FiRECAM<TM> Property Loss Model (PLMD)

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ABSTRACT

This report describes the Property Loss Model of the NFL risk-cost assessment model FiRECAM™. The Property Loss Model is used to calculate the expected fire losses in a building from heat, smoke and water for each fire scenario. The expected losses include both damages to the building and damages to building contents.

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FiRECAM™ Property Loss Model (PLMD)

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1. INTRODUCTION

The Property Loss Model (PLMD) is used to calculate the expected losses from a fire in a building. The expected losses are based on the probabilities of fire spread and smoke spread, as well as the capital building costs and the cost of the building contents. This calculation is done for each fire scenario that may occur in the building.

The expected losses from each scenario are then used by the Fire Cost Expectation Model [1] which combines the results of all scenarios to calculate the Fire Cost Expectation.

In this report, a number of terms, listed below, are used in a context slightly different than the definitions given in the National Building Code of Canada [3] (NBCC) and the National Fire Code of Canada [4].

Compartment is used to define an enclosed space which contains combustible materials and has well defined boundaries and openings for ventilation and smoke spread. A compartment in this submodel does not necessarily have fire-rated boundaries, as is defined in the NBCC [3].

Floor assembly is used to define the construction comprising the lower surface of a compartment, which may or may not be fire-rated.

Floor in the context of this submodel means a storey as defined in the NBCC [3], i.e. that portion of a building which is situated between the top surface of a floor assembly and the top surface of the floor assembly next above it, and if there is no floor above it, that portion between the top surface of such a floor assembly and the top surface of the ceiling above it.

Floor area in this submodel is the greatest horizontal area on any one floor within the outside surfaces of the exterior walls.

2. PROPERTY LOSS MODEL SUMMARY SHEET

Table 1: FiRECAM™ Model Summary Sheet for Residential and Office Buildings

Submodel	Property Loss Model
Objectives	To calculate the expected fire losses to the building and its contents for each fire scenario considered by FiRECAM™.
Methodology	To calculate the fire losses, the PLMD uses the probabilities of smoke spread and fire spread, computed by the smoke movement model and the fire spread model, respectively. Damages from heat, water and smoke are assumed to be proportional to these probabilities, hence, the expected losses are obtained by multiplying these probabilities by the building costs and the contents costs.
Main input	Scenario characteristics Building layout characteristics Probabilities of fire and smoke spread Sensitivity of contents to damage Probabilities of damage Value of contents Building capital costs
Main output	Expected losses from damages to building Expected losses from damages to contents

3. DESCRIPTION OF MODEL

3.1 Major Assumptions

This section includes a list of the major assumptions which are used in the formulation of the model:

- All compartments on a particular level are the same (dimensions, contents, etc.).
- Building components all have an equal probability of damage due to a particular fire type and damage type.
- Contents components in a compartment all have an equal probability of damage due to a particular fire type and damage type.
- Damage to building and contents can occur as a result of exposure to any combination of smoke, heat and water.
- All compartments on a given floor, excluding the compartment of fire origin, have an equal probability that smoke or fire will spread to that compartment.
- The probability that water will be present at any location in the building is equal to the probability that fire will spread to that location.
- The probability that excessive heat will be present at any location in the building is equal to the probability that fire will spread to that location.
- The probability that smoke and fire will spread to a compartment on the floor of fire origin is the same for all compartments on that floor excluding the compartment of fire origin.

3.2 Model Formulation

This section describes the methodology used to calculate the costs associated with a fire scenario.

3.2.1 Probability of Damage to a Single Component

The probability that a building element will be damaged by heat, smoke or water, given that a scenario occurs, is evaluated as follows:

$$P(SD_{heat}|scen) = P(SD|FT,heat) * P(FS|scen) \quad (1)$$

$$P(SD_{smk}|scen) = P(SD|FT,smk) * P(SS|scen) \quad (2)$$

$$P(SD_{H2O}|scen) = P(SD|FT,H_2O) * P(FS|scen) \quad (3)$$

where:

$P(SD_{heat}\|scen)$	is the probability of building element damage due to heat given that scenario, scen, occurs
$P(SD_{smk}\|scen)$	is the probability of building element damage due to smoke given that scenario, scen, occurs
$P(SD_{H2O}\|scen)$	is the probability of building element damage due to water given that scenario, scen, occurs
$P(SD\|FT,heat)$	is the probability a building element will be damaged in a scenario with fire type FT (either flashover, flaming or smouldering) if excessive heat is present (see Table 2 for these probabilities)
$P(SD\|FT,smk)$	is the probability a building element will be damaged in a scenario with fire type FT if smoke is present (Table 2)
$P(SD\|FT,H2O)$	is the probability a building element will be damaged in a scenario with fire type FT if water is present (Table 2)
$P(FS\|scen)$	is the probability that fire will spread to the location of interest given scenario, scen, occurs
$P(SS\|scen)$	is the probability that smoke will spread to the location of the building element given scenario, scen, occurs.

