

RAPID FIRE RISK ASSESSMENT

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This paper describes the principles of "Rapid Fire Risk Assessment", explains how it is performed and how it could be developed as a diagnostic tool for fire safety improvement.
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INTRODUCTION

All large multinational firms have premises world-wide that may be in many locations remote from the centre of the organisation. This diversity and separation makes corporate activities such as fire safety management difficult to control. A particular problem arises when attempting to plan and implement Fire Safety Audits.

Fire is one of the main risks to most facilities and to the business that they support. It is essential that adequate fire prevention and protection is provided at all locations and monitored by regular and effective fire safety auditing. It is particularly important to be able to identify sites where a fire could interrupt a key product supply chain and cause severe business interruption. Key sites such as these require priority for fire safety audits and fire prevention expertise.

Rapid Fire Risk assessment was developed for use in the international pharmaceutical industry, but is applicable to other industries. It was developed to set up fire safety audit programmes and to prioritise sites for fire safety audits. Since the local technical staff available to assess fire risks on some sites had little fire safety knowledge, a simple yet consistent fire risk assessment method was needed. The "Rapid Fire Risk Assessment" (RFRA) method was developed to meet this need[1].

TILE RFRA METHOD

RISK ASSESSMENT PRINCIPLES:
RFRA uses the risk assessment process described in Figure 1. The risk acceptability criterion is based on the principle that the greater the severity of the consequences, the less should be the likelihood of occurrence. By considering only order-of-magnitude differences, a scale of severity and a scale of likelihood can be used to define the boundary of acceptability for a range of identified hazards (Figure 2). This principle can be developed and simplified further as a 5 X 5 matrix with suitable numbers allocated to define acceptability limits (Figure 3).

RAPID FIRE RISK ASSESSMENT:
Rapid Fire Risk Assessment (RFRA) of a facility or premises involves six steps:
1. Divide the area into separate blocks, each of which could contain a fire.
(The boundaries of each block are defined either by natural separation or by suitable firewalls or barriers. A maximum of between six and en blocks is practical for most facilities. Complex facilities may require more sub-division.)
2. Inspect each block and identify a realistic fire scenario.
(The assessor is advised to identify several possible fire scenarios for each block ranging from a"Worst Case" to a "Typical Case "fire and to choose the most realistic scenario for

the RFRA. Alternatively each of the scenarios iden4fied can be assessed separately to decide a representative combination although this is more time-consuming)
3. Assess the scenario consequences using a simple scoring method *(Table 1):*
4. Assess the scenario likelihood of occurrence by a simple scoring method *(Table 2):*
5. Plot the consequences and likelihood on a risk-ranking matrix *(Table 3)* to determine the "RIFRA Mark" for the block being studied.
6. Use the "RIFRA Mark" to decide if the risk is "Acceptable", "Unacceptable" or "Unknown: Needs follow-up". *("Acceptable" implies that an audit is not thought to be necessary)*

It is important to record the six-step RERA process on auditable documents such as paper forms or electronic spreadsheets to analyse results and to identify areas for improvement. The RERA six-step method and documentation is explained in more detail in the following text.

RAPID FIRE RISK ASSESSMENT DOCUMENTATION:
The method and documentation developed to provide this is described as follows: -

1. Assess the Consequences:
The consequences of a fire in the area being assessed are in four categories of harm: -
Harm to people.
Harm to the environment.
Harm to buildings and equipment.
Harm to the product supply chain and business.
The severity of the consequences for each category of harm is assessed as either *"High"*, *"Normal"* or *"Low"* by using numerical guide values to aid the assessor's judgement. The guide values will depend on the company standards and will include values for loss of life and markets that are specific to the organisation. As a general guide to the overall monetary loss, a *"High"* loss would be above £10 Million of Net Present Value, a *"Normal"* from £1 - £10 Million, and a *"Low"* less than £1Million. The four factors in the assessment are then scored 3 for *"High",* 2 for *"Normal"* and 1 for *"Low".* The scores are added to give the total score for the overall consequences. Results are recorded on a form or spreadsheet (see Table 1).
The Block Consequences Total Score is then used to define whether the overall consequences are "Very Severe" (Score = 11 or 12), "Severe" (Score = 9 or 10), "Moderate" (Score = 8), "Slight'[1] (Score 6 or 7) or "Very Slight" (Score = 4 or5). The result is then ticked off on the vertical axis of the RFRA matrix in Table 3 to heap determine the block overall RFRA mark.

