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Report – Part 2

Detailed Risk Analysis of the effect of 4G Interference on BA Telemetry

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EXECUTIVE SUMMARY

All Fire and Rescue Services (FRS) equip their firefighters with respiratory protective equipment in the form of breathing apparatus. This supplies individual firefighters with a self-contained supply of breathable air in order to protect them during fire fighting and other activities at a range of incidents.

Some FRS make use of an additional piece of radio equipment attached to the BA set which provides a data link to continually update officers on their firefighters' remaining air levels. The combination of both is known as BA telemetry.

The BA Telemetry Working Group has agreed that consideration should be given to assessing the risks that will affect those fire and rescue services with BA Telemetry. This piece of work is necessary to ensure that all the risks associated with the issue of potential interference to BA Telemetry are mitigated so far as reasonably practicable before the introduction of LTE (4G) in 2013.

This report builds on the work previously reported in Reference 1 which identified the causes of potential failure of BA Telemetry from interference from other devices for a range of options.

A high level Fault and Event tree model has been developed to show the benefits of BA Telemetry in three specific areas and then to show how much interference from LTE and other devices reduces this benefit across a range of options.

This model does NOT set out to evaluate the actual risk to a firefighter whilst using BA sets within a burning building, merely to indicate the relative change in risk across a range of options. This relative risk is modelled purely from a BA Telemetry point of view and it is likely that the actual benefit (and hence relative risks) could be much smaller in practice. It also assumes that, without interference, BA Telemetry is 100% perfect – however this is not the case in practice due to other issues which are not considered in this report or by the BA Telemetry Interference Project.

Never the less, the results show that there is a clear benefit to be gained from the deployment of BA Telemetry with no interference present from LTE. This benefit is reduced (but still exists) when interference causing Telemetry failure is added but then increases again until option 3 is showing similar benefits to the original frequency with no interference.

Care, however, needs to be taken when using these results to choose a final option since this analysis takes no account of the technical or project risks involved in any option and there are large assumptions in the data used (although statistical data from the IRS has been used where possible).

ISSUE RECORD

Issue	Date	Revision History
1.0	08-Feb-2012	First issue
2.0	09-Feb-2012	Incorporation of comments
3.0	27-Feb-2012	Incorporation of data from IRS statistics

DISTRIBUTION

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1 INTRODUCTION

All Fire and Rescue Services (FRS) equip their firefighters with respiratory protective equipment in the form of breathing apparatus. This supplies individual firefighters with a self-contained supply of breathable air in order to protect them during fire fighting and other activities at a range of incidents.

Some FRS make use of an additional piece of radio equipment attached to the BA set which provides a data link to continually update officers on their firefighters' remaining air levels. The combination of both is known as BA telemetry.

The BA Telemetry Working Group has agreed that consideration should be given to assessing the risks that will affect those fire and rescue services with BA Telemetry. This piece of work is necessary to ensure that all the risks associated with the issue of potential interference to BA Telemetry are mitigated so far as reasonably practicable before the introduction of LTE (4G) in 2013.

1.1 Scope and methodology

This report builds on the work previously reported in Reference 1 which identified the causes of potential failure of BA Telemetry from interference from other devices for a range of options.

The purpose of this report is to outline the work undertaken to create a detailed risk analysis of the potential failure of BA Telemetry using Fault and Event Tree analysis. This was carried out in the following stages:

- Identification of the key benefits of BA Telemetry (in reducing the risk to firefighters),
- Deriving probabilities that BA Telemetry would fail to work when required due to interference,
- Creation of the Fault and Event Tree Model

These are discussed in detail in the following Sections.

2 BENEFITS OF BA TELEMETRY

2.1 Calculation of air remaining

When a firefighter enters a building a manual calculation is carried out by the BA Entry Control Officer that identifies the time at which the firefighter is due out of the building. This is a shared responsibility between the BA wearer and the BA Entry Control Officer and this calculation also takes into account the requirement for the BA wearer to return to the BA Entry Control Point before operation of the low pressure warning device. This is important information as it highlights to the BA Entry Control Officer when a firefighter is overdue and allows emergency teams to be committed into the risk area.

This calculation uses an equation that is based on a standard work rate. This has the potential for error in two ways that can lead to rescue being delayed:

- The BA Entry Control Officer can make a mistake in the calculation,
- The fixed algorithm does not take account of increasing work rate and so the firefighter may well use the available air in a much shorter time than predicted.

An additional safety feature of the manual calculation process is to adjust the TOW to the lowest duration of the members of a BA Team and there is a safety margin built into the calculations.

BA Telemetry, however, removes the potential for both of these errors since it provides a direct record of the pressure in each BA set and, since it is continually updated, allows a dynamic calculation of the remaining air to be done.

Use of BA Telemetry therefore removes the risk in miscalculation of the time a firefighter is due out and also has the potential to allow earlier indication areas of concern with the dynamic link to the air remaining.

2.2 Automatic / Manual Alarms: Distress Sign Unit

The BA set is fitted with two alarms. A manual alarm that the firefighter can use to indicate they are experiencing difficulties and an automatic alarm that is initiated if the firefighter is motionless for a small period of time.

For this study we have selected to model the benefit of the automatic alarm only. This allows significantly earlier intervention by an emergency team when this information is received by the BA Telemetry. Without the alarm the earliest warning could be when the firefighter did not appear out of the building at the calculated time (see above).

It is also noted that the BA wearers always operate as a team when committed to a premise. No credit is taken, however, for the partner as both firefighters could be immobilised or there is no action the other firefighter can take (which results in a faster response than via BA Telemetry).

2.3 Evacuation Alert

BA Telemetry also provides a means of alerting all firefighters to evacuate the premises by pressing a single alarm on the BA Entry Control Board. This also allows provision of feedback as each firefighter should acknowledge the alarm which is fed back to the BA Entry Control Board. Should any firefighter not acknowledge the alarm there is early indication of difficulties which allows earlier assessment of the situation and use of an emergency team.

Without the BA telemetry the evacuation would take place either by fireground radio (which has numerous potential problems with reception and ability to hear) or by using manual whistles near to the building.

3 BA TELEMETRY FAILURE

This section shows the assumptions that are used to calculate the probabilities of interference causing BA Telemetry to not function when it is required. The previous report (Reference 1) discussed how interference from different sources would affect BA Telemetry for the different options. What is also discussed is the fact that the effect would vary depending on the relative distances between the firefighter and the Entry Control Board (ECB) and the source of interference and the ECB.

