

F.R.A.M.E.

EVENT NETWORKS used in "FRAME" .

In 2004, Dipl. Ing. Trond Maag wrote his doctorates' thesis "Risikobasierte Beurteilung der Personensicherheit von Wohnbauten im Brandfall unter Verwendung von Bayes'schen Netzen ", a document that can be found on :

<http://e-collection.ethbib.ethz.ch/show?type=diss&nr=15366>

The aim of his work was the development of a methodology to assess the risk of fire fatality in residential buildings. It uses a Bayesian network, which determines risk as the expected number of fatalities per 100 million hours of exposure to a building (fatal accident rate). The acceptance criteria are those determined according to the ALARP approach, which takes the view that a building's fire risk should be rendered as low as reasonably possible through fire safety measures, which are then assessed in terms of their economy.

Reading through his thesis, a lot of similarities can be found between the R1 calculation in "FRAME" and his approach. Unfortunately, he was probably unaware of the existence of "FRAME", as he did not mention it in his references, and he used the Gretener (SIA81) method for comparison, which is a poor choice, as that method is aimed at property risks not at life safety. His conclusion is that the SIA81 method is not very suitable for life safety assessments, as could be expected.

It must be a hole in my education, as I did not know what a Bayesian network was, but I learned from "Wikipedia": A Bayesian network (or a belief network) is a probabilistic graphical model that represents a set of variables and their probabilistic independencies.

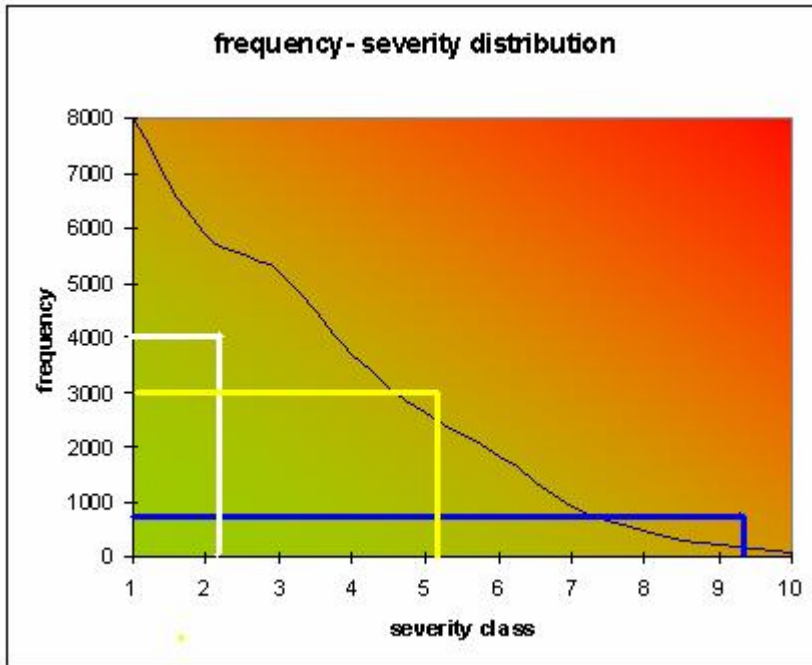
"FRAME" is also based on event networks, as the risk calculation is a combination of "cause and effect" relationships, with probabilities of success. However, "FRAME" is not a "pure" Bayesian network as it combines probability and severity, where a Bayesian network, like the one developed by Dr. Maag calculates the risk for one type of severity : fire fatalities..

E.g. by adding sprinkler protection in the calculation, the reduction factor in "FRAME" corresponds not only with a 90% probability reduction for a major loss, but also with the damage reduction on any fire controlled by sprinklers.

The next flow-charts show the networks used to evaluate the fire risk for property, people and activities. As these are three independent but related evaluations, three distinct networks are used.

The outcome of each network will be a "fire risk", identified by a probability and a severity value, or a position on a frequency / severity diagram or risk profile. The fire risks located in the lower left corner (green area) are below the average frequency / severity and are considered acceptable, where those in the upper right corner (red area) are certainly unacceptably high.

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The weighing factors in "FRAME" assess the elements that have an impact on the probability as well as on the severity of a fire. An increase of probability means a shift upward on the y-axis of the risk profile, whereas an increase of severity results on a shift to the right on the x-axis. In both cases, it means a change towards less acceptable risks.


Usually probabilities are written as a number of occurrences per period, like 10^{-5} / 50 years of exposure. In a "pure" Bayesian network, the outcome of the network calculation would be the probability of occurrence of a single event, based on a combination of influence factors.


This is what Trond Maag has done in his thesis: He defines the probability of a fatal fire for a particular building (fatal accident rate) and when this probability is below the socially accepted level, the building is considered safe enough for life safety.


In "FRAME", a logarithmic scale is used. This corresponds with the integration of the probability / severity curve, i.e. it includes all incidents with various combinations of probability and severity. And it has the additional benefit of producing "user-friendly" results: A risk reduction from $R=2$ to $R=1$ is easier to understand for a decision maker than a "probability x severity" reduction from 10^{-2} to 10^{-3} / 50 years.

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The yellow and grey fields indicate input data, to be identified for the compartment that is assessed. The "yellow"  data have an impact on the severity of the fire damage and/or the number of casualties of a fire in the concerned compartment. The "grey"  data in the fields have an effect on the probability of occurrence of such a fire. Some input data have an effect on both severity and probability: these are shown with yellow/ grey backgrounds.

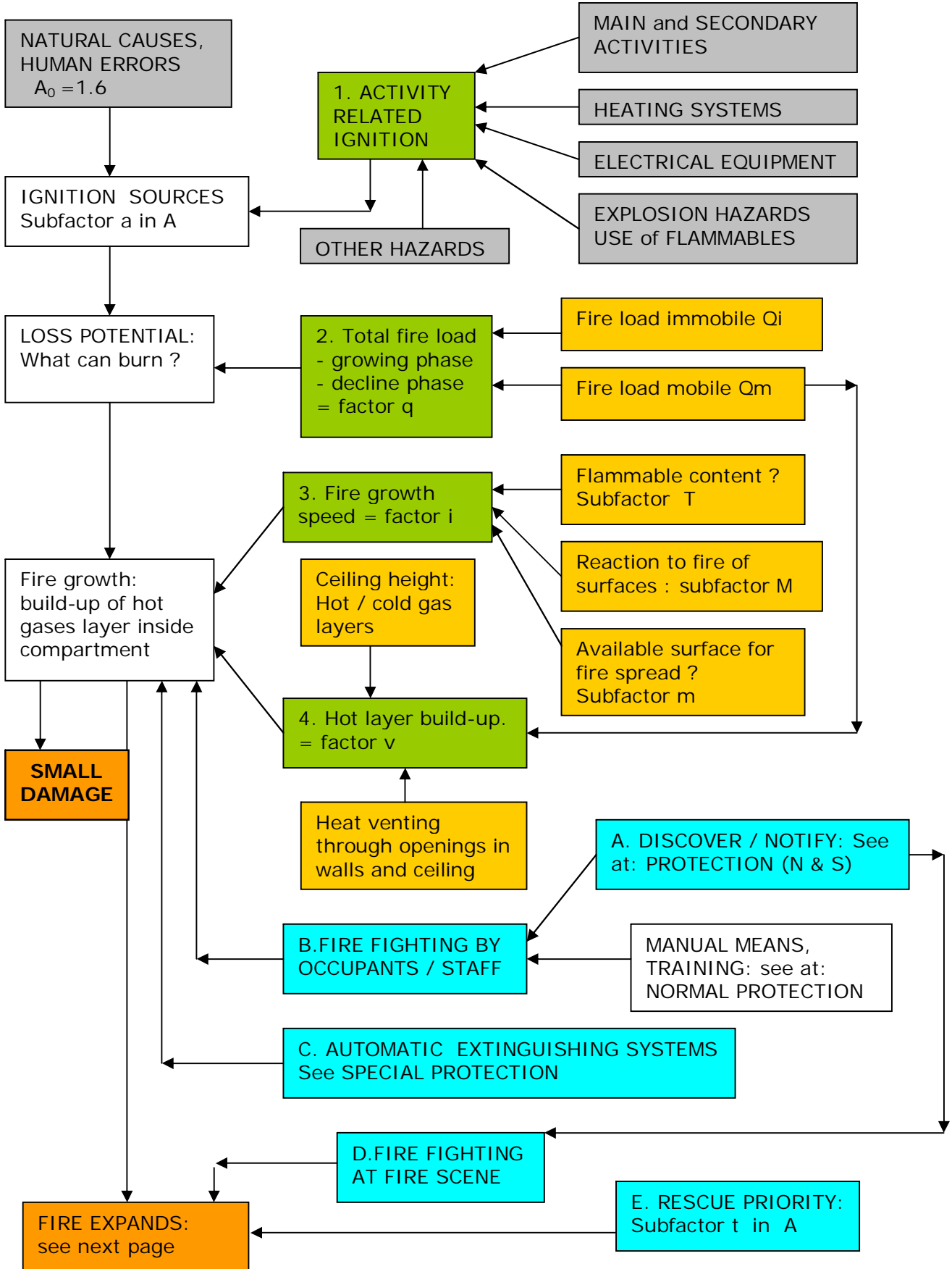
The green  fields indicate related values, which are directly calculated from the yellow and grey input data.

