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SPECIAL MOBILITY STRAND

FIRE SAFETY IN BUILDINGS

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***FIRE**: UNCONTROLED, UNWANTED BURNING*

GRENFEL TOWER, LONDON

How the Grenfell Tower fire spread (video)

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CONTEMPORARY FIRE SAFETY ENGINEERING

scientific research
engineering principles

calculations
measurements
empiricism
judgment

SAVE LIVES, PROTECT GOODS, ENVIRONMENT AND HERITAGE

Fire risk assessment is an assessment of the fire risks, or the levels of fire safety, that are provided to the occupants and property in a performance-based fire safety design.

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FIRE SAFETY CODES

Traditional practice : simply follows the prescriptive code requirements
Contemporary approach to fire safety design: based on fire safety analysis to obtain the required level of fire safety for the occupants.

Many countries moving towards the more flexible performance-based codes, which allow flexibility in fire safety designs as long as the designs can provide the required level of fire safety to the occupants.

The primary goal of fire protection is to limit, to acceptable levels, the probability of death, injury, and property loss in an unwanted fire.

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FIRE SAFETY CODES

*The **life safety** has been given more emphasis by recent national codes than property protection.*
Many codes consider that fire damage to a building is the problem of the building owner or insurer, with the code provisions only intended to provide life safety and protection to the property of other people.

Automatic sprinkler systems, as many other measures, provide both life safety and property protection.
It is important for the owner of the building to understand the distinction between life safety and property safety, because there is a possibility for fire damage extension to the building and contents,
even if the building complies with minimum code requirements.

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LIFE SAFETY

Ensuring the safe escape is the most important goal in providing life safety. First of all, it is necessary to alert people to the fire, provide suitable escape paths, and make them safe of fire and smoke, so people can not be injured while escaping through those paths to a safe place.

It is also necessary to provide safety for people unable to escape, as well as people in adjacent buildings.
There are also provisions to be made for fire-fighters who enter the building for rescue or fire control purposes.

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Property protection *includes protecting the structure and fabric of building, and the moveable contents. Protection also must apply to neighboring buildings.*

If there is a possibility of irreplaceable loss of heritage values or major damage to main infrastructures, it is necessary to apply an extra level of fire protection.

Environmental protection *is an additional objective, formulated in a way to limit environmental damage in the event of major fire. Emissions of gaseous pollutants in smoke and liquid pollution in fire-fighting run-off water can both have major environmental impacts.*

All of above listed objectives can be met if any fire is extinguished before growing large, which depends on the reliability of predicted fire protection measures.

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Fire risk assessment

A simple risk assessment considers the probability of the occurrence of a certain unwanted fire scenario and the consequence of that scenario.

$$\text{Expected risk to life} = P \cdot C$$

A comprehensive risk assessment considers all probable unwanted fire scenarios and their consequences.

$$\text{Expected risk to life} = \Sigma i\,(Pi \cdot Ci)$$

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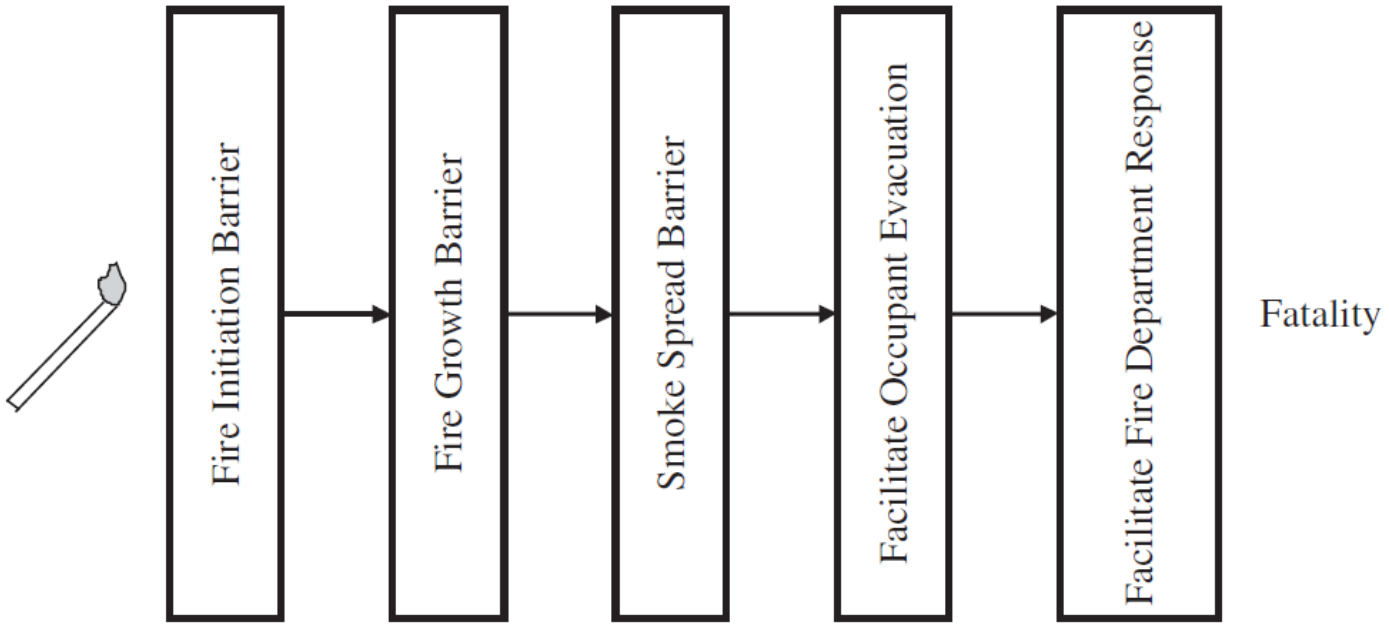
Five major fire barriers between fire source and fatality