For modelling simplicity, we have looked to calculate the effects of interference for two different scenarios:

- Simple Building Structures – e.g. domestic dwellings, where the distance between the firefighter and the ECB is comparatively small
- Complex Building Structures – e.g. factories, warehouses, high rise buildings – where the distance between the firefighter and the ECB is competitively large.

IRS statistics show that, for 2010-2011 approximately 70% of all building fires are in dwellings, with 30% for other residential and non-residential. This is assumed to apply to the split between simple and complex structures.

3.1 Option 1 – Remain at current frequency

There are no specific calculations that can show precisely the likelihood of loss of telemetry from LTE interference. However, Reference 1 shows from the summary of a range of analysis that it is highly likely for interference to cause a loss of telemetry if there is a LTE device close to the ECB and that device is providing continuous transmission of data (i.e. receiving data only does not cause interference).

Given the public interest in fires, it is accepted that with the new technology, it is not unrealistic to assume that there will be at least one LTE terminal providing this upload at a fire and that this is likely to be even more so at complex structures. From this we have estimated two probabilities of interference causing a loss of telemetry when required as:

- Simple Structures - 5%
- Complex Structures - 20%

The complex structure being higher than simple structures purely due to the relative distances involved between the firefighter and the ECB.

While these are assumptions and are almost certainly not accurate, they provide a basis for the remainder of the analysis and do allow a comparison of the risks of the different options to be made.

3.2 Option 2 – Move frequency to the SRD band

It has been show that by moving the frequency of the BA Telemetry away from the LTE band will give an approximately factor of 10 reduction in the effect of interference on telemetry. Applying this to the probabilities calculated in Option 1 gives us:

- Simple Structures - 0.5%
- Complex Structures - 2%

However, in this band there is also the potential interference from SRD devices. These devices are more likely to be found and have an effect at industrial sites, and therefore again, different values are required for simple and complex structures. Best evidence suggests that, at worst, the effect of SRD interference will be the same as LTE on complex sites (and conservatively, it is assumed there is also a risk at simple structures, but a factor of ten less). This gives us the following probabilities for SRD interference causing loss of telemetry as:

- Simple Structures - 0.2%
- Complex Structures - 2%

3.3 Option 3 – Move frequency to 870-876MHz

This option is similar to option 2, however since the frequency is further removed from the potential for out of band emissions from LTE, an additional reduction in probability of interference causing loss of telemetry of a factor of 3 is assumed. This therefore gives us the following probabilities of LTE interference causing loss of telemetry of:

- Simple Structures - 0.15%
- Complex Structures - 0.60%

Similarly to the SRD band, there are also other devices present in this band that have the potential to cause interference. There is no difference in effect over simple or complex structures, and the likelihood of this causing loss of telemetry could be as low as zero. This has been conservatively assumed to be 0.1% for modelling purposes.

3.4 Option 4 – Move frequency to 450-470MHz

There is no effect from LTE on BA Telemetry in this frequency band, however there are many unknowns in this band and therefore it was decided not to provide a model for this option.

4 MODELLING

The fault and event trees used for this model are shown in Appendix 1 with Option 2 selected (i.e. the SRD band). In practice, switches are used in the model to allow selection of the option being investigated. It is noted that the models in the appendix are subject to change if assumptions on data are revised (or as better data becomes available).

4.1 Firefighter immobilised

This scenario models one or more firefighters being trapped or unconscious in a building and that the other firefighters are unable to provide assistance.

IRS statistics for 2010-2011 show that there were 21,674 dwelling, other residential and non-residential fires where BA was used in England.

It is further assumed that there is a 0.1% chance of a firefighter being immobilised (by whatever means) during these fires and a further 10% chance that other firefighters are available to provide assistance.

The event tree then models a different (though similar) series of events for simple or complex structures.

4.1.1 Simple Structures

The first event models if the BA Alarm is received at the ECB via BA Telemetry (simple structures). The Fault tree for this simply sums the probability of interference for the option selected. If the alarm is received then it is assumed there is 95% of a successful emergency intervention (given the early information). If the alarm is not received then it is assumed that the only means of rescuing the firefighter is through manual calculation of remaining air and realising that a firefighter has not returned on time. In this case it is assume that the chance of a successful rescue is only 50%.

4.1.2 Complex structures

The event tree for complex structures is similar to that for simple structures; however the first event now models if the BA Alarm is received at the ECB via BA Telemetry (complex structures). The fault tree for this is different to that for simple structures since there is a higher probability of interference causing a loss of BA Telemetry for complex structures (Section 3).

It is also assumed that, for a complex structure, there is a chance that more firefighters could be immobilised.

4.2 Firefighter fails to return in time

This scenario models one or more firefighters becoming trapped in the building (disorientated) or miscalculating their own air supplies and not returning in time. As above, the initiating event uses 21,674 building fires where BA is used across England. It is further assumed that there is a 0.1% chance of a firefighter being either disorientated or running out of air during these fires and a further 10% chance that other firefighters are available to provide assistance.

The event tree is similar to that described above, however information does not reach the BA Entry Controller as soon as with the automatic alarm and therefore for a successful BA Telemetry alert it is only assumed there is a 90% chance of carrying out a successful rescue.

4.3 Structural Collapse

This scenario models the building beginning to collapse and the BA Entry Controller recognising this and carrying out an urgent evacuation. Again, using the IRS statistics, there were 119 cases of structural collapse in connection with BA incidents. It is assumed that using BA Telemetry there is a 95% chance of successfully evacuating and, where necessary, rescuing any trapped firefighter. Where BA Telemetry is not available, this is reduced to a 50% chance.

5 RESULTS

The model was run for five separate scenarios. It is important to note the following however:

- The calculated risk is not a true risk, however due to the consistent modelling approach across the options it does allow the difference in risk to be calculated between options.
- The initiating incidents are based on statistical data taken from the IRS for England for 2010-2011.
- The model ONLY models the effect of interference on BA Telemetry – where additional options for rescue are available (e.g. fireground radio, other firefighters) these are not modelled as apply equally to all options (i.e. do not affect the relative risk).
- It is assumed that BA Telemetry is 100% effective with no interference (this is not actually true).

Scenario	Risk per year	Benefit
BA Telemetry not installed	5.71	0.0
BA Telemetry prior to LTE (i.e. no interference)	0.64	-5.07
Option 1	1.73	-3.98
Option 2	1.00	-4.71
Option 3	0.68	-5.03

While not showing a 'true' risk this table does allow an assessment of the potential effectiveness of each option (noting this does not take account of the technical or project risks in developing each option).

It does demonstrate that there is a clear benefit in having BA Telemetry installed prior to the switch on of the 4G band, and that even staying with option 1, there is still benefit in having BA Telemetry than reverting to manual techniques.

