A statistics based Fire Risk Assessment methodology to support decisions in Building Life-cycle Management

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Background and Objective

Building Lifecycle Management (BLM) aims to improve the information exchange in an integrated IT environment to manage the building life-cycle. If combined with Fire Risk Assessment (FRA), the BLM can support decisions in risk management.

Research goal:

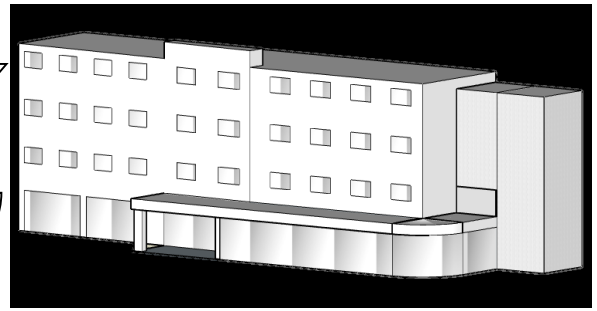
Provide fire engineers and decision makers with a semi-automatic tool for quantitative estimation of fire risk during the whole building life-cycle.

Research steps:

1. Proposal of a FRA Methodology based on statistics
2. Definition of a Building Lifecycle Management (BLM) - FRA data model
3. Integration and automation of quantitative fire risk assessment by incorporating FRA methodology into BLM.

Method

Case study: Hotel



- space floor area
- use of spaces
- automatic protection systems
- slow, medium or fast fire

Statistics

- building average ignition frequency
- branch probabilities

Support Decision making

S \ P	Extremely Improbable	Improbable	Remote	Occasional	Frequent
	$\leq 10^{-7}$	$10^{-7} - 10^{-6}$	$10^{-6} - 10^{-5}$	$10^{-5} - 10^{-4}$	$\geq 10^{-4}$
High Building (>0,20)					
Medium-High Max 2 floors (0,10−0,20)					
Medium Room of origin (0,05 −0,10)					
Low Item 1st ignited (< 0,05)					