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Fire risk assessment based on past fire experience

valid only if the situation in the past and that to be assessed at the present are the same

Questions to be asked:

- Are controlling parameters that govern the fire scenarios in both situations the same?
- Was there a changes in furnishing materials or fire protection systems?
- Or regarding sprinklers that control the fire development?
- Or fire alarm that expedite the evacuation of the occupants?
- Or in the type and amount of combustibles that govern the development of a fire or
- the number and length of the egress routes that govern the required evacuation time?

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Fire statistics - fire loss information from fire incident reports, stored in databases that can be extracted for various statistical analyses , could provide valuable information for risk assessment.

For example, data can be extracted for certain type of occupancy, such as residential buildings. Within that occupancy type, further breakdown of the information can be obtained.

Fire loss information can be obtained based on the area of fire origin,
or source of ignition,
or object first ignited …

Fire loss information can also be obtained based on the presence or absence of fire protection systems, such as smoke alarms or sprinklers.

Following this approach, one can extract statistical information for a specific set of controlling parameters.

For example, one can extract statistical information on fires originating in the kitchen in apartment building, with or without alarms or any other preventive measure.

This allows the results to be applicable to situations with similar controlling parameters.

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Qualitative fire risk assessment

Qualitative fire risk assessment is based on subjective judgment of not only the probability of a fire hazard or fire scenario occurring, but also the consequence of such a fire hazard or fire scenario.

Qualitative fire risk assessment is usually employed in order to obtain a quick assessment of the potential fire risks in a building and to consider various fire protection measures to minimize these risks.

- Check list method or event tree method – both resulting with descriptive terms.

PROBABILITY					
	Anticipated	Negligible Risk	Moderate Risk	High Risk	High Risk
	Unlikely	Negligible Risk	Low Risk	Moderate Risk	High Risk
	Extremely unlikely	Negligible Risk	Low Risk	Low Risk	Moderate Risk
	Beyond extremely unlikely	Negligible Risk	Negligible Risk	Negligible Risk	Negligible Risk
		Negligible	Low	Moderate	High
	CONSEQUENCE				

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Quantitative fire risk assessment

This assessment involve numerical quantifications of

- the probability of occurrence of a fire hazard or fire scenario,
- the consequence of that fire hazard or scenario.

The multiplication of the numerical values of probability and consequence gives each fire scenario a numerical fire risk value.
The cumulative sum of the risk values from all probable fire scenarios gives an overall fire risk value.
The assessed risk can be risk to life, loss of property and so on. Quantitative fire risk assessment allows a numerical comparison of the overall fire risk values of different fire safety designs in a building. It also allows the assessment of equivalency by comparing the fire risk of an alternative fire safety design with that of a code-compliant design.

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CASE STUDY

The group of residential high rise buildings, observed in the case-study, includes three buildings with cellar, ground floor and 14 stories.

Similar groups of two or three buildings with 9 to 14 floors are standing at four other locations in Novi Sad city area. These buildings were built in the period from 1968 to 1976, applying „IMS“ prefabricated building technology – prestressed reinforced concrete elements, skeleton system. The load bearing construction is designed to be stable in case of fire for at least 2 hours