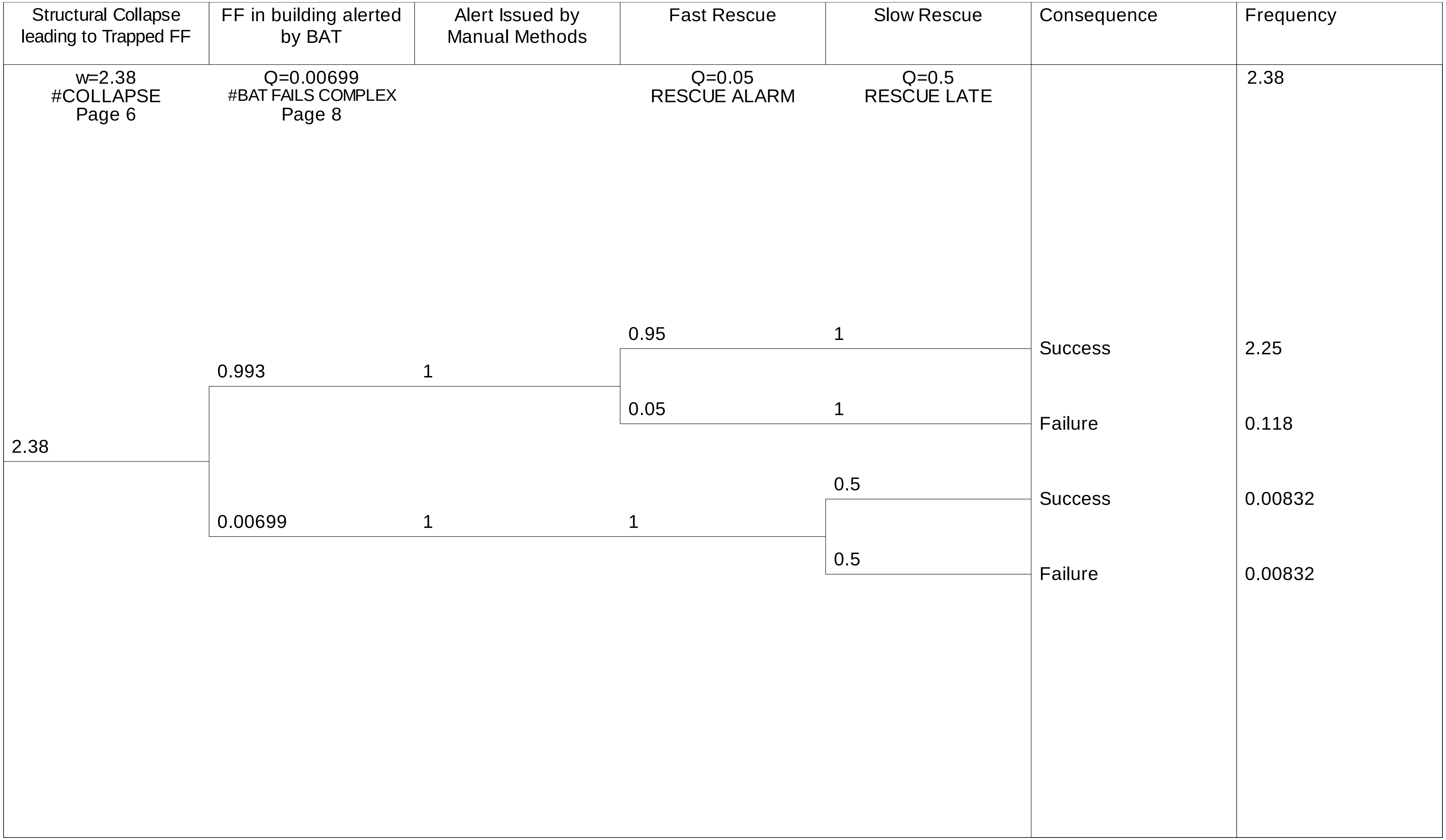
There are, however, distinct additional gains in risk saved per year from the other two options. The selection of any option, however, must be treated with caution as this analysis is extremely simple and does not allow for any future changes that may arise in any of the options, and hence the chance of future interference.

