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DEVELOPMENT OF PROBABILISTIC DESIGN AND ANALYSIS TOOLS FOR PERFORMANCE-BASED FIRE SAFETY ENGINEERING

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ABSTRACT

New Zealand was one of the first countries internationally to introduce a performance-based building regulatory system in 1991. The flexibility of this new regulatory environment was ideally suited to the emerging field of fire safety engineering and offered the opportunity for innovation and efficiencies to be achieved while still maintaining appropriate levels of life safety. In a situation where one "self-contained" New Zealand Building Code applies nationally, coupled with a small market size, the intervening period has provided the ability to thoroughly review the effectiveness of the performance-based regulatory regime. Opportunities for improvement identified by such reviews are being addressed in a number of ways, including the development of a new methodology to demonstrate compliance with the fire safety provisions of the New Zealand Building Code.

Part of the infrastructure needed to support the next generation of risk-informed stochastic fire safety engineering regulation in New Zealand is suitable calculation tools. Therefore in 2007, a five year joint research project involving BRANZ Limited and the University of Canterbury was initiated. The project has the overall objective of providing practitioners with new design and analysis tools which will demonstrate that defined levels of fire safety are being achieved in buildings. Specifically, the research project aims to integrate significant enhancements into the deterministic BRANZFIRE computer zone model. This will produce a new probabilistic model that generates outputs in the form of cumulative distribution functions of probability that can be directly compared with probabilistic statements of building fire safety performance.

This paper provides a summary of the work involved, giving background to the project and the building regulatory system in New Zealand, as well as details of progress to date of the research.

KEY WORDS: BRANZFIRE; Zone Modelling; Deterministic Models; Probabilistic Models; Performance-Based Design; Design Fires

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1.0 INTRODUCTION

BRANZ Limited (BRANZ) and the University of Canterbury are currently collaborating in a research project entitled "Building Safety Design-Fire Tool for Use in a Risk-Informed Regulatory Environment". This fire research project is substantially funded by the research funding agency of the New Zealand Government, the Foundation for Research, Science and Technology, but the project is also co-funded 30% by the Building Research Levy and 10% by the New Zealand central building regulatory agency, the Department of Building and Housing (DBH) of the New Zealand Government. The research project is of five years duration, having started in October 2007 and scheduled for completion in June 2012.

The overall objective of the research project is to improve the quality and methodology currently employed by fire safety engineering practitioners in New Zealand and to support effective performance-based fire safety design in the New Zealand building and construction industry. This will be achieved by developing new design and analysis tools to help assess the risk and uncertainty inherent in fire safety engineering calculations. The outcome of this research will be an improvement in both life safety and property protection in the event of fire occurring in the built environment in New Zealand.

Concurrently to this fire research project, the DBH is developing a new methodology for fire safety engineering practitioners to be able to demonstrate compliance with the Fire Safety Clauses of the New Zealand Building Code (NZBC). This new methodology is known as the Fire Safety Design Framework and it is intended that this will lead to quantification of some performance criteria in the NZBC and provide practitioners with the ability to demonstrate compliance with the NZBC in a consistent manner.

1.1 Background to Research Project

The collaborative research project described in this paper aims to help address significant areas of concern that exist about the quality and rigour of fire safety engineering in New Zealand. Due to the life safety considerations involved in the fire engineering design of buildings, such concerns are relevant and important.

The research will contribute to the development of new design and analysis tools which will demonstrate that defined levels of fire safety are being achieved in buildings, and which will therefore help to facilitate the next generation of risk-informed regulatory criteria.

Conventional fire engineering practice attempts to determine the environment in a building during a fire to ensure that occupants can evacuate safely in the event of a fire breaking out and that Fire Service personnel are able to carry out fire fighting and rescue operations without undue risk. Fire engineering calculations are often carried out using simple deterministic models to characterise the hazard that will be present in the building and their impact on the occupants. Generally a few specific scenarios are considered and single-point values for key design parameters are incorporated into the calculation procedures. This approach makes no allowance for the probability of these scenarios occurring or the variability of input parameters.

BRANZFIRE is a two-zone computer fire model that is widely used by professional fire engineers in New Zealand as a tool for fire safety design of buildings. Currently, BRANZFIRE is a deterministic fire model that represents the phenomena occurring in compartment fires by solving inter-related mathematical equations that are based on physics and chemistry.

