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Managing industrial risk—Having a tested and proven system to prevent and assess risk

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Abstract

Some relatively easy techniques exist to improve the risk picture/profile to aid in preventing losses. Today with the advent of computer system resources, focusing on specific aspects of risk through systematic scoring and comparison, the risk analysis can be relatively easy to achieve. Techniques like these demonstrate how working experience and common sense can be combined mathematically into a flexible risk management tool or risk model for analyzing risk.

The risk assessment methodology provided by companies today is no longer the ideas and practices of one group or even one company. It is reflective of the practice of many companies, as well as the ideas and expertise of academia and government regulators. The use of multi-criteria decision making (MCDM) techniques for making critical decisions has been recognized for many years for a variety of purposes. In today's computer age, the easy accessing and user-friendly nature for using these techniques, makes them a favorable choice for use in the risk assessment environment. The new user of these methodologies should find many ideas directly applicable to his or her needs when approaching risk decision making. The user should find their ideas readily adapted, with slight modification, to accurately reflect a specific situation using MCDM techniques. This makes them an attractive feature for use in assessment and risk modeling.

The main advantage of decision making techniques, such as MCDM, is that in the early stages of a risk assessment, accurate data on industrial risk, and failures are lacking. In most cases, it is still insufficient to perform a thorough risk assessment using purely statistical concepts. The practical advantages towards deviating from strict data-driven protocol seem to outweigh the drawbacks.

Industry failure data often comes at a high cost when a loss occurs. We can benefit from this unfortunate acquisition of data through the continuous refining of our decisions by incorporating this new information into our assessments. MCDM techniques offer flexibility in accessing comparison within broad data sets to reflect our best estimation of their importance towards contribution to the risk picture. This allows for the accurate determination of the more probable and more consequential issues. This can later be refined using more intensive risk techniques and the avoidance of less critical issues.

Keywords: MCDM; AHP; Risk scoring; Pairwise comparison

1. Introduction

When an industrial facility is constructed and operated, hazards that would not otherwise be present are introduced. Society, i.e. owners, insurance bodies, governmental agencies, workers, and third parties generally accept that the benefits of these hazards far outweigh the increased risk.

The prevention of loss and assessment of risk implies that industrial risk is something that should be managed. In order to manage something, it must be thoroughly understood. Having a reasonable, convenient and easy approach to assessing risk allows for a broader acceptance in participation from safety professionals and risk managers who would less otherwise be inclined to approach the task either due to the expense or its complex nature.

Approaching the risk assessments by deviating from strict scientific procedure to build a risk model allows real life experience to assist in the risk modeling process as well as risk making decisions.

This also avoids the pitfalls associated with quality verification issues related to variable source or limited data, which

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in many cases is the only available information for broad scoped scientific project analysis.

While multi-criteria decision making (MCDM) technique introduces a certain level of subjectivity, rather than approaching the subjective experience factors as detraction to the process, this approach accesses experts' experience to strengthen the risk management process for the purpose of making critical risk decisions. Decision making techniques are ideal for use in the early stages of risk qualification and review, and allows for justification in determining the need for more intensive scientific risk analysis, which can either be limited to a specifically identified critical area or determined not necessary.

The following discusses the development and example of the results of the use of a risk assessment model for making risk decisions using a combination of a multi-criteria decision making technique, i.e. analytic hierarchy process (AHP) and a risk scoring, indexing technique.

2. Model

AHP is a multi-criteria decision making technique, which has been widely used for over 20 years. AHP is a method of prioritizing decisions through the incorporation of relevant decision criteria. This is achieved through pairwise comparisons of competing objectives (risk) and involves making subjective judgments [1]. This results in the determination of a ratio scale of relative values. It is a beneficial technique because it avoids the biases that can be present when comparing assorted data sets which may be related subject wise, but not situationally.

AHP is carried out in two phases. The design phase in which a hierarchy is set up and the evaluating phase which comprises the pairwise comparisons. The design of the hierarchy requires an evaluator's experience and knowledge of the problem area. The hierarchy is structured such that the topmost node is the overall objective. Subsequent nodes at lower levels in the hierarchy consist of the criteria used in arriving at this decision. An example that illustrates this technique, determines which of the three locations has the greatest risk potential for exposure to a loss of business operations. In this example, controlling risk factors and sub factors/risk characteristics are compared as either greater, less risk or equal risk exposures when compared against the other as representative of each location. The bottom level of the hierarchy consists of the alternative (three locations being compared) from which the choice of weighted risk exposure is made. Each element in an upper level is a common attribute for each element in the level immediately below it (Fig. 1).