The blue  fields indicate subsystems where several (sub) factors are combined. These inputs are further detailed in the subsystems.

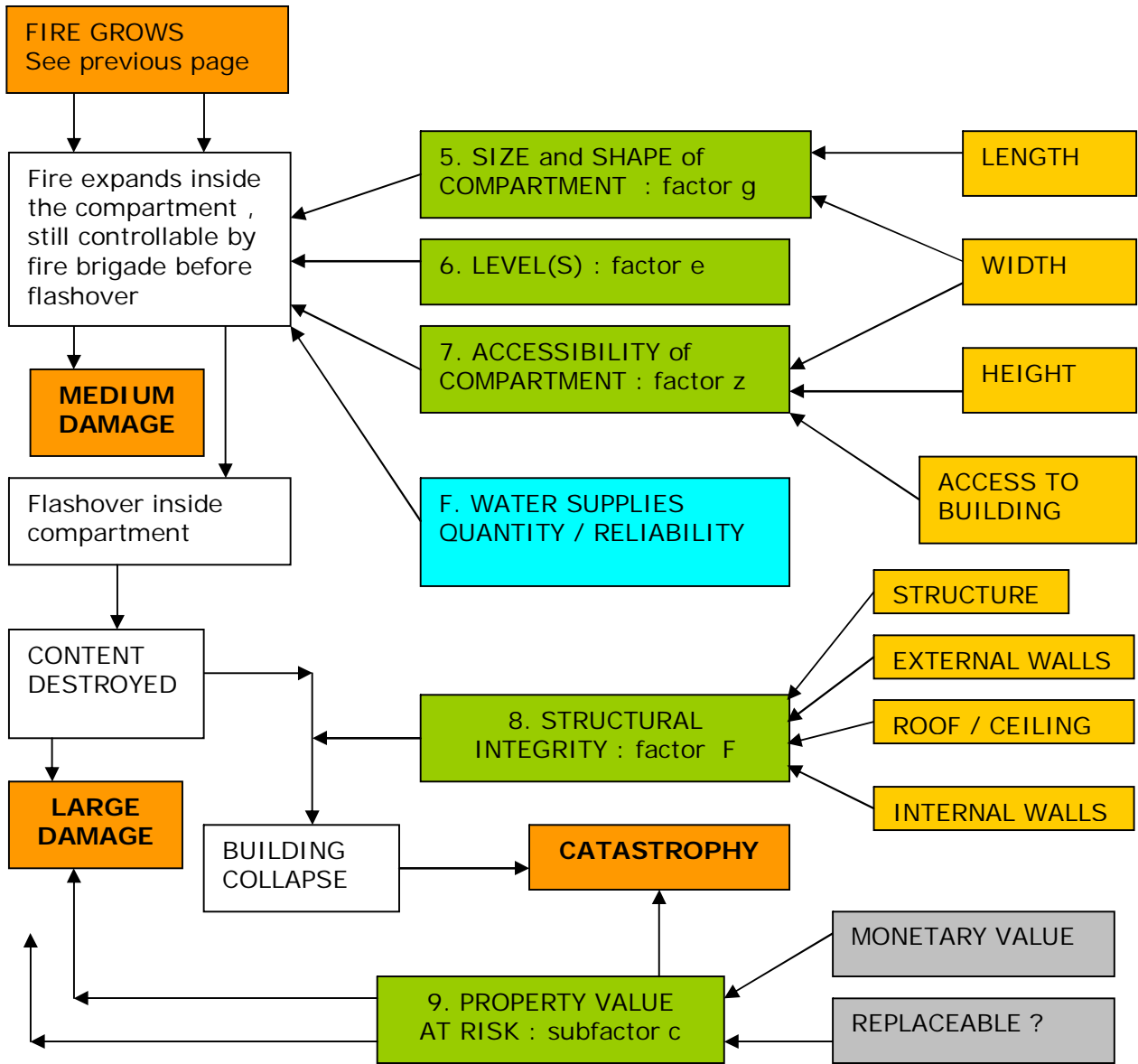
The orange  fields indicate the possible outcome on a time scale.

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NETWORK FOR PROPERTY RISK.

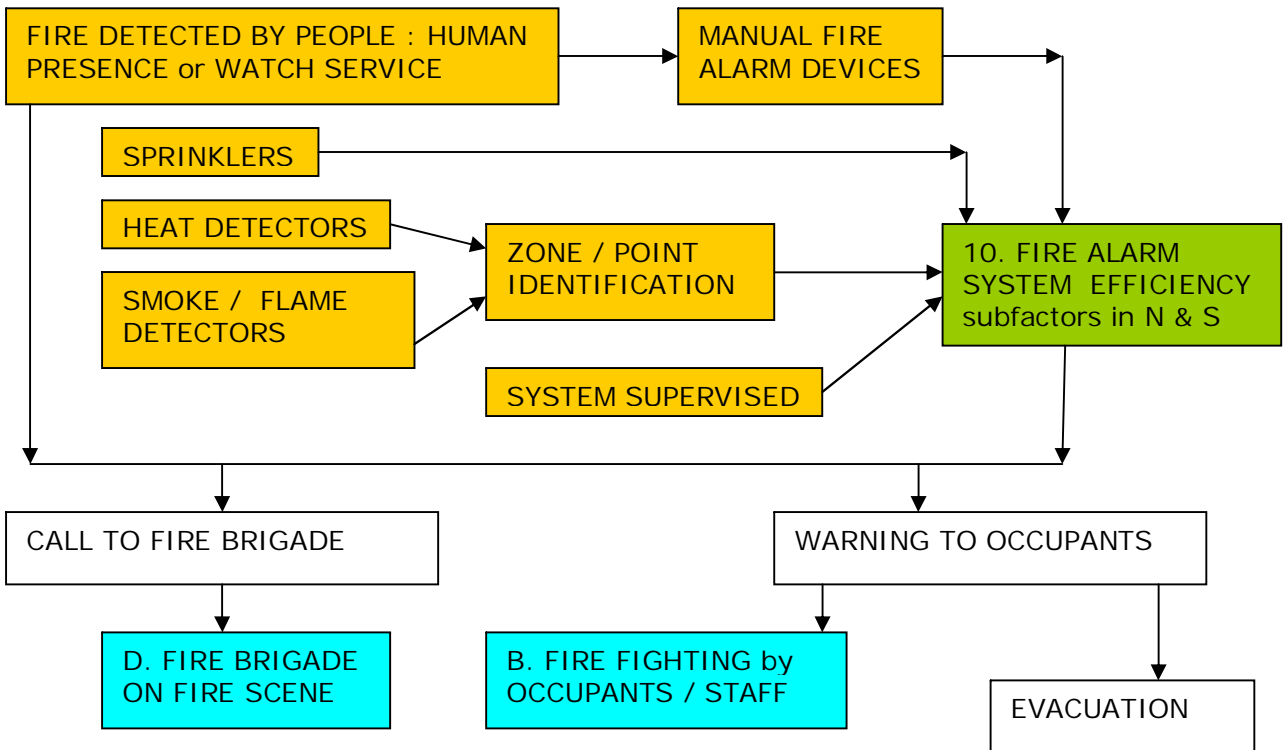


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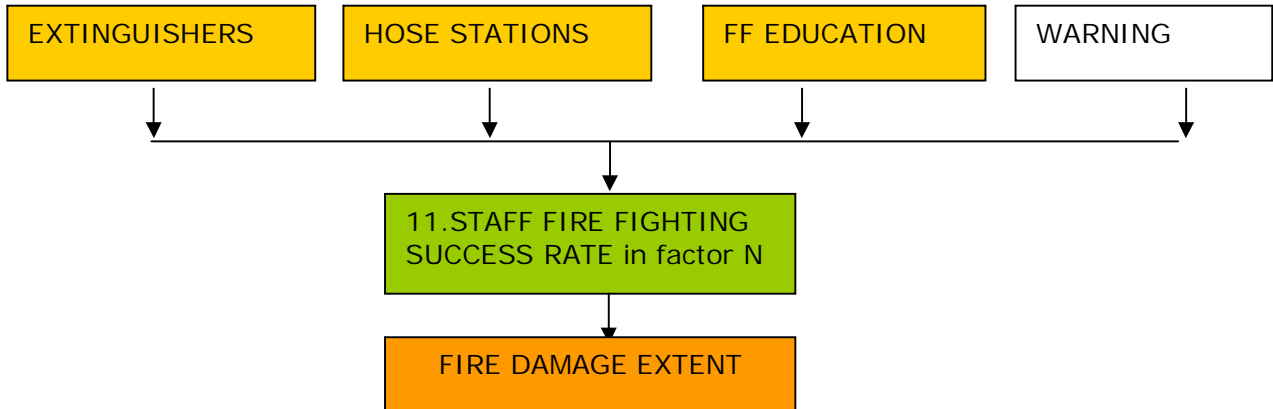