The probabilities of damage to the contents are computed following an approach similar to the probabilities of building damage:

$$P(CD_{heat}|scen) = P(CD|FT,heat) * P(FS|scen) \quad (4)$$

$$P(CD_{smk}|scen) = P(CD|FT,smk) * P(SS|scen) \quad (5)$$

$$P(CD_{H2O}|scen) = P(CD|FT,H_2O) * P(FS|scen) \quad (6)$$

where the replacement of SD by CD indicates that the probabilities refer to the contents rather than the building elements.

The probability that a component is damaged, given that a particular scenario occurs, can be obtained by adding the probabilities of damage by heat, smoke and water:

$$P(SD|scen) = P(SD_{H2O}|scen \cup SD_{heat}|scen \cup SD_{smk}|scen) \quad (8)$$

$$P(CD|scen) = P(CD_{H2O}|scen \cup CD_{heat}|scen \cup CD_{smk}|scen) \quad (9)$$

where the probabilistic AND of three events A, B and C is defined as:

$$P(A \cup B \cup C) = P(A) + P(B) + P(C) - P(A)P(B) - P(B)P(C) - P(A)P(C) + P(A)P(B)P(C) \quad (10)$$

3.2.2 Cost of Damage for a Particular Location

Using the assumptions of equal probabilities of smoke and fire spread to all components in a compartment, the probability of damage at a particular location, $P(SD|scen)_{location}$, is calculated, where location is a particular compartment. The cost of damage for a particular location is then computed using the probabilities of building element and contents damage, and the cost of the building elements and contents as follows:

$$(\text{Cost of building damage given scenario})_{location} = P(SD|scen)_{location} * \text{Cost of Building}_{location} \quad (11)$$

And similarly for the costs of contents damage:

$$(\text{Cost of contents damage given scenario})_{location} = P(CD|scen)_{location} * \text{Cost of Contents}_{location} \quad (12)$$

3.2.3 Cost of Damage for a Particular Scenario

To calculate the total cost of a fire scenario, the following procedure is used:

1. Evaluate P(SD|scen) and P(CD|scen) for each of the non fire origin floors in the building using the smoke spread and flame spread probabilities and the probabilities of damage.
2. Determine the Cost of Contents and Cost of Building for each of the non fire origin floors in the building.
3. Evaluate P(SD|scen), P(CD|scen) and the costs for the compartment of fire origin.
4. Evaluate P(SD|scen), P(CD|scen) and costs for the remainder of the floor of fire origin.
5. Determine the losses as in Section 3.2.2 for the locations in steps 2 to 4.
6. Summing these losses, the costs of fire-related damage due to this scenario is obtained.

4. MODEL INPUTS

4.1 Scenario Characteristics

To calculate the expected fire losses for each scenario, the model requires the following scenario characteristics:

- Fire type (flashover, flaming - non flashover, or smouldering)
- Compartment door state (open or closed)

4.2 Building Layout Characteristics

The following are characteristics of the building design which are required to calculate both the costs of building and contents damages:

- Number of floors
- Occupancy type (apartment or office)
- Dimensions of compartment of fire origin

For each floor:

- Floor concept (open, divided or hybrid)
- Number of compartments
- Total floor area
- Total corridor area

4.3 Probabilities of Fire and Smoke Spread

The outputs of the Fire Spread and Smoke Movement submodels of FiRECAM™ are used within the PLMD to indicate the probabilities that fire or smoke will be present at different locations in the building, so that the probability of damage to building and contents components can be calculated. The following probabilities from the fire spread and smoke spread models are used:

- Probabilities of fire spread from the compartment of fire origin to other compartments on the floor of fire origin and to compartments on other floors, for the scenario of interest (flashover fire, doors closed, etc.)
- Probabilities that smoke will be present for the scenario of interest in the compartment of fire origin, in other compartments on the floor of fire origin, and in compartments on the other floors.
- Probabilities that smoke will spread for the scenario of interest from the compartment of fire origin to the corridor on the floor of fire origin and to the corridors on other floors.