2. Assess the Likelihood:
The likelihood of a fire occurring in the selected area is more difficult to assess than the consequences. Also, human judgement of the likelihood of a hazard is notoriously unreliable. To overcome these problems, a step-by-step procedure is used, supported by suitable training using benchmark examples for guidance.
The likelihood of a significant fire depends on three simultaneous occurrences. A source of combustible material must be present *and* an effective source of ignition must be present *and* the fire must escalate. This is shown as a simple fault tree in Figure 4, where the probabilities of the key factors "Fire Load, "Ignition Source" and "Escalation" are combined to determine the overall likelihood of the block scenario.

Table 1. RFR.A Consequences assessment form:
BLOCK REF NO. _____ Assessors:_____ RFRA Date:_____

Block Description: _____

FACTOR:	*High*	*Normal*	*Low*	*SCORE: H=3; N= 2; L = 1)*
Harm to People:				
Harm to the Environment				
Harm to Buildings and Equipment:				
Harm to Product and Business:				
			BLOCK CONSEQUENCES TOTAL SCORE:	

By ranking each of these factors *"High', "Normal"* or *"Low",* the overall likelihood can be assessed using a form similar to that shown in Table 2. An additional ranking *"Not sure"* (Scored as *"High")* is also practical to cover atypical situations when the assessor needs expert assistance.

Table 2. RFRA Likelihood assessment form:
BLOCK REF.NO. _____ Assessors:_____ RFRA Date:_____

Block Description: _____

FACTOR:	*High*	*Normal*	*Low*	*Not Sure*	*SCORE: (H = 3; N= 2; L 1)*
Fire Load:					
Likelihood of Ignition					
Likelihood of Escalation					
BLOCK LIKELIHOOD TOTAL SCORE:	-	-	-	-	

As with the consequences, the rankings can then be scored and converted to an assessment of overall likelihood. The levels are "Very High" (Score = 8 or 9), "High" (Score = **7),** "Normal' (Score = 6), "Low" (Score = 5*)* or "Very Low" (Score = 3 or 4). The result is then ticked off on the horizontal axis of the RFRA matrix in Table 3 and with the consequences result on the vertical axis enables the assessor to determine the block overall RFRA mark.
However, most assessors would find it difficult to assess the three factors "Fire Load", "Ignition Source" and "Escalation" accurately in one step, so a further breakdown of each is provided to make it easier.

Fire Load:
The Fire Load is assessed in "Kilograms of Wood Equivalent" per square metre of floor area[2].

In the pharmaceutical industry, guidance values are provided for the assessor derived from typical pharmaceutical facilities data. Benchmark areas are visited during training to instil a visual impression sufficient to rank the loads as "High", "Normal" or "Low". The ranking "Not sure" is essential to cover the situations when the inexpert assessor encounters an atypical fire load and cannot obtain expert assistance over the telephone.

Likelihood of Ignition:

The likelihood of ignition is assessed by considering how the combustibles and sources of ignition are controlled when they are present. These are ranked using the form in Table 2.1.