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SUBSYSTEM A: DISCOVER / NOTIFICATION

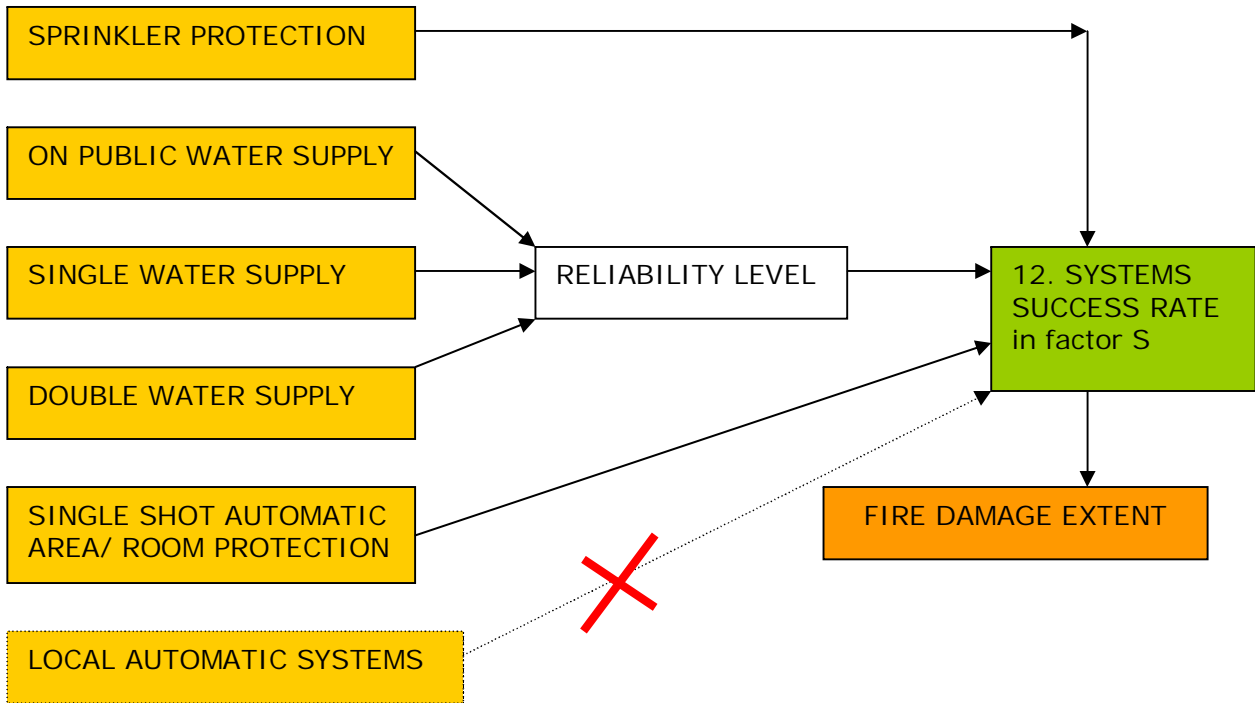


SUBSYSTEM B : FIRE FIGHTING BY OCCUPANTS / STAFF

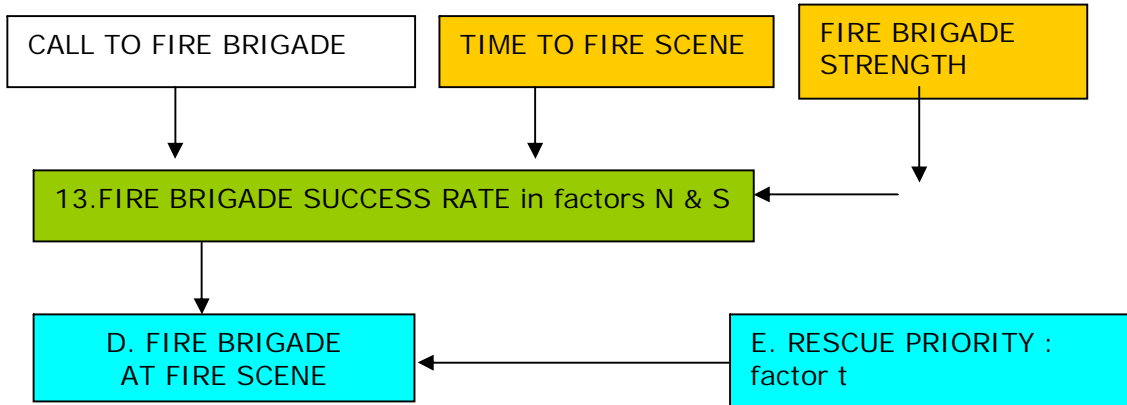


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SUBSYSTEM C: AUTOMATIC EXTINGUISHING SYSTEMS.