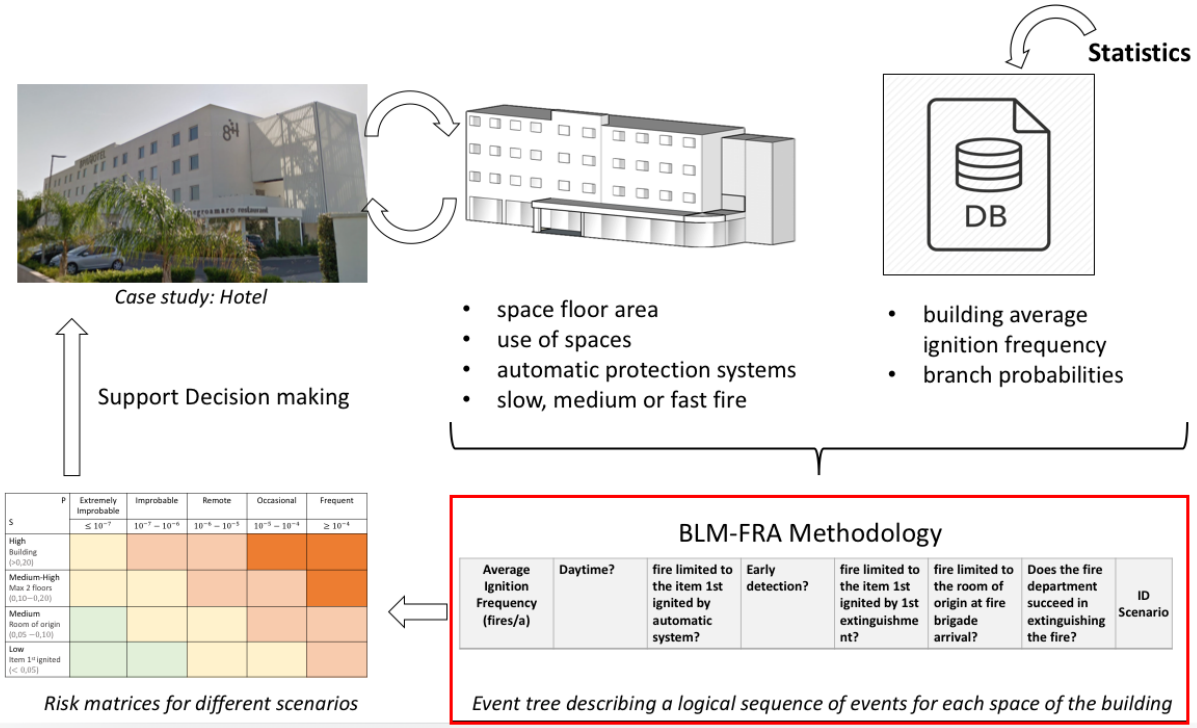
Risk matrices for different scenarios

BLM-FRA Methodology

Average Ignition Frequency (fires/a)	Daytime?	fire limited to the item 1st ignited by automatic system?	Early detection?	fire limited to the item 1st ignited by 1st extinguishment?	fire limited to the room of origin at fire brigade arrival?	Does the fire department succeed in extinguishing the fire?	ID Scenario

Event tree describing a logical sequence of events for each space of the building

The Fire Risk Assessment Methodology



1. FRA Methodology could be applied to different buildings
2. An event tree is proposed to evaluate fire consequences for each space category of the building
3. Probabilities associated to the event tree are estimated using statistical data
4. Information about building spaces will be automatically updated by the integrated FRA data model
5. The outcome are risk indices for each space of the building can be combined to obtain the building risk index
6. Information about risk will be visualized as risk matrices

The Fire Risk Assessment Methodology:
Application of the methodology to a hotel in Italy

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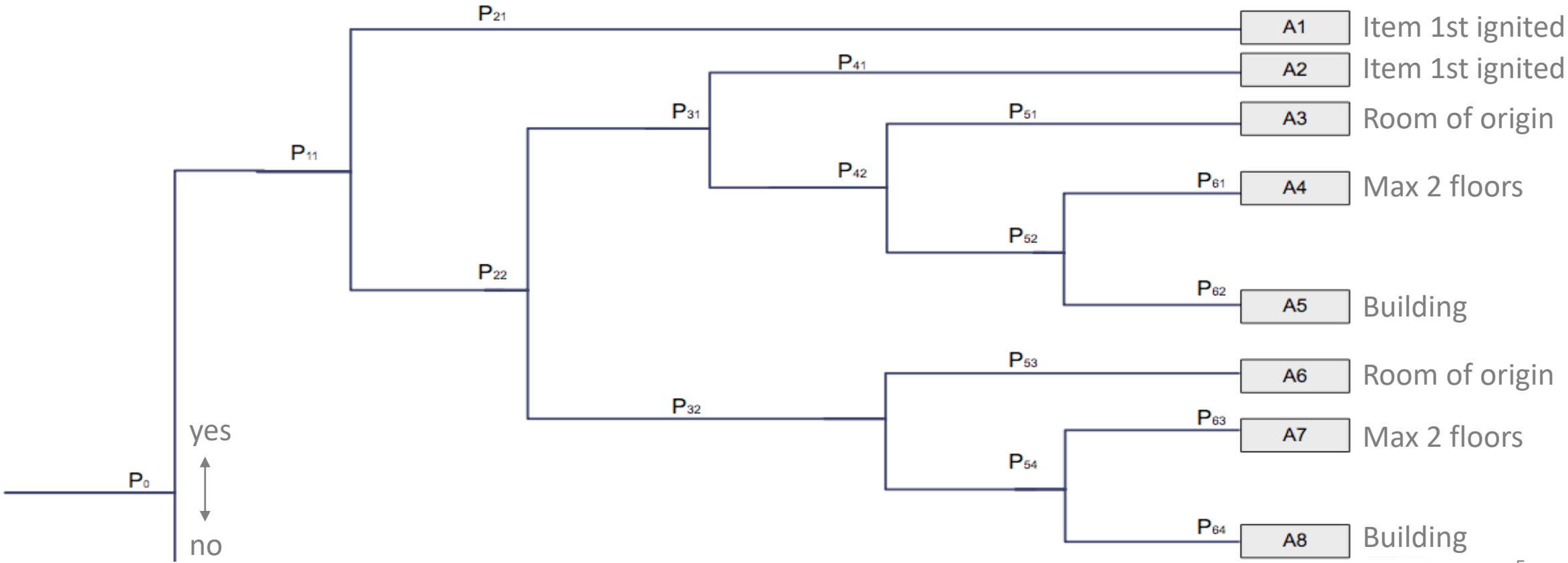
EVENT TREE: Logical Sequence



