporting system. Precedence is given to accident reporting over safety monitoring. After reporting, the remaining time is dedicated to monitoring. The graph reveals initially a high proportion of the time resource dedicated to accident reporting, as this falls off quite sharply safety monitoring takes prominence over reporting thereafter.

These graphs demonstrate that a blend of reactive and proactive safety is sufficient in controlling workplace hazards, given the same time resources as the purely reactive system. A total of only 40 accidents were generated over the 60 month period using the concurrent approach to hazard control.

Archetype in the Model

The **Limits to Growth** generic archetype structure (figure 10) contains a reinforcing loop which fuels a growing action to improve a condition, but a limiting condition is met in some other part of the system which generates a balancing loop, worsening the condition (Wolstenholme and Corben 1993). A process fuels itself to grow (Senge 1992), then the growth ceases or even reverse leading to collapse. The growth results from a reinforcing feedback process, while the slowing is due to a balancing process arising as a limit is approached. The limiting factor could be a resource constraint, or external or internal response to growth.

The causal diagram fits into the **Limits to Growth** archetype. The accident monitoring is the growing action, and accident reporting the slowing action. The limiting condition is the safety time resource. The rate at which hazards can become identified and controlled is dependent upon accident reporting and safety monitoring. The accident reporting is reactive to accident generation, and the safety monitoring is proactive to accidents.

Reporting takes priority over monitoring as regards time allocation, i.e. the level of monitoring is directly dependent upon the level of reporting, therefore, it is forever restraining the growth of the monitoring. Very quickly the time resource ceiling is met and the growth in monitoring activity ceases.

Consequences of the Proactive Safety System

Although the level of accident reporting is checked by the safety time resource, this is set at a sufficiently high level to allow the reactive and proactive safety policies to concurrently control hazards in the workplace. Appendix B presents the full system dynamics model used in the simulation.

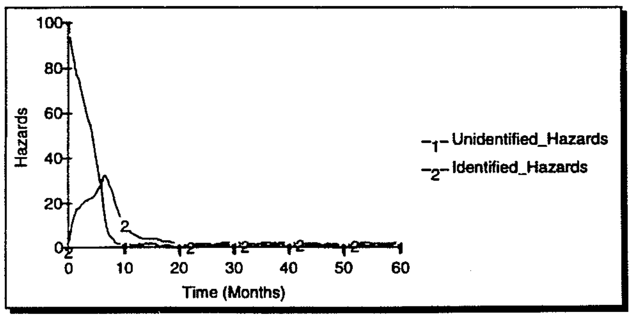

Figure 7 Stock of unidentified hazards versus identified hazards in the workplace

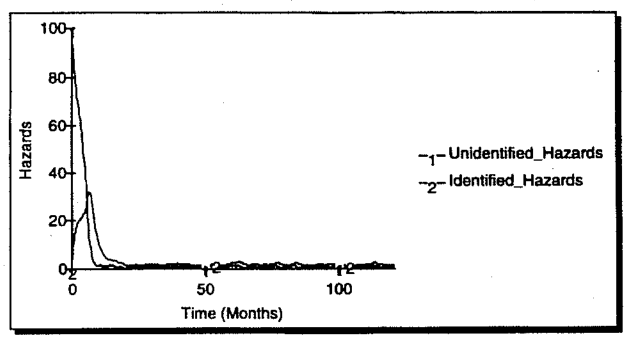

Figure 8 Stock of unidentified hazards versus identified hazards in the workplace over an extended simulation

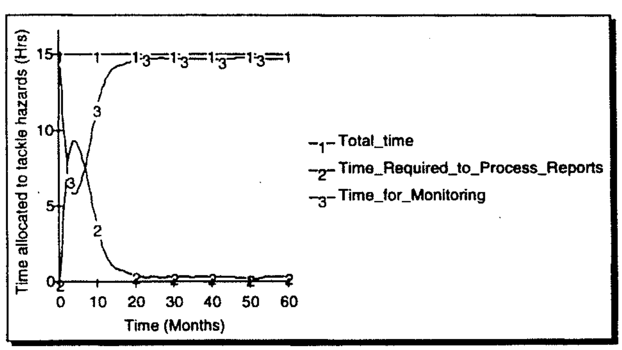

Figure 9 Allocation of total time resource between safety monitoring and accident reporting