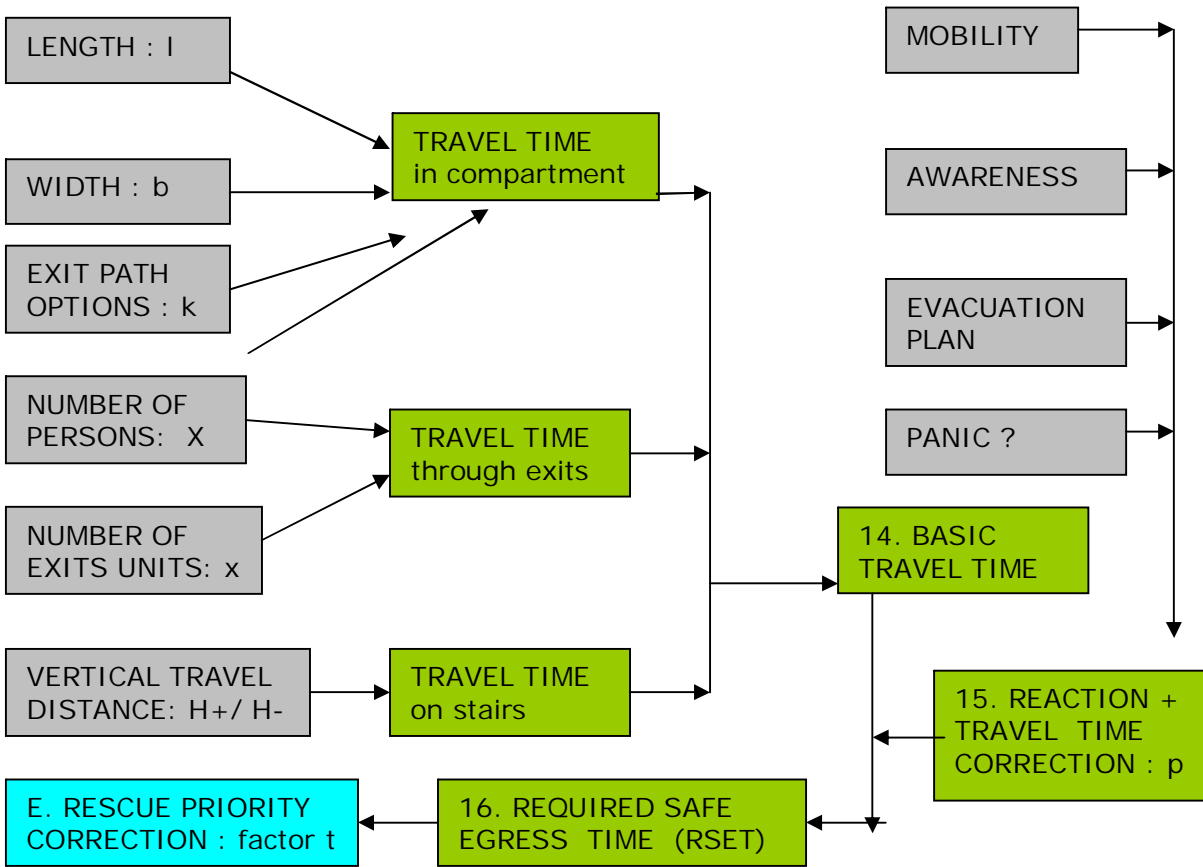


SUBSYSTEM D: FIRE BRIGADE AT FIRE SCENE



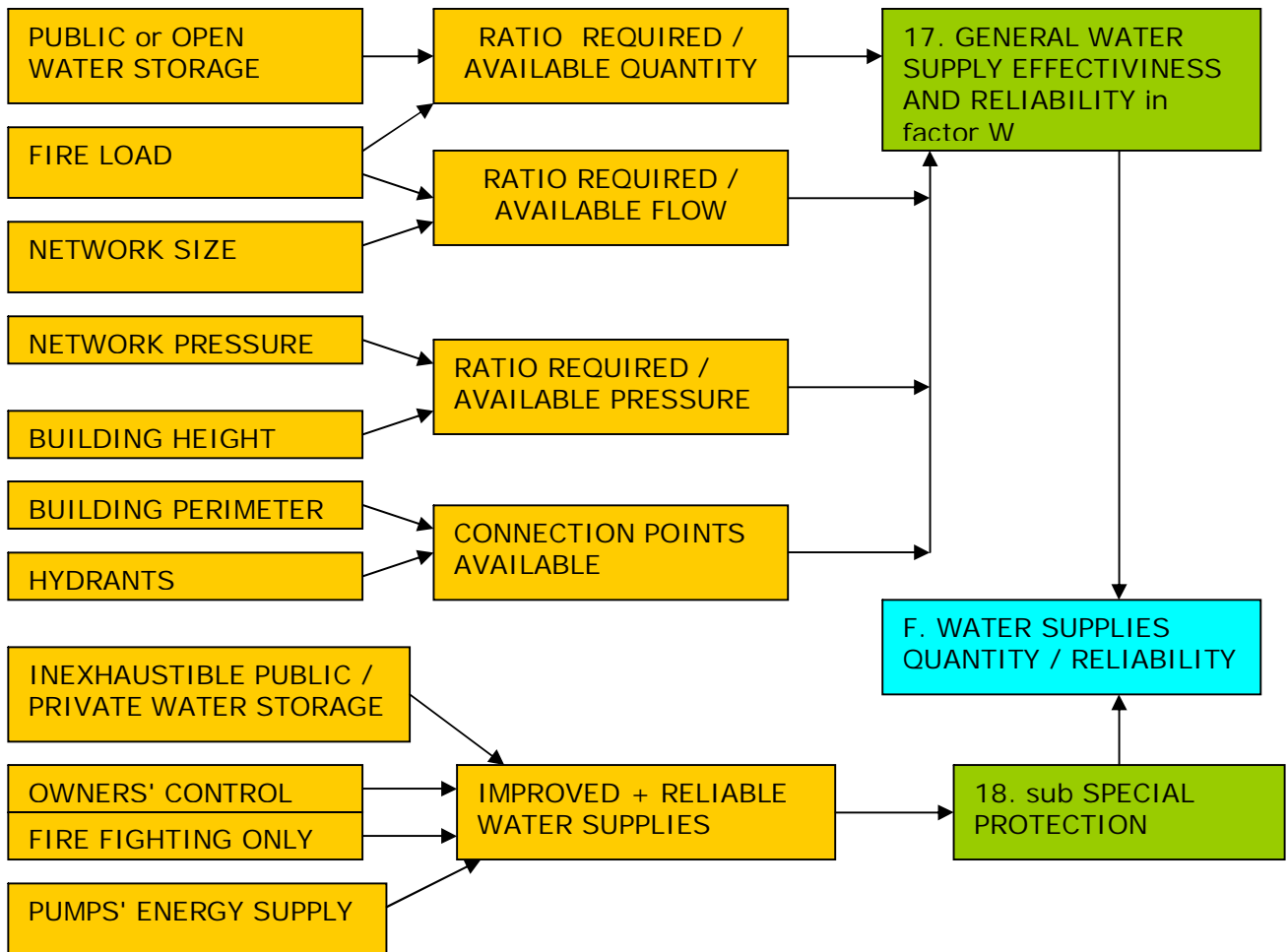
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SUBSYSTEM E : RESCUE PRIORITY / EVACUATION TIME



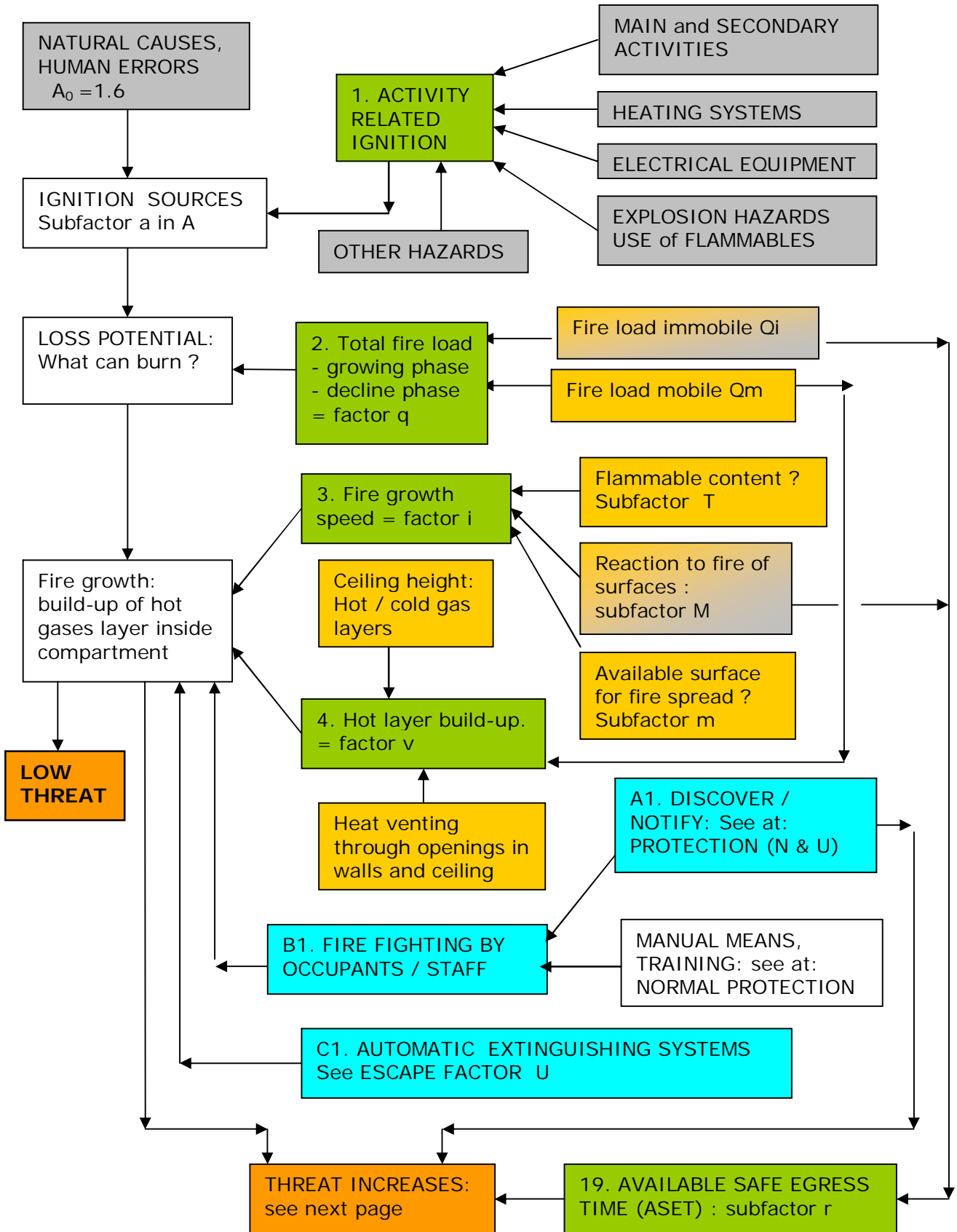
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SUBSYSTEM F : WATER SUPPLIES