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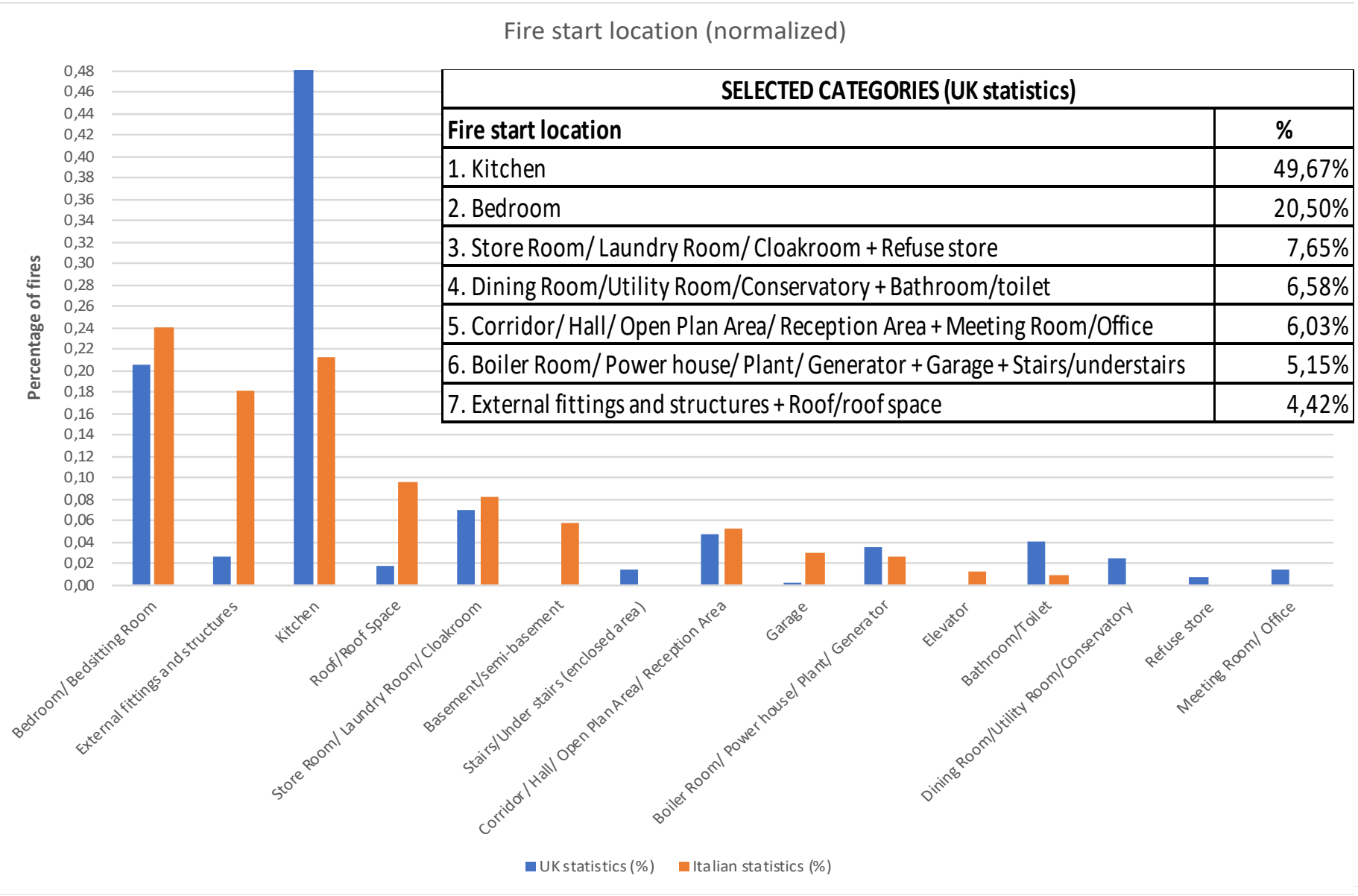
Building average IF (Fires/a· m^2) x Space floor area (m^2) x Probability that the fire occurs in the space category