The primary output of the BRANZ/University of Canterbury joint research project is a new version of BRANZFIRE which has significantly enhanced features such that monte-carlo results from the model will be expressed in probabilistic terms, thus providing users with more realistic estimates of the uncertainty associated with achieving specific performance criteria.

1.2 Building Research Levy

In 1969 the Building Research Levy Act [1] was enacted by the New Zealand parliament so as to set up a funding mechanism to conduct research to help ensure that high standards of construction were achieved in the New Zealand building industry. The Building Research Levy is an activity-based levy that is applied to all building works in New Zealand, whether it is new work or improvements to existing buildings.

The Building Research Levy is applied at a rate of $1 per $1000 value of the building works and is collected by the local government agencies that are responsible for enforcement of the building regulations at a regional level, on behalf of the Building Research Association of New Zealand. This latter organisation is a not-for-profit, non-government entity that is controlled by the wider New Zealand building and construction industry and whose purpose for being is to invest the Building Research Levy proceeds for the benefit of the wider building industry.

A typical detached residential dwelling in New Zealand would cost approximately NZD$300,000 to build, meaning that a levy amount of NZD$300 would be collected for such a building project. In a typical year in New Zealand 15,000 to 25,000 new detached houses are constructed, and when combined with other residential, commercial and industrial building projects, the annual value of New Zealand building industry activity is NZD$10-15 billion.

The Building Research Association invests these proceeds in a programme of industry-good research and information services. The research programme includes areas such as fire safety, structural engineering, building physics, indoor air quality, weathertightness, materials performance, sustainability, energy efficiency and building economics. Much of this research provides technical input into the NZBC and the development of building standards. The Building Research levy also funds a contribution to more than 50 building standards committees, publication of a wide range of industry information for practitioners, industry training and a building industry Advisory Service.

1.3 Research Providers

The fire research project described in this paper involves collaboration between BRANZ and the University of Canterbury.

BRANZ is the commercial trading arm of the BRANZ Group, of which The Building Research Association is the parent. BRANZ has a staff of approximately 100 people and is based near Wellington, the capital city of New Zealand. Approximately 40% of BRANZ income comes from the Building Research Levy, with the balance from either commercial fees for building product testing and consulting services, sales of publications, fees to attended training courses, or external research funding. BRANZ has eight professional and technical fire engineering staff members who conduct research, consulting and product testing.

The University of Canterbury is located in Christchurch and offers the only post-graduate qualifications in New Zealand for fire engineering. The programme was started approximately 15 years ago by Professor Andy Buchanan and the academic staff now includes Associate Professor Charley Fleischmann and Dr Mike Spearpoint. Each year approximately 15 masters students graduate from the programme and in any one year there are approximately five PhD students undertaking research.

BRANZ is providing project management for the research project and has its own and subcontracted staff contributing to the project, while the University of Canterbury has academic staff and students as part of the programme.

2.0 BUILDING REGULATORY SYSTEM IN NEW ZEALAND

Performance-based fire safety regulations which specify the objectives and minimum performance requirements for fire safety are becoming more common internationally. Generally such systems allow these objectives to be met in a number of different ways so long as the prescribed level of fire safety is achieved. New Zealand has had a performance-based building code since 1992, and with regard to fire safety, the provisions of the NZBC can be met by either complying with a prescriptive "acceptable solution" or by specific fire engineering design. In this regard, New Zealand has a similar regulatory regime to countries such as Sweden, England and Wales, and Australia [2].

2.1 Legislative Hierarchy

The building regulatory system in New Zealand consists of a four tier hierarchy. The over-arching piece of legislation is the Building Act 2004 [3] which sets out the framework for the building controls system in New Zealand and must be adhered to when undertaking building work. The purpose of the Building Act is to ensure that people can safely use buildings without endangering their health, can escape from the building in the event of fire breaking out and that the building provides amenity for users and the building promotes principles of sustainable development.

The second tier of the overall building controls framework are six sets of building regulations which provide more specific details relating to administration and the like. The third level of this hierarchy is the NZBC which is an annex to the one of the six building regulations, the Building Regulations 1992 [4]. The fourth level is the *Compliance Documents*, one of which is published by the building regulator for each individual NZBC clause. They prescribe one, non-mandatory, way of meeting the NZBC by providing details of construction that are deemed to comply with the NZBC – this is known as an *Acceptable Solution*. A *Compliance*

Document may, but not always, contain a *Verification Method* which is either a test method or a calculation procedure, which again prescribes one way of meeting the NZBC. The *Compliance Document* in some cases consists of another formal document, such as a standard, being cited.

