A Stochastic Approach to Occupant Pre-Movement in Fires

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Acknowledgements

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  - Paper presented at 8th IAFSS Symposium in Beijing (2005) prepared by Jamie Vistnes, Stephen Grubits and Yaping He
  - Masters Thesis by Jamie Vistnes (2004)

Introduction

- Evaluation of the required safe egress time is an important step
- Required Safe Egress Time (RSET)
  - detection time
  - pre-movement time
  - movement time
- Parameters that affect pre-movement times

Introduction

- Some current pre-movement models reviewed
  - SFPE Handbook
  - Method by Sime
  - CESARE Risk
  - CRISP
  - FIERAsystem
- Findings
  - Limited use of probability distributions
  - Simplistic treatment of actions using discrete values
  - Not accounting for varying abilities within a population

Introduction

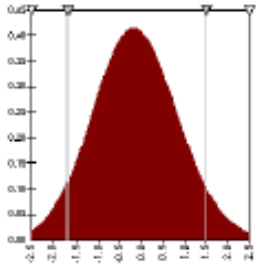
- Objective: To develop an occupant pre-movement model that will adequately consider both the building and occupant characteristics in estimating the likely pre-movement times of occupants in a fire situation
- Improvements on current models
  - More actions
  - Greater variability
  - Stochastic treatment

Methodology

- Stochastic system
  - dynamic system that involves random parameters or parameters that are too complicated to be described by deterministic means
- Parameters of human behaviour have a large degree of uncertainty or randomness
  - Best handled with stochastic methodology

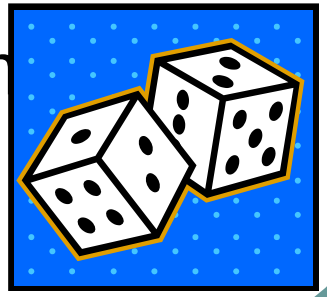
Methodology

- Response Period - Interpretation of the cue as a cause for action
  - time for the interpretation and decision process
- Delay Period - Occupants undertaking a number of actions prior to evacuating.
  - which actions occur
  - how often they occur
  - time the occupant takes to undertake each action
- Occupants have different priorities and varying levels of ability and commitment
  - probabilities of occurrence
  - probability density distribution function



Methodology

- A limited set of actions are defined
- Probability distribution functions for various actions
- A Monte Carlo simulation utilising a Latin hypercube sampling algorithm
  - Divides into regions, values randomly selected within each region
- Microsoft Excel add-in @RISK



Response Time

- Every occupant undertakes this process
- General trend in occupant pre-movement suggests a log-normal distribution
- Mean and standard deviation derived from experimental studies of evacuations and current research (refer to references within paper)
- Dependant on warning system (in current model - bell or sounder or EWIS)

Delay Actions

- The number, type and duration of delay actions may vary from occupant to occupant
- Process:
  - Identification of actions
  - Probability of occurrence
  - Duration
- These will vary as occupants would have different priorities in a fire situation as well as varying levels of ability and commitment

Delay Actions

- Notify others
- Telephoned others
- Collect belongings
- Investigate/search for fire
- Close/open doors/windows
- Rescue
- Call Fire Brigade
- Fight fire
- Inaction
- Shut down equipment
- Got dressed
- Woke up

Delay Action Probability

- Percentage of occupants undertaking certain delay actions based on literature
- Discrete probabilities associated with each delay action derived from percentage undertaking action
- No limits set on the number of delay actions undertaken by an occupant

Delay Action Probability

Table 1. Definitions of delay actions and associated percentages of being undertaken.