Model/statistics	Case study Average Ignition frequency (A_{tot}=4940 m2)
Italian statistics (hotels)	1,84E-06
Finnish statistics (commercial buildings)	6,60E-06
Ramachandran model	8,00E-05
Generalized Barrois Model	4,20E-06

SELECTED CATEGORIES (UK statistics)	
Fire start location	**%**
1. Kitchen	49,67%
2. Bedroom	20,50%
3. Store Room/ Laundry Room/ Cloakroom + Refuse store	7,65%
4. Dining Room/Utility Room/Conservatory + Bathroom/toilet	6,58%
5. Corridor/ Hall/ Open Plan Area/ Reception Area + Meeting Room/Office	6,03%
6. Boiler Room/ Power house/ Plant/ Generator + Garage + Stairs/understairs	5,15%
7. External fittings and structures + Roof/roof space	4,42%

The Fire Risk Assessment Methodology: Application of the methodology to a hotel in Italy



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Space categories are chosen according to the fire start locations in the hotels. Italian and UK statistics are compared.

Main differences:

- External fittings and structures;
- Kitchen;
- Roof space.

UK fire start locations are grouped to have a more consistent sample size

-> 7 space categories

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EVENT TREE: Logical Sequence

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If the building is sprinklered -> P(yes)=0,93[1]

1 Source: "Efficiency and Effectiveness of Sprinkler Systems in the United Kingdom: An Analysis from Fire Service Data", March 2019, National Fire Sprinkler Network (NFSN) and UK National Fire Chiefs Council (NFCC).

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Success -> P(yes)= $0,3^{(2)}$

Not Success -> P(no)=$0,7^{(2)}$

USE OF FIRST EXTINGUISHING IN BUILDING FIRES (Normalized value in %)									
	2010	2011	2012	2013	2014	2015	2016	2017	Average value
Used	0,372	0,379	0,371	0,370	0,360	0,352	0,362	0,368	0,367
Not used	0,628	0,621	0,629	0,630	0,640	0,648	0,638	0,632	0,633
EFFECT OF FIRST EXTINGUISHING IN BUILDING FIRES (Value in %)									
	2010	2011	2012	2013	2014	2015	2016	2017	Average value
Extinguished fire	0,557	0,559	0,589	0,568	0,587	0,600	0,590	0,588	0,580
Limited Fire	0,315	0,316	0,298	0,305	0,299	0,286	0,283	0,298	0,300
No effect	0,125	0,122	0,110	0,121	0,113	0,110	0,122	0,112	0,117
Extinguisher did not work	0,002	0,003	0,003	0,006	0,001	0,005	0,004	0,003	0,003

2 Finnish Rescue Services' Pocket Statistics, Johannes Ketola, Esa Kokki, 2018

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According to the space category, the fire is considered fast or medium. The time from ignition to set-up is compared to a critical point (HRR=15 MW). If the time from ignition to set-up does not exceed the critical time -> P(yes) = 0,8 [Tillander, 2004].