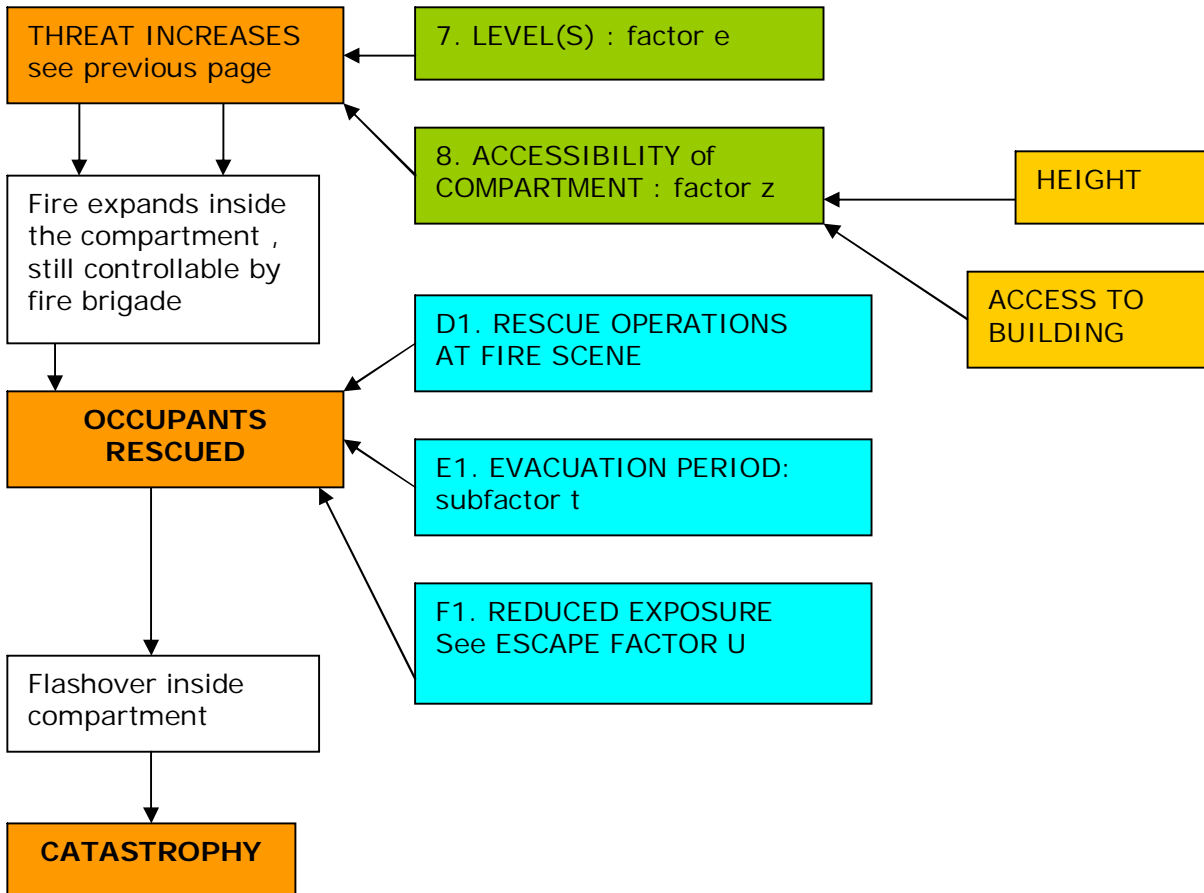


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NETWORK FOR OCCUPANTS' RISK.

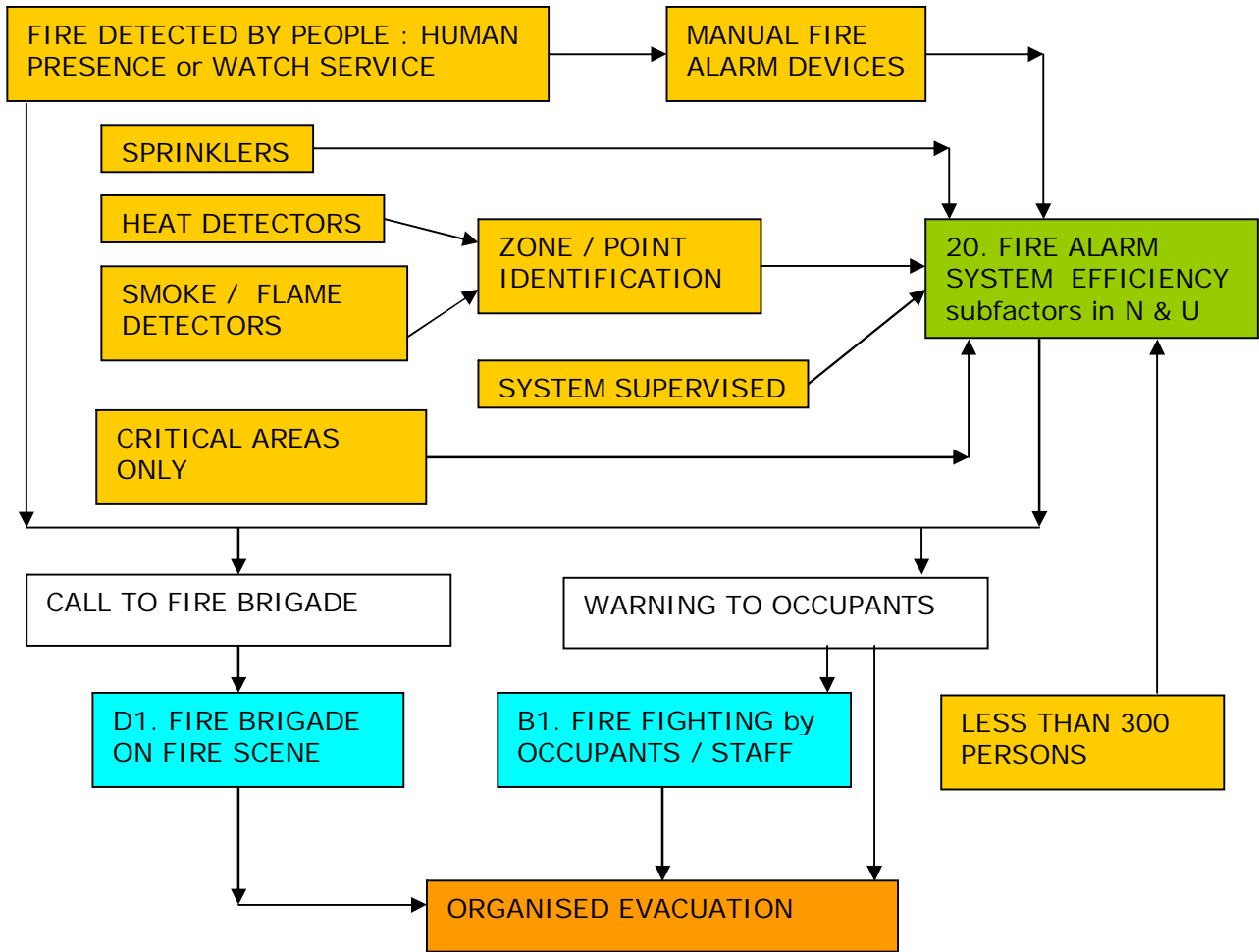


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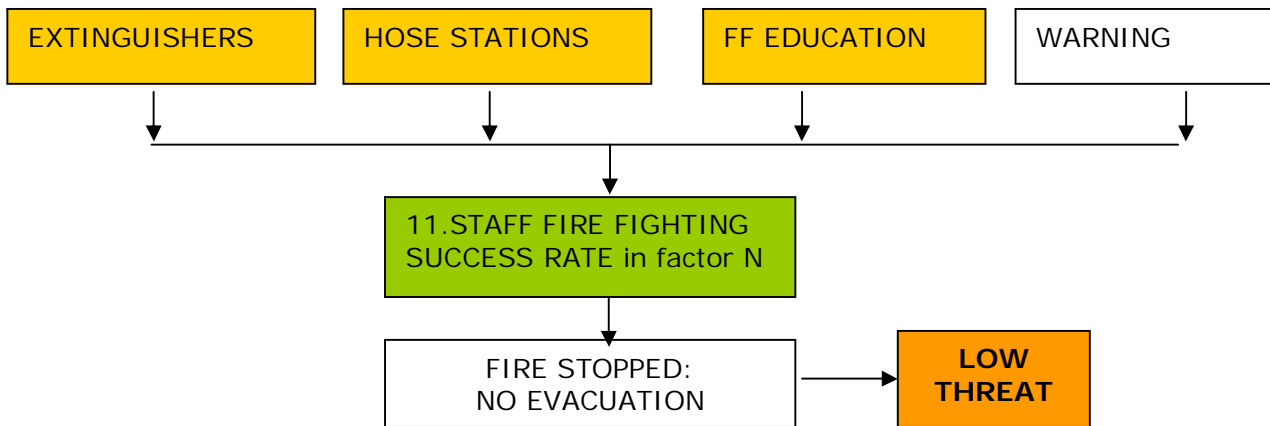
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SUBSYSTEM A1 : DISCOVERY AND NOTIFICATION.