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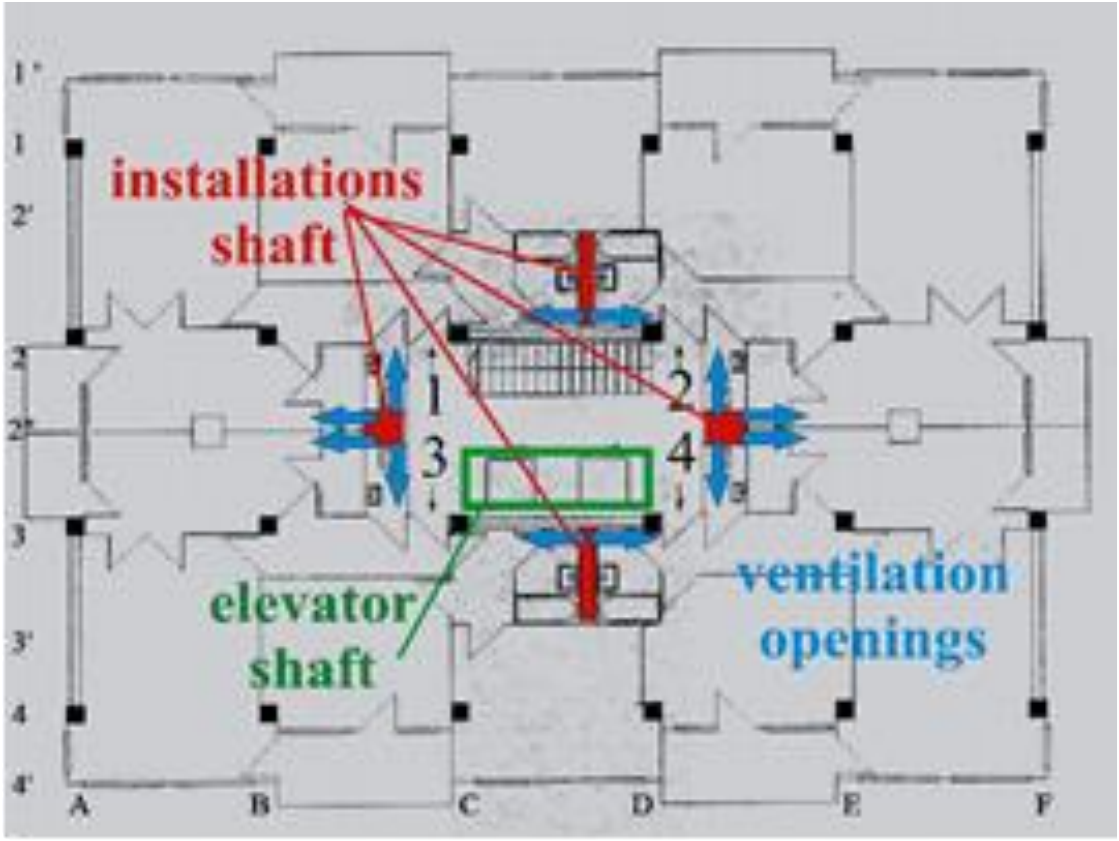
FLOOR PLAN

NOVI SAD, 2009:
881 fire events,
215 in buildings,
67% residential,
22% offices and
11% others.
In residential buildings, 37% fires started in kitchens (forgotten meal on stove or malfunction of kitchen apparatus), and 23% fires started on electrical installations in apartments.



In the period 2000-2004 in Novi Sad, the year average number of fires was 750 and 19 deaths in fire. According to that data, the inherent rate of risk for human life in a fire is 0.02533.

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FIRE SCENARIO – HIGH RISE RESIDENTIAL BUILDING WITH NO FIRE STAIRS
FIRE RISK ASSESSMENT – LIFE SAVETY – FORGOTTEN MEAL ON STOVE

Based on statistics of fire events in Serbia in the period 2001 – 2009, two main fire hazards in apartment buildings are

- human negligence and
- inaccurate or untested electrical installations.
- Consequently, the inherent rates of fire occurrence for those hazards are 37% and 23% respectively.
- In both cases**, fire initiation barrier** can be formulated as **fire prevention education for residents** in order to raise awareness about fire events and to apply prevention measures:
- (1) to examine the apartment before leaving it and
- (2) to test electrical installations regularly, especially when the building is over 40 years old and there are no records of regular maintaining activities or testing.

FIRE STARTS DUE TO FORGOTTEN MEAL ON STOVE.....

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Assumed fire ignition source in fire event scenario is forgotten meal on stove or malfunction of kitchen apparatus when no one is at home.

FIRE BARRIERS ? SMOKE BARRIERS?

The apartment door is locked. No one is at home to extinguish the initial fire. There are no sprinklers to prevent fire growth to flashover in the apartment.

The whole building is one fire sector: there are no fire or smoke compartments separated or any additional fire barriers.