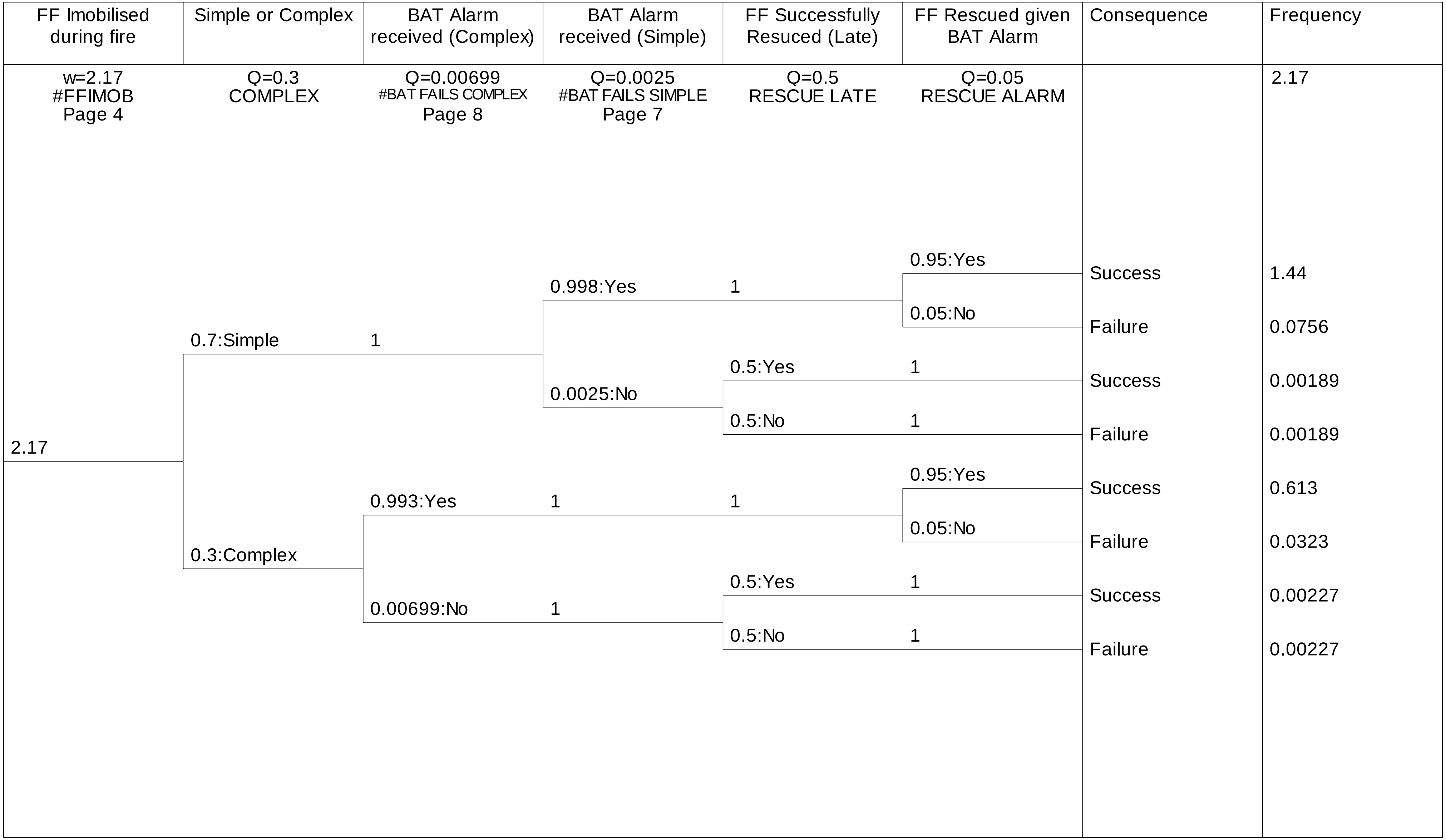
6 REFERENCES

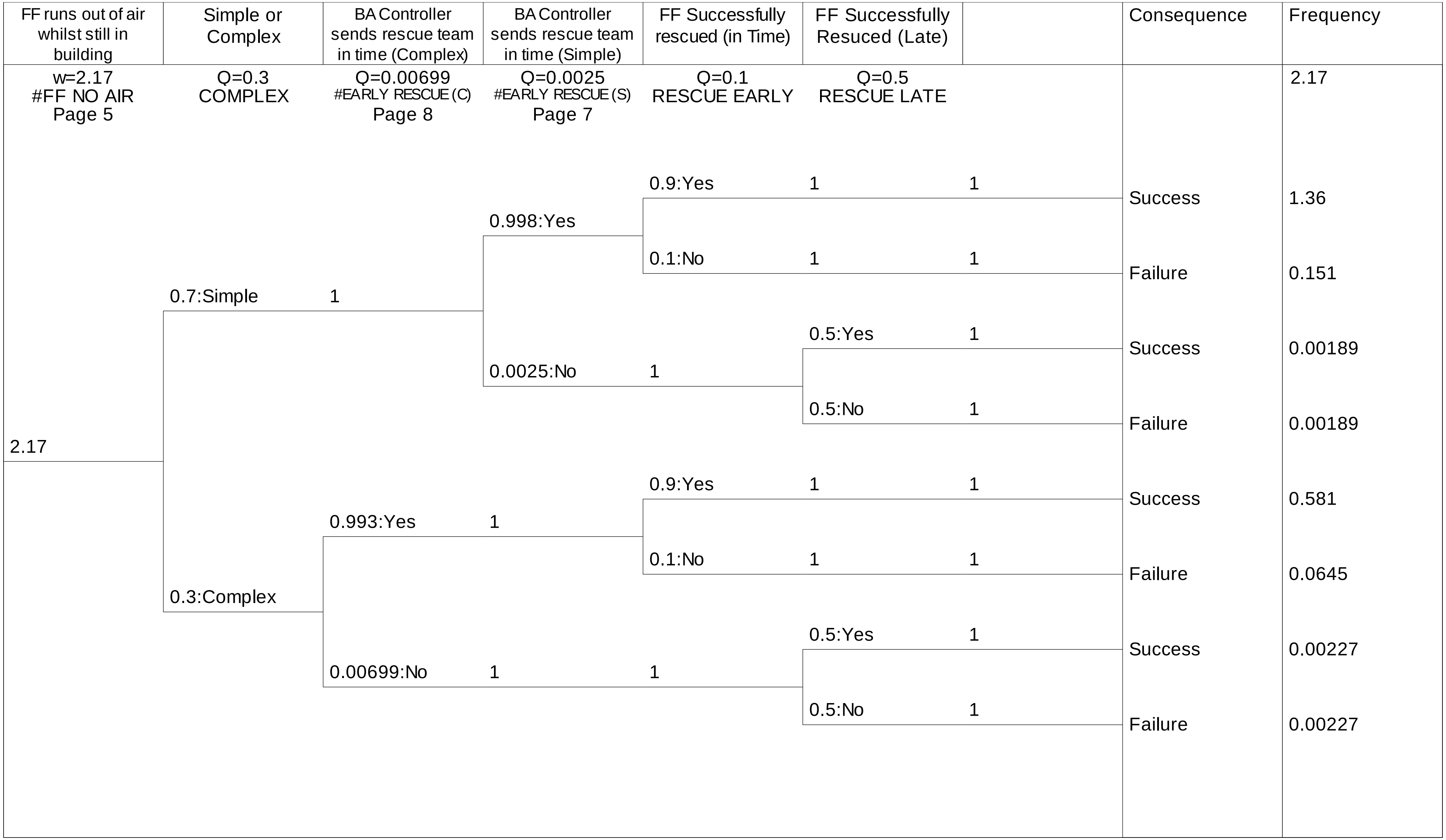
Ref	Title
1	Risktec Solutions Ltd. *Risk Analysis of the Impact of 4G on Breathing Apparatus Telemetry* ESFRS-02-R-01 Issue 3.0.

