Fire and Evacuation Modeling Technical Conference
(FEMTC) 2014 Gaithersburg, Maryland, September 8-10, 2014

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"DEFINING A CROWD SAFETY FACTOR FOR THE DESIGNS OF ASSEMBLIES"

Rodrigo Machado Tavares, Ph.D.

RMT Fire & Crowd Safety
http://www.rmtengineering.net
http://www.rmt-fire-crowd-safety.com

All the information (i.e., figures, graphs, jornal papers etc.) in this presentation were developed by the presenter.

Some fotos and companies´ logos are available to the public on the internet.

“Travel distances suggested in the prescriptive documents probably might not be considered as a design factor (parameter) for enclosures where the population density can become an issue”

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PERFORMACE

FIRE LOAD (TYPE OF OCCUPANCY)

HUMAN FACTORS

TIME BASED ANALYSIS (instead of “magic numbers”)

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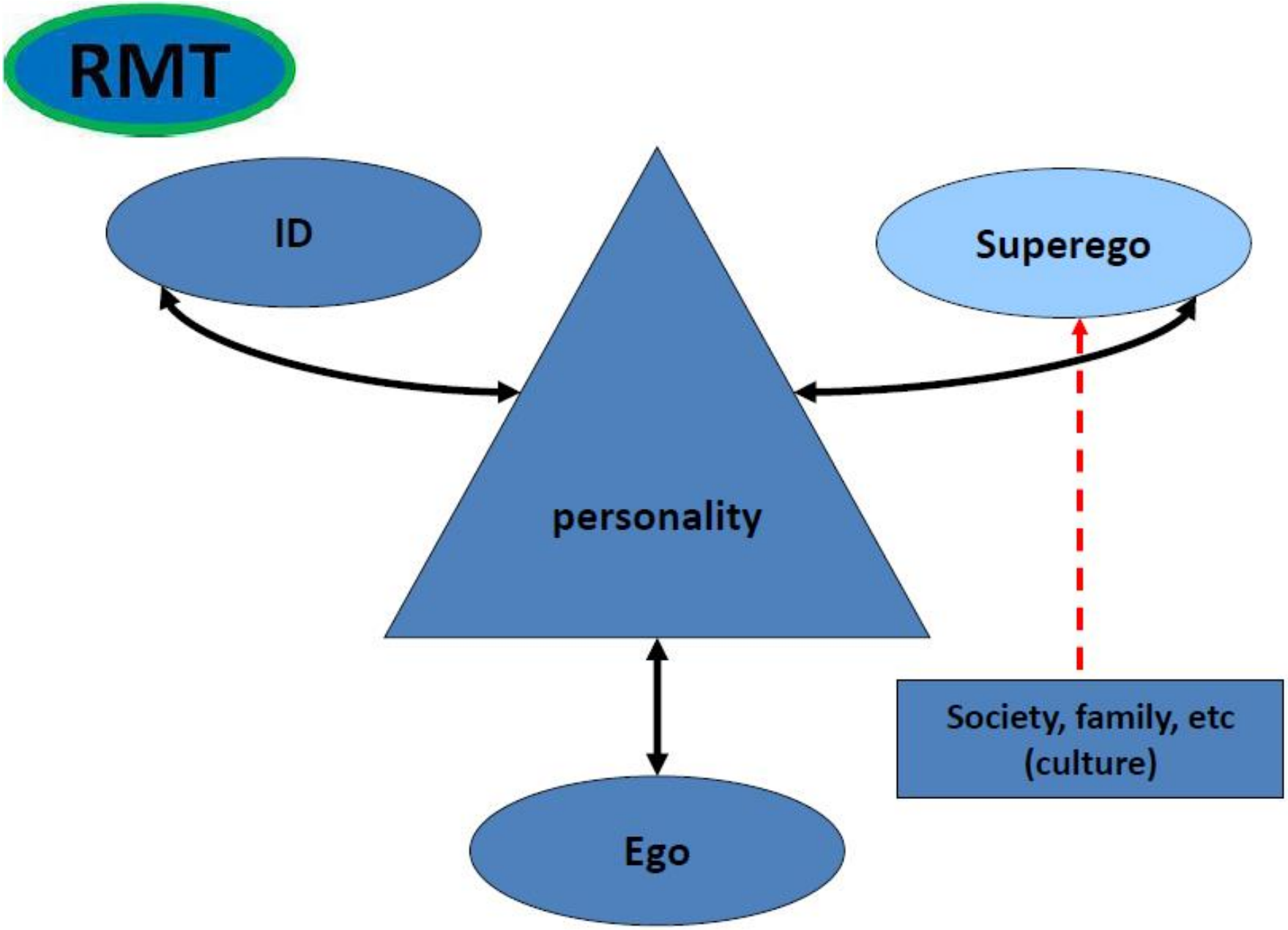
Nightclubs are Complex Environments:

- Tend to be highly dense populated;
- Occupants profile is potentially challenging (i.e., due to the use of alcohol, their mobility as well as their response time can be substantially compromised);
- Different environment (i.e., loud music; darkness; strobe light effect; artificial smoke etc.);
- The architecture is different from a “conventional” building (i.e., “labyrinthic”; subterranean etc.).

Environmental Psychology

"Psychophysics" **Weber–Fechner law**

It attempts to show the relationship between the psychological sensation and the physical intensity of a stimulus


RMT
ID
Superego
personality
Society, family, etc
(culture)
Ego

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Acknowledgments:

- Thunderhead Engineering
http://www.thunderheadeng.com
-Mr. Bryan Klein;

-Mrs. Sara Lynne M-Jones;
-Mr. Philip Richard M-Jones;
-Mr. Samuel George M-Jones.

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Contents:

1) Introduction;
2) People Movement Models;
3) The Scenarios;
4) The Results and Discussion;
5) Concluding Remarks.

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-Fire safety design (AFP & PFP systems; Evacuation Plans etc.);

-Fire Safety Management (FRA etc.).

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The Fire Safety Design => inefficient

AFP & PFP systems were inadequate or non-existent

The Fire Safety Management => inefficient

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SFPE SOCIETY OF FIRE PROTECTION ENGINEERS

Advancing the Science and Practice of Fire Protection Engineering Internationally

NIST

National Institute of Standards and Technology

NFPA

National Fire Protection Association

The authority on fire, electrical, and building safety

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The United Kingdom (England and Wales)

- General approach – Prescriptive solutions

Government guidance: Approved Document B (AD B)

- Performance-based solutions (Fire Safety Engineering - FSE solutions)

BS 7974 with supporting Published Documents (PD´s)

- Advanced approach

BS 9999, a flexible and structured approach to risk-based design based on FSE

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http://www.planningportal.gov.uk/uploads/br/BR_PDF_AD_B2_2013.pdf

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PERFORMANCE-BASED SOLUTIONS (FIRE ENGINEERING SOLUTIONS)

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Fire Safety/Protection Standards bring the minimum level of safety conditions.

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HOW SAFE IS SAFE?

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PERFORMANCE

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"Very likely, many (fire safety) Prescriptive documents are indeed based on the performance of (theoretically) known relations"

Relations:

- Occupant(s)-Built Environment;
- Occupant(s)-Occupant(s);
- Occupants-External Stimuli.

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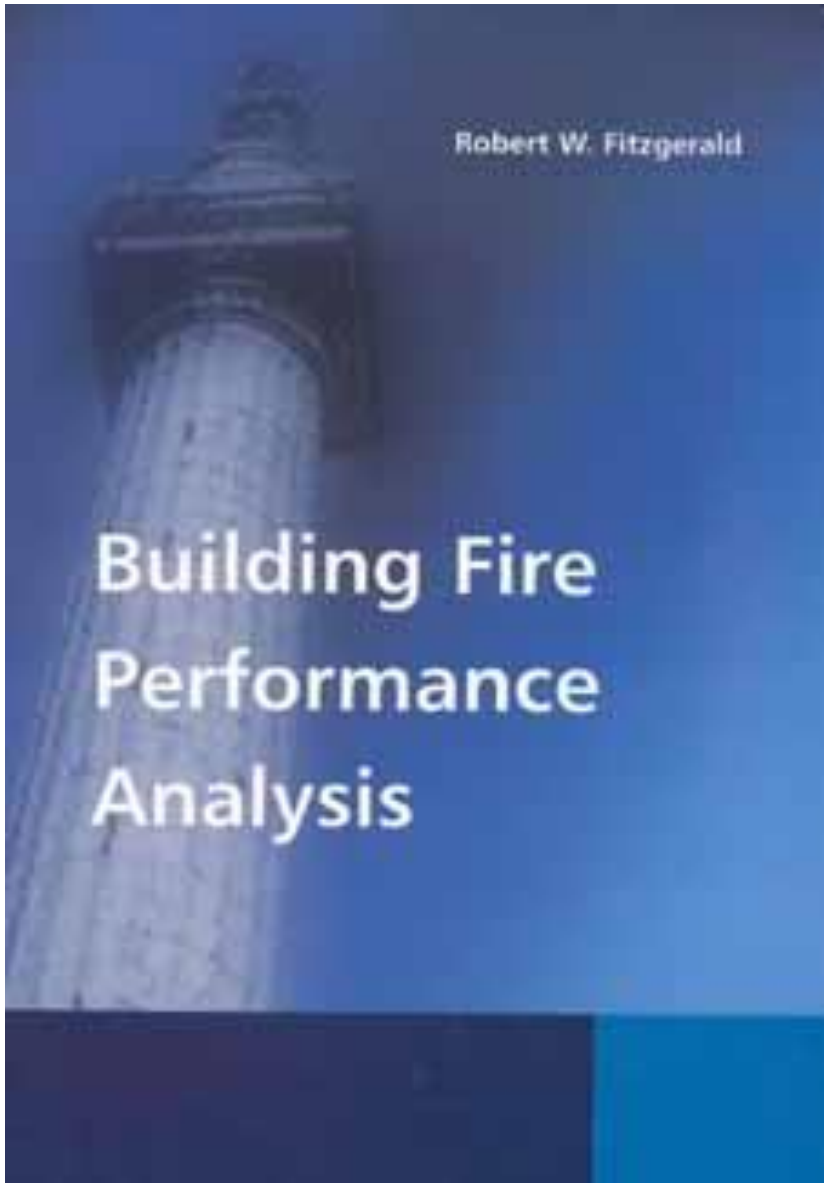