2.2 New Zealand Building Code and Compliance

The NZBC contains the mandatory provisions for new building work but in a general sense it states the required level of building performance but does not prescriptively describes how the level of performance should be achieved. The NZBC contains 35 technical clauses that set out the difference performance criteria that must be met and cover structural stability, fire safety, access, moisture control, durability, services and facilities, and energy efficiency.

There are three levels to each of the technical clauses which describe the requirements of that particular clause. Firstly, an *Objective* is stated, which gives the social objective that must be achieved by the building. Secondly, *Functional Requirements* give the functions that the building must perform to meet the *Objective*. Thirdly, the *Performance* is stated whereby the performance criteria that must be met by the building are given and in meeting the performance criteria, the *Functional Requirement* and *Objective* are met [2]. The statements of *Performance* are generally qualitative rather than quantitative.

Four of the technical clauses in the NZBC relate to Fire Safety – clauses C1 to C4. These four clauses are:

1. Clause C1 – Outbreak of Fire
2. Clause C2 – Means of Escape
3. Clause C3 – Spread of Fire
4. Clause C4 – Structural Stability During Fire

There are two ways of demonstrating compliance with the NZBC, either by following the *Compliance Document* for the particular NZBC clause, or via the *Alternative Solution* pathway. Specific fire engineering design is the most common form of *Alternative Solution* used with regard to the Fire Safety clauses and the approval authority must be satisfied on reasonable grounds that the performance requirements of the NZBC will be met.

The Compliance Document for the Fire Safety Clauses of the NZBC [5] does not contain a *Verification Method* but only an *Acceptable Solution*, which provides extensive details on the option of the deemed-to-satisfy pathway for achieving compliance.

2.3 Other Legislation

Although the Building Act has consolidated the majority of the legislation applicable to buildings into one framework, there are some examples of other legislation that is applicable to buildings. One example of this are requirements for flammable liquids and gases that are contained in the Hazardous Substances and New Organisms legislation [6], which has specific provisions for flammable substances that are housed within a building.

Another example is legislation relating to the Fire Service activities where specific requirements relating to fire and rescue operations in buildings are stipulated. As a result, there is an automatic requirement that a *Building Consent* application that involves an *Alternative Solution* is submitted to the Fire Service to ensure that the building design deals with Fire Service issues adequately. The Design Review Unit of the New Zealand Fire Services provides its advice to the Building Consent Authority (BCA) in the form of a written memorandum. The relevant legislation in this case is the over-arching Fire Service Act [7] and then the second tier documents, the Fire Safety and Evacuation of Building Regulations [8], and the Fire Fighting Water Supply Code of Practice [9].

2.4 Enforcement

While the building regulations in New Zealand are set at a national level and apply to the whole country, an arm of local government administers and enforces the application of the NZBC at a local and regional level. There are approximately 70 local government agency BCA's, that each has a unique geographical jurisdiction that collectively cover the whole country. In the larger metropolitan areas, separate BCA's are contained within the boundaries of the city, while in rural areas, one BCA may have a very large geographical area to administer.

A *Building Consent* application is submitted to the BCA and includes suitable evidence that the building design complies with the relevant clauses of the NZBC. Where the design has been done fully in accordance with the *Compliance Documents*, the design must be accepted by the BCA as meeting the requirements of the NZBC. Where the application involves an *Alternative Solution*, the BCA must exercise its judgement as to whether the requirements of the NZBC will be met, giving consideration to any advice received from the New Zealand Fire Service. Often the BCA will employ expert external assistance where the *Alternative Solution* involves complexity. Because of the subjectivity that can occur in such a process, a disputes mechanism exists where the applicant can seek a *Determination* from the DBH, which is a formal interpretation of the requirements of the NZBC as they apply to the particular application.

3.0 FIRE SAFETY ENGINEERING PRACTICE IN NEW ZEALAND

3.1 Fire Safety Engineering Design

New Zealand first introduced a performance-based building code in the early 1990's and this signalled the evolution of a new discipline - fire engineering. A lack of quantitative fire safety performance criteria in the NZBC however has hampered the full benefits of performance-based design being realised in the New Zealand built environment.