Table 2.1. Likelihood of ignition assessment form:

BLOCK REF.NO. _____ Assessors:_____ RFRA Date:_____

Block Description: _____

Control of Combustibles:	**Control of Ignition Sources:**	LIKELIHOOD OF IGNITION
Uncontrolled	Uncontrolled Sources present	High
Uncontrolled	Well Controlled Sources	High
Uncontrolled	Sources rarely present	Normal
Well Controlled	Uncontrolled Sources present	High
Well Controlled	Well Controlled Sources	Normal
Well Controlled	Sources rarely present	Low
Combustibles rarely present	Uncontrolled Sources present	Normal
Combustibles rarely present	Well Controlled Sources	Low
Combustibles rarely present	Sources rarely present	Low

Likelihood of Escalation:

The burning rate of the materials present, the passive and active fire protection measures, the fire-fighting response time and the management of the combustible materials govern fire "Escalation". It is practical to assess an area for each of these factors separately. As a first step, fire escalation has already been subdivided in the simple fault tree (Figure 4) into "Rapid Burning" and "Safeguards Fail", but a further subdivision of the safeguards on a form is even more helpful *(See Table 2.2).*

The form shown in Table 2.2 is used to assess the factors "Compartmentation", "Housekeeping", "Fire Detection" and "Fire-fighting Response Time as *"Good"* (Score = 1), *"Average"* (Score = 2) or *"Bad"* (Score = 3). The "Maximum Burning Rate" is weighted to score a *"Good"* or low rate = 1, an *"Average"* rate = 3 and a *"Bad"* or rapid burning rate = 9.

As previously, the scores for the factors are added and the total score is converted to enable an entry of *"High", "Normal"* or *"Low"* in the "Likelihood of Escalation" row of the Overall Likelihood of Fire Table 2. The Block Escalation Score is translated into "Likelihood of Escalation" as follows: Block Escalation Score = 13 to 21 rates as *"High";* 8 to 12 rates as *"Normal"*; 5 to 7 rates as *"Low".*

Whereas 'Housekeeping' and 'Compartmentation' are relatively easy to assess, some explanation is required for the other factors as follows:

Maximum Burning Rate:

The maximum burning rate of a fire is governed by the configuration of the Fire Load[2]. To rank this factor, the assessor must consider how the combustibles are arranged. For example, combustible material stacked high so that fire can rapidly spread vertically will be rated *'Fast'* or '*Bad'*. A low roofed building that allows heat and fire to spread rapidly horizontally and affect adjacent combustibles would also be rated as *'Bad'*. The use of fireproof cabinets or

containers will minimise the burning rate, as will combustibles that are well separated from each other. (Compartmentation is assessed separately in the next row of Table 2.2). The RFRA marking for Maximum Burning Rate is weighted as follows:
Fast/Bad = 9,Average = 3, Low/Good = 1

Table 2.2. Likelihood of escalation assessment form:
BLOCK REF.NO._____Assessors:_____ RFRA Date._____

Block Description:_____

FACTOR:	*Good*	*Average*	*Bad*	*SCORE:*
Maximum Burning Rate: (Low = 1= Good Ave. = 3 = Average; Fast = 9 = Bad)				
Compartmentation: (Good = 1; Average = 2; Bad = 3)				
Housekeeping: (Good = 1; Average = 2; Bad = 3)				
Fire Detection: (Good = l; Average = 2; Bad = 3)				
Firefighting Response Time: Good = l; Average = 2; Bad = 3				
BLOCK ESCALATION SCORE:	-	-	-	

Fire Detection:
To rate as *'Good'* the correct type of automatic detection and alarm system must be in place in the block studied[3]. 24-hour attendance by vigilant staff will also rate as *'Good'*. No automatic fire detectors, no staff present and no regular surveillance would be rated as *'Bad'*.
Firefighting Response Time:
To rate as *'Good'* the appropriate automatic firefighting measures using sprinklers, deluge or foam systems must be in place in the block studied[3]. If the fire service can arrive in less than 5 minutes from fire discovery, this may also be rated as *'Good',* although reliance on external fire service usually rates as *'Average',* on the assumption of 10 minutes to respond. A response time of more than 15 minutes from discovery of fire rates as *'Bad'*.