ID No.[a]	Delay Action	Description	Delay Time	Total %
1	Notify others	Time to notify other occupants (within immediate area)	Time to travel within immediate area + time to talk or notify	25.3
2	Investigate/ search for fire	Time to search for the fire (within an area familiar to the occupant)	Time to travel within familiar area	12.1
3	Call Fire Brigade	Time to get to phone and call the fire brigade	Time to travel half distance within immediate area + time to talk on phone to fire brigade	32.8
4	Inaction	No active action	Idling time	11.8
5	Collect belongings	Time to travel to belongings and collect	Time to travel within immediate area + time to collect belongings	12.6
6	Telephoned others	Time to get to a phone and call others (such as relatives)	Time to travel half distance within immediate area + time to talk on phone to others	5.1
7	Close/open doors/windows	Time to travel to opening and open or close it	Time to travel within immediate area + time to close or open	9.3
8	Shut down equipment	Time to travel to equipment and shut it down	Time to travel within immediate area + time to shut down	1.5
9	Rescue	Time to travel to occupant & assist rescue	Time to travel within immediate area + time to assist in rescue	12.4
10	Got dressed	Time to put clothes on	Dressing time	48.5
11	Woke up	Time to wake up	Wake up time	3.8

[a] ID number is purely for identification purpose. It does not indicate action sequence.

Delay Action Duration

- Occupant pre-movement time dependant on both building and occupant characteristics
- Building characteristics define travel distances
- Occupant characteristics define travel speed
- Delay action time $t_i = \frac{d_i}{v} + a_i$

a_i = time taken for action i, d_i = travel distance, v = travel speed

eg Call Fire Brigade = Time to travel to phone + time to talk on phone to fire brigade

Delay Action Duration (a_i)

- Estimated times (due to lack of data)

Table 2. Parameters for time constant distributions.

Action ID Number	Delay Action	Mean (s)	Standard Deviation (s)
1	Notify others	10	3
2	Call Fire Brigade	30	9
3	Inaction	60	18
4	Collect belongings	30	9
5	Telephoned others	30	9
6	Close/open doors/windows	5	1.5
7	Shut down equipment	20	6
8	Rescue	30	9
9	Got dressed	60	18
10	Woke up	60	18