This current lack of quantified performance criteria has resulted in the unsatisfactory situation of fire designers both proposing and applying their own criteria. In addition, a lack of suitable verification methods has resulted in a general design approach that is not standardised and sensitivity analysis, to address uncertainty, is rarely done. The current process of design and regulatory approval appears to involve a high degree of subjective judgement and has resulted in inconsistency in fire engineering and disputes about fire safety [10].

3.2 Design Documentation

An independent audit [11] of fire engineering reports in New Zealand, commissioned by the New Zealand Fire Service, concluded that over 90% of such reports submitted in support of *Building Consent* applications did not follow a formal fire engineering process and over 90% did not use appropriate engineering methods.

In a recent research project [12], a sample of commercial and institutional buildings in New Zealand was surveyed to assess the standard of passive fire protection features. Widespread non-compliance was identified and one of the areas indentified in the project report was a lack of detail being provided by fire engineering designers in the design documentation.

Anecdotal evidence from building officials in New Zealand also suggests that the standard of fire engineering documentation being provided in support of *Building Consent* applications is of a generally poor standard. The fire engineering profession is currently undertaking a project which aims to develop consensus amongst the key stakeholders as to what the minimum requirement for fire engineering documentation should be.

3.3 Fire Safety Design Framework

Since August 2006 the DBH has been developing a new methodology to demonstrate compliance with the requirements of the NZBC Fire Safety clauses, called the Fire Safety Design Framework. In relation to *Compliance Documents*, it is possible that this published framework will be classed as a non-mandatory *Guidance Document* which provides an option for demonstrating compliance with the NZBC. Currently an initial version of the framework document has been released for field testing by fire safety engineering practitioners to ascertain viability, usability and practicality.

The philosophy underpinning the framework addresses the major areas of concern with the practise of fire safety engineering in New Zealand. While the NZBC will maintain its performance-based approach for fire safety, inputs will be pre-determined. This will put fire safety engineering on a similar footing to structural engineering, where design loads for buildings are clearly defined in a loadings code. While innovation and flexibility will still remain, consistency will be more readily achieved.

The current proposed framework has the following general features:

- all buildings will have to be assessed against a set of ten fire scenarios

- in some cases protocols will be developed to identify suitable calculation methods such as computer models
- designers who follow the framework will have to go through a systematic series of steps in the design process
- the relative importance of buildings will influence the level of performance required
- sensitivity analysis will be required
- the fire engineering design will be assessed against quantitative acceptance criteria

For the relevant scenarios, a designer will need to demonstrate that occupants can safely escape from the building, that fire fighters can undertake their duties without undue risk and that the fire will not spread to neighbouring property.

While it was recognised that a quantified risk-informed approach is the ultimate goal in performance-based design, it is also appreciated that the quality of data and tools needed to support such an approach does not currently allow these methods to be used with a sufficiently high level of confidence that the required levels of fire safety will be achieved. Therefore, the current framework being developed is 'deterministic' in nature, similar to current design practice in the industry. Over time, as new data and tools become available and confidence in their use increases, they can be accommodated by amending the regulatory framework for performance based fire design.

The major difference however is that the regulator will be providing detailed guidance on the scenarios to be considered, the design fire characteristics to be used, the occupant response characteristics to be assumed and the quantitative acceptance criteria to be applied in evaluating the threat to life, and risk of damage to other property.

It is anticipated that the design tool resulting from the research project, will be customised to fit within the DBH's framework, so that relevant fire scenarios, and design fires will be available within the program, but the intent of the research is to go far beyond this and to lay the groundwork for the next-generation of building code compliance methods.

The proposed framework does not explicitly deal with uncertainty, but recognises that design solutions must be robust and reliable. Emphasis will be placed on the use of recognised standards for the design and installation of fire safety systems. Further, it is expected that designers will include sensitivity analysis on important variables when carrying out designs using the framework.

This research aims to develop a design tool that will incorporate such sensitivity analysis in a much more structured way. By assigning probability distributions to important input parameters in an analysis and then conducting a large number of simulations where inputs are randomly sampled from the input distributions, the results of the analysis will also have distributions assigned to them.

For example, the DBH framework may include criteria for tenability such that the fractional effective dose (FED) shall not exceed 0.3. The design tool is intended to be able to assign a level of confidence to the design value e.g. there is a 90% probability that the FED will not exceed a value of 0.3. An important advantage of such a design tool is that it could include scenarios addressing the reliability and possible failure of fire safety systems, and therefore provide better understanding of the trade-offs involved.