In the case of fire, in every apartment, fire and smoke are easy to spread around and get into the neighbor's apartment and the whole staircase in at least three ways: Installation shafts, elevator shaft, apartment doors, façade openings…

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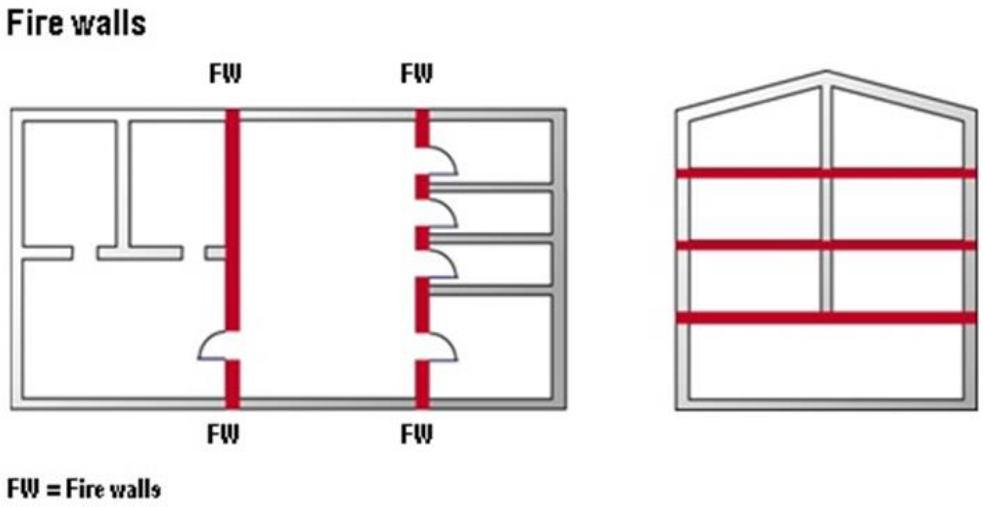
FIRE COMPARTMENTATION

Compartment walls and floors (including openings and holes and gaps in the walls – piping and wiring installation) are specifically intended to ensure that fire is contained in the compartment of origin, and is not allowed to spread horizontally or vertically through a building.



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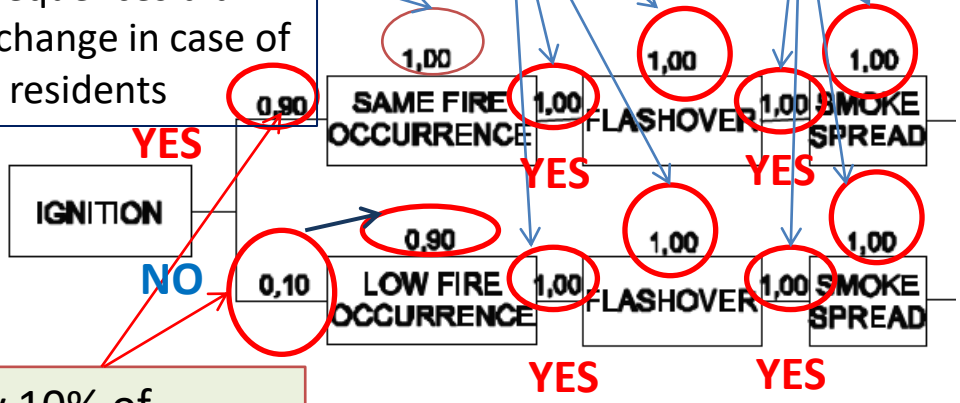
FIRE SCENARIO DEVELOPMENT AND CALCULATION

The inherent rate of fire risk to human lives in case of fire started due to forgotten meal
on the stove or malfunction of kitchen apparatus: 37%

Preventive measure: education and fire drill

Possibility of fire occurrence and consequences did not change in case of 90% residents

No fire and smoke barriers, the same possibility of flashover, smoke spreading and the same consequences



Only 10% of residents attended education and fire drill – the possibility of ignition is 90:10

residual probability multiplier

IN THIS PART OF EVENT TREE THERE IS NO **NO** BRANCH, SINCE WE DID NOT INTRODUCE A NEW FIRE BARIERRS TO STOP FIRE AND SMOKE SPREADING (COMPARTMANTATION, SPRINKLERS, SMOKE VENTILTION…)

EVACUATION PLAN AND FIRE ALARM ?
ON TIME EVACUATION?

The floor layout design includes no fire stairs, so the only evacuation route is down the main staircase, or they can be trapped in apartments, until the fire brigade comes and rescues them.
Smoke is spreading through ventilation and installation shafts into other apartments in the building.
In time, someone would notice the smoke or fire and try to alarm the residents in other apartments and the Fire brigade. The fire alarm system - manual pull stations were installed once, but some of them disappeared and the rest of them were never checked, so it is incomplete and unreliable. A manual fire alarm system depends on a human factor, which is in most cases unpredictable, but in these circumstances there are no other options to include fire alarms in event scenario.
Based on investigation, it can be assumed that the reliability of the fire alarm is 35%.

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SAFE EVACUATION ?

Smoke evacuation from staircase is possible only through a one-square-meter large exit opening on the flat roof. Smoke spreading after flashover develops fast into main staircase through apartment door. Single smoke vent on the roof is usually locked, so it cannot be taken into account in event scenario. Staircase becomes a deadly trap, soon after flashover.