3. Determine the Block Assessment (RIFRA Mark):
The foregoing explained how several key factors are used to assess the consequences and likelihood of a significant fire in the block. The results then provide the coordinates to define The block "RFRA Mark" in the matrix in Table 3.
The numbers in the matrix determine the final assessment of the block as "Acceptable", "Unacceptable" or "Unknown: Needs follow-up". The matrix numbers are weighted to ensure that a professional fire engineer always investigates events with very severe consequences. A mark of less than 5 is ranked as "Acceptable", marks of 5 or 6 require investigation and a mark of greater than 6 is "Unacceptable". An "Unacceptable" Fire Risk Assessment would initiate an immediate follow-up by a qualified fire engineer.
The results of the assessment are recorded on pre-printed forms or spreadsheets for use in subsequent investigations, for fire safety audits or for entry into a database. Rapid Fire Risk Assessment of each block is performed using the "Consequences" versus "Likelihood" matrix in Table 3 as follows.

Table 3. Rapid Fire Risk Assessment Matrix:

Consequences Severity:					
Very Severe	7	8	9	10	10
Severe	5	7	8	9	10
Moderate	3	5	7	8	9
Slight	2	4	5	7	8
Very Slight	1	2	3	5	6
	Very Low	*Low*	*Normal*	*High*	*Very High*

Likelihood of Occurrence

IMPLEMENTATION:
The forms and checklist tables described were thoroughly tested by experienced fire prevention staff and selected professional staff in a variety of different situations and premises. Several "Bench marks" of typical areas were defined for staff training purposes. A computerised database of RFRA results was developed to monitor the use of the method, to identify improvements, and to train new assessors. As the method was used more widely a significant body of data was collected. The database made it possible to identify anomalies and inconsistencies quickly so that results could be queried directly with the assessors. Although the methods used are not very precise, RFRA proved to be a useful and credible tool for deciding priorities for fire safety audits and site visits by a qualified and experienced fire engineer. RFRA also provided a useful pre-audit stage for a fire safety auditing protocol developed for use internationally.

RFRA EXAMPLE:

This example is based on the RFRA of a contract warehouse made by an experienced warehouse manager with some knowledge of fire safety engineering. He assessed the warehouse as a single block as follows:
Table 1. RFRA Consequences form:
"Harm to People" = *Normal* Score = 2
"Harm to the Environment" = *Normal* Score = 2
"Harm to Buildings and Equipment" = *Normal* Score = 2
"Harm to Product and Business" = *High* Score = 3
Block Consequences Total Score = 9 = *Severe*
Table 2. RFRA Likelihood Assessment Form:
"Fire Load" = *Normal* Score = 2
Likelihood of Ignition = *Normal* Score = 2
Likelihood of Escalation = *High* Score = 3
Block Likelihood Total Score = 7 = *High*
Table 3. RFRA Assessment Matrix:
Locating *Severe* Consequences and *High* Likelihood on the RFRA Matrix Table 3, indicates Block RFRA Mark = 9

A Block RERA Mark of 9 is "Unacceptable" and requires that a qualified fire engineer should visit the warehouse immediately. It is now useful to refer to the supporting tables that the assessor completed to study how the Likelihood assessments were made: -

Table 2.1: Likelihood of Ignition Assessment Form:
Both The combustibles and the sources of ignition were considered to be "Well controlled". From Table 2.1 this results in a "Normal" assessment for entry into Table 2. It would be difficult to make changes to the warehouse to improve on this assessment except by excluding all sources of ignition which would then result in a "Low" assessment for entry into Table 2.

Table 2.2: Likelihood of Escalation Assessment Form:

Maximum Burning Rate:
The warehouse contained combustibles that were stacked together vertically. This fire load configuration was expected to result in an Average Maximum Burning Rate giving a score = 3. (By relocating the combustibles so that they were not stacked together, and by not stacking them vertically above each other, this arrangement could be considered to be "Good" with a score = 1)

Compartmentation:
There was no compartmentation in the warehouse. The assessor rated this as "Bad" giving a score = 3. (The installation of partitions capable of resisting fire for >2hrs. could be considered as "Good" compartmentation with a score = 1)