The framework's ten scenarios will be characterised by one or more of the following parameters, for both pre- and post-flashover conditions:

- Fire growth rate
- Fire load energy density
- Peak heat release rate
- Species production
- Heat flux
- time

There is inherent uncertainty associated with each of these variables, which in turn results in uncertainty in the result of any engineering calculations that are undertaken. One option for dealing with these uncertainties would be to have inbuilt conservative assumptions to characterise the fire. An alternative option would be to use best estimates for each parameter and then apply a factor of safety at the end of the deterministic calculation procedure.

The engineering focus of the research project is probabilistic simulation techniques, which differs from the purely deterministic focus of the framework. However, there are strong linkages between the research project and the framework.

The ultimate output from the research will be a design tool for fire engineering practitioners to use. The tool will have the capability to fully encapsulate the fire scenarios and the acceptance criteria that form the backbone of the framework. The design tool will therefore deal with the engineering calculation procedures implicit in the framework, by providing deterministic results where required by the user but still giving the option of more sophisticated probabilistic results where the situation demands.

3.4 Practitioner Licensing

Another issue facing the fire safety engineering community in New Zealand is that fire engineering practitioners do not currently need to be licensed. Although registration through the engineering institute in the discipline of fire engineering, and other competency assessment measures, are available, this is purely voluntary. There is no mandatory requirement for fire safety engineers to be registered. It is entirely at the discretion of a BCA when reviewing a *Building Consent* application whether they accept fire engineering designs from registered or non-registered practitioners.

The DBH is in the process of introducing new practitioner licensing requirements which covers part of the field of fire safety engineering.

4.0 FIRE MODELLING

The widespread use of fire modelling is one of the areas of inconsistency identified in the practice of fire safety engineering in New Zealand. Generally fire modelling will be in the context of an *Alternative Solution*, where the designer will need to provide supporting evidence to the BCA in support of a *Building Consent* application [2]. A considerable number of fire computer models are available to the practitioner which cover a range of different applications – a summary is given by Olenick and Carpenter [13].

Karlsson and Quintiere [14] describe in detail the five generic stages of the development of a fire in an enclosure – namely ignition, growth (pre-flashover), flashover, fully developed and decay. In relation to these stages of development, models that simulate the fire growth stage are of most interest. Models will generally require the user to input a ‘design fire’ for the pre-flashover stage, usually in the form of a heat release rate time history. Considerable experience and engineering judgement is required in this regard. This aspect was one of a number identified as lacking consistency in practice amongst fire safety engineers, and yet the outputs from fire models are generally very sensitive to the design fire input. These issues are being addressed by both the DBH Fire Safety Design Framework as well as the research project described in this paper.

As noted by Beard [15], there are generally two types of models: probabilistic and deterministic. Walton *et al*. [16] note that probabilistic (also known as stochastic) models generally "treat fire growth as a series of sequential events or states". Mathematical models are used to determine the transition from one stage to another over a series of discrete stages of the fire, each with associated probabilities being assigned. While probabilistic models are desirable for dealing with reality, Beard [15] indicates that probability distributions for input variables are difficult to define. A full description of probabilistic (stochastic) models is given by Ramachandran [17].

Deterministic models get their name from the fact that a given set of input parameters give rise to a determinate set of output values [2]. These computational models used to analyse compartment fires can be further classified as either being zone or field models. A description of the most commonly used type of field model for enclosure fires, known as computational fluid dynamics (CFD) models, can be found in the literature [18]. The primary focus of this research project is zone modelling. The idealised situation shown in Figure 1 gives rise to the computer model most commonly used for fire safety engineering, the two-zone deterministic fire model, of which BRANZFIRE [19, 20] is an example. Walton *et al*. [16] note that zone models solve equations for conservation of mass and energy in two discrete and relatively large control volumes (zones) and they generally also include sub models for various transport and combustion processes.