Emergency light and signalization is badly damaged and incomplete, so it can slow down people movement during evacuation and increase disorientation.

Elevators are as old as the buildings, so they are still in function in the case of fire (without an automatic shutdown system), and there is a possibility that someone could try to go down with the elevator. Its shaft would be soon filled up with smoke, and even if the fire does not damage it, it is another trap to residents. It is positive that poll results showed that no one would take a lift in the case of fire. .

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FAST AND SAFE EVACUATION?

….Staircase becomes a deadly trap, soon after flashover.
Residents who took part in the drill and education process knew about it (10%), but the others did not know that it was recommended

- to evacuate immediately when they spot first signs of smoke and fire,
- or to block the apartment door and the ventilation openings with wet blankets and stay in their apartments until fire brigade arrives.

For that reason, it is assumed that there is only a 10% possibility for fast/safe evacuation.
The results of the poll conducted among residents of high-rise residential building showed that only 25% paid attention on evacuation routes and the signs in their buildings, therefore it is assumed that they will try to take the main staircase.
Poll results also showed that 90% of residents will use fire stairs for evacuation - if there is one, and 65% thinks that the fire brigade will come in time to rescue them and they will be waiting in their apartments in the case of fire.

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FAST AND SAFE EVACUATION?

…. According to the fire department dates and time measuring during the drill, it takes 8 to 10 minutes for the Fire brigade to arrive.
Additionally, difficult circumstances are included in arrival time, before they start the operation:

- inappropriate building position regarding approach possibility for fire interventions,
- parked cars or other barriers at access routes, or
- impossibility to approach some sides of buildings.

Their activities are focused on saving lives and limiting fire on actual stage and extinguishing it.
Smoke can also slow down fire-fighter teams' intervention and make life-saving operations more difficult. For that reason, first activity the fire brigade takes is to open the roof door and engage mobile smoke ventilation and suppression facilities.
Fire scenario development after fire brigade arrived is possible in two deferent ways – depending on protection measures:

(1) fire brigade came in time to limit and extinguish the fire, but too late to save residents who started late evacuation and
(2) Fire brigade came in time to save the residents who started late evacuation through staircase filled with smoke.

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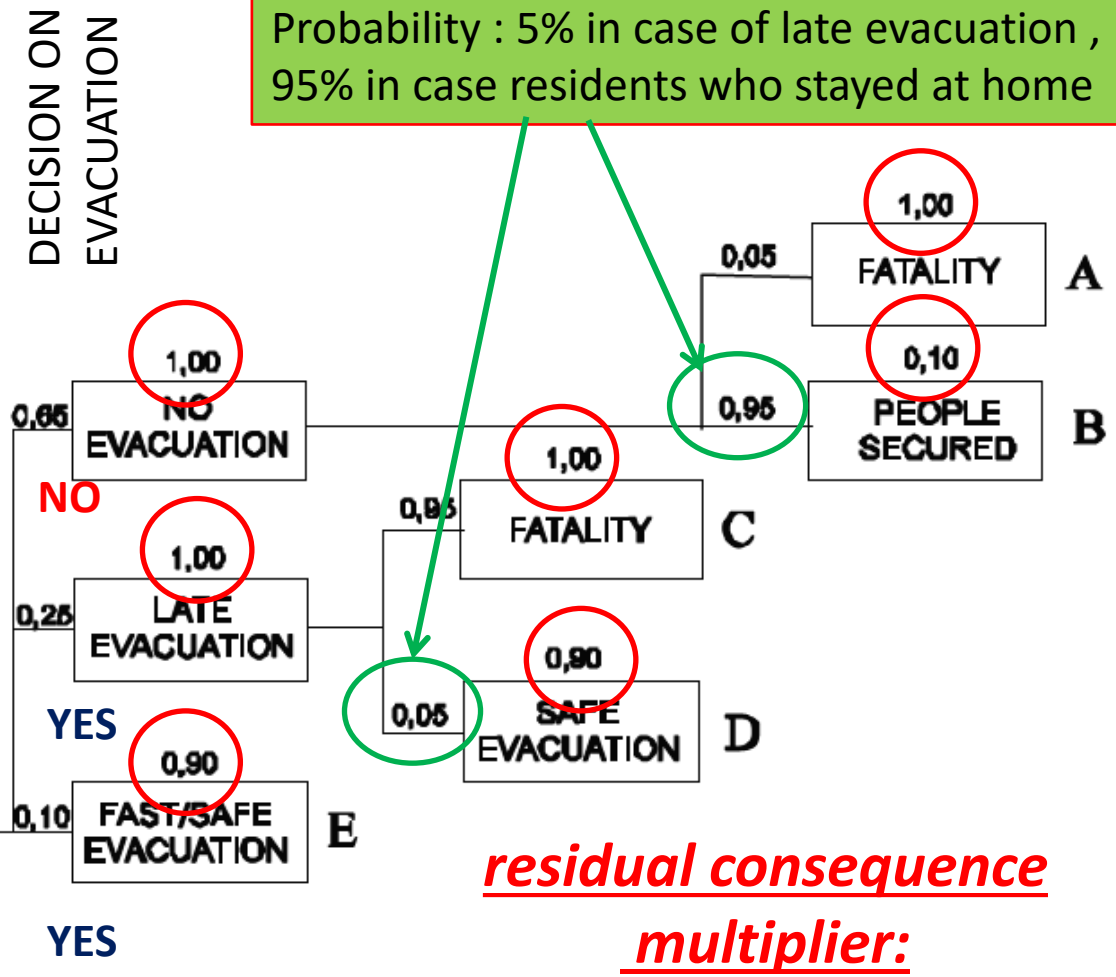
FIRE SCENARIO DEVELOPMENT AND CALCULATION