Risk scoring is a technique for assigning conditions or scores which contribute to the risk profile. The individual scores are determined from a combination of statistical failure data and operational experience [2]. To ensure the correct order in priority of importance for each individual risk factor group, with respect to the situation being compared against, a

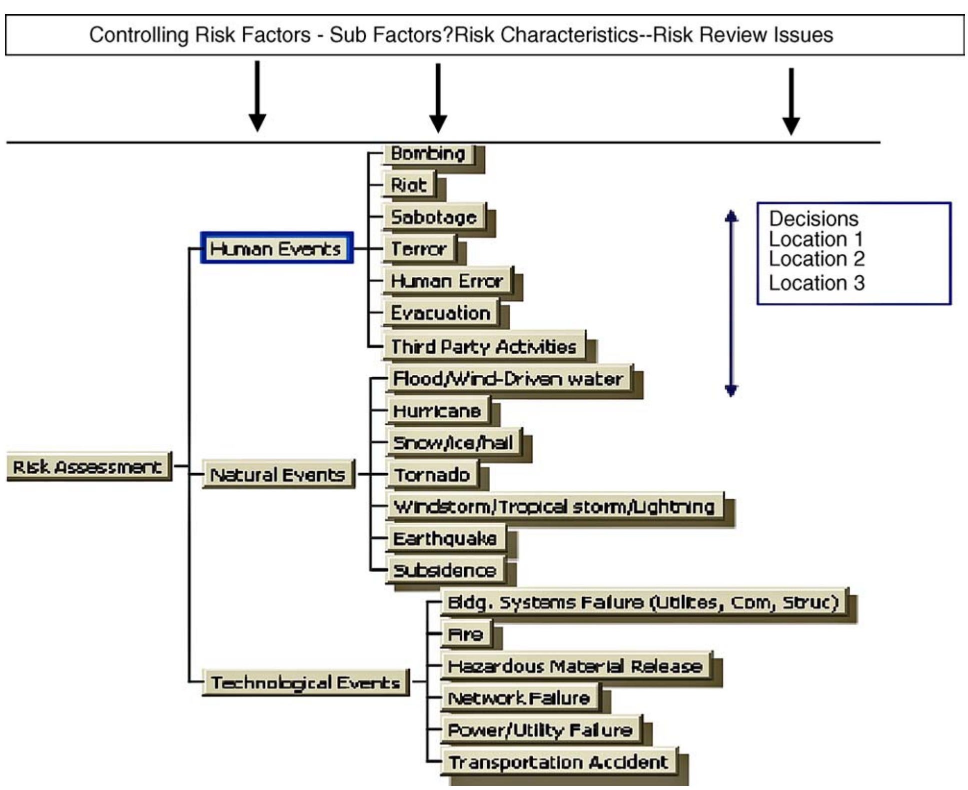

Fig. 1. Hierarchical structure [4,5].

Hazard / Risk	E	P	C	RS
Riot	1	0.5	15	7.5
Earthquake	0.5	0.5	50	13
Sabotage	1	0.5	25	13
Transportation Act	2	0.5	15	15
Haz Release	2	0.5	15	15
Subsidence	1	0.5	50	25
Terror	1	0.5	50	25
Bombing	1	0.5	50	25
Power/Utility Failure	2	3	5	30
Network Failure	2	3	5	30
Wind/Tropical Storm/Lightning	1	3	15	45
Forced Evacuation	1	3	15	45
Snow/Ice/Hail	1	3	15	45
Hurricane	1	3	15	45
Flooding/Wind-Rain	1	3	15	45
Fire	1	3	15	45
Bldg Failure	1	3	25	75
Human Error	1	3	25	75
Third Party	1	3	25	75
Tornado	1	3	25	75

E = Exposure Rating Weight	Frequency of occurance of the hazarard -event at or near Hazard Event Occurs:
10	Continuously (many times daily)
6	Frequently (about once daily)
3	Occasionally (once per week to once per month)
2	Unusually (once per month to once per year)
1	Rarely (it has been known to occur)
0.5	Remotely Possible (not known to have occurred)

P = Probability	(Likelihood accident sequence will follow to completion)
10	Is the most likely and expected result if the hazard event takes place
6	Is quite possible, not unusual, has an even 50-50 chance
3	Would be an unusual sequence or coincidence
0.5	Has never happened after many years of exposure, but is conceivably possible
0.1	Practically impossible sequence (has never happened)

C - Consequence (Loss of Operations) Rating Weight	
1	Less than 60 Minutes
5	Less than 24 Hours
15	Less Than 7 Days
25	Less than 54 Weeks
50	Less than 12 Months
100	1 or more Years

R=C x E x P

C = consequence rating
E = exposure
P = probability

Risk Score Summary and Actions

Fig. 2. Risk score (numbers are arbitrary only) [2].

separate risk score is calculated for each individual risk factor (Fig. 2). From individual risk scores a weighted average is applied to each controlling risk factor group.