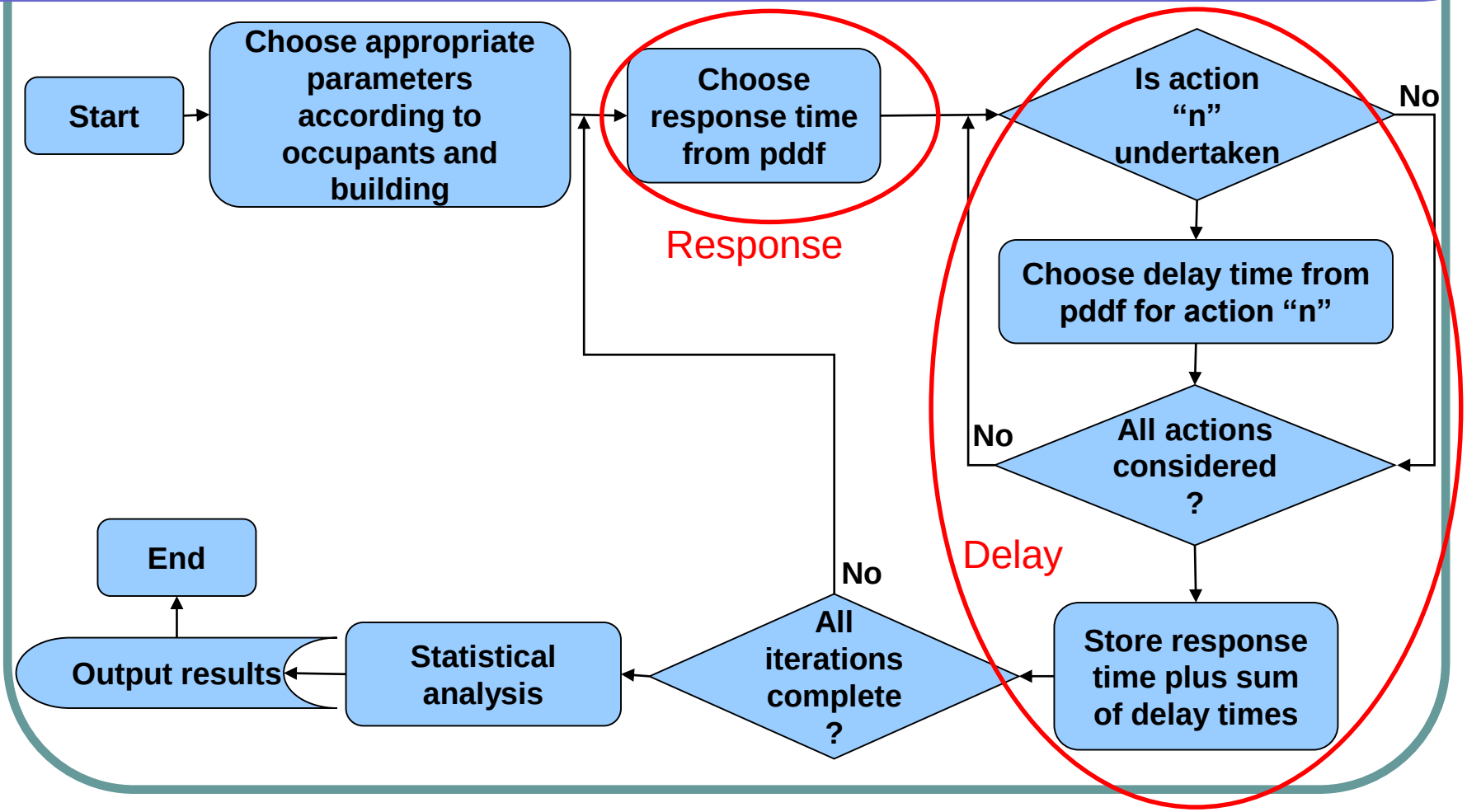
Pre-Movement Time

- Total pre-movement time, t_p

$$t_p = t_r + \sum_{i}^{N} t_i$$

t_r = response time, t_i = delay time for action i