Fire brigade will arrive in time to save lives
Probability : 5% in case of late evacuation ,
95% in case residents who stayed at home

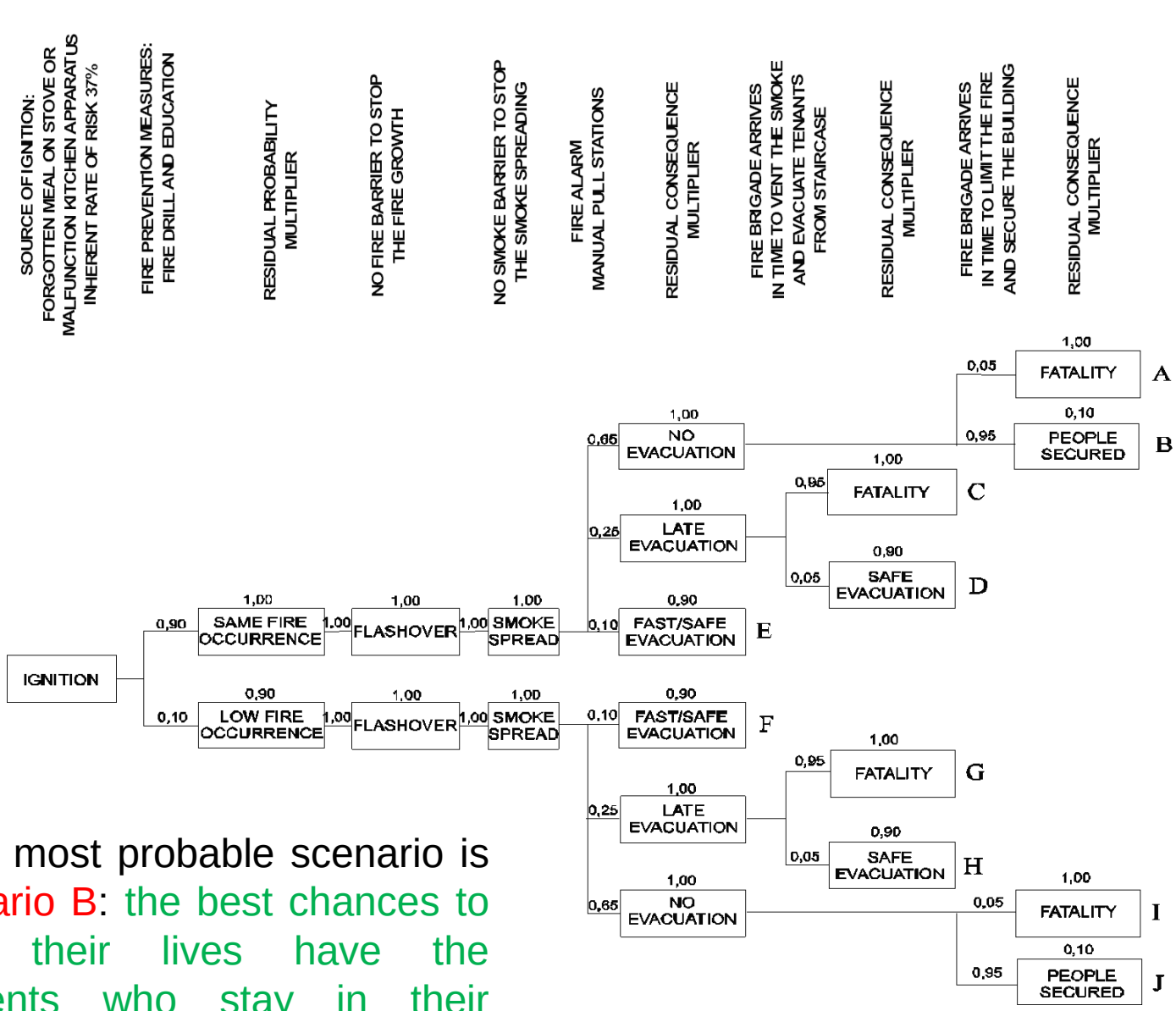
35% of fire alarms are working – precondition for fast and safe evacuation,
But
Only 10% of residence attended the fire drill and 25% Paid attention on evacuation signs and escape route
65% said that they will wait for firefighters to save them



residual consequence multiplier:

Statistic based or subjective judgment

(Video Facades in Fire)



The most probable scenario is Scenario B: the best chances to save their lives have the residents who stay in their apartments and wait for fire brigade to come to rescue them.

Fire Scenario	Scenario Probability	Residual Probability Multiplier	Residual Consequence Multiplier	Residual Risk Multiplier
A	0.02925	1.00	1.00	0.02925
B	0.55575	1.00	0.90	0.50018
C	0.21375	1.00	1.00	0.21375
D	0.01125	1.00	0.10	0.00112
E	0.09000	1.00	0.90	0.08100
F	0.01000	0.90	0.81	0.00729
G	0.02375	0.90	0.90	0.01924
H	0.00125	0.90	0.09	0.00010
I	0.00325	0.90	0.90	0.00263
J	0.06475	0.90	0.81	0.04502
	1.00			**0.89958**

The most probable fatal consequence scenario is in the case the residents try to evacuate with delay – late evacuation, when the stairway is filled with smoke (Scenario C).

(Video Vladivostok)

EVENT TREE FIRE RISK ASSESSMENT RESULT

The fire scenario was formulated according to the present state of building and its fire safety performance (structure, materialization, floor layout, existing route of escape, fume ventilation, etc) and recorded fire protection measures applied:

(1) fire drill and education,

(2) manual fire alarm,

(3) fire brigade intervention.

Combined residual risk multiplier of implementing these three fire protection measures is 0.89958; which means that the residual risk to human lives is reduced to 89.96% of its inherent value (37%).

That is, in the case of a fire, protection measures applied so far are insufficient to reduce the risk to an acceptable level.

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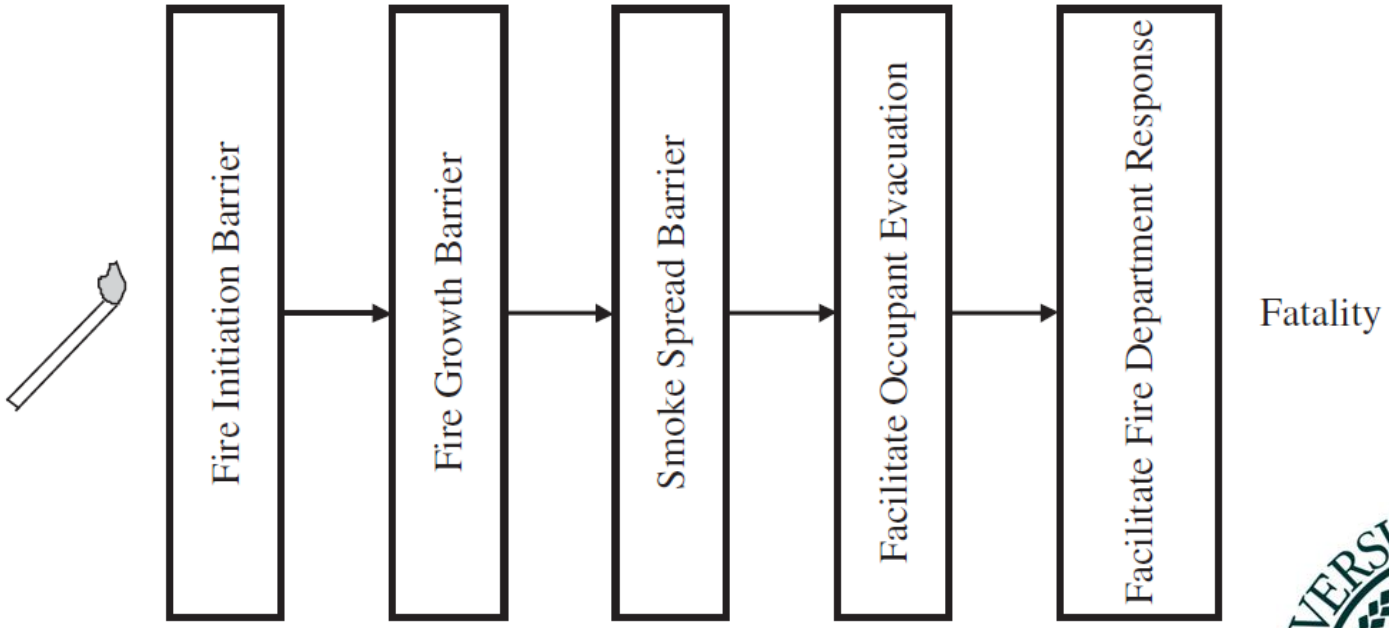
Five major fire barriers between fire source and fatality



*Every building is unique for its location, structure, building material and floor layouts, so the fire risk assessment based on **fire scenario event tree method** assesses different combinations and provides detailed information about **success** or **failure** of proposed protection measures, as well as comparison of different combinations.*

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The various fire scenarios that a fire initiation can develop into are governed by the success and failure of fire protection measures.