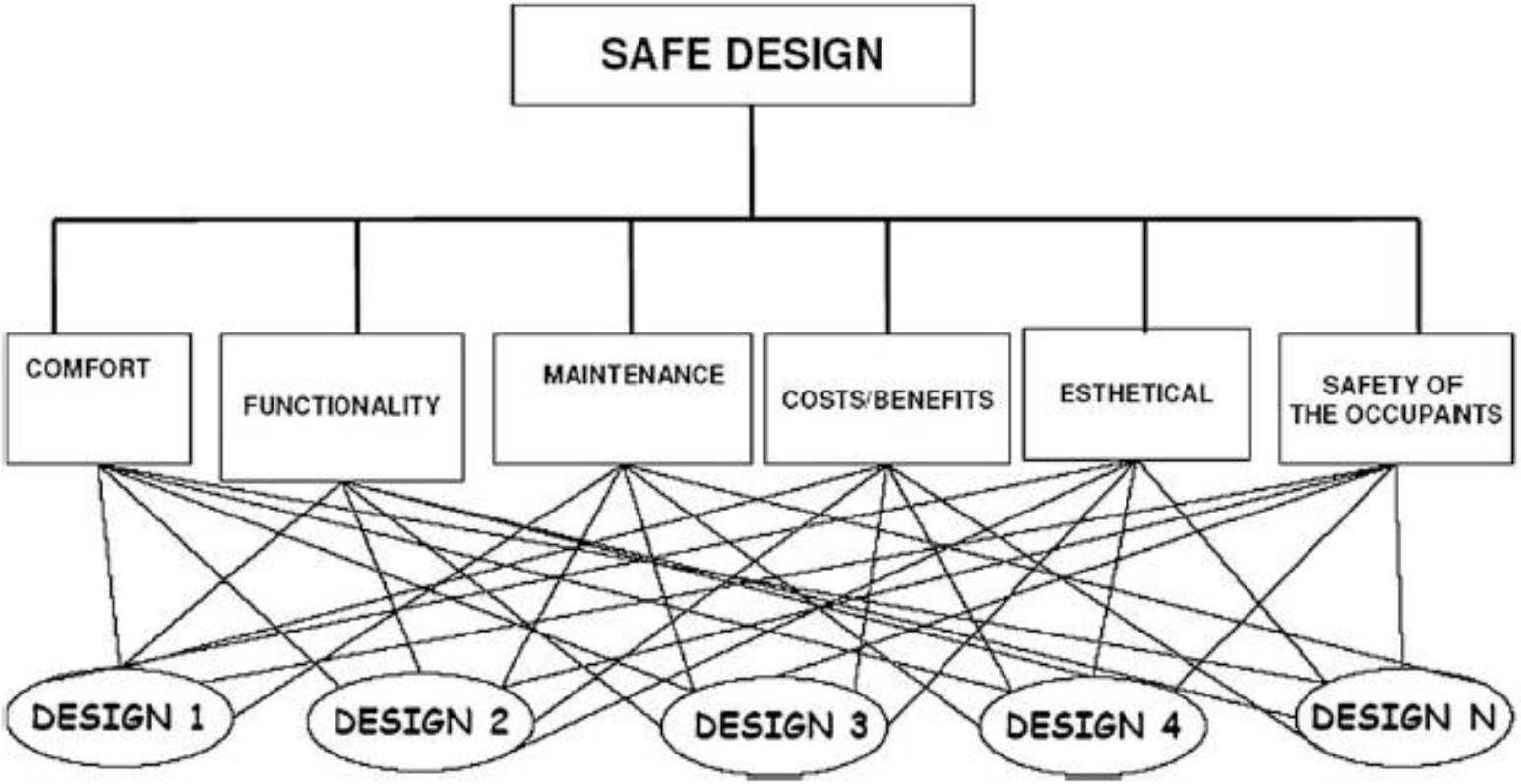
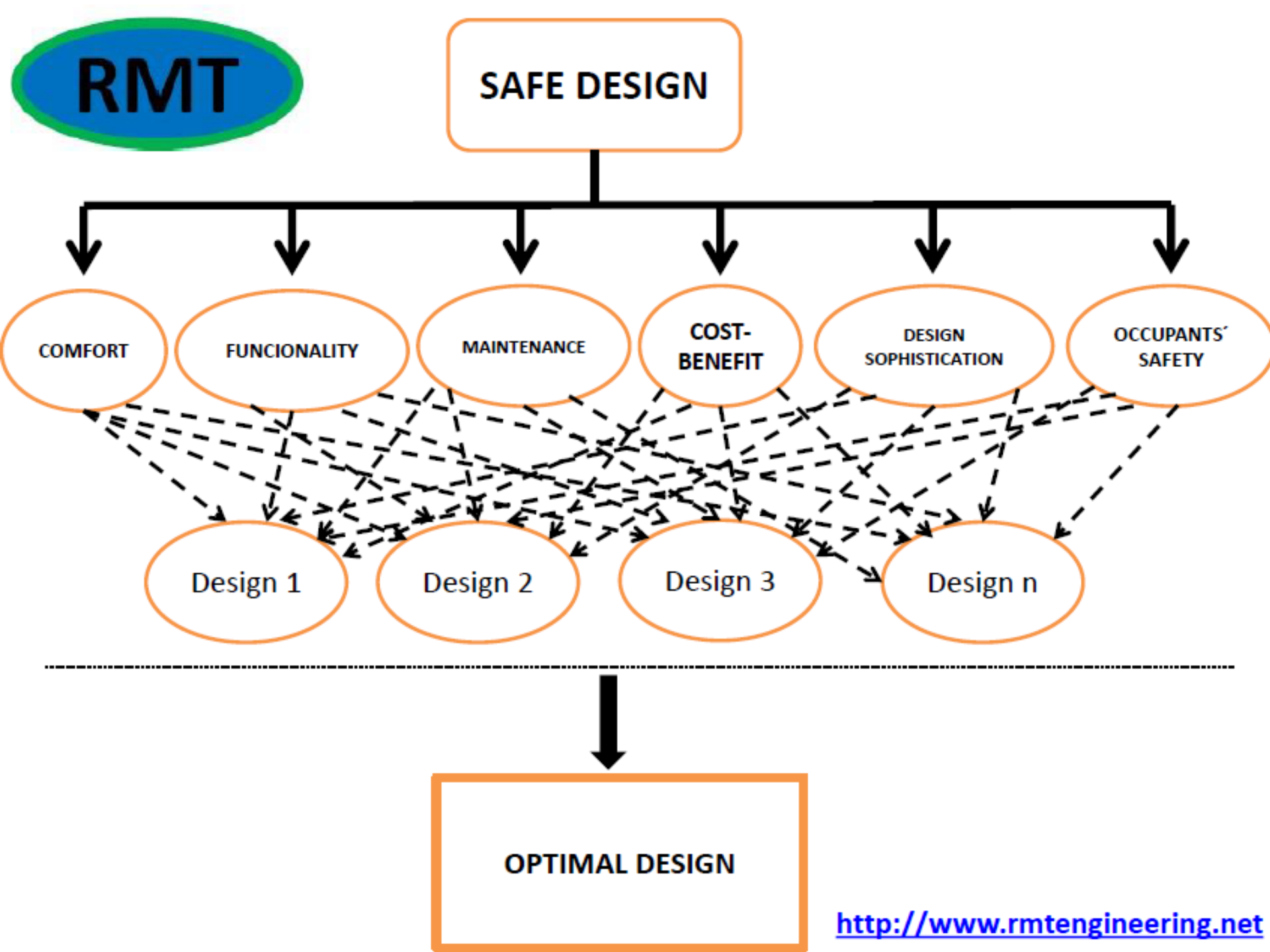


Fig. 4. Defining a safe design taking into account the criteria [1].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SAFE DESIGN
COMFORT
FUNCIONALITY
MAINTENANCE
COST-BENEFIT
DESIGN SOPHISTICATION
OCCUPANTS´ SAFETY
Design 1
Design 2
Design 3
Design n
OPTIMAL DESIGN
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ASET x RSET analysis

TIME = *f* (a , b, c, ... n)

These variables come from the following relatioships:

- "ENVIRONMENT – OCCUPANT"

- "OCCUPANT – OCCUPANT"

- "OCCUPANT – EXTERNAL STIMULI"