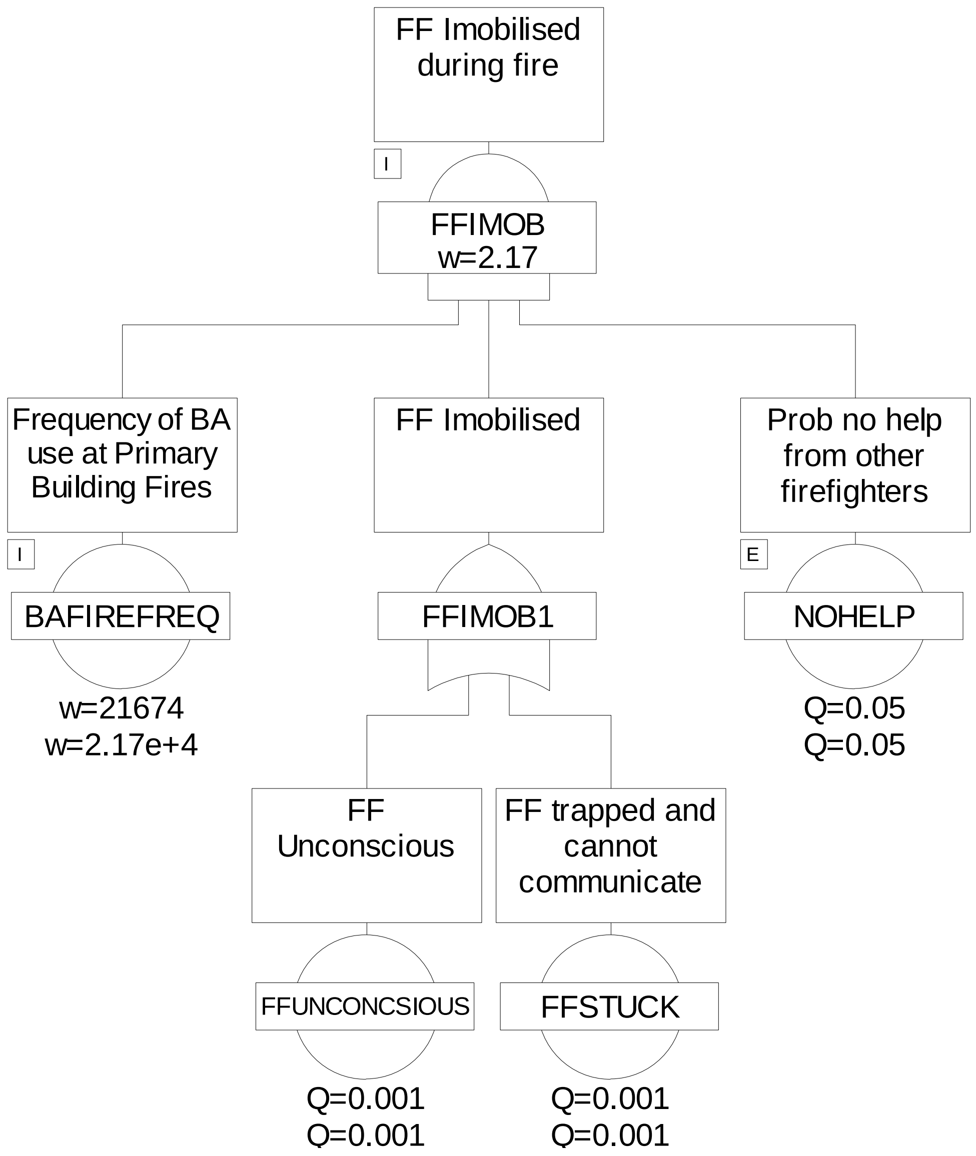
APPENDIX 1

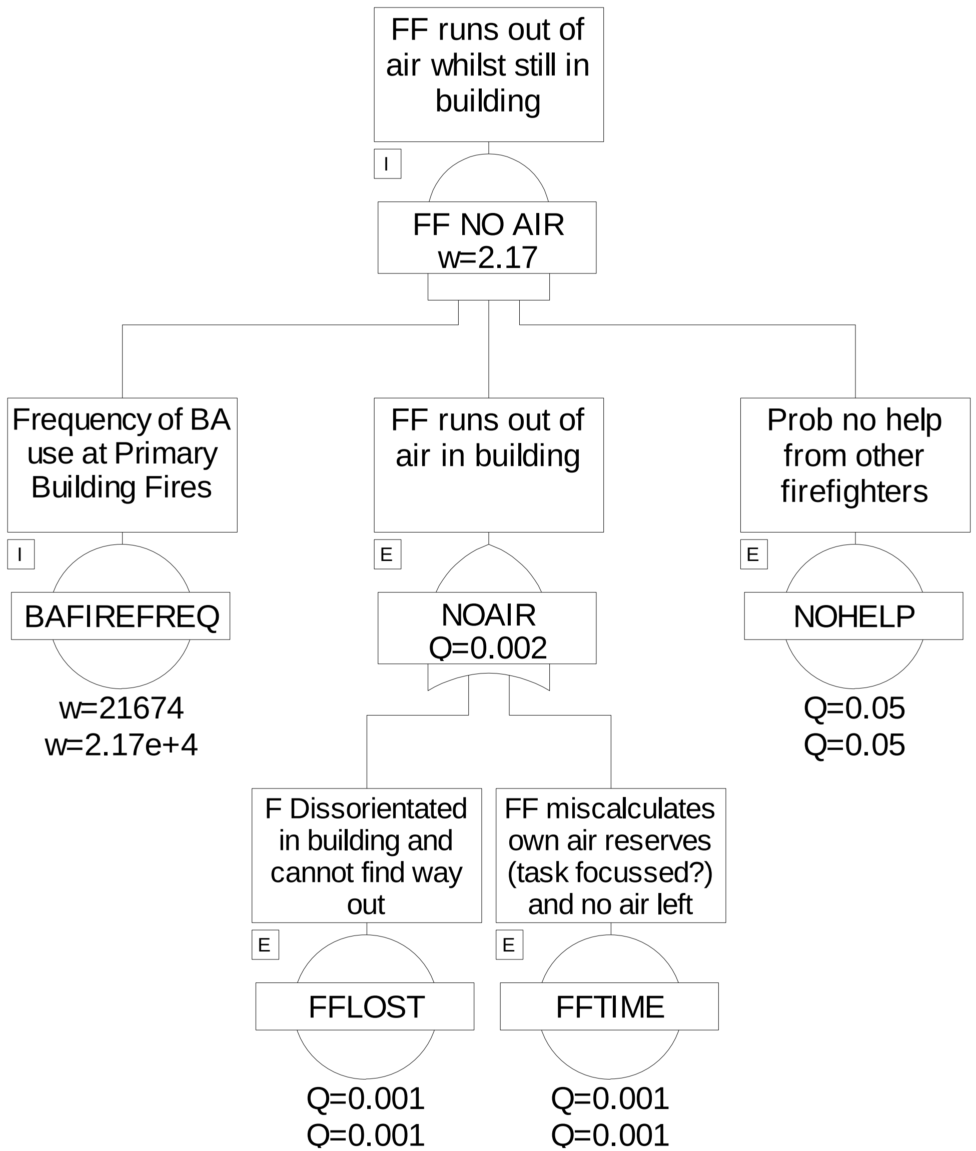
FAULT AND EVENT TREES

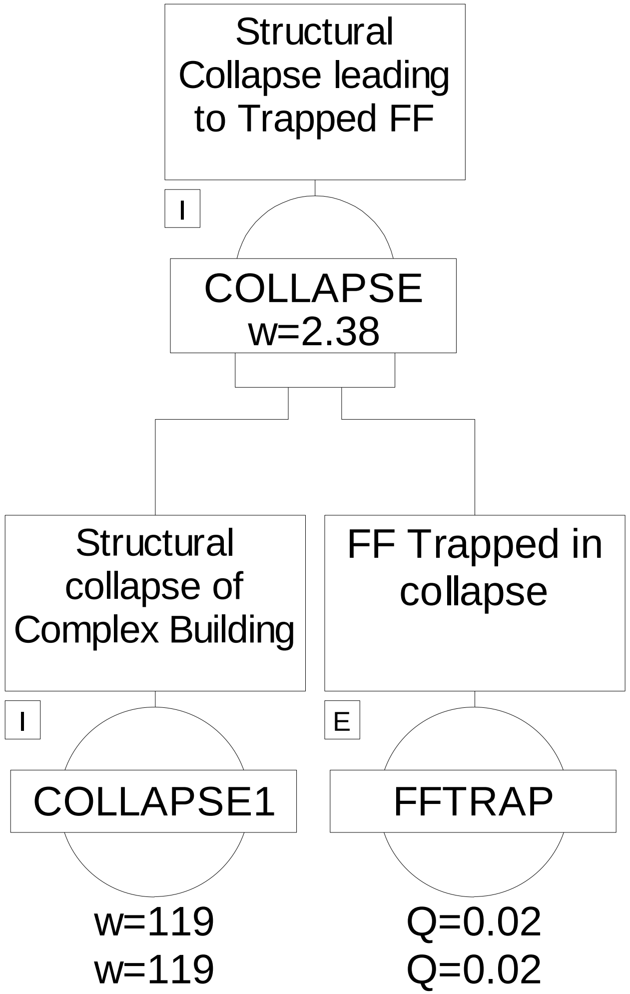

Structural Collapse leading to Trapped FF
FF in building alerted by BAT
Alert Issued by Manual Methods
Fast Rescue
Slow Rescue
Consequence
Frequency
w=2.38
#COLLAPSE
Page 6
Q=0.00699
#BAT FAILS COMPLEX
Page 8
Q=0.05
RESCUE ALARM
Q=0.5
RESCUE LATE
2.38
0.95
1
Success
2.25
0.993
1
0.05
1
Failure
0.118
2.38
0.5
Success
0.00832
0.00699
1
1
0.5
Failure
0.00832

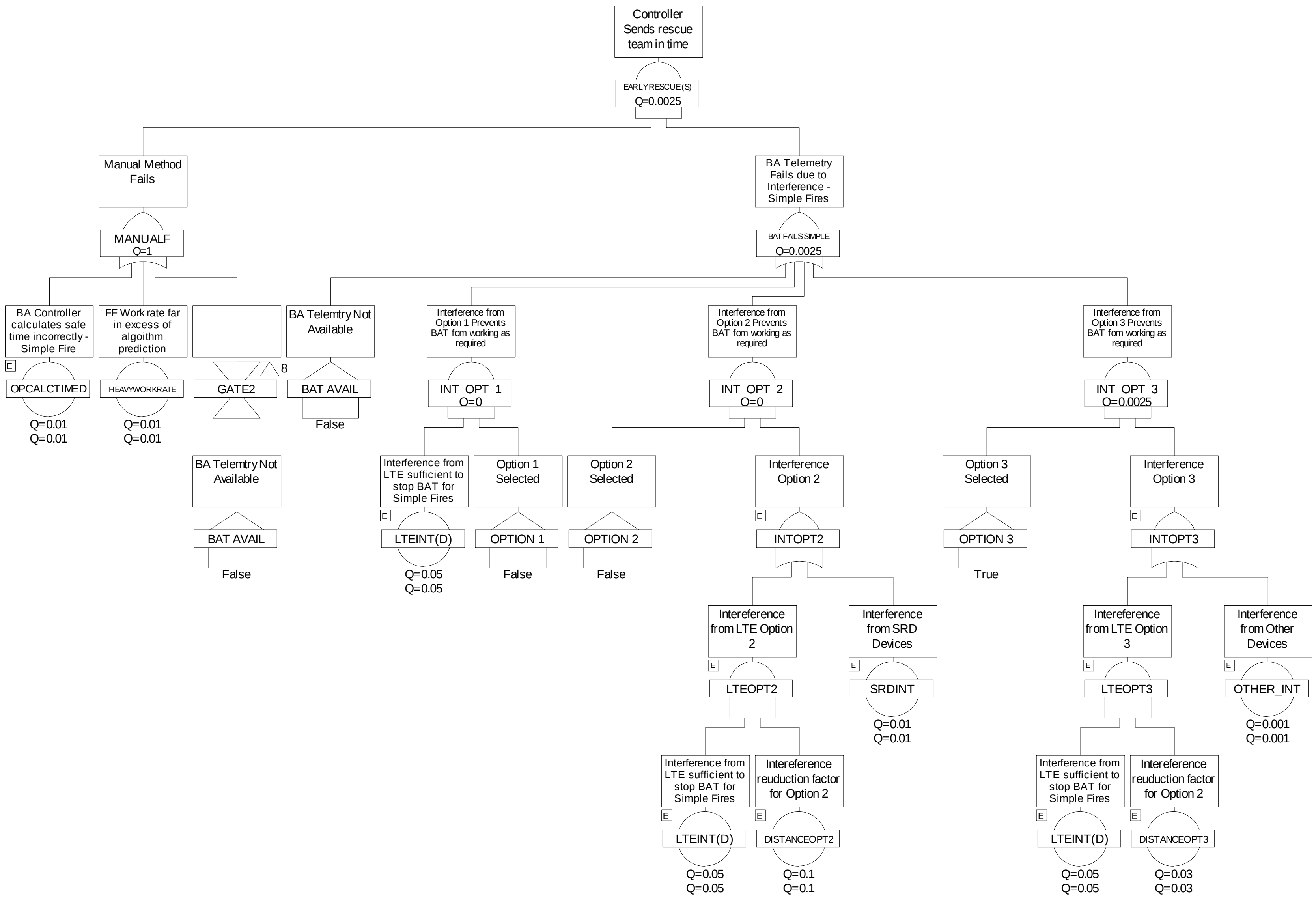

FF Imobilised during fire
Simple or Complex
BAT Alarm received (Complex)
BAT Alarm received (Simple)
FF Successfully Resuced (Late)
FF Rescued given BAT Alarm
Consequence
Frequency
w=2.17
#FFIMOB
Page 4
Q=0.3
COMPLEX
Q=0.00699
#BAT FAILS COMPLEX
Page 8
Q=0.0025
#BAT FAILS SIMPLE
Page 7
Q=0.5
RESCUE LATE
Q=0.05
RESCUE ALARM
2.17
0.95:Yes
0.998:Yes
1
0.05:No
0.7:Simple
1
0.5:Yes
1
0.0025:No
0.5:No
1
2.17
0.95:Yes
0.993:Yes
1
1
0.05:No
0.3:Complex
0.5:Yes
1
0.00699:No
1
0.5:No
1
Success
1.44
Failure
0.0756
Success
0.00189
Failure
0.00189
Success
0.613
Failure
0.0323
Success
0.00227
Failure
0.00227