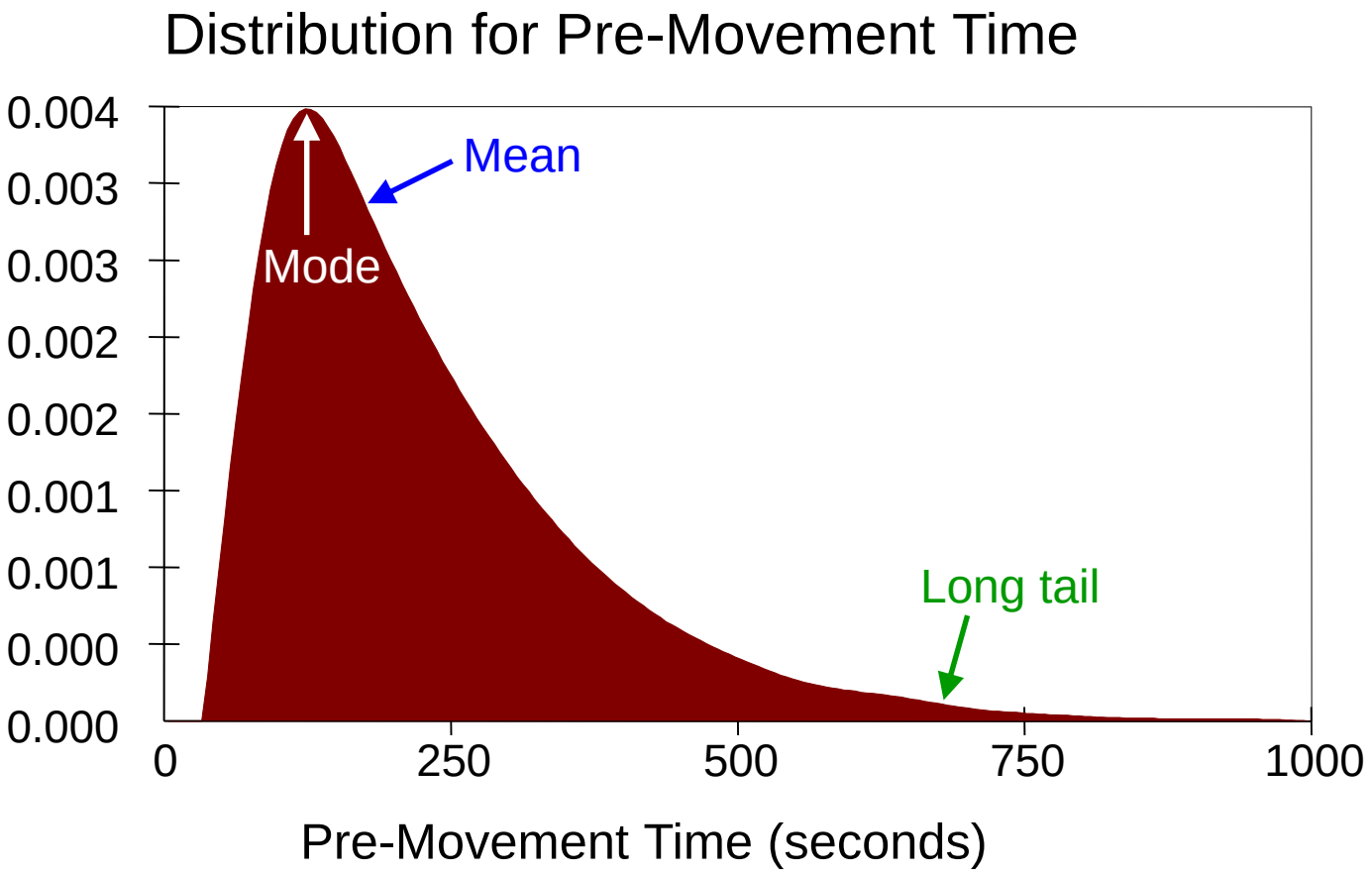
Outline of the Model



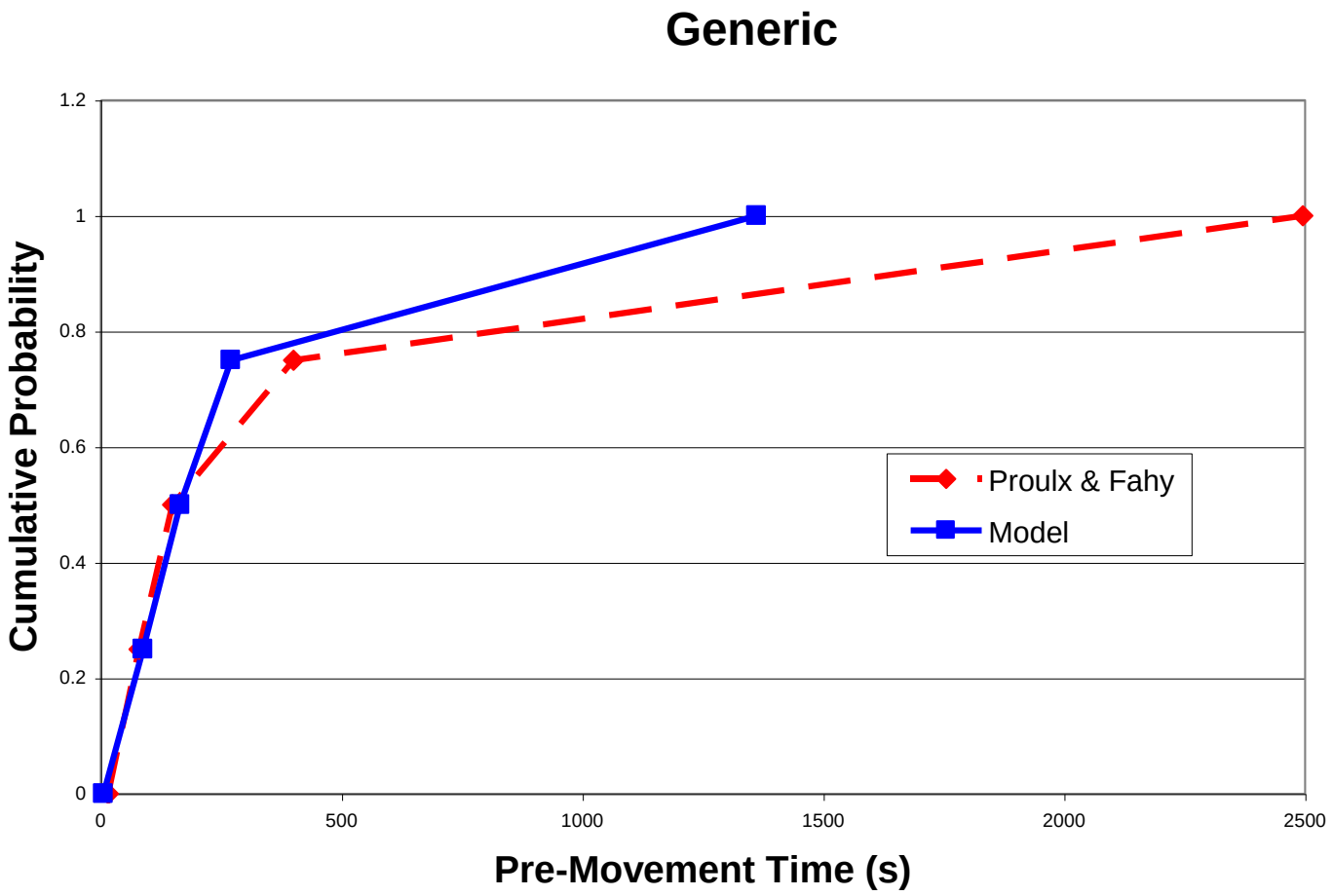
Results

- Results compared to actual research data (Proulx and Fahy)
- Data available for generic and residential occupancies
- To permit comparison of results data analysed to derive cumulative probability distribution function $P(t) = \text{Prob}\{t_p \leq t\}$