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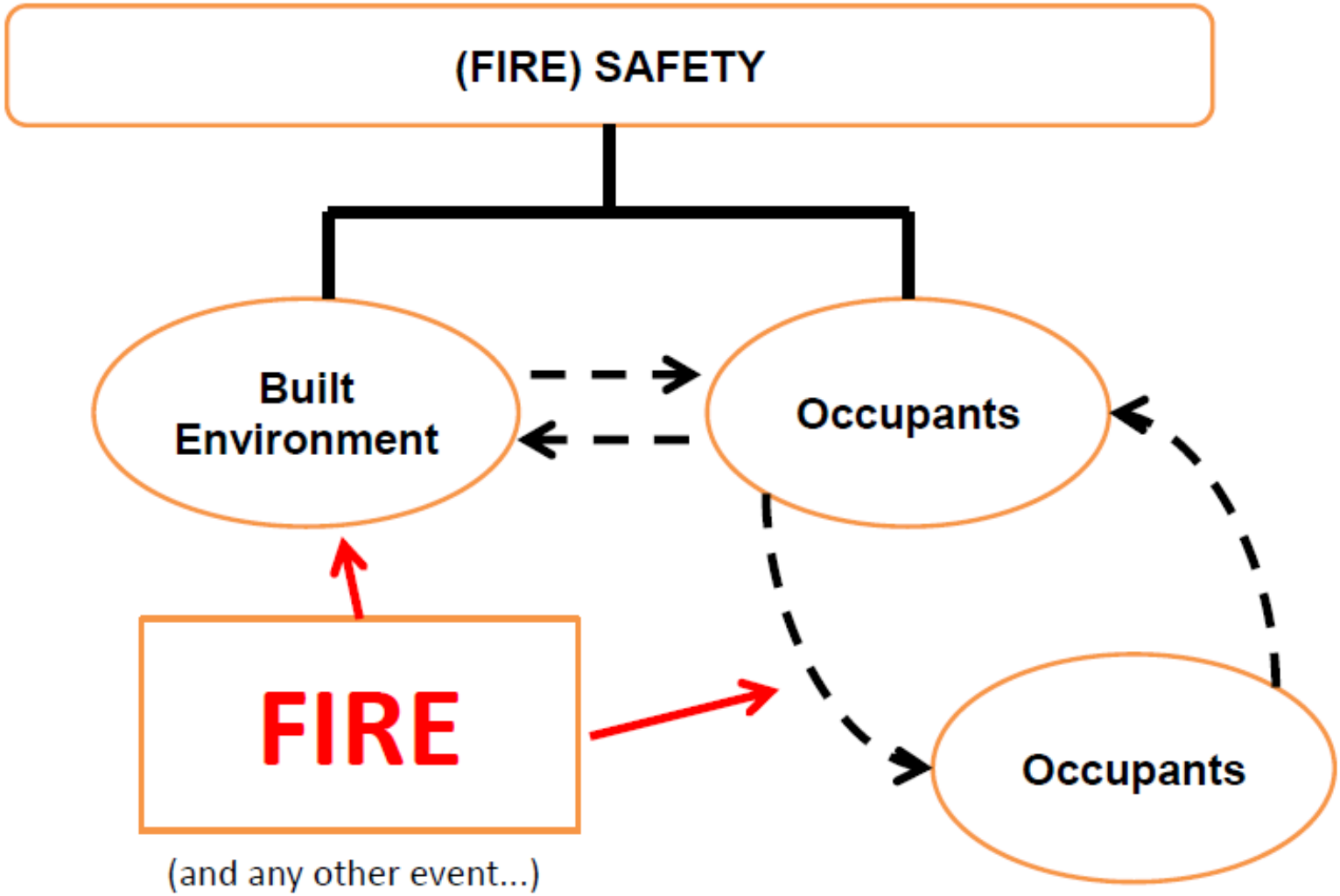

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FIRE LOAD (TYPE OF OCCUPANCY)

HUMAN FACTORS

TIME BASED ANALYSIS (instead of “magic numbers”)

Safety Science 48 (2010) 1242–1247

Contents lists available at ScienceDirect

Safety Science

journal homepage: www.elsevier.com/locate/ssci

Design for horizontal escape in buildings: The use of the relative distance between exits as an alternative approach to the maximum travel distance

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ABSTRACT

In the UK, Fire Safety Strategies (FSS) for buildings have been adopting fire engineering solutions to address complex issues. These issues are commonly related to fire, such as: positioning and dimensioning of smoke vent extractors, atria dimensions, etc. Nevertheless, in terms of means of escape, the FSS appear to be attached to a more prescriptive approach. In reality, the principal building regulations document for fire safety in the UK, well known as Approved Document B (AD B), is essentially prescriptive in nature.

Table 1
Limitations on travel distance (Approved Document B (The Building Regulations, 2007)).

Use of the premises of part of the premises	One direction only (m)	Maximum travel distance where travel is possible in more than one direction (m)
Institutional	9	18
Other residential:		
(a) in bedrooms	9	18
(b) in bedroom corridors	9	35
(c) elsewhere	18	35
Office	*18*	*45*
Shop and commercial	18	45
Assembly and recreation:		
(a) buildings primarily for disabled people	9	18
(b) areas with seating in rows	15	32
(c) elsewhere	18	45
Industrial:		
(a) Normal hazard	25	45
(b) Higher hazard	12	25
Storage and other non-residential:		
(a) Normal hazard	25	45
(b) Higher hazard	12	25
Place of special fire hazard	9	18
Plant room or rooftop plant:		
(a) distance within the room	9	35
(b) escape route not in open air (overall travel distance)	18	45
(c) escape route in open air (overall travel distance)	60	100

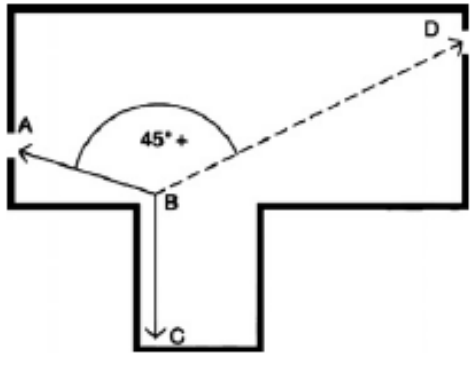

Fig. 1. Travel distance in dead-end condition (Approved Document B (The Building Regulations, 2007)).

- t_{pre}: occupant pre-evacuation time defined as time interval between the warning of fire and the move towards an exit;
- t_{move}: occupant movement time required for occupants to reach a safe place (the exits).

Regarding the t_{move}, this time can also be split into two main sub-times, namely: time spent during the actual movement within the enclosure (tsm) and time spent during the queuing towards the exits areas (tsq). Thus, in summary, t_{move} can be estimated through the simple equation:

$$t_{move} = tsm + tsq \tag{2}$$

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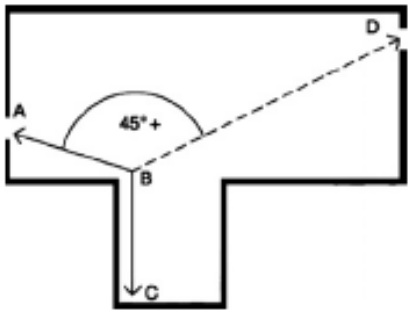

Fig. 1. Travel distance in dead-end condition (Approved Document B (The Building Regulations, 2007)).

3. The relative distance between exits (RDBE)

As mentioned previously, the exits locations do impact the egress efficiency in structures. It was shown, for instance, that for enclosures with two exits of equal sizes, taking as parameter the relative distance between them, the ideal location would be a symmetrical position along the wall perimeter (Tavares and Tavares, 2008; Tavares and Galea, 2009a,b; Tavares, 2008, 2009). In other terms, when the exits are located apart from each other symmetrically along the wall perimeter, an improvement on the occupants' movement flow rate during the escape movement as well as during the time spent towards the exits areas was observed. In the other hand, when the exits were located apart from each other asymmetrically along the wall perimeter, more congestion during the escape movement and in the areas nearby the exits were observed.

It is well known that the RSET (Required Safe Egress Time) can be estimated using a simple equation as it follows:

$$\mathrm{RSET} = t_{de} + t_{alarm} + t_{pre} + t_{move} \quad (1)$$

where:

$$\mathrm{RSET} = t_{de} + t_{alarm} + t_{pre} + t_{move}$$

$$t_{move} = tsm + tsq$$

$$ET = T_1 + T_2$$

ET – Evacuation Time

T_1 – Time spent during the movement

T_2 – Time spent towards the exit

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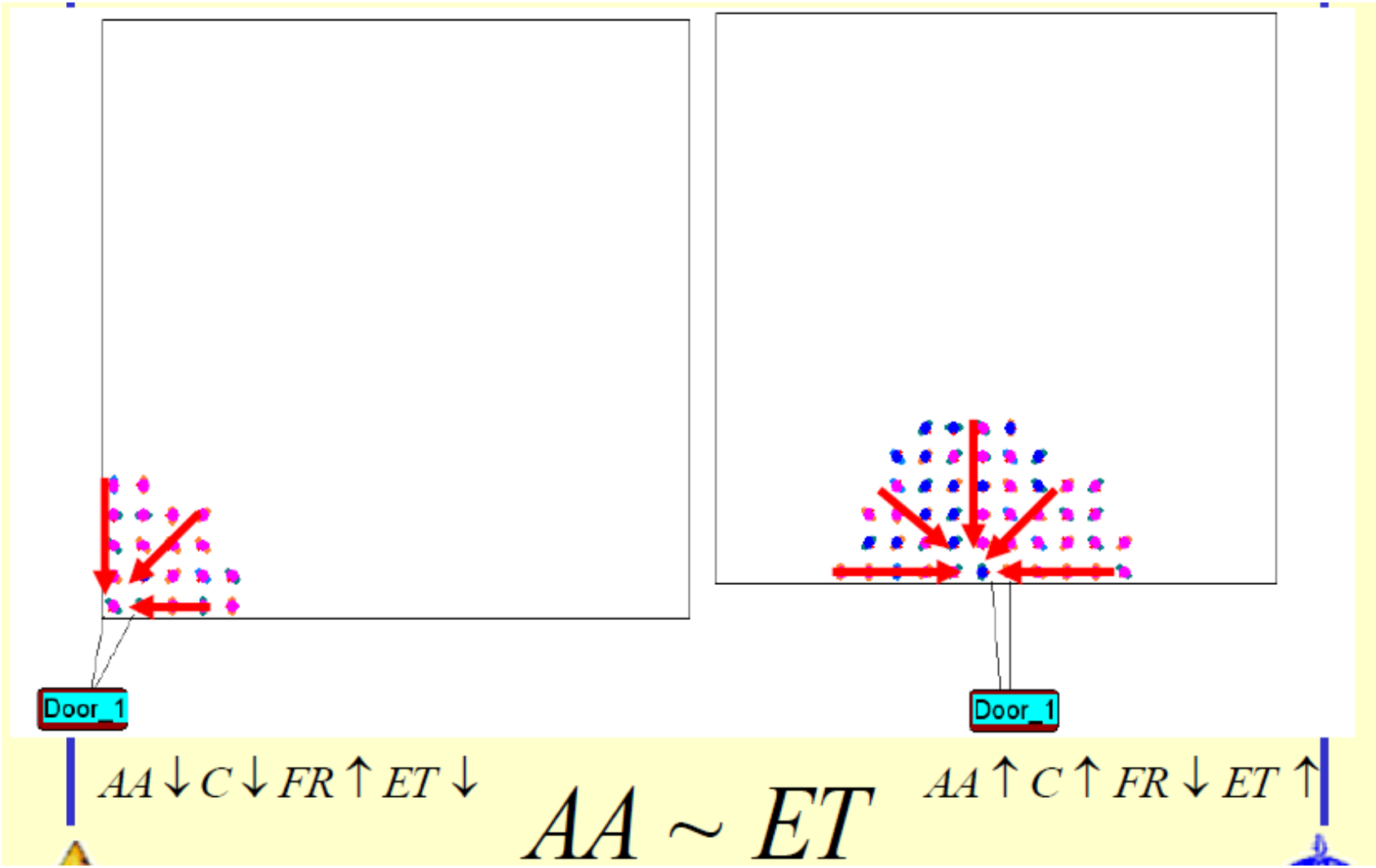