Housekeeping:
The assessor rated the housekeeping in the contract warehouse as "Bad" giving a score = 3. (Improved training and management might possibly rate a "Good" assessment, but the housekeeping might be due to an unacceptable contractor attitude that, at the best would only rate an "Average" assessment with a score = 2)

Fire Detection:
No automatic fire detection was installed in the warehouse and the warehouse was unoccupied for most of the time. The assessor rated this as "Bad" giving a Fire Detection Score = 3. (The Fire Detection Score could be reduced to 1 if suitable fire detectors and alarm systems were installed together with improvements to the security arrangements)

Firefighting Response Time:
No automatic firefighting systems were installed in the warehouse and the local fire officer considered that access to the warehouse for firefighting appliances would be difficult. The assessor rated this as "Bad" giving a score = 3. (The Firefighting Response Time Score could be reduced to 1 if suitable automatic sprinkler systems were installed.)

Initial "Likelihood of Escalation" Assessment:
The assessor's initial scores were: 3 + 3 + 3 + 3 + 3 = 15. These scores resulted in a *"High"* likelihood of escalation. (If all of the improvements suggested were made, the scores would reduce to: 1 + 1 + 2 + 1 + 1 = 6 to give a new assessment as *"Low"* for the likelihood of escalation)

ASSESSMENT OF IMPROVEMENTS IN WAREHOUSE FIRE SAFETY:
Because the warehouse was the only one available to supply markets in that country the local materials manager was reluctant to alter stock and materials movements to reduce the potential consequences of a fire before fire safety improvements had been considered.

The improvements to the Likelihood of Fire Escalation (suggested in brackets in the foregoing text) to gain a *Low* assessment would reduce the Block Likelihood Score in Table 2 from 7 to 5 which would then rate as *Low* for use in the RFRA Matrix in Table 3. Since the Consequences of a fire would remain *Severe* the Block RFRA Mark would then reduce from 9 to 7. Unfortunately this would still be "Unacceptable".
If additional measures were taken to exclude ignition sources from the warehouse, the Likelihood of Ignition would reduce to *Low* which would reduce the Block Likelihood Score in Table 2 to a value of 4 and give a *Very Low* rating for use in the RFRA Matrix in Table 3. The Block RFRA Mark would then be reduced to 5, which is at the boundary of acceptability using the RFRA criteria. It is thus essential for a qualified fire engineer to visit the contract warehouse and investigate whether the suggested improvements would be effective.

At this point the local materials manager was willing to consider how the Consequences of a fire could be reduced. As the largest contributor to the Consequences was "Harm to the Product and Business" it might be possible to locate some of the key items in different premises to reduce the rating from *High* to *Normal* even though this would not be a popular alternative. If containment could be provided for firefighting water, the "Harm to the Environment" might also be reduced from *Normal* to *Low.* Both of these measures would then reduce the Block Consequences Score from 9 to 7 to give a consequences severity rating as *Slight.* With *Slight* Severity and *Very Low* Likelihood in the Table 3 RFRA Matrix the Block RERA Mark would become 2 that would be "Acceptable". If only one of these two severity reduction measures was implemented, the severity rating would be *Moderate.* Assuming that the fire safety improvements were implemented this would result in a Block RFRA Mark of 3 which would also be "Acceptable".
There are several other alternatives that the reader may choose to study. These, together with those described above are then plotted on the Table 3 RFRA Matrix to decide which is the most "Acceptable". This exercise will demonstrate how RFRA can be a valuable tool for studying different fire safety alternatives from a range of options.

RFRA DATA COLLECTION AND ANALYSIS

PLANNING THE PROGRAMME:
The collection of RFRA data across an international business requires careful preparation and planning if it is to be successful. All operating units in the business must be contacted to explain the reasons for performing RFRA in order to gain commitment. Instructions and examples, similar to those in the preceding text, must be provided to explain how to perform RFRA locally. With careful preparation and planning, a worldwide RERA exercise for about two hundred locations was completed in less than two months.