Turn out+travel time (min)	
Italian statistics_Lecce	
t	16,08
UK statistics	
t	8,5
Finnish statistics	
t	14,5

In case of early detection, **time from ignition to set-up** :

- Ignition to discovery = 2 minutes (average value);
- Discovery to call = 2 minutes (average value);
- Call to first vehicle arrival on the scene = 8,5 minutes [Home Office statistical bulletin, 01/19];
- Arrival on the scene to intervention = 4 minutes [Claridge, 2010].
- Time from ignition to set-up = 16,5 minutes

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EVENT TREE: Estimation of Economic Risk Index

ID Scenario	**Average annual frequency**	**Economic Loss** (euro)	**Economic Risk Index - ERI** (euro/a)
Aj *A* index refers to the space category *j* index refers to the specific event tree scenario within the space category	P_{Aj} Is the average annual frequency related to Aj scenario	$Loss_i$ Is the Economic loss category. 4 possible cases: ▪ Fire damage limited to item 1st ignited; ▪ Fire damage limited to the room of origin; ▪ Fire damage limited to maximum two floors; ▪ Fire involves the whole building	$ERI_i = P_i \cdot Loss_i$ *i* index refers to the economic loss category (*i*=1,4) P_i is the Loss category probability $P_i = \sum_{j=1\ /Loss(j)=Loss(i)}^{b} P_{Aj}$ *j = 1, b* Event tree scenario index (b = number of event tree scenarios)

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RESULTS: BEDROOMS

average ignition frequency (fires/a)	daytime?		Is the fire damage limited to the item 1st ignited by automatic system?		Early detection?		Is the fire damage limited to the item 1st ignited by 1st extinguishment?		Is the fire limited to the room of origin at fire brigade arrival?		Does the fire department succeed in extinguishing the fire?		ID Scenario	Average annual frequency	Loss (euro)	fire damage
7,27E-04	y	0,74	n		y	0,46	y	0,32			y		B1	7,97E-05	11517	item 1st
7,27E-04	y	0,74	n		y	0,46	n	0,68	y	0,89	y		B2	1,50E-04	28600	room
7,27E-04	y	0,74	n		y	0,46	n	0,68	n	0,11	y	0,2	B3	3,53E-06	2490800	max 2 floors
7,27E-04	y	0,74	n		y	0,46	n	0,68	n	0,89	n	0,8	B4	1,20E-04	6422000	building
7,27E-04	y	0,74	n		n	0,54	n		y	0,78	y		B5	2,24E-04	28600	room
7,27E-04	y	0,74	n		n	0,54	n		n	0,22	y	0,2	B6	1,28E-05	2490800	max 2 floors
7,27E-04	y	0,74	n		n	0,54	n		n	0,22	n	0,8	B7	5,12E-05	6422000	building
7,27E-04	n	0,26	n		y	0,15	y	0,32			y		B8	9,31E-06	11517	item 1st
7,27E-04	n	0,26	n		y	0,15	n	0,68	y	0,89	y		B9	1,74E-05	28600	room
7,27E-04	n	0,26	n		y	0,15	n	0,68	n	0,11	y	0,2	B10	4,23E-07	2490800	max 2 floors
7,27E-04	n	0,26	n		y	0,15	n	0,68	n	0,11	n	0,8	B11	1,69E-06	6422000	building
7,27E-04	n	0,26	n		n	0,85	n		y	0,71	y		B12	1,16E-04	28600	room
7,27E-04	n	0,26	n		n	0,85	n		n	0,29	y	0,2	B13	9,46E-06	2490800	max 2 floors
7,27E-04	n	0,26	n		n	0,85	n		n	0,29	n	0,8	B14	3,79E-05	6422000	building