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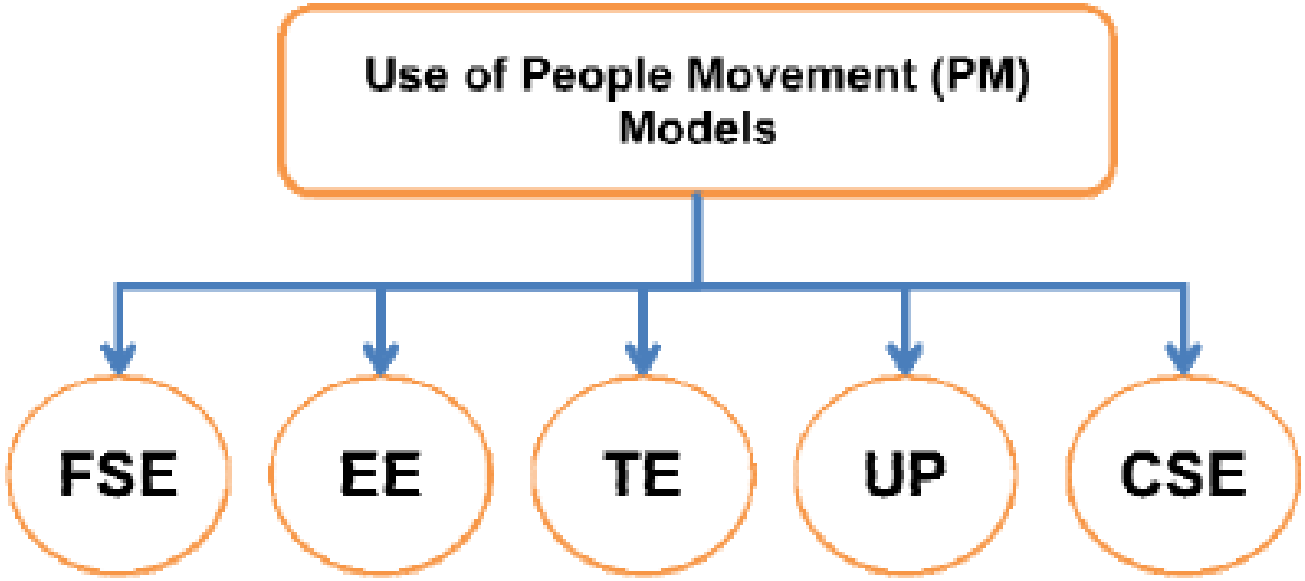
2) People Movement Models



- FSE: Fire Safety Engineering;
- EE: Earthquake Engineering;
- TE: Transportation Engineering;
- UP: Urban Planning;
- CSE: Crowd Safety Engineering.

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2) People Movement Models

Fire Technology 2008

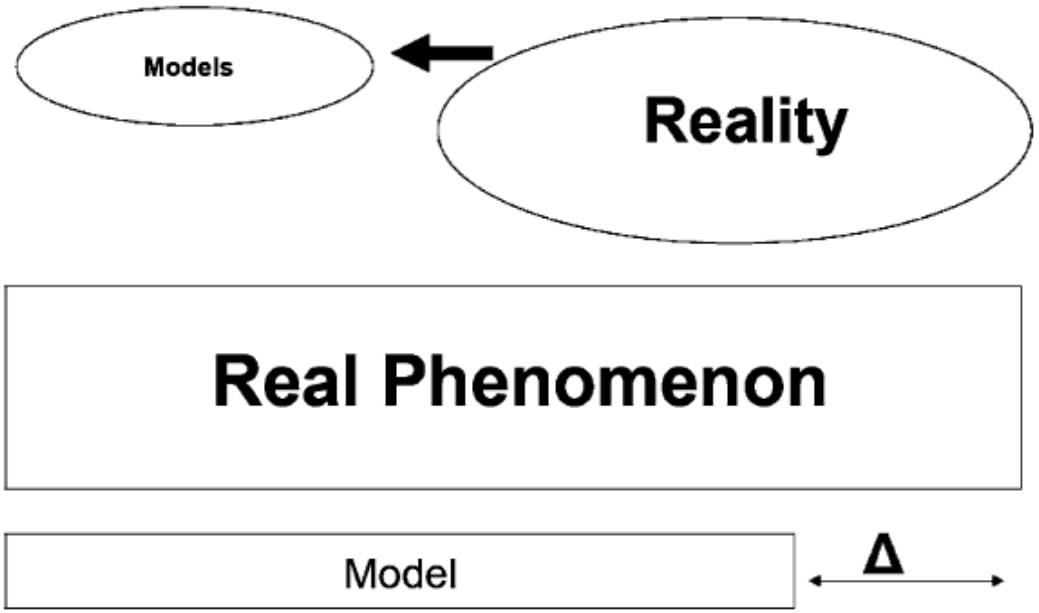

Figure 3. Model ''versus'' reality.

http://www.rmt-fire-crowd-safety.com/downloads

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2) People Movement Models

Fire Technology

DOI: 10.1007/s10694-008-0063-7

Evacuation Processes Versus Evacuation Models: "Quo Vadimus"?

Rodrigo Machado Tavares, OPTSEG—Optimal Safety Engineering, Research Department, GEDIPE—Grupo de Estudos sobre DInâmica de PEdestres, F. 13, Mackworth House, Augustus Street, Regent's Park, NW1 3RE London, UK*

Received: 25 March 2008/**Accepted:** 16 June 2008

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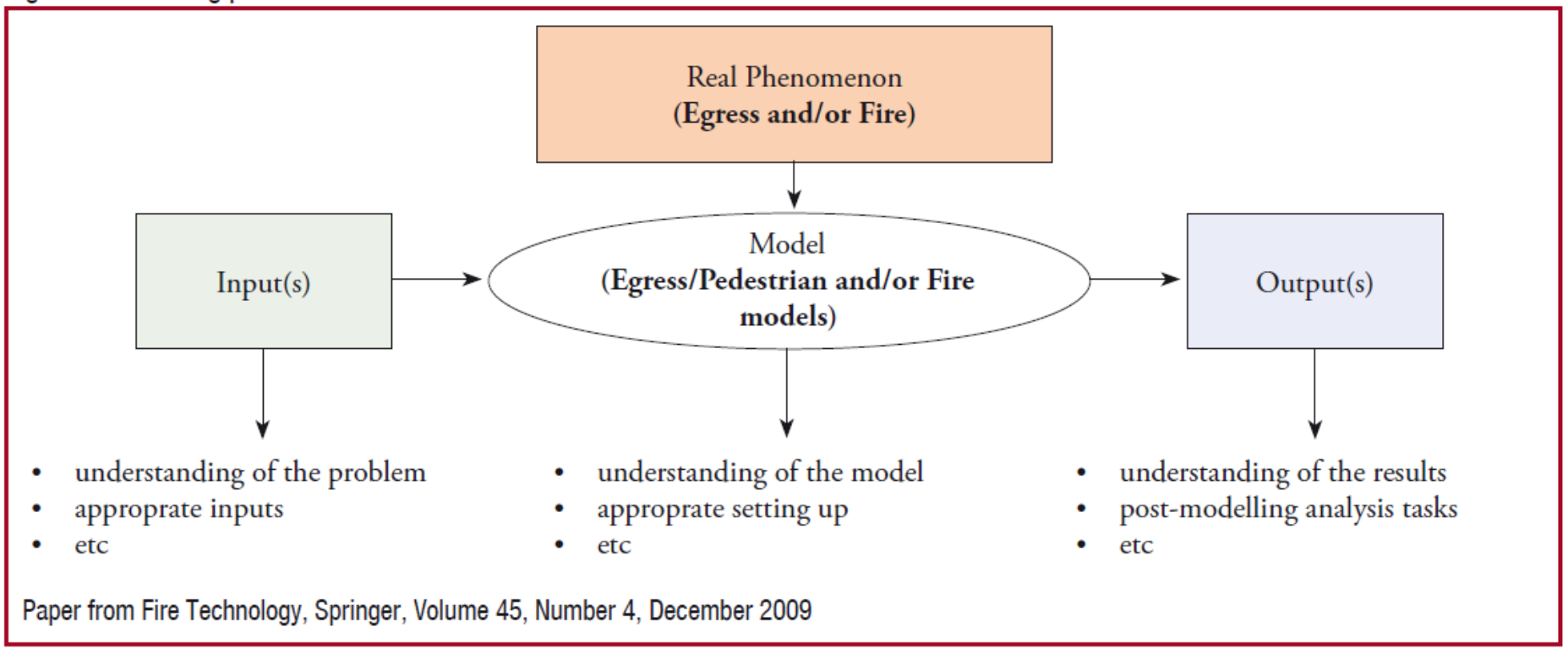
2) People Movement Models