METHOD OF DATA COLLECTION:
All operating units should use the same RFRA forms or spreadsheets described in Tables 1 to 3. These must be returned to a central co-ordinator for checking and entry into a computerised database. Alternatively, if there is a secure company e-mail system, results can be e-mailed.

ASSIGNING BLOCK BOUNDARIES:
Each site can be assessed as a single entity by dividing it into about 6 - 10 blocks and then averaging the RFRA marks over all of the blocks to get a site mark. This method does not work well for large sites, however. For large sites, it is wiser to divide the site into separate facilities and then sub-divide these into about six blocks. It is best to collect the RFRA marks

for each of the blocks studied as this identifies the hazardous areas more clearly. Assessors in some facilities may find it difficult to decide how many blocks to use for their facility.
On large sites as many as 40 blocks may be needed, on smaller sites that are mainly offices or warehouses, one or two blocks should prove adequate. The number of blocks chosen has a significant effect on the block marks. The optimum number of blocks is usually decided by iteration and experienced judgement.

INEXPERIENCED ASSESSORS:
In most cases, even with little fire safety knowledge, assessors are able to complete the RFRA forms without problems. Most problems can be resolved via the telephone or e-mail, and by reference to the database. As results flow in, any anomalous results can be queried immediately. Fire safety specialists always review the blocks rated as 'Unacceptable' and experience has revealed that about half of these may be overestimated. The RFRA method was designed to be conservative, so this should not be a cause for concern.

DATA STRUCTURE:
Each block record in the database needs about 20 fields to contribute to the RFRA overall mark. These fields together with the location data, assessor data, date, description and reference number, etc, give a total of about 30 fields. The data can be studied at different levels of detail to assess consistency and specific problem areas as described in the following examples.

TYPICAL RFRA RESULTS
The RFRA database information can be used to answer three main questions:-

1. Does the fire risk in the area need further study?
2. Where are the main areas of fire risk in the business?
3. What factors contribute to fire risk in specific areas?

In addition, the consistency of RFRA marking can be investigated across a wide range of assessors, countries and facilities, to seek potential improvements to the method and to define 'Benchmarks'. The range of RFRA marks across a typical international pharmaceutical business is shown in Table 6. The RFRA results in the table conform to the Pareto principle with about 10% of the blocks studied having 90% of the fire risk. It is simple to interrogate the database for further information to answer the three questions posed above. An analysis of the spread of "Consequence" and "Likelihood" scores is given in Tables 7 and Table 8.

The data can be analysed to study the distribution of the fire risk between blocks of different types to enable benchmarking and for comparing RFRA results. An analysis of the RFRA overall marks for the warehouses is shown in Table 9 as an example.

Table 6. RFRA Marks Distribution for a typical Pharmaceutical Business:

RFRA Overall Mark:	Number of Blocks with this RFRA Overall Mark:	Percentage of all blocks studied:
1	43	18
2	62	25
3	34	14
4	31	13
5	50	20.5
6	**3**	**1**
7	**13**	**5**
8	**6**	**2.5**
9	**2**	**1**
10	**0**	**0**
TOTAL:	244	100

Table 7. RFRA Overall Consequences for all Block Types:

Overall Consequences Score:	Number of Blocks with this Score:	Percentage of all Blocks studied:
4	32	13
5	58	24
6	54	22
7	52	21
8	38	16
9	8	3
10	2	1
TOTAL:	244	100

Table 8. RFRA Overall Likelihood for all Block Types:

Overall Likelihood Score:	Number of Blocks with this Score:	Percentage of all Blocks studied:
2	4	1.6
3	39	16
4	67	27
5	63	26
6	48	20
7	19	8
8	3	1
9	1	0.4
TOTAL:	244	100

Table 9. Summary of Typical RFRA Overall Marks for Warehouses:

RFRA Overall Mark for Warehouses:	Number of Records with this RFRA Mark:
1	2
2	10
3	3
4	9
5	9
6	0
7	5
8	3
TOTAL:	41

FURTHER DEVELOPMENT OF RFRA:

The six-step RFRA process described is relatively simple and easy to use for deciding fire safety audit priorities, but not very useful for diagnosis or facility design. However, by using the same principles of subdivision with lower levels of definition and extra data input, it is possible to improve the method. *(The subdivision principle has already been used in the case of "Likelihood of Escalation" by providing a lower level table of 5 contributory elements.)*
For example:
Assess "Housekeeping" at a lower level by ranking all of the factors considered to be significant contributors, such as "Cleaning Procedures", "Plant inspections", "Waste Materials Control", etc. Then suitably combine the marks for each element to determine a "Housekeeping" assessment of *"Good", "Average" or "Bad".*
The principle is illustrated in Figure 5.

CONCLUSIONS:

- RFRA is an effective way to decide if an area needs to be assessed by a fire engineer.
- RFRA can be performed by staff with only a basic understanding of fire safety and is useful for assessing facilities with no local fire engineering expertise.
- RFRA is a rather crude method, but the data can be stored and analysed in a database to gain an overview of the fire risk profile for a typical international business.
- RFRA can be developed further as a diagnostic tool

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Figure 1. The Risk Assessment Process

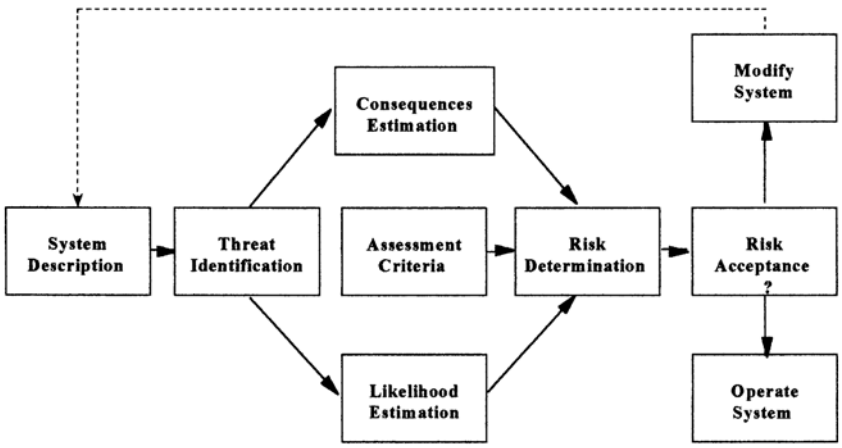


Figure 2. Risk Assessment Criteria

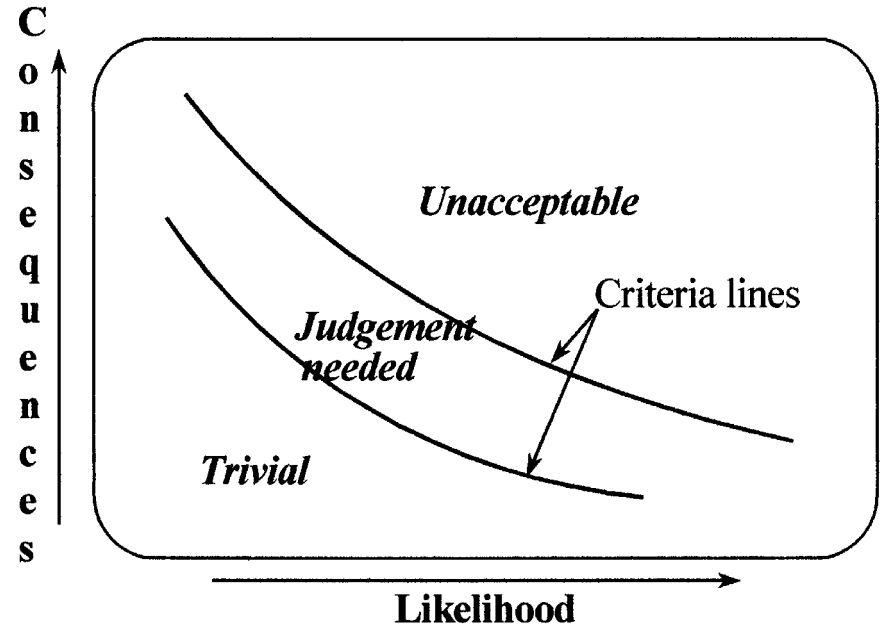
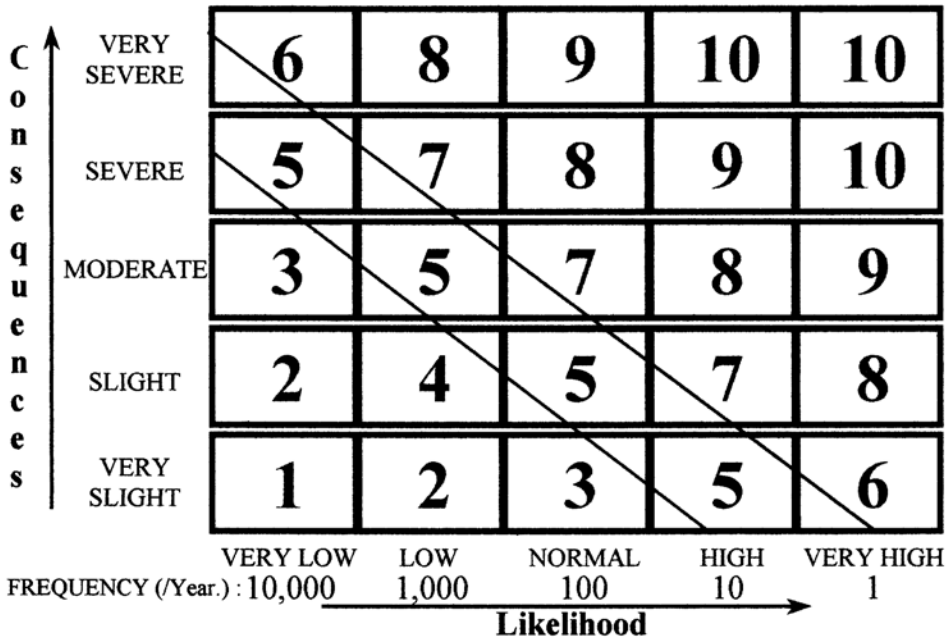
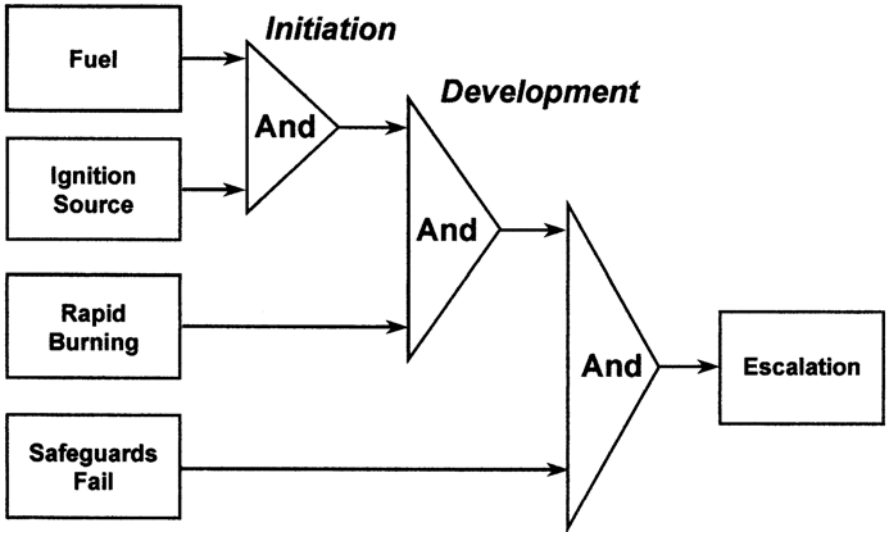


Figure 3. Fire Risk Assessment Criteria




Fuel
Ignition Source
Rapid Burning
Safeguards Fail
Initiation
And
Development
And
And
Escalation