Not sprinklered

Economic Risk Index -ERI (euro/a)	
ERI1 - Item 1st ignited	1,03
ERI2 - room of origin	14,49
ERI3 - Max 2 floors	65,32
ERI4 - Building	1352,60

average ignition frequency (fires/a)	daytime?		Is the fire damage limited to the item 1st ignited by automatic system?		Early detection?		Is the fire damage limited to the item 1st ignited by 1st extinguishment?		Is the fire limited to the room of origin at fire brigade arrival?		Does the fire department succeed in extinguishing the fire?		ID Scenario	Average annual frequency	Loss (euro)	fire damage
7,27E-04	y	0,74	y	0,93									BS1	4,98E-04	11517	item 1st
7,27E-04	y	0,74	n	0,07	y	0,46	y	0,32			y		BS2	5,58E-06	11517	item 1st
7,27E-04	y	0,74	n	0,07	y	0,46	n	0,68	y	0,89	y		BS3	1,05E-05	28600	room
7,27E-04	y	0,74	n	0,07	y	0,46	n	0,68	n	0,11	y	0,2	BS4	2,47E-07	2490800	max 2 floors
7,27E-04	y	0,74	n	0,07	y	0,46	n	0,68	n	0,89	n	0,8	BS5	8,39E-06	6422000	building
7,27E-04	y	0,74	n	0,07	n	0,54	n		y	0,78	y		BS6	1,57E-05	28600	room
7,27E-04	y	0,74	n	0,07	n	0,54	n		n	0,22	y	0,2	BS7	8,97E-07	2490800	max 2 floors
7,27E-04	y	0,74	n	0,07	n	0,54	n		n	0,22	n	0,8	BS8	3,59E-06	6422000	building
7,27E-04	n	0,26	y	0,93									BS9	1,78E-04	11517	item 1st
7,27E-04	n	0,26	n	0,07	y	0,15	y	0,32			y		BS10	6,52E-07	11517	item 1st
7,27E-04	n	0,26	n	0,07	y	0,15	n	0,68	y	0,89	y		BS11	1,22E-06	28600	room
7,27E-04	n	0,26	n	0,07	y	0,15	n	0,68	n	0,11	y	0,2	BS12	2,96E-08	2490800	max 2 floors
7,27E-04	n	0,26	n	0,07	y	0,15	n	0,68	n	0,11	n	0,8	BS13	1,18E-07	6422000	building
7,27E-04	n	0,26	n	0,07	n	0,85	n		y	0,71	y		BS14	8,09E-06	28600	room
7,27E-04	n	0,26	n	0,07	n	0,85	n		n	0,29	y	0,2	BS15	6,63E-07	2490800	max 2 floors
7,27E-04	n	0,26	n	0,07	n	0,85	n		n	0,29	n	0,8	BS16	2,65E-06	6422000	building

Sprinklered

Economic Risk Index -ERI (euro/a)	
ERI1 - Item 1st ignited	7,86
ERI2 - room of origin	1,01
ERI3 - Max 2 floors	4,57
ERI4 - Building	94,68

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RESULTS: BEDROOMS

S \ P	Extremely Improbable	Improbable	Remote	Occasional	Frequent
	$\leq 10^{-7}$	$10^{-7} - 10^{-6}$	$10^{-6} - 10^{-5}$	$10^{-5} - 10^{-4}$	$\geq 10^{-4}$
High Building (>0,20)			ERI_4	ERI_4	
Medium-High Max 2 floors (0,10−0,20)		ERI_3	ERI_3		
Medium Room of origin (0,05 −0,10)			ERI_2	ERI_2	
Low Item 1st ignited (< 0,05)			ERI_1	ERI_1	

Not Sprinklered Bedrooms

Sprinklered Bedrooms

□ percent of fires that can possibly cause casualties or fatalities per year.