Figure 1: Modelling process



Paper from Fire Technology, Springer, Volume 45, Number 4, December 2009

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2) People Movement Models

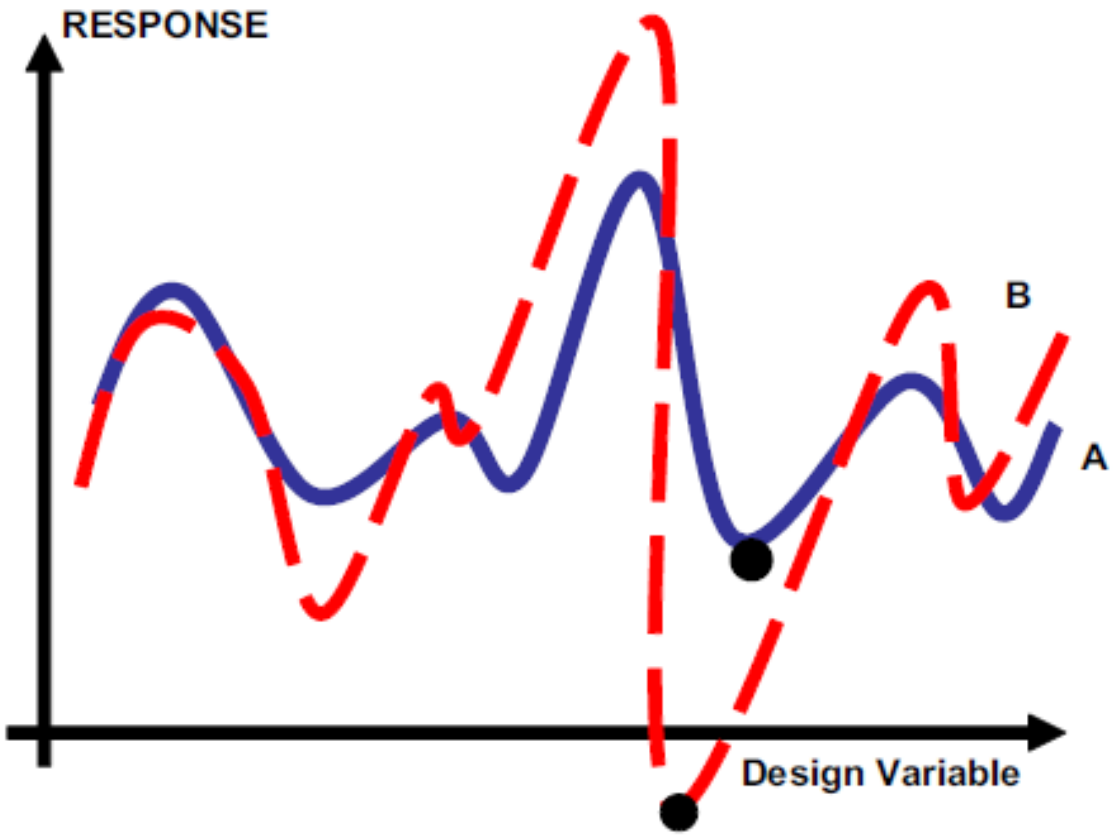

Fig. 12. Response curve for a hypothetical problem in which the objective function depends on 1 design variable.

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2) People Movement Models

Pathfinder

http://www.thunderheadeng.com/pathfinder

Pathfinder

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2) People Movement Models

The Fire Strategy Panel should meet at key stages of the strategy development

7.1.3 Fire strategies for existing buildings

For existing buildings, all the Fire Strategy inputs given in Figure 1 will be applicable to a greater or lesser extent. Where no other guidance exists, the flow chart given in Figure 7 could be followed. This covers the following:

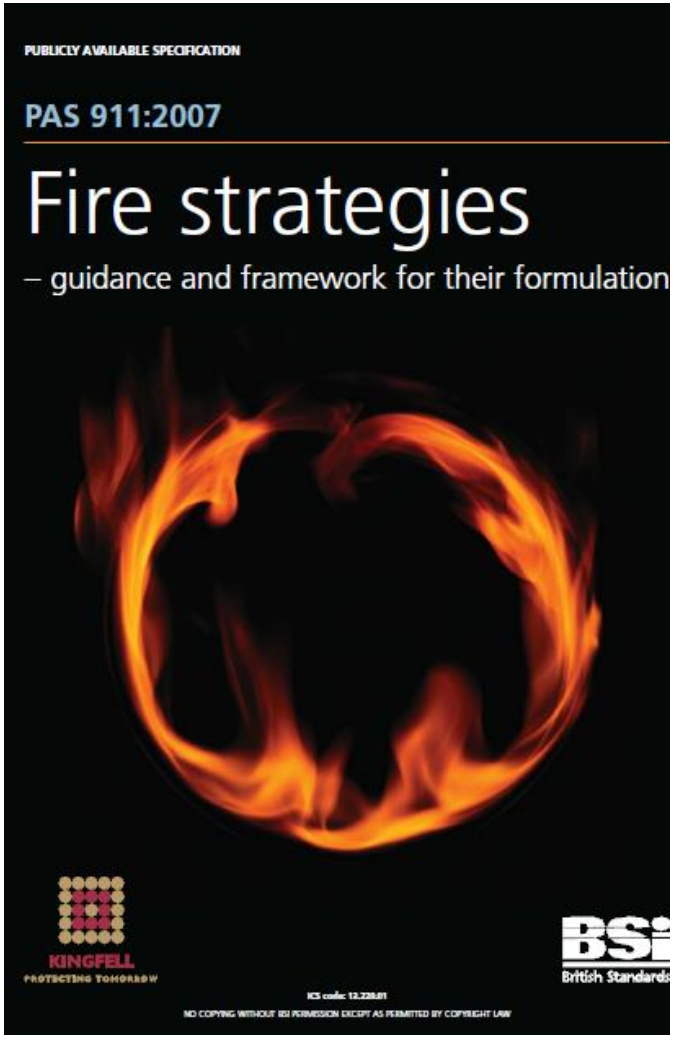
a) *Planning Meeting(s):* Procedure, timescales and design basis are agreed;

b) *Research:* All data, records, documents and relevant codes are subjected to detail review;

health checks. This will involve one or more meetings with stakeholders;

f) *Outline Draft Strategy:* To prepare a strategy with the key findings to date and the overall structure;

g) *Second Review:* Consideration of the first draft together with further recommendations for investigation. This is also the point to determine if the objectives set are "SMART". This will involve one or more meetings with stakeholders. At this point, issues not properly resolved or covered can be reassessed in a revised outline draft strategy;



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3) The Scenarios

Scenarios	Geometry	Number of Exits	Exit´s Widths	Number of People
Scenario 1	Squared space (20m X 20m)	Four	1m each	1026
Scenario 2	Squared space (40m X 40m)	Four	1m each	2460

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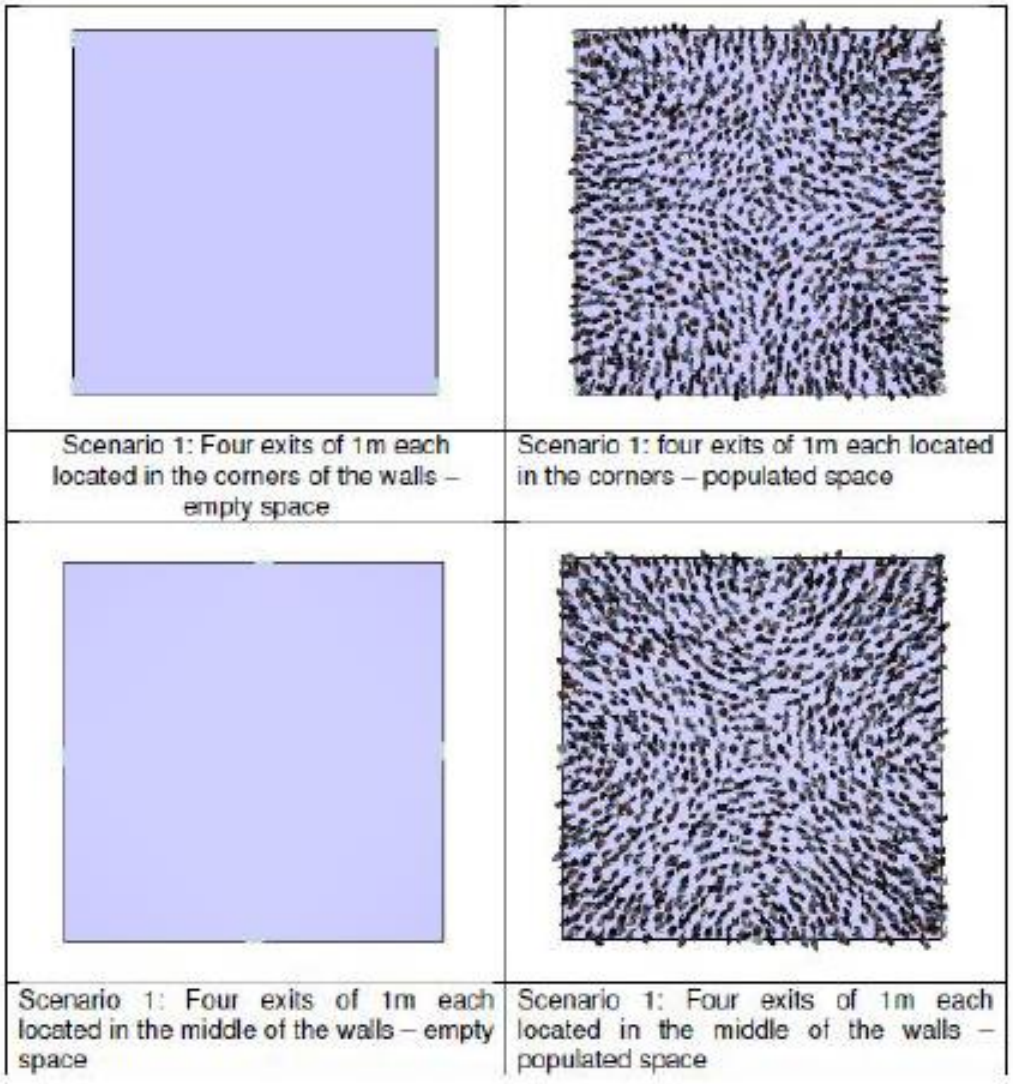
3) The Scenarios