4.4 Sensitivities of Contents to Damage

The contents in a particular building design can have varying sensitivities to both smoke and water. In order to represent this in FiRECAM™, the following may be specified:

- Sensitivity of contents to damage from water
- Sensitivity of contents to damage from smoke

The user has the option of selecting either a rating of high, medium or low for each of these sensitivities. For example, computer equipment may have a high sensitivity to smoke, and steel cabinets may have a low sensitivity to smoke. Each must be entered for the compartment of fire origin, the remainder of the floor of fire origin, and the other floors. These ratings of high, medium and low have associated values of 0.9, 0.5 and 0.1 respectively.

4.5 Probabilities of Damage

The probabilities that a building element or contents component will be damaged given that a specific fire type occurs (flashover, flaming or smouldering fire) and a damage type is present (water, smoke or heat) are listed in the following tables along with their default values. These default values are input from the FiRECAM™ expert database.

Table 2: Probabilities of Damage to Building

Fire Type	Damage Type	Notation	Probability of Damage
Flashover fire	Heat	P(SD|FO,heat)	1.00
	Smoke	P(SD|FO,smk)	0.25
	Water	P(SD|FO,H_2O)	0.80
Flaming fire	Heat	P(SD|FL,heat)	0.50
	Smoke	P(SD|FL,smk)	0.25
	Water	P(SD|FL,H_2O)	0.40
Smouldering fire	Heat	P(SD|SM,heat)	0.50
	Smoke	P(SD|SM,smk)	0.25
	Water	P(SD|SM,H_2O)	0.00

Table 3: Probabilities of Damage to Contents

Fire Type	Damage Type	Notation	Probability of Damage
Flashover fire	Heat	P(CD|FO,heat)	1.00
	Smoke	P(CD|FO,smk)	Smoke sensitivity
	Water	P(CD|FO,H_2O)	Water sensitivity
Flaming fire	Heat	P(CD|FL,heat)	0.50
	Smoke	P(CD|FL,smk)	Smoke sensitivity
	Water	P(CD|FL,H_2O)	0.00
Smouldering fire	Heat	P(CD|SM,heat)	0.50
	Smoke	P(CD|SM,smk)	Smoke sensitivity
	Water	P(CD|SM,H_2O)	0.00

4.6 Value of Contents

The values of the contents in the following locations are required by PLMD:

- Compartment of fire origin
- Floor of fire origin (excluding compartment of fire origin)
- Other floors

These costs are input from the expert database of FiRECAM™.

4.7 Building Capital Costs

The following costs of the building required by PLMD are computed by the Economic Model [2]:

- Capital cost of compartment of fire origin
- Capital cost of floor of fire origin (excluding compartment of fire origin)
- Capital cost of other floors

5. OUTPUT

The output generated by this sub-model includes all the costs for the occurrence of each scenario. These costs are output for both the building and contents for each of the following scenarios, occurring on each of the floors of the building (fire floor):

- Flashover fire, doors open FL/DO
- Flashover fire, doors closed FL/DC
- Flaming fire, doors open NF/DO
- Flaming fire, doors closed NF/DC
- Smouldering fire, doors open SM/DO
- Smouldering fire, doors closed SM/DC

A typical output screen is displayed in Figure 1 for a 3 storey building. This output is used by the Fire Cost Expectation model of FiRECAM™ [1] to calculate the Fire Cost Expectation for the building.

Plmd

Scenario	Fire Floor	Cost of Structure Loss ($)	Cost of Content Loss ($)
FL/DO	1	$282,192.09	$857,242.31
FL/DO	2	$629,346.50	$1,524,511.25
FL/DO	3	$629,346.75	$1,524,261.00
FL/DC	1	$188,793.44	$375,894.63
FL/DC	2	$604,457.75	$1,363,555.25
FL/DC	3	$604,509.38	$1,363,823.00
NF/DO	1	$17,867.78	$44,772.44
NF/DO	2	$50,474.53	$81,582.41
NF/DO	3	$49,613.31	$77,601.04
NF/DC	1	$10,459.44	$7,512.21
NF/DC	2	$37,977.36	$7,587.81
NF/DC	3	$37,977.36	$7,587.82
SM/DO	1	$138,842.48	$640,836.13
SM/DO	2	$110,792.41	$434,432.00
SM/DO	3	$66,522.60	$223,554.38
SM/DC	1	$12,460.94	$27,853.28
SM/DC	2	$38,014.23	$51,992.22
SM/DC	3	$38,418.82	$54,454.59

Figure 1: PLMD Output

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