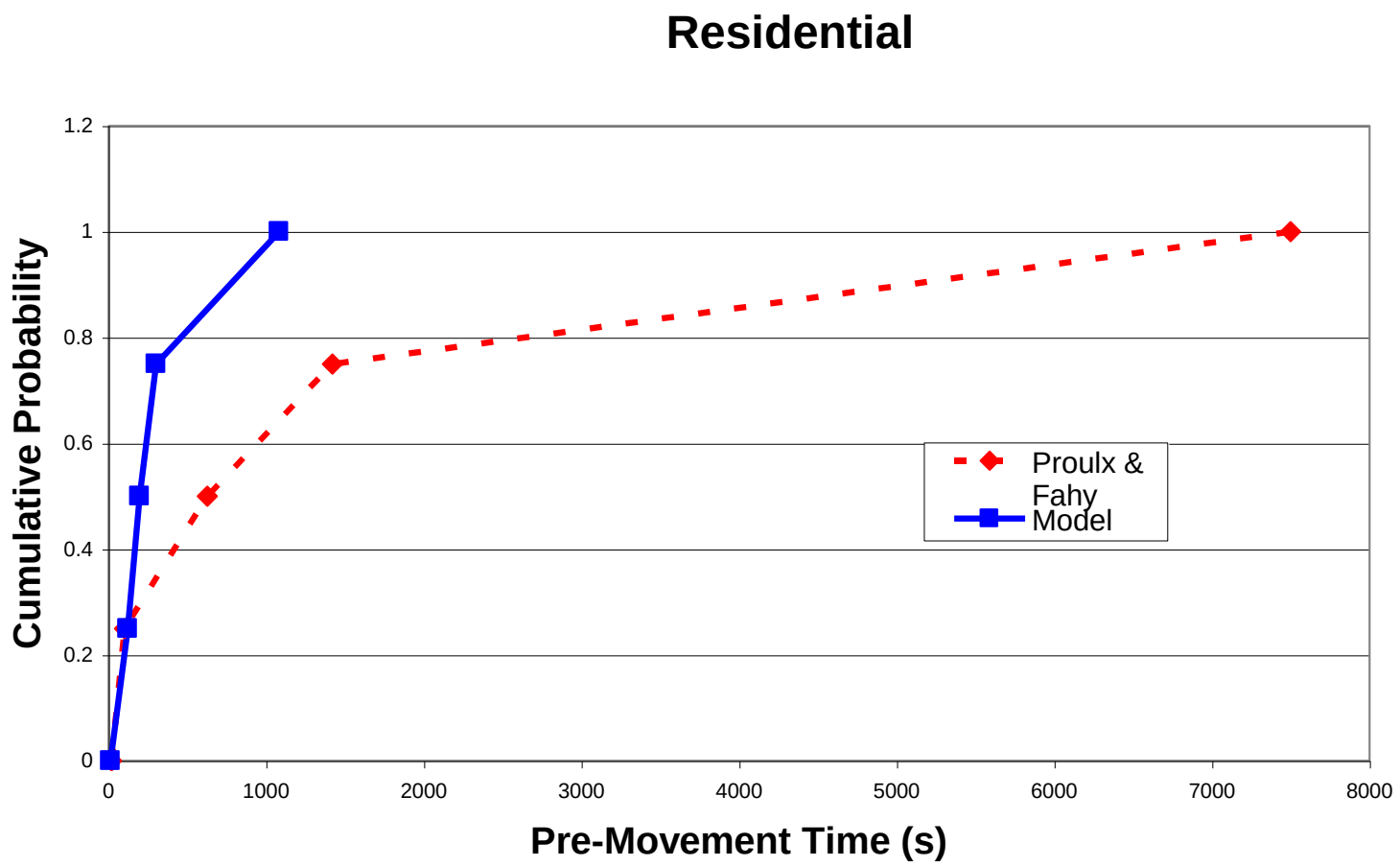
Results


Distribution for Pre-Movement Time
0.004
0.003
0.003
0.002
0.002
0.001
0.001
0.000
0.000
Mean
Mode
Long tail
0
250
500
750
1000
Pre-Movement Time (seconds)