Scenario 1: Four exits of 1m each located in the corners of the walls – empty space

Scenario 1: four exits of 1m each located in the corners – populated space

Scenario 1: Four exits of 1m each located in the middle of the walls – empty space

Scenario 1: Four exits of 1m each located in the middle of the walls – populated space

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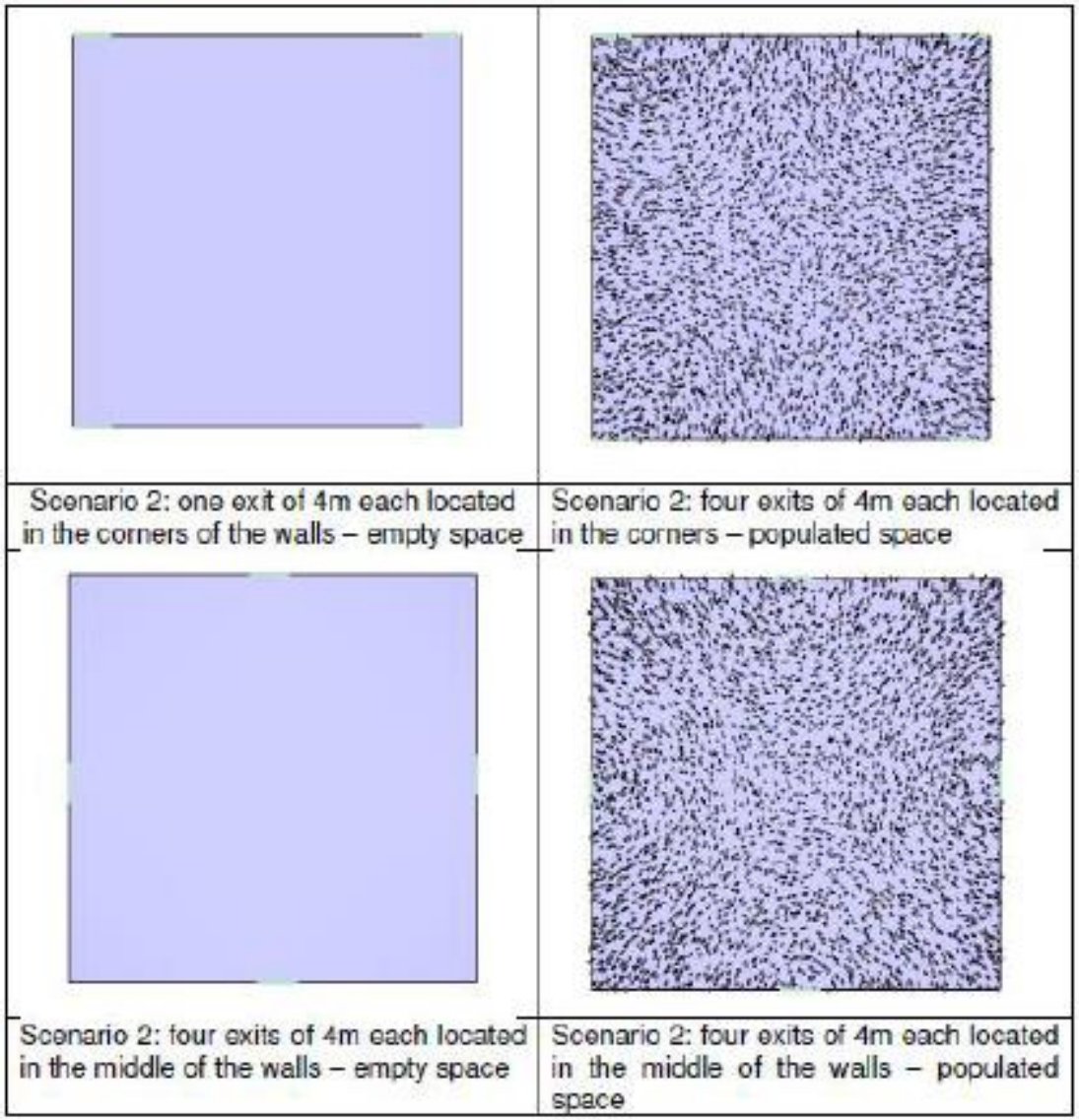
3) The Scenarios



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5) The Results and Discussion

Scenarios	Exits´ Locations	Escape Times
Scenario 1	Exits located in the corners of the walls	164.78sec
	Exits located in the middle of the walls	215.73sec
Scenario 2	Exits located in the corners of the walls	96.48sec
	Exits located in the middle of the walls	104.38sec

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5) The Results and Discussion

As it is possible to see, the RDBE does have a substantial impact on the people's escape performance. In reality, the "corner effect" observed in previous studies becomes more evident for high dense populated environments. With these simulations, becomes clear how its influence increases proportionally to the increase of the population density.

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5) The Results and Discussion

Nevertheless, for the crowd safety context, this is not the case, since the population density is a major factor and therefore, the time spent during the congestions is a bigger issue than the time spent during the movement towards them exit(s).

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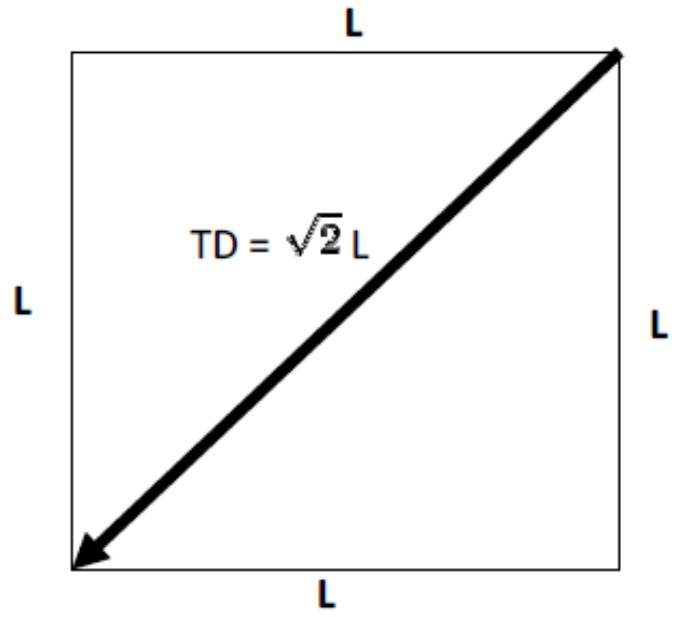
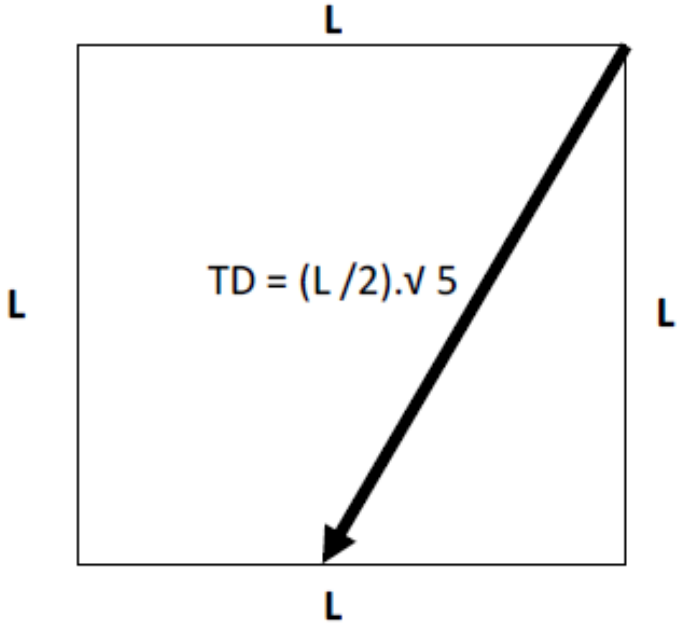
5) The Results and Discussion



Exit located in the corner of the wall will give a bigger Travel Distance (TD)



Exit located in the middle of the wall will give a smaller Travel Distance (TD)

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6) Concluding Remarks

This paper explored the influence of the positioning of exits on the escape performance of people within highly populated spaces. For this purpose, the investigated three scenarios which represented a music concert hall/space. These investigations were conducted through People Movement Modelling Analysis (PeMMA).

The results of the simulations revealed that the relative distance between exits (RDBE) does have a substantial impact on the escape performance of people in high dense places.