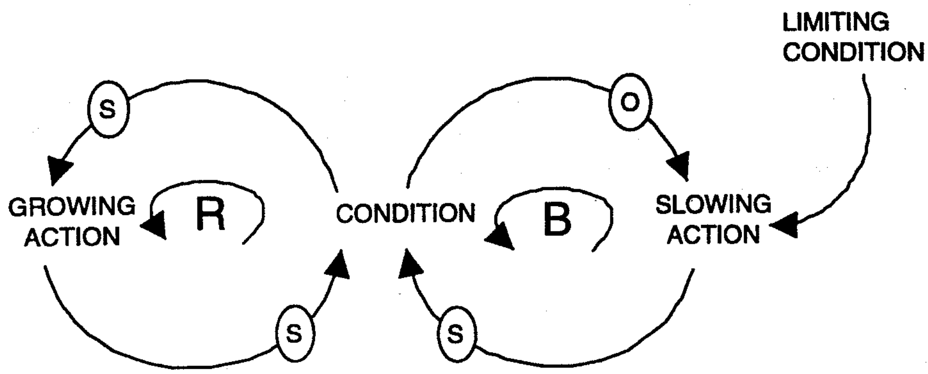

Figure 10 Limits to Growth Archetype

DISCUSSION OF RESULTS

The policy decision-maker is presented with two different approaches to hazard control, either implementing a purely reactive approach using accident reporting to drive hazards through their ***life cycle***, or simultaneous use of the reactive reporting in combination with proactive safety monitoring. Reactive hazard control emulates the **Fixes that Fail** problem archetype, and reactive and proactive control fits the **Limits to Growth** archetype.

Given an equal ceiling on allocated safety time resources in both models (figures 1 and 6) one clear winner emerges. The reactive policy alone is only able to sufficiently deal with hazard control over the short-term, in the long-term the stock of unidentified hazards grows (figure 11). The total safety time resource is never fully utilised, despite the accident reporting working at maximum efficiency. Conversely, an alternative policy using safety monitoring in addition to reporting proves that given the same time allocation, hazards can be effectively controlled both in the long and short-term. All the time allocation is fully utilised, the consequence being an immediate sharp reduction in unidentified hazards from the onset of the simulation, and the stock remaining at a near zero point thereafter.

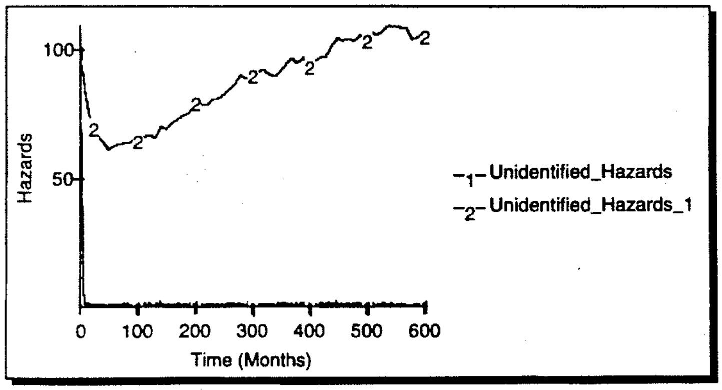

Figure 11 Stock of unidentified hazards present in reactive safety system versus proactive safety system

The consequences of ineffective hazard control in the reactive safety model is the generation of in excess of 200 accidents over the 60 month simulation, contrary to a mere 40 accidents occurring over the same time period in the combined reactive and proactive safety model (figure 12).

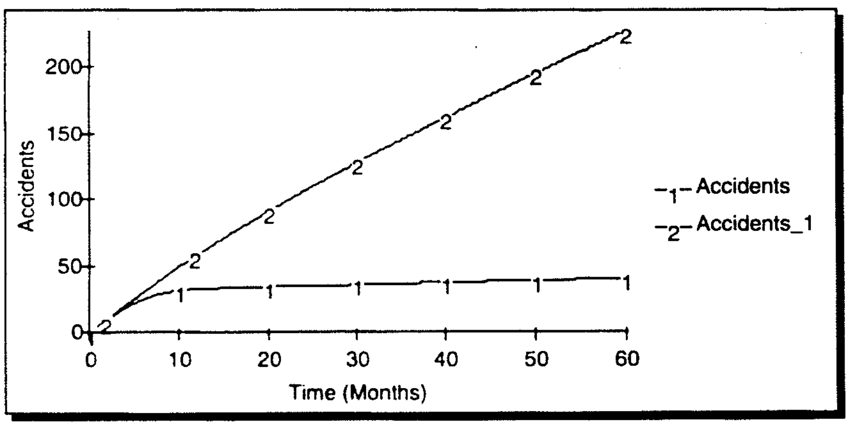

Figure 12 Accidents generated from reactive safety versus proactive safety approaches