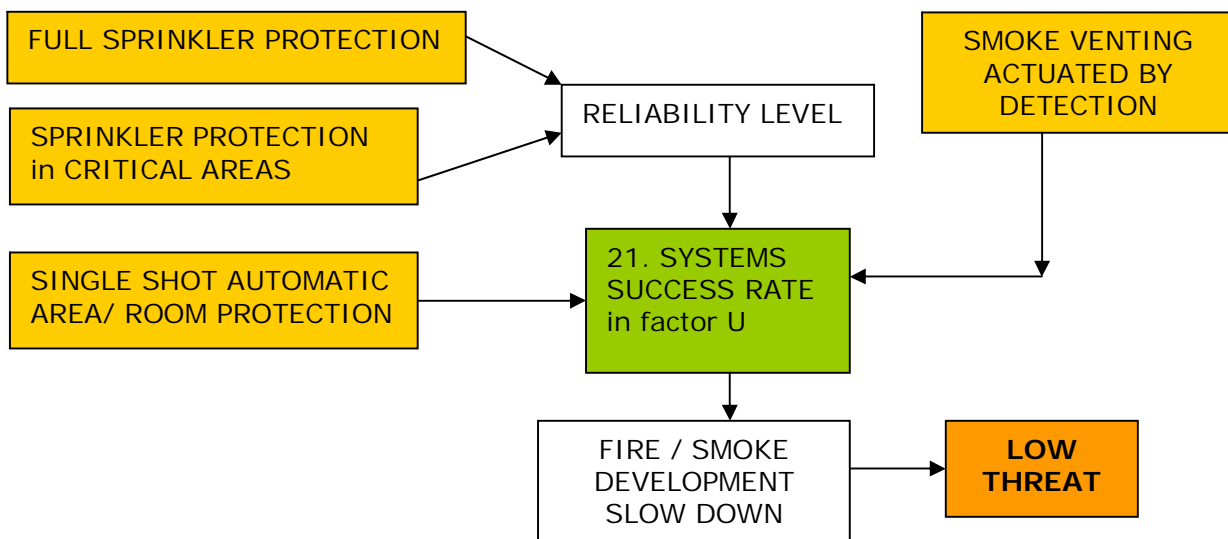


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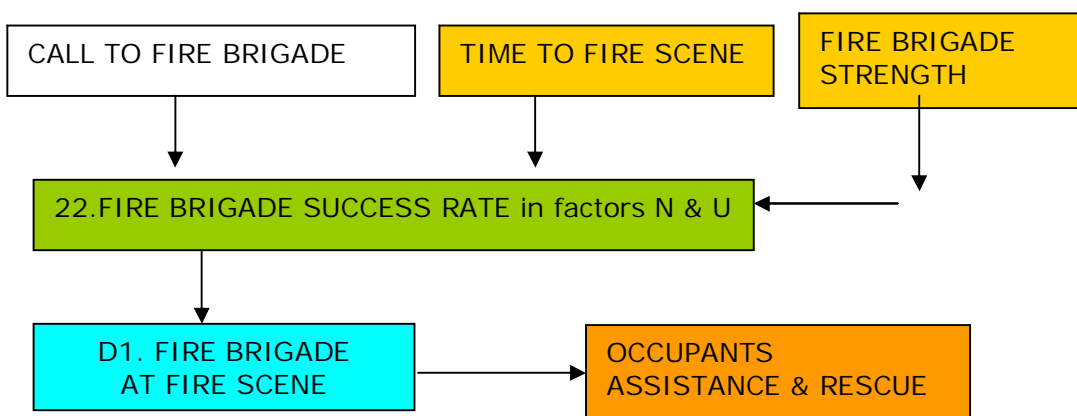
SUBSYSTEM B1: FIRE FIGHTING BY OCCUPANTS and STAFF



SUBSYSTEM C1 : AUTOMATIC EXTINGUISHING SYSTEMS.

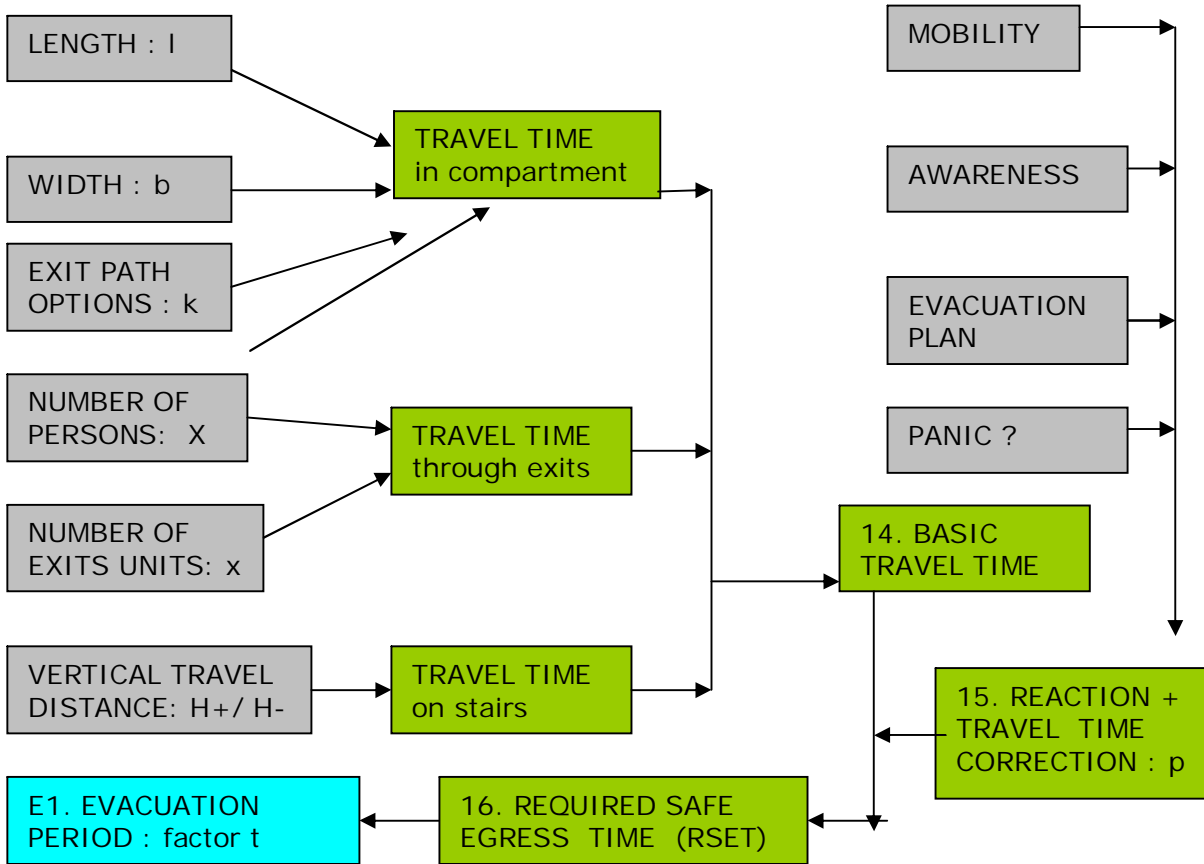


SUBSYSTEM D1: FIRE BRIGADE ON FIRE SCENE.