THE USE OF NUMERICAL OPTMISATION TECHNIQUES IN COMPUTATIONAL FIRE ENGINEERING MODELS: A STUDY THROUGH EVACUATION MODELLING ANALYSES

Rodrigo Machado Tavares

A thesis submitted in partial fulfilment of the requirements of the University of Greenwich for the Degree of Doctor of Philosophy

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QUO VADIMUS ?

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(FIRE) SAFETY = COMFORT = SUSTAINABILITY

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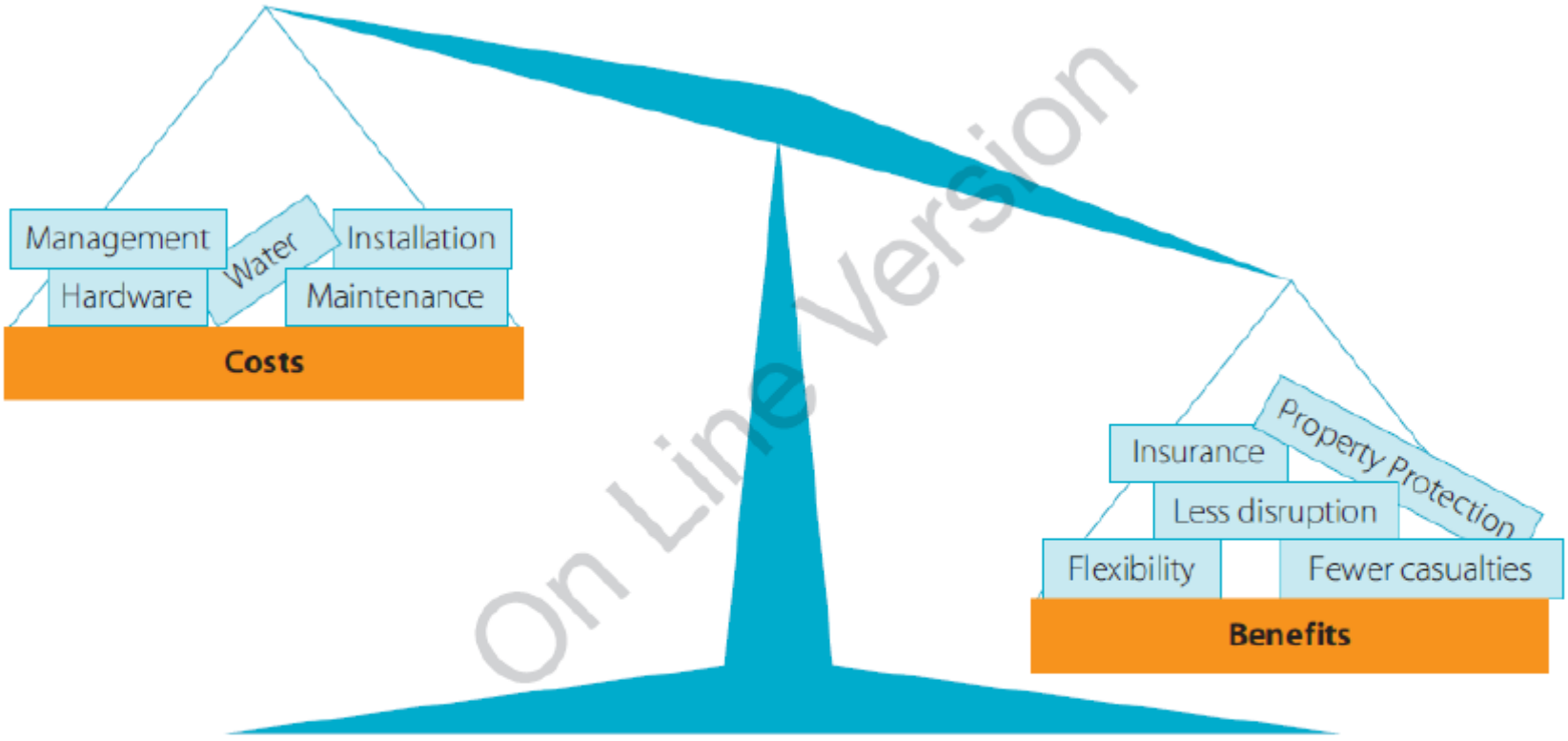

Source: Building Bulletin 100 (BB100) - UK

Insurance Companies, ISO 9001, ISO 14001, OSHAS 18001

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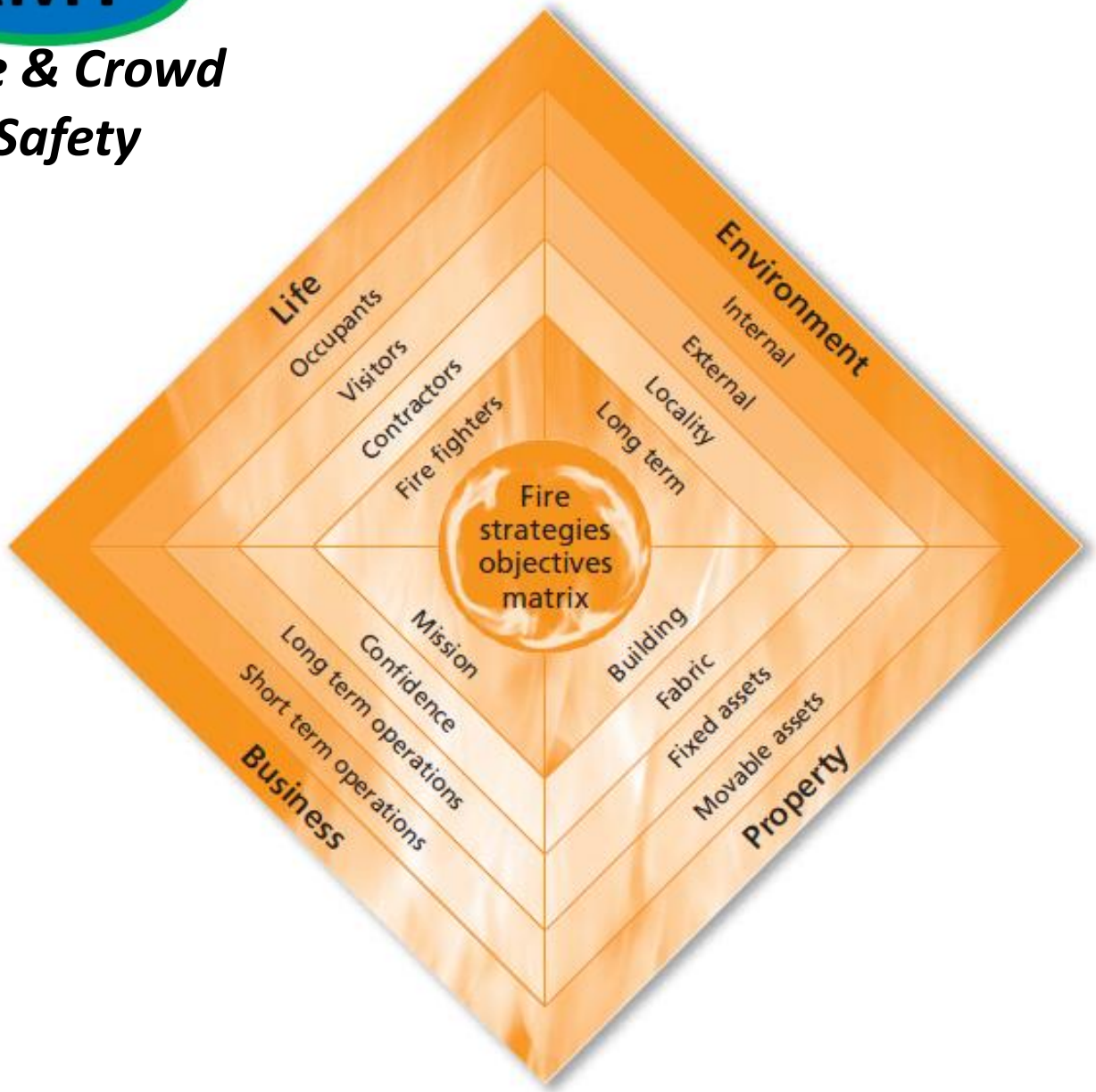