The sequence of fire events that follows the course of an actual fire development includes
fire growth,
smoke spread,
occupant evacuation and
fire department response.

The performance based approach is to follow the logical development of these fire events in specific building.

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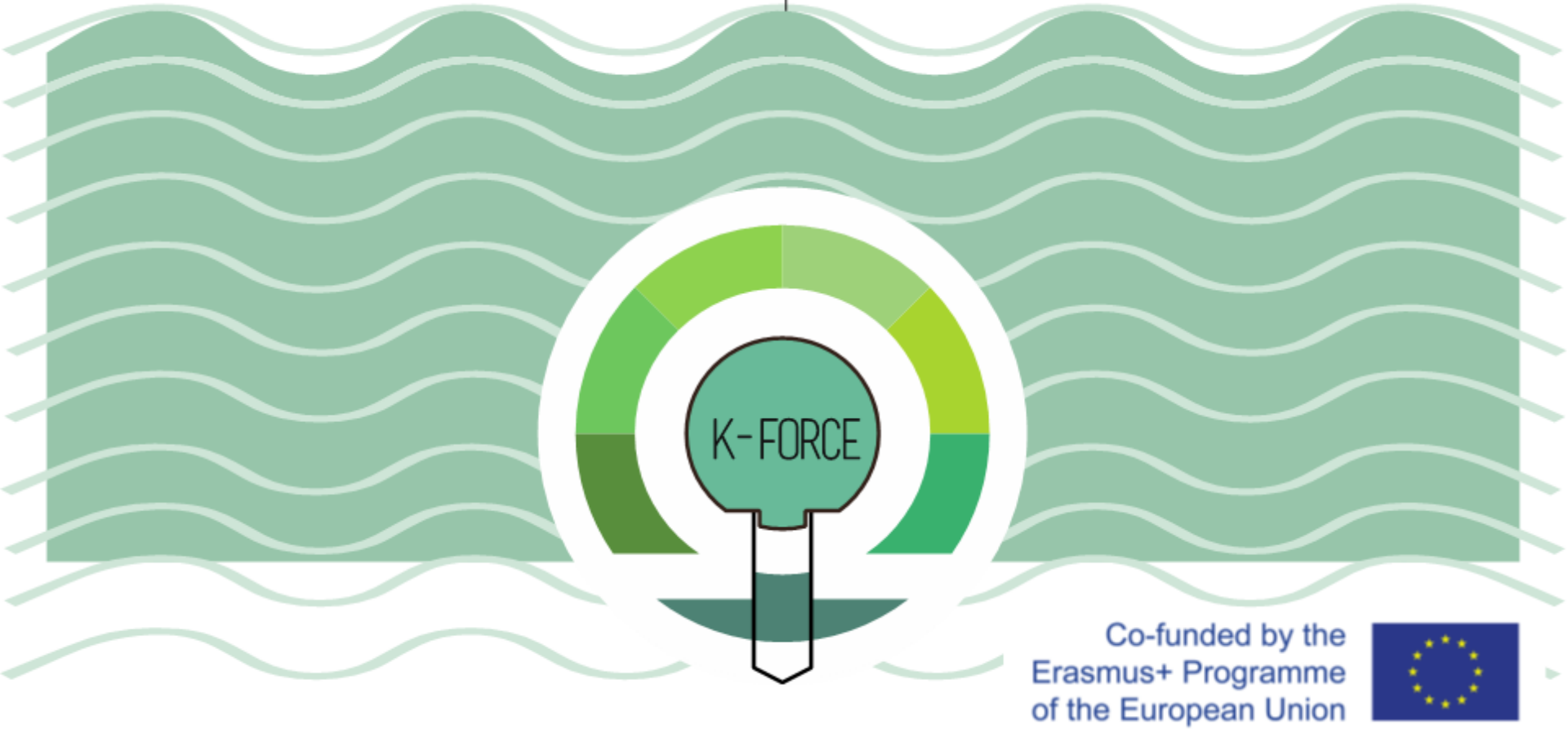

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Thank you
for your attention!

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Knowledge **FO**r **R**esilient so**C**i**E**ty