In case of not sprinklered bedrooms in hotels the lower limit is 0,13

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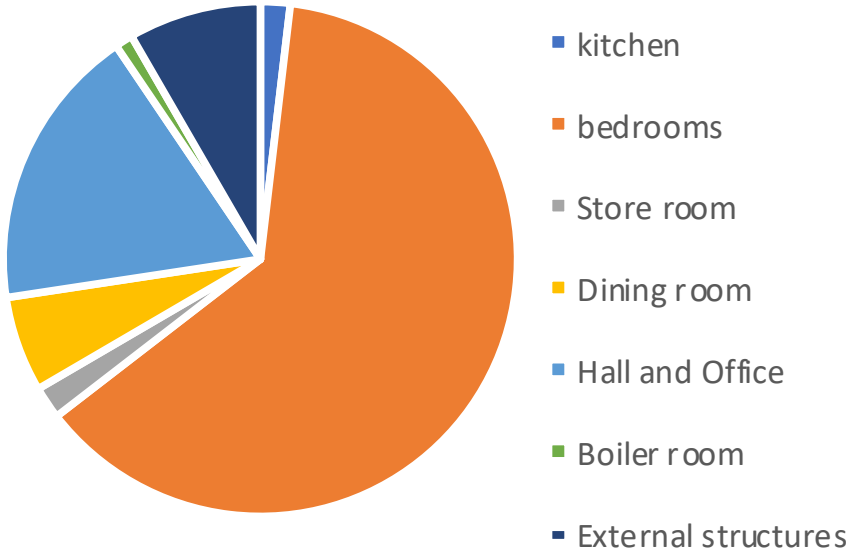
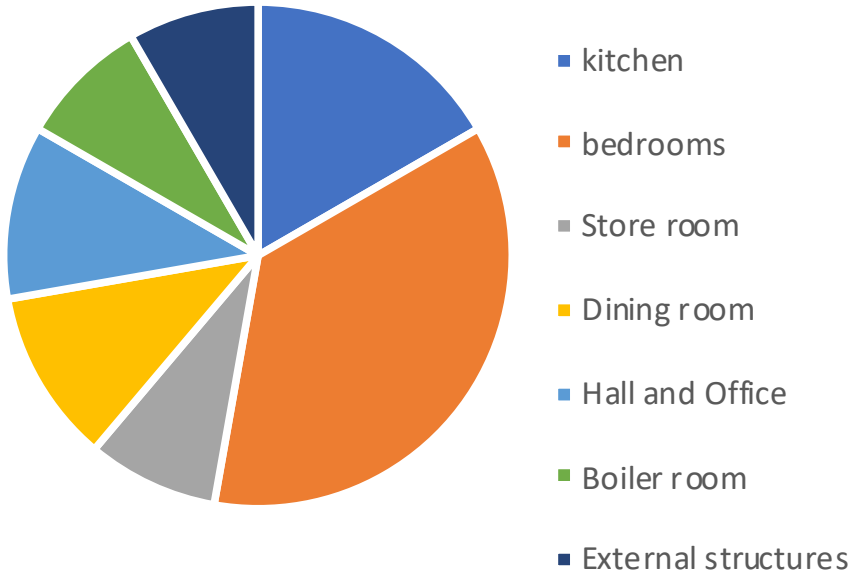
Distribution of Economic Risk Index



Distribution of Fires that can cause casualties



- Bedrooms are the space category with the highest values
- External space and Hall or office show high economic risk index
- Kitchen and Hall or office show high percent of fires involving casualties
- The distribution of fires that can cause casualties is more uniform than the distribution of the economic index

Conclusions

- The lack of statistical data increases the level of uncertainty of the results.
  - UK statistics - Number of fatalities or injuries per each fire is not provided
  - Italian statistics - Not useful for the estimation of branch probabilities
- Improvement in statistics:
  - Larger samples for space categories
  - Early detection not useful - high level of uncertainty
  - More information about fatalities or injuries must be gathered.
  - A scheme for the standardization of fire related statistical databases should be developed
  - Standard and unambiguous definitions of the terms used in the database should be provided.
- The methodology is designed in order to:
  - Simplify the work of fire safety engineers (traceability and availability of information)
  - Improve communication among stakeholders
  - Support decisions in case of renovation of the building.

Kiitos!