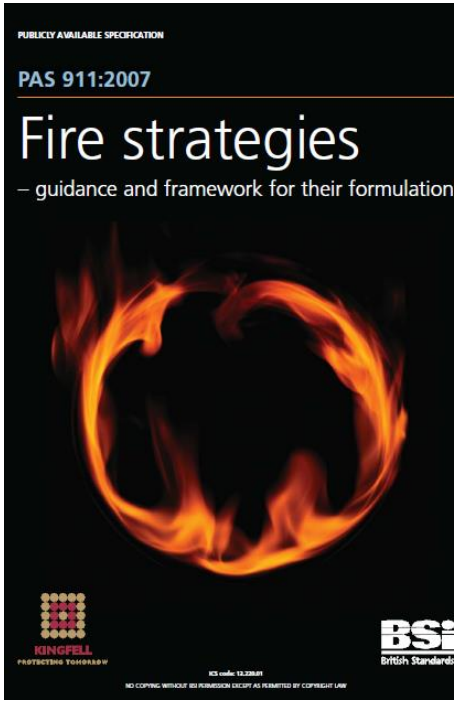

SOURCE: PAS 911: 277 Fire Strategies, BSI

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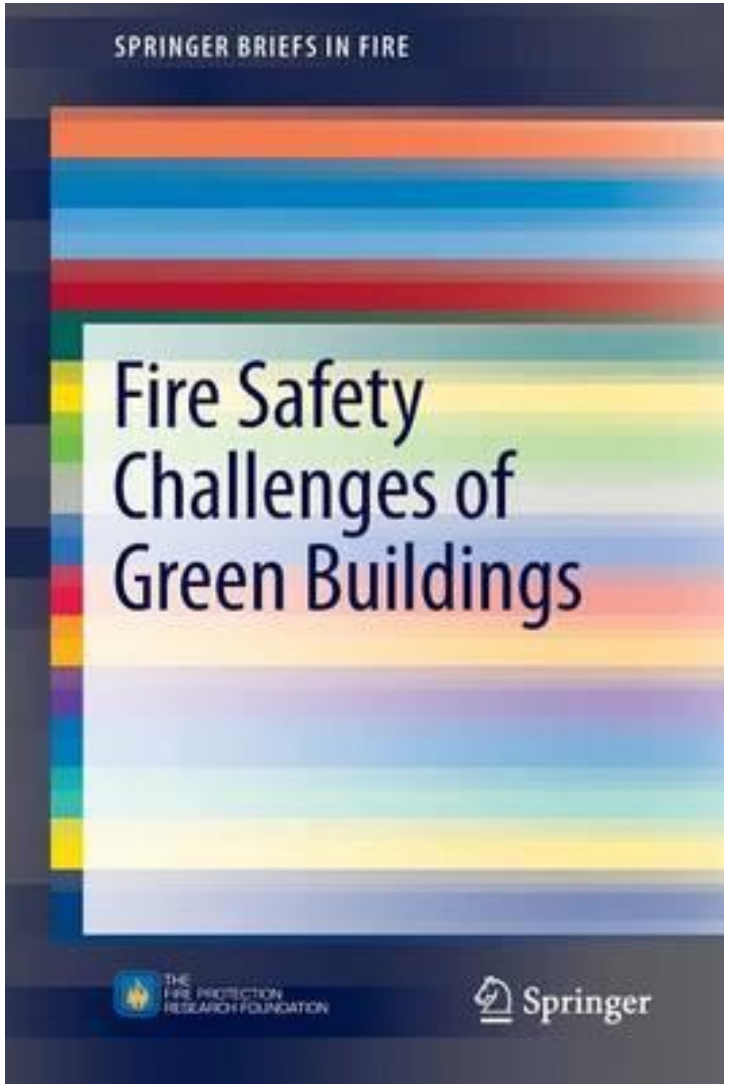

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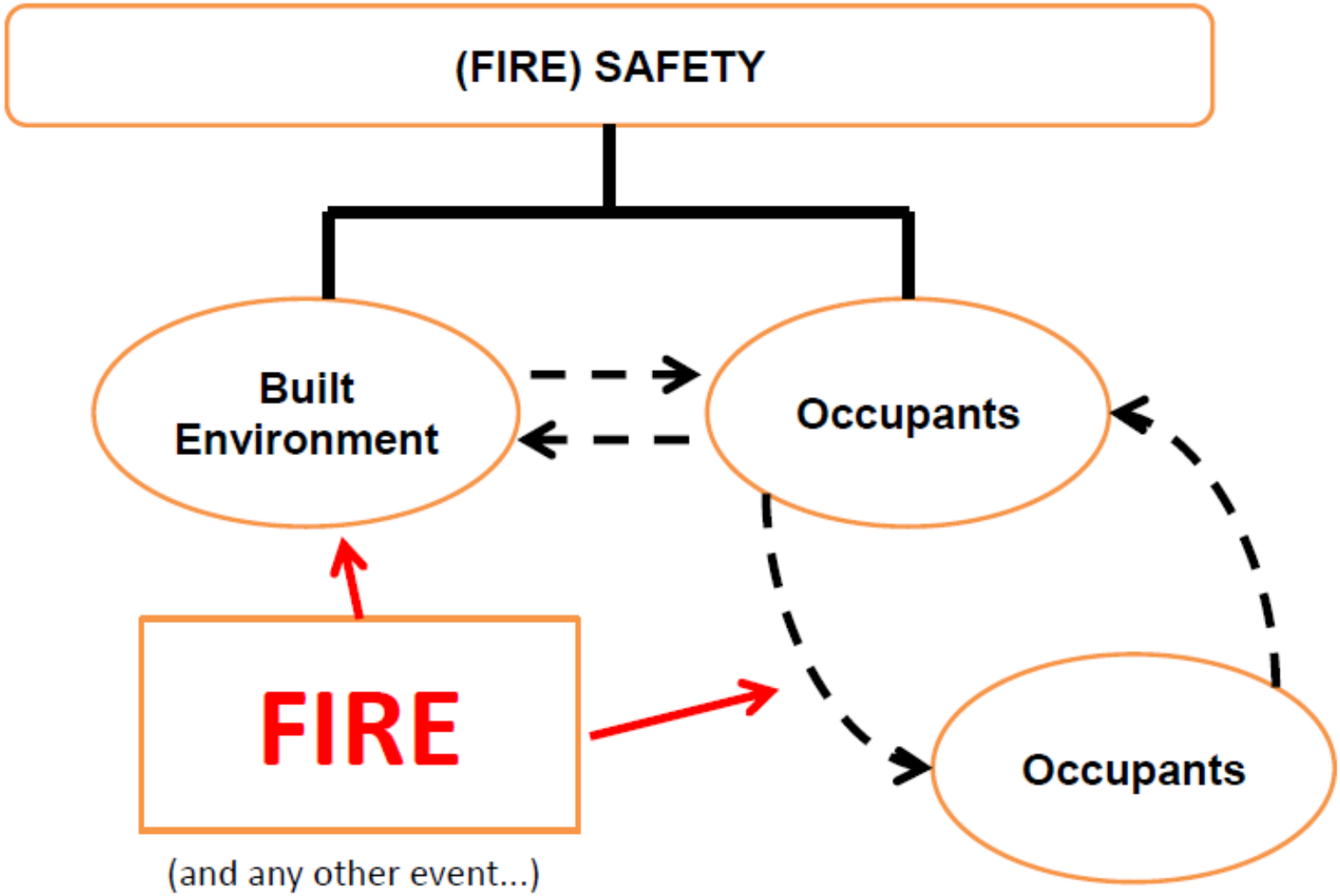

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International Standard ISO 6241

Performance standards in building - Principles for their preparation and factors to be considered

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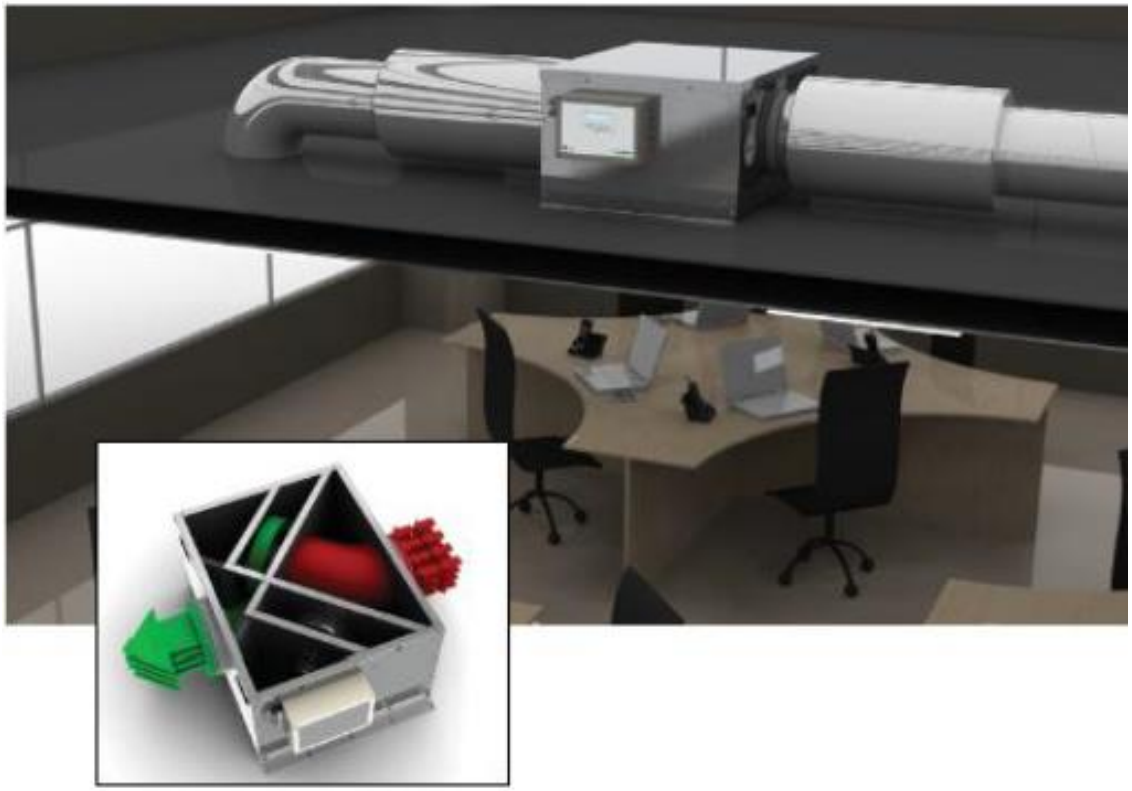

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Performance Based Building – PeBBu

International Council for Research and Innovation in Building and Construction

International Code Council

American Society of Heating, Refrigerating and Air Conditioning Engineers

Building-Energy simulation tests (BESTEST) - US Department of Energy

http://www.nrel.gov/buildings/bestest_ex.html

Certification for BIM models.

IMO

INTERNATIONAL MARITIME ORGANIZATION

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An Association for such types of models…

Similar to some Active and Passive Fire Protection Systems…

Associação de Amigos do Autista

AMA

(Association of Friends of the Austistic)

http://www.ama.org.br

AUTISM SPEAKS®

It's time to listen.

http://www.autismspeaks.org

rodrigotmj@gmail.com

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http://www.rmtengineering.net

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THANK YOU VERY MUCH!