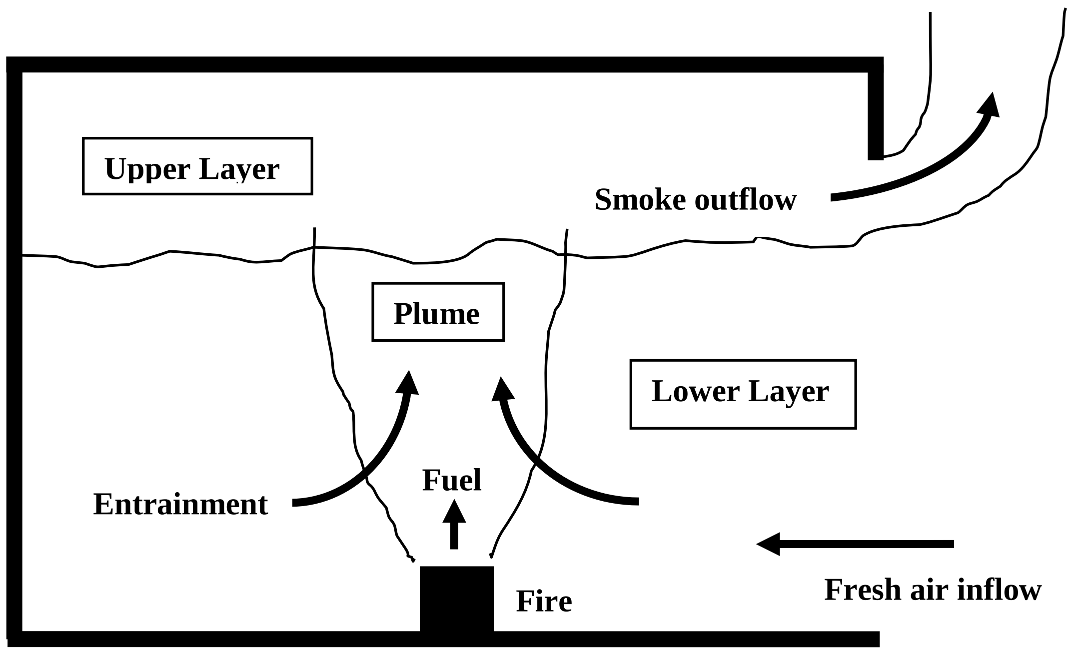

Figure 1. Two-layer Zone Model Stratification

The first control volume consists of the gases in the upper layer and the fire plume, while the second control volume consists of all the remaining gas in the enclosure. The upper and lower control volumes are idealised as being homogeneous such that temperature and species mass concentration are spatially uniform but can vary with time, and conservation of mass, species and energy are all assumed to occur. For each control volume, two mass and energy equations result, from which the temperature of each control volume is calculated, as well as the interface height and compartment pressure. The ideal gas law is used to calculate densities. The solution process is then completed by the relevant “source” and “transport” terms being included, either based on the layer properties or other appropriate variables [14, 21].

5.0 RESEARCH PROJECT

This research project will produce a computer design tool that fire safety engineers will be able to use to help demonstrate compliance with risk-informed statements of building fire safety performance. The model will be a combination of a deterministic two-layer zone model but with key input parameters dealt with in a probabilistic manner such that model outputs give a better indication of the associated variability and uncertainty.

This research project will contribute to the fire safety of New Zealanders, due to fires in buildings, by ensuring that buildings are better designed to provide a level of risk that meets societal expectations. The project will therefore contribute to achieving better social outcomes, but will also have associated economic and environmental benefits.

The project has a number of discrete components as follows:

1. Fire properties database
2. Residential fire scenario and occupancy characterisation
3. Item-to-item fire spread sub model
4. Design fire generator
5. Reliability of fire safety features
6. Fire model integration
7. Fire scenario and occupancy characterisation for other occupancies
8. Validation and testing of new tool
9. Documentation
10. Industry engagement and technology transfer

5.1 Fire Properties Database

The technical objective of this part of the project was to design a new fire test Data Base Management System which was built to overcome the limitations of existing systems. One important aspect of the functionality was data reduction algorithms. This therefore provides more efficient access for practitioners to usable fire engineering data required by analysis procedures.

This component of the project was completed in 2008 with the publication of a Master's thesis entitled "Data Structures and Reduction Techniques for Fire Tests".

Subsequent to this work, the fire database structure within the BRANZFIRE model has now been modified to accommodate additional input parameters that will be required for the item-to-item fire spread model.

5.2 Residential Fire Scenario and Occupancy Characterisation

The objective of this component of the overall research project is to characterise typical residential fire scenarios in a format suitable for modelling purposes. The four ongoing items of work in this area are; continuing to populate the item fire properties database, summary reports on New Zealand residential fire incident data, development of a methodology for populating building spaces with fuel items suitable for modelling, and programming interfaces between BRANZFIRE and the database. This segment of work is scheduled for completion by the end of the 2009 calendar year. A paper on this topic has been accepted for presentation at the upcoming 8th International Conference on Performance-Based Codes and Fire Safety Design Methods and two technical reports are currently being written.