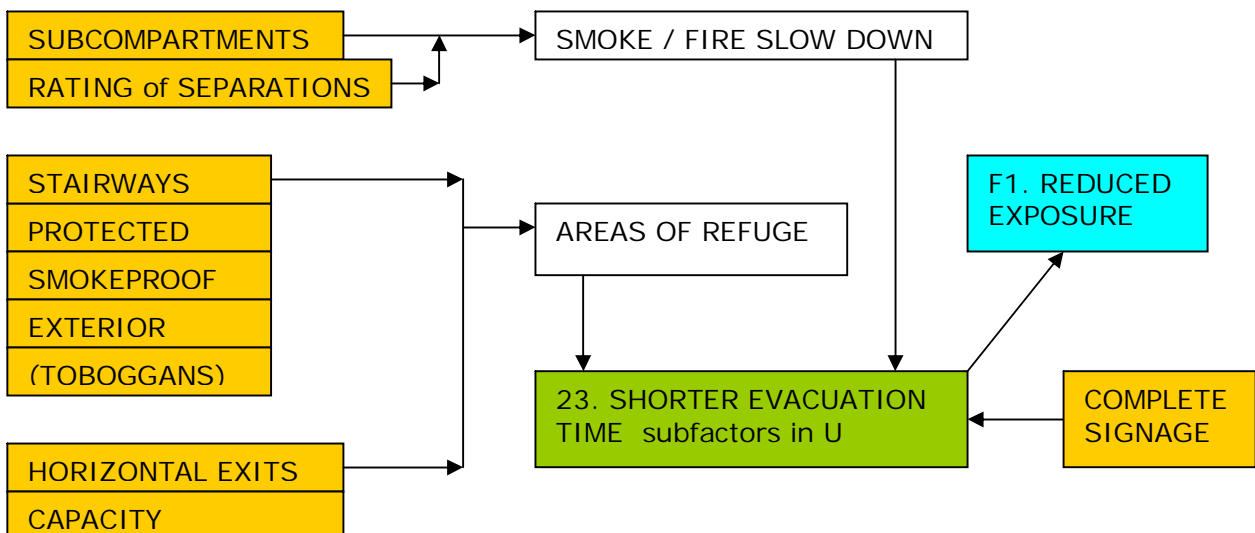


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SUBSYSTEM E1: EVACUATION PERIOD

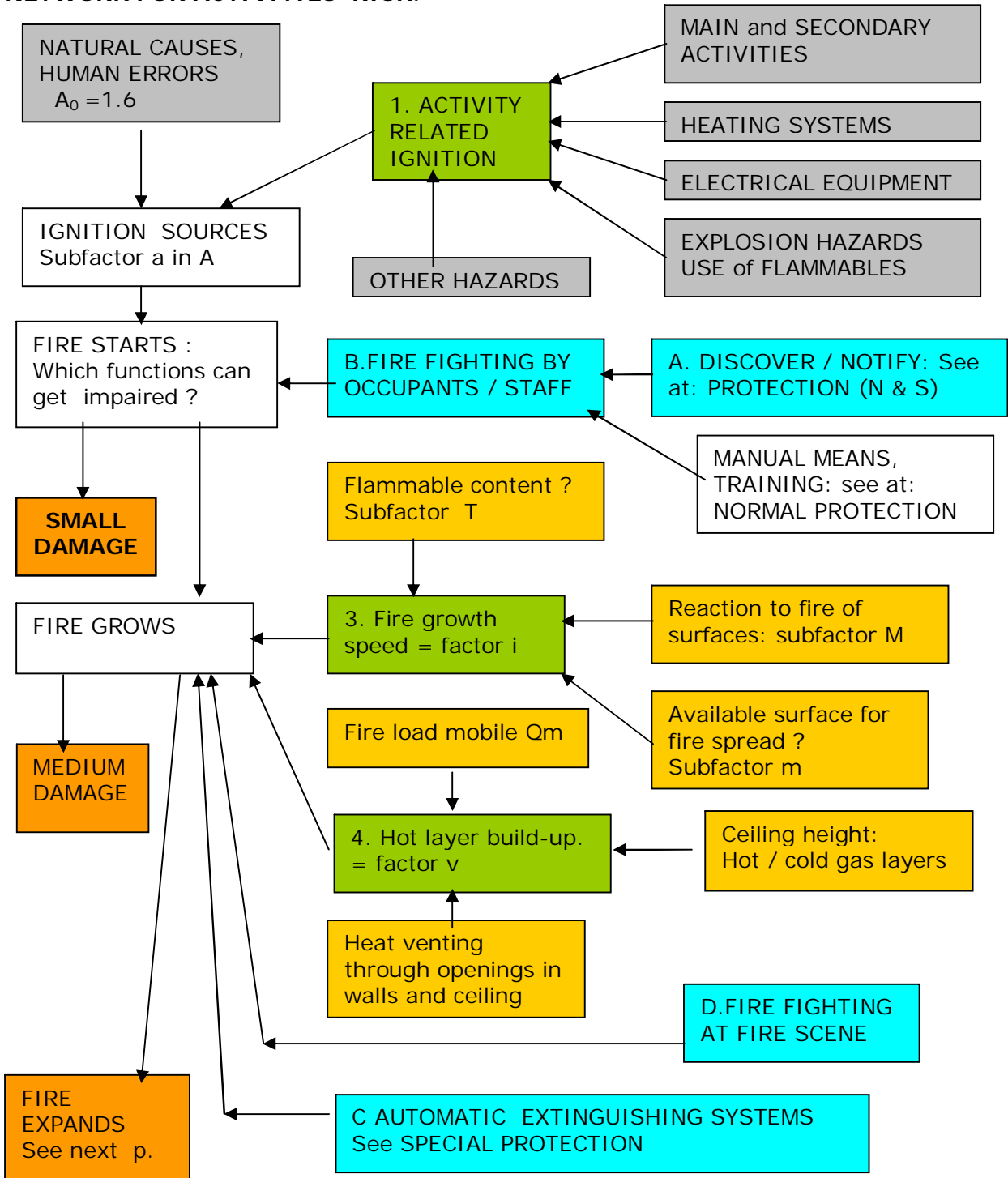


SUBSYSTEM F1: REDUCED EXPOSURE

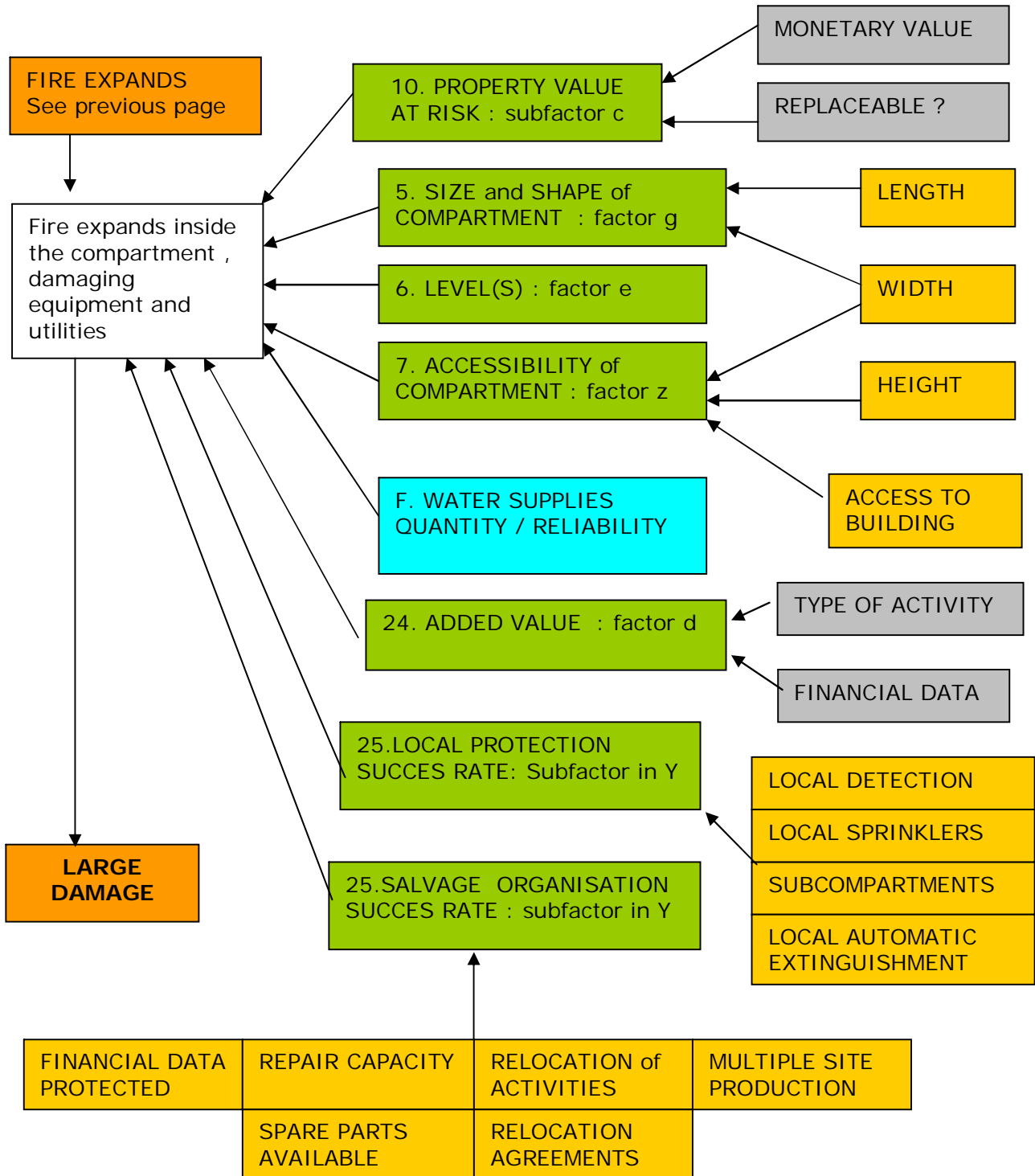


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NETWORK FOR ACTIVITIES' RISK.