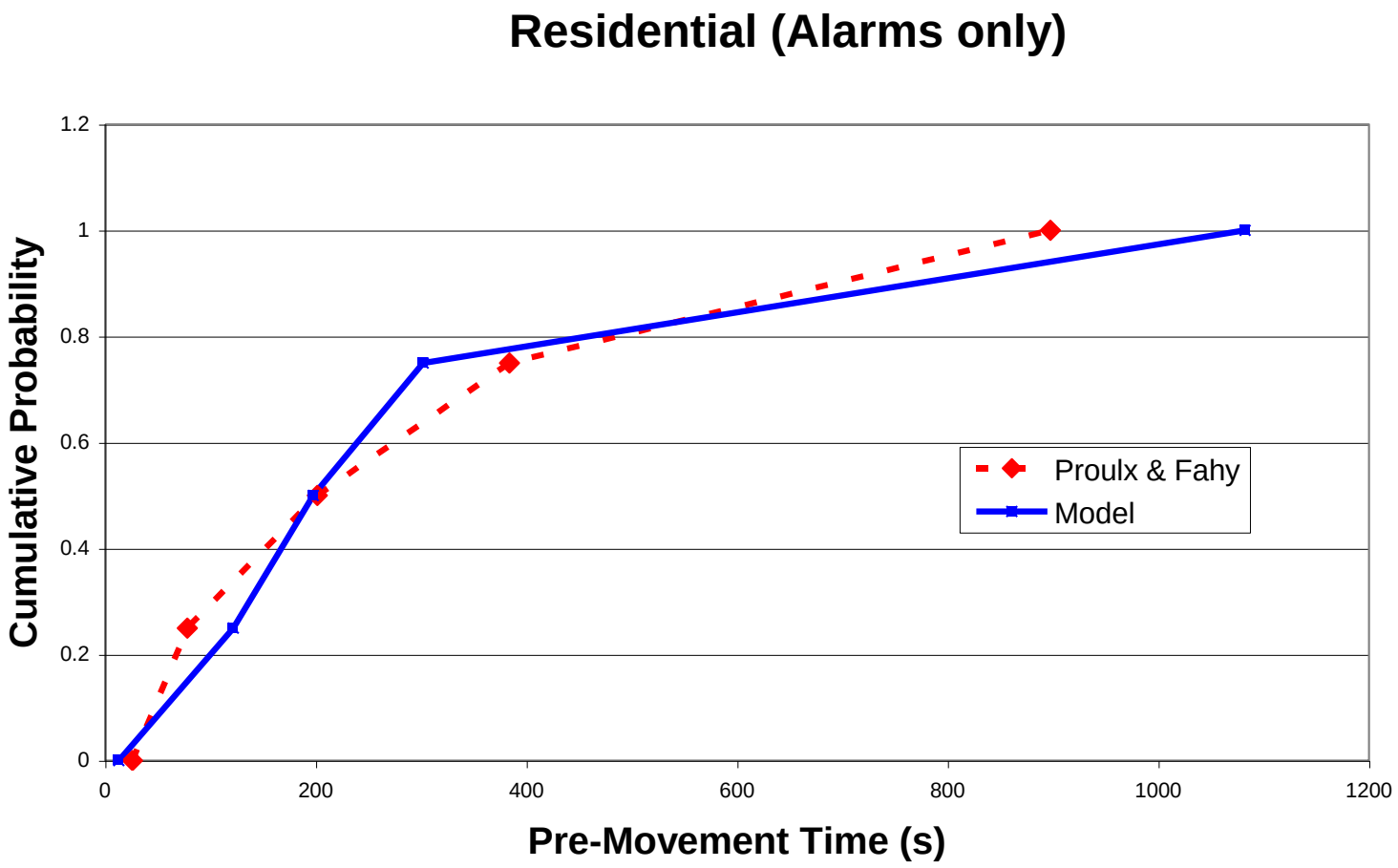
Results


Generic
Cumulative Probability
1.2
1
0.8
0.6
0.4
0.2
0
0
500
1000
1500
2000
2500
Pre-Movement Time (s)
Proulx & Fahy
Model

Results


Residential
Cumulative Probability
1.2
1
0.8
0.6
0.4
0.2
0
0
1000
2000
3000
4000
5000
6000
7000
8000
Pre-Movement Time (s)
Proulx & Fahy Model

Results


Residential (Alarms only)
Cumulative Probability
1.2
1
0.8
0.6
0.4
0.2
0
0
200
400
600
800
1000
1200
Pre-Movement Time (s)
Proulx & Fahy
Model

Sensitivities

- Number of iterations
- Doubling means and standard deviations for time constants
- Regression
- Correlation

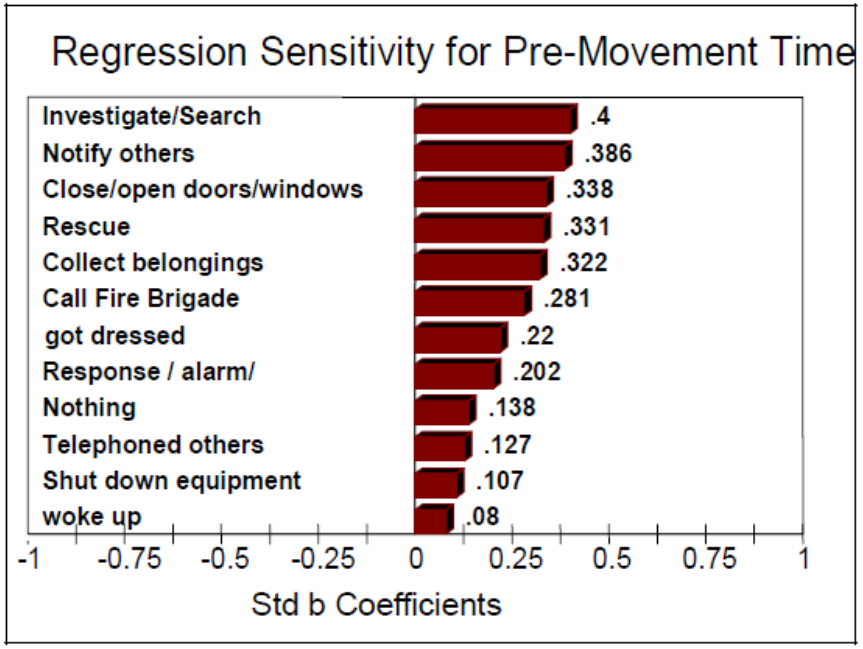


Fig. 5. Regression Sensitivity for Pre-Movement Time (residential).

Conclusions

The Model:

- Building-occupant interaction
- Uncertainties explicitly treated
- Many factors considered
- Covers variation in behaviour
- Good correlation
- Extensible to treat movement time

Conclusions

- Limitations
  - Markovian process – no memory
  - Interactions between individual occupants or occupant groups not considered
  - Data available
- Guides further research
  - Nature and times of delay actions
  - Specific occupancies
  - Outputs would also be useful for input into other probabilistic models