5.3 Item-to-Item Fire Spread Sub Model

The objective of this part of the project is to develop a simple sub model, for inclusion in the enhanced version of BRANZFIRE via the Design Fire Generator (refer to sub-section 5.4). The sub model will calculate when secondary fuel items in a fire modelling compartment will ignite.

The purpose of this sub model is to enable investigation of the potential range of realistic fire growth patterns within a given space, given different potential ignition sources and locations, and the proximity of the first item ignited to other items within a room.

The first iteration of the item-to-item sub model has been completed and the first of two technical papers on this aspect of the project has been submitted to an international scientific journal for publication, the second of which will be submitted later in 2009. A series of flame radiation experiments is currently being conducted which will inform the sub model enhancement exercise as part of sub-section 5.6. A Master's thesis associated with this latter aspect is expected to be published in early 2010.

5.4 Design Fire Generator

The intention with this part of the project is to develop a semi-automated mechanism for providing probabilistic design fire input (the so-called Design Fire Generator) to the enhanced BRANZFIRE. The conversion of the existing BRANZFIRE code to the current version of Visual Basic has been completed, the selection of suitable simulation techniques is in progress. Work is currently in progress to identify probability distributions for the major species production parameters required and an associated Master's thesis is expected to be complete by late 2009/early 2010. Work will also be starting shortly to develop probability distributions for fuel item variables and the first iteration of the Design Fire Generator is scheduled for completion by late 2010.

5.5 Reliability of Fire Safety Features

This component of the research project will investigate the reliability of fire safety features such as passive fire protection systems, smoke management systems and active fire safety features (e.g. sprinklers and detectors). The research into passive fire protection [12] previously discussed will provide input into this aspect of the project. This section of work is currently scheduled for completion by the end of the 2010 calendar year.

5.6 Fire Model Integration

This segment of work integrates the Design Fire Generator, simulation procedures and system reliability parameters into the BRANZFIRE software to create the first version of the enhanced probabilistic tool and will include work on pre- and post-processing of data as well as optimisation. Included in this package of work will be enhancement of the first iteration of both the item-to-item sub model and Design Fire Generator. This phase of the project is underway with initial trials of probability distributions for input parameters and data sampling procedures coded into BRANZFIRE which are producing model outputs in the form of cumulative distribution functions. This part of the project is programmed to be complete by the end of the 2011 calendar year.

5.7 Fire Scenario and Occupancy Characterisation – Other Occupancies

This is essentially a repeat of sub-section 5.2, but for commercial buildings such as offices, retail spaces and car park facilities. This phase of the project is scheduled to commence at the start of the 2010 calendar year and be completed within that 12 month period.

5.8 Validation and Testing of New Tool

During 2011, and in parallel with the integration stage described in sub-section 5.6, the new tool will undergo a programme of validation and testing as required.

5.9 Documentation

A comprehensive set of documentation will be prepared during the second half of the 2011 and first half of the 2012 calendar years.

5.10 Industry Engagement and Technology Transfer

A number of presentations were made by project team members at the 7th International Conference on Performance-Based Codes and Fire Safety Design Methods, held in Auckland, New Zealand in April 2008. As previously mentioned in sub-section 5.2, a paper on the characterisation of fire scenarios will be presented at the 8th International Conference on Performance-Based Codes and Fire Safety Design Methods, being held in Sweden in June 2010. A second paper based on the research into passive fire protection [12] and associated with this project is also being presented at the same conference.

Project team members have, and will continue to, attend all related meetings of ISO TC92 SC4 Fire Safety over the duration of the project.

A number of theses, technical reports and journal articles will be published and conference presentations will occur during the course of the project.

Progress of, and findings from, the project are publicised on a regular basis through various communications channels to practitioners in the fire protection industry in both New Zealand and further afield.

6.0 SUMMARY

This paper has presented details of a collaborative research project between BRANZ and the University of Canterbury which was prompted by pending changes in the fire safety regulatory regime in New Zealand as well as a desire to contribute to improvements in the consistency of the practice of fire safety engineering in New Zealand. The paper has provided background information including a summary of the performance-based regulatory environment in New Zealand and details about the research project and progress to date. The five year research project commenced in October 2007 and is scheduled for completion in June 2012. The major output from the project will be an enhanced probabilistic version of the zone modelling software BRANZFIRE.

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