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Explanation of the 3 risk networks.

The networks begin with the basic probability that a fire starts by "accident" : a lightning strikes, a human error, the cat jumps and turns over a burning candle... This basic probability gives the value of $A_0 = 1.6$.

Node 1. In a number of situations, there are additional ignition sources present, linked to main and secondary activities, the heating systems, electrical equipment, the use of inflammable products, etc. These items define the value of factor a and increase the probability of fire occurrence and hence increase the value of the risk .

Node 2. An ignition source is not sufficient for a fire, there must be something to burn: This is defined as the fire load, split up in a fixed "immobile" fire load from all the building products, and a "mobile" fire load from the contents. The "immobile" fire load influences also the evacuation environment (factor r) and the "mobile" fire load plays a role in the build-up of the hot gases layer (factor v). Factor q represents the fire load in the risk calculation

Node 3. Once a fire has started , it will grow at a certain speed: a fast growing fire will increase the risk and factor i copes with that. The fire growth is defined by 3 sub factors : flammability of the content (sub factor T), reaction to fire characteristics (sub factor M) , and available surface for fire growth (sub factor m). The reaction to fire characteristics also play a part in factor r .

Node 4. As a fire grows, a hot gas layer is built up at the ceiling. The feed for this layer comes mainly from the content or mobile fire load, and the layer development can be controlled by smoke venting. The ceiling height defines the space available for the hot and cold layers. This is reflected by factor v .

Subsystem A. In many cases, the occupants and/or the staff can extinguish the fire in its growing phase with only small damage. The success rate of these first interventions depends on the speed of discovery and notification, which are evaluated by the subsystem A discovery/ notification.

Subsystem B. The success of the first intervention depends also on the available means as well as on the training of the staff: this is evaluated in subsystem B , fire fighting by occupants and staff.

Subsystem C. When automatic protection such as sprinklers is installed, the fire will be controlled very fast in most cases: The success rate of the automatic protection is evaluated by subsystem C.

Subsystem D. If the fire is not controlled yet by the staff and/or sprinklers, the growing fire will be tackled by the fire brigade. It will take some time for the fire brigade to reach the fire scene: This and the strength of the fire brigade is considered in subsystem D: fire brigade at the fire scene.

Subsystem E. At the fire scene, the fire brigade may have to give priority to rescue operations, reducing the effectiveness of the fire fighting: this priority is measured by subsystem E , that includes the elements to calculate factor t (evacuation time).

Nodes 5, 6 and 7. The success of the fire fighting operations before flash-over occurs depends much on the local conditions : size and shape of the compartment, level and accessibility of the fire compartment: factors g , e and z are used to evaluate this.

Subsystem F. Fire fighting success depends also on the availability and the reliability of the water supplies: this is considered in subsystem F, combining the water supplies factor W and sub factors of S .

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Node 8. If flash-over occurs, the total content of the compartment will certainly be lost. It will depend on the structural fire protection whether a building will collapse after flash-over. Factor F considers the structural fire protection and the probability of building collapse.

Node 9. Whatever the size of the loss is, the actual cost will depend on the value of the content, which is evaluated by sub factor c.

Subsystem A, discovery/ notification.

This subsystem evaluates the probability of a successful early evacuation and intervention. It takes into consideration the presence or absence of manual and automatic fire detection and notification systems as well as the reliability and capabilities of such systems. In *node 10*, the result is split up between sub factors of N, normal protection and S, special protection.

Subsystem B, fire fighting by occupants and staff, takes into account the presence of portable extinguishers, hose reels, and staff training. In *node 11*, it gives a combination of sub factors of N, normal protection.

Subsystem C, automatic extinguishing systems : takes into account the presence of automatic extinguishment systems like sprinklers covering a complete compartment. In *node 12*, it groups those sub factors of S that consider the existence and reliability of such systems.

Subsystem D, fire brigade at the fire scene : takes into account the arrival time of the fire brigade, the type and strength of the brigade and in *node 13*, it is split up between sub factors of N and S.

Subsystem E, evacuation time.

In *node 14* the travel time inside the compartment, through exits and on stairs for independent and mobile persons is calculated. *Node 15* considers sub factor p which gives a correction for mobility, organisation and risk awareness .

The combination of both in *node 16* defines the RSET, the required safe egress time to leave the building. The higher this evacuation time is, the longer the exposure is for life safety, hence an increase in risk. Equally, the fire brigade will spend more time on rescue operations, thus reducing the effectiveness of fire fighting.

Subsystem F, water supplies:

Node 17 considers the type of water supplies available for fighting, the quantity compared with the fire load, the distribution system, as defined by factor W. Large quantities, reliability, redundancy and energy supplies are combined through sub factors of S in *node 18*.

For the life safety risk network a somehow different combination is made.

Nodes 1, 2, 3, and 4 come back in the network, but the impact of the subsystems A1, B1 and C1 is not same for life safety as for property protection, hence a slightly different calculation.

In *node 19*, the "immobile" fire load and the reaction to fire characteristics (sub factor M) are combined to evaluate the ASET, the available safe egress time. Factor r, the environment factor considers the speed of fire and smoke growth and the effect of it on the life safety risk.

Subsystem A1 : discovery/ notification. This subsystem evaluates the probability of a successful early evacuation and intervention. It takes into consideration the presence or absence of manual and automatic fire detection and notification systems as well as the reliability and capabilities of such systems. It is split up in *node 20* in sub factors of N, normal protection and U, the escape factor.

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Sometimes evacuation may be not necessary, as the fire is controlled by the first intervention by the staff: this is evaluated in **subsystem B1**, which has the same components as subsystem B.

Node 5 is not present in the life safety network: size and shape of the compartment are considered in the evacuation time calculation.

When automatic protection such as sprinklers is installed, the fire will be controlled very fast in most cases, reducing the need for a total evacuation. The success rate of the automatic protection is evaluated by **subsystem C1**, automatic extinguishment systems.

Subsystem C1 takes into account the presence of automatic extinguishment systems, be it for a complete compartment or locally in a high risk zone. In [node 21](#), it contains those sub factors of U that consider the existence of such systems. Reliability of water supplies is not an issue for life safety and is not considered.

If the fire is not controlled yet by the staff and/or sprinklers, the growing fire will be tackled by the fire brigade. It will take some time for the fire brigade to reach the fire scene: This and the strength of the fire brigade is considered in **subsystem D1**, fire brigade at the fire scene. In [node 22](#) it is split up between sub factors of N and U.

People are at risk as long as they are in the building on fire. This is measured by **subsystem E1**, which is identical to subsystem E.

However, the occupants can be in safety in a shorter time, when measures are taken that shorten the exit travel time, by redundant evacuation means, and by additional barriers for smoke and heat propagation. This is measured in **subsystem F1**. In [node 23](#) this is considered by sub factors of U.

If flash-over occurs, all people still present will be killed. Therefore, the compartment shall be evacuated before flash-over occurs. It means that the structural fire protection plays no significant role for the safety of the occupants and shall not be considered as beneficial for life safety. Factor F is not taken into account.

For the activities' risk network an other combination of risk factors is used.

Nodes 1 "ignition sources", 3 "fire growth", and 4 "smoke and heat ventilation" come back in the network. The duration of the fire has no considerable influence on the activities' risk. Hence the node 2 (fire load factor q) is not considered.

Subsystems A, B, C and D play a similar role as for the property risk and come back in this network.

Node 5 "compartment size and shape", 6 "levels", and 7 "accessibility" define the growth of fire damage from small to medium damage in a similar way as for the property risk.

Node 10 "property value at risk" defines the size of the cost of any fire loss, while subsystem F "water supplies" is taken into account to evaluate the water supply resources for the fire brigade and sprinkler systems.

[Node 24](#) evaluates the dependency of the activities on that particular location by considering the added value generated at that place.

[Node 25](#) considers the existence and success rate of local systems that are installed to protect areas or equipment with a high impact on business continuity.

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And finally [node 26](#) brings up all organisational measures that can be taken to speed up a restart after a fire, thus reducing the impact on the activities.