CONCLUSIONS

Three conclusions can be drawn from this paper. The first is that workplace hazards and consequently accidents can be reduced through the use of proactive safety monitoring when in conjunction with reactive accident reporting; the second is that potential exists for reduction in the safety time resource through using proactive safety control; and thirdly, system dynamics can act as an effective tool in the identification of strategic policy decisions involving occupational health and safety.

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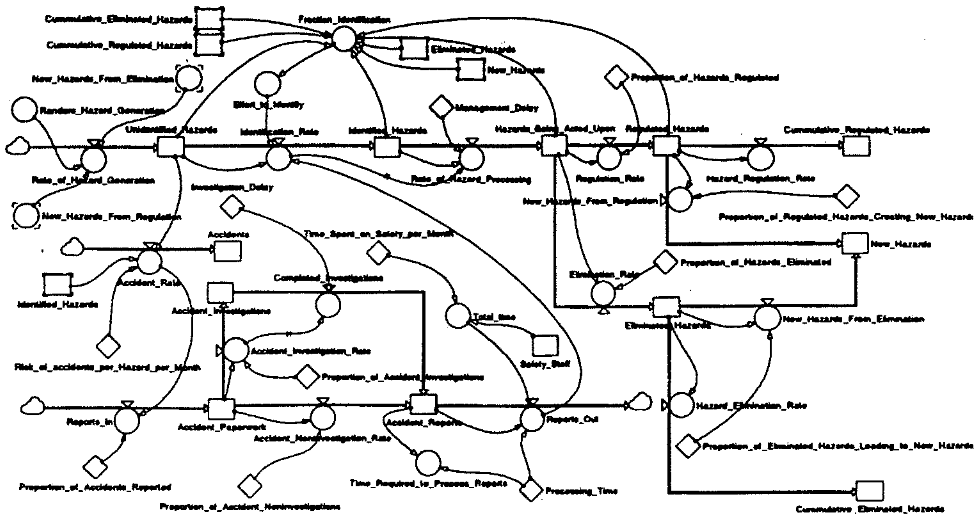
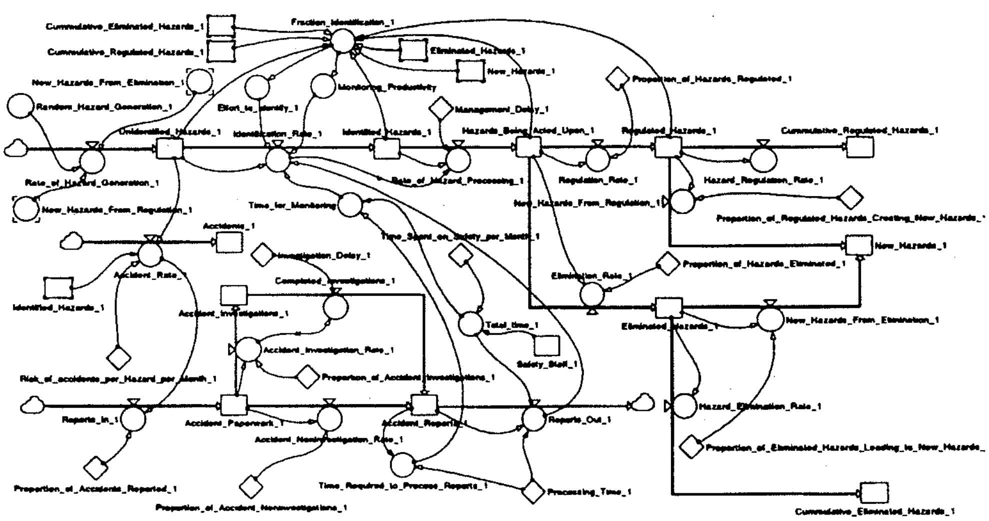
APPENDICES



Appendix A Reactive system dynamics hazard control model



Appendix B Reactive and proactive system dynamics hazard control model