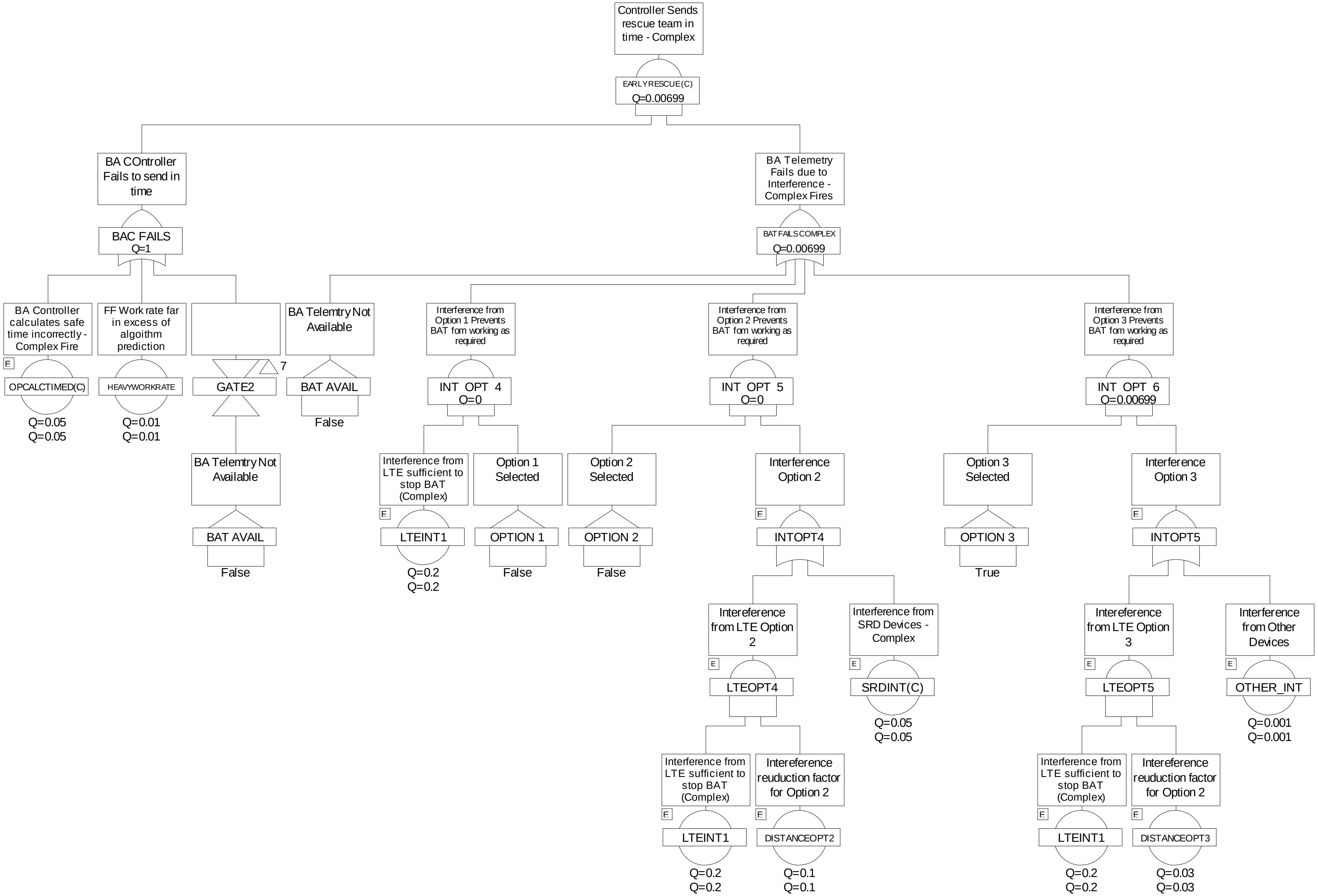

FF runs out of air whilst still in building
Simple or Complex
BA Controller sends rescue team in time (Complex)
BA Controller sends rescue team in time (Simple)
FF Successfully rescued (in Time)
FF Successfully Resuced (Late)
Consequence
Frequency
w=2.17 #FF NO AIR Page 5
Q=0.3 COMPLEX
Q=0.00699 #EARLY RESCUE (C) Page 8
Q=0.0025 #EARLY RESCUE (S) Page 7
Q=0.1 RESCUE EARLY
Q=0.5 RESCUE LATE
2.17
2.17
0.7:Simple
1
0.998:Yes
0.9:Yes
1
1
Success
1.36
0.1:No
1
1
Failure
0.151
0.0025:No
1
0.5:Yes
1
Success
0.00189
0.5:No
1
Failure
0.00189
0.3:Complex
0.993:Yes
1
0.9:Yes
1
1
Success
0.581
0.1:No
1
1
Failure
0.0645
0.00699:No
1
1
0.5:Yes
1
Success
0.00227
0.5:No
1
Failure
0.00227

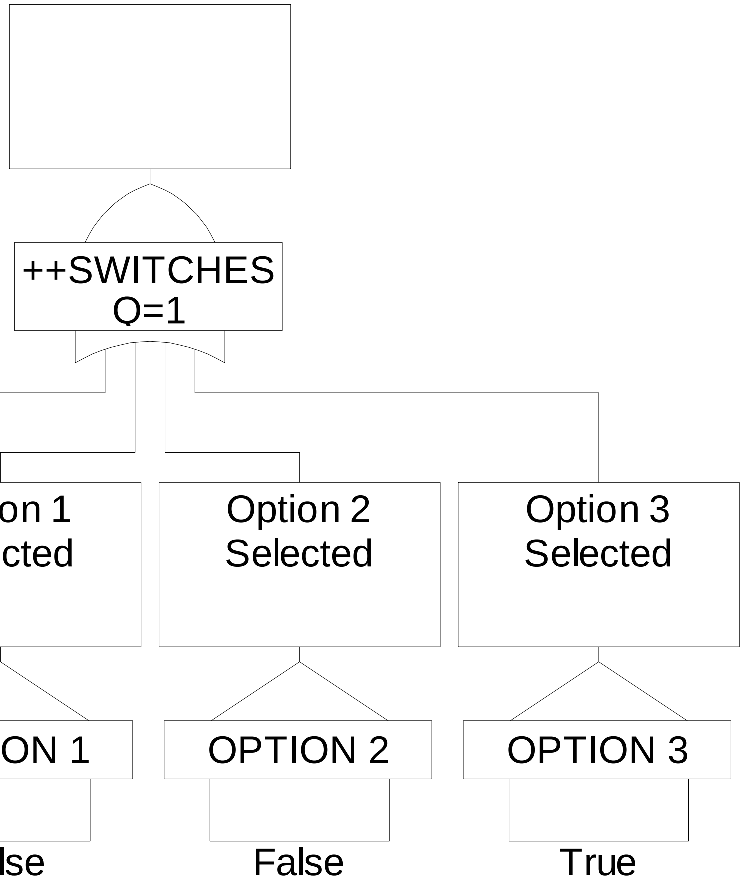

FF Imobilised during fire
I
FFIMOB
w=2.17
Frequency of BA use at Primary Building Fires
I
BAFIREFREQ
w=21674
w=2.17e+4
FF Imobilised
FFIMOB1
Prob no help from other firefighters
E
NOHELP
Q=0.05
Q=0.05
FF Unconscious
FFUNCONCSIOUS
Q=0.001
Q=0.001
FF trapped and cannot communicate
FFSTUCK
Q=0.001
Q=0.001


FF runs out of air whilst still in building
I
FF NO AIR
w=2.17
Frequency of BA use at Primary Building Fires
I
BAFIREFREQ
w=21674
w=2.17e+4
FF runs out of air in building
E
NOAIR
Q=0.002
Prob no help from other firefighters
E
NOHELP
Q=0.05
Q=0.05
F Dissorientated in building and cannot find way out
E
FFLOST
Q=0.001
Q=0.001
FF miscalculates own air reserves (task focussed?) and no air left
E
FFTIME
Q=0.001
Q=0.001


Structural Collapse leading to Trapped FF
I
COLLAPSE
w=2.38
Structural collapse of Complex Building
I
COLLAPSE1
w=119
w=119
FF Trapped in collapse
E
FFTRAP
Q=0.02
Q=0.02


Controller Sends rescue team in time
EARLY RESCUE(S)
Q=0.0025
Manual Method Fails
MANUALF
Q=1
BA Telemetry Fails due to Interference - Simple Fires
BAT FAILS SIMPLE
Q=0.0025
BA Controller calculates safe time incorrectly - Simple Fire
OPCALCTIMED
Q=0.01
Q=0.01
FF Work rate far in excess of algoithm prediction
HEAVYWORKRATE
Q=0.01
Q=0.01
GATE2
8
BA Telemtry Not Available
BAT AVAIL
False
BA Telemtry Not Available
BAT AVAIL
False
Interference from Option 1 Prevents BAT fom working as required
INT_OPT_1
Q=0
Interference from LTE sufficient to stop BAT for Simple Fires
LTEINT(D)
Q=0.05
Q=0.05
Option 1 Selected
OPTION 1
False
Interference from Option 2 Prevents BAT fom working as required
INT_OPT_2
Q=0
Option 2 Selected
OPTION 2
False
Interference Option 2
INTOPT2
Intereference from LTE Option 2
LTEOPT2
Interference from LTE sufficient to stop BAT for Simple Fires
LTEINT(D)
Q=0.05
Q=0.05
Intereference reuduction factor for Option 2
DISTANCEOPT2
Q=0.1
Q=0.1
Interference from SRD Devices
SRDINT
Q=0.01
Q=0.01
Interference from Option 3 Prevents BAT fom working as required
INT_OPT_3
Q=0.0025
Option 3 Selected
OPTION 3
True
Interference Option 3
INTOPT3
Intereference from LTE Option 3
LTEOPT3
Interference from LTE sufficient to stop BAT for Simple Fires
LTEINT(D)
Q=0.05
Q=0.05
Intereference reuduction factor for Option 2
DISTANCEOPT3
Q=0.03
Q=0.03
Interference from Other Devices
OTHER_INT
Q=0.001
Q=0.001


Controller Sends rescue team in time - Complex
EARLYRESCUE(C)
Q=0.00699
BA COntroller Fails to send in time
BAC FAILS
Q=1
BA Telemetry Fails due to Interference - Complex Fires
BATFAILSCOMPLEX
Q=0.00699
BA Controller calculates safe time incorrectly - Complex Fire
OPCALCTIMED(C)
Q=0.05
Q=0.05
FF Work rate far in excess of algoithm prediction
HEAVYWORKRATE
Q=0.01
Q=0.01
GATE2
7
BA Telemtry Not Available
BAT AVAIL
False
BA Telemtry Not Available
BAT AVAIL
False
Interference from Option 1 Prevents BAT fom working as required
INT OPT 4
Q=0
Interference from LTE sufficient to stop BAT (Complex)
LTEINT1
Q=0.2
Q=0.2
Option 1 Selected
OPTION 1
False
Interference from Option 2 Prevents BAT fom working as required
INT OPT 5
Q=0
Option 2 Selected
OPTION 2
False
Interference Option 2
INTOPT4
Intereference from LTE Option 2
LTEOPT4
Interference from LTE sufficient to stop BAT (Complex)
LTEINT1
Q=0.2
Q=0.2
Intereference reuduction factor for Option 2
DISTANCEOPT2
Q=0.1
Q=0.1
Interference from SRD Devices - Complex
SRDINT(C)
Q=0.05
Q=0.05
Interference from Option 3 Prevents BAT fom working as required
INT OPT 6
Q=0.00699
Option 3 Selected
OPTION 3
True
Interference Option 3
INTOPT5
Intereference from LTE Option 3
LTEOPT5
Interference from LTE sufficient to stop BAT (Complex)
LTEINT1
Q=0.2
Q=0.2
Intereference reuduction factor for Option 2
DISTANCEOPT3
Q=0.03
Q=0.03
Interference from Other Devices
OTHER_INT
Q=0.001
Q=0.001


++SWITCHES
Q=1
BA Telemtry Not Available
Option 1 Selected
Option 2 Selected
Option 3 Selected
BAT AVAIL
OPTION 1
OPTION 2
OPTION 3
False
False
False
True