The second phase is the evaluation stage in which each alternative (location/decision) is compared with all other alternatives (location/decision). This is done in a risk matrix format. This determines the relative importance of each alternative with respect to the criterion (sub factor risk) in the level immediately above it. For example, Location 1 is compared to Location 2 for risk to exposure to a transportation accident. Since Location 2 is closer to a major highway which has major traffic daily which carries hazardous waste, it would have slightly more risk than Location 1 which is a farther away from a similar major highway. However, both could be exposed from a major accident releasing toxic materials. As a result of this conclusion, an intensity of magnitude is assigned from Fig. 4, the “Red 2” is entered into Fig. 3 table. The intensity of magnitude is not selected as 1 or 2 because although Location 2 is closer to the hazard; both locations are relatively similar in being exposed to a major accident of a released toxic material. A similar comparison would be made between Locations 1 and 3 and Locations 2 and 3 (Fig. 3).

The process is repeated for all combinations of sub factor risk characteristics and criteria risks. This results in a risk matrix which is used to derive a ratio scale by an eigenvector technique [3].

This is achieved by averaging over normalized columns in the matrix. In this way the relative weights are calculated for

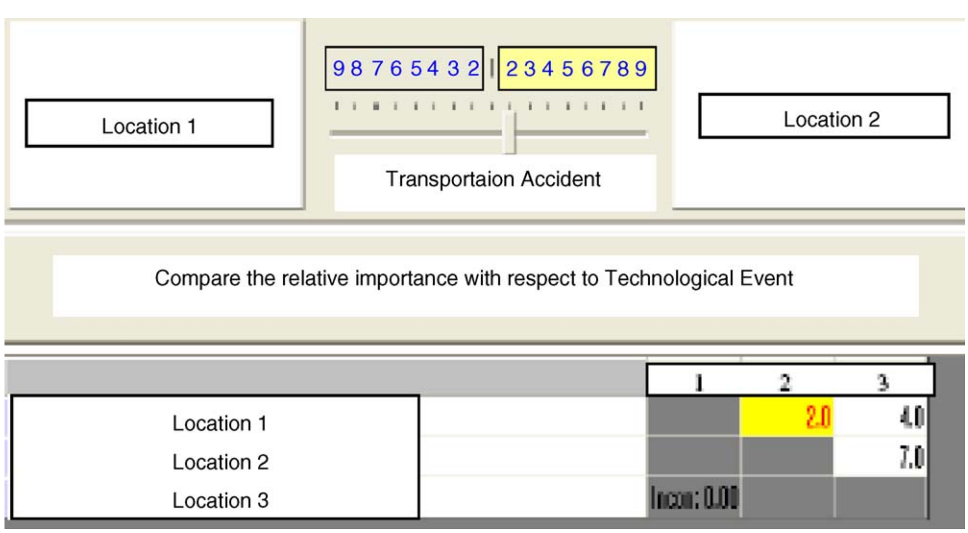

Fig. 3. Pairwise comparison.

Intensity of importance	Definition	Explanation
1.	Equal importance	Two activities contributed equally to the objective
3.	Weak importance of on over another	Experience and judgement slightly favour one activty over another
3.	Essential of strong importance	Experience and judgement favour favour one activty over another
7.	Demonstrated imortance	An activity is strongly favoured and its dominance demonstrated in practice
9.	Absolute importance	The evidence favouring one activity over another is of the highest possible order of affirmation
2,4,6,8	Intermediate values between the two adjacent judgement	When compromise is needed
Reciprocals of above non-zero	If activity *i* has one of the above non-zero numbers assigned to it when compared with activity *j*, then *j* has the reciprocal value when compared with *i*	

Fig. 4. Pairwise comparison ratings.

each of the alternatives in relation to the dimension on which they are compared, in this case the risk of loss of business operations.

The results are then prioritized (synthesized) throughout the model using a weighting and adding process derive the overall risk weight for each location. The results of the calculation are present in Fig. 4. In this case, the highest risk is attributed to the highest relative risk weight score for one location versus another.

3. Example results from application of method

A screening level qualitative risk analysis was conducted for three designated locations using the risk evaluation method described. The risk analysis for the locations evaluated the relative exposure for loss of business operation from power outage, fire, flood, earthquake, hurricane, building failures, bombing, snow/ice storms, network failures, hazardous materials release, evacuation, riot, and other significant factors (third parties, lightning, human error, subsidence, transportation exposure). AHP was used to model and generate a relative weight/rank for comparing risk exposure. The weighted relationships for the controlling risk factors were established by scoring the risk characteristics. The results were in turn pairwise compared to evaluate the level of risk exposure between each location.

Sites reviewed:

Location 1	50,000 ft^2 leased space (less than two total floors) of a 26 story high rise office building; non-combustible; 1975 construction
Location 2	40,000 ft^2 leased space (less than two floors); 15 story high rise office building; non-combustible; 1980 construction
Location 3	No current lease; 90,000 ft^2 total – eight story high office building with adjoining 35,000 ft^2 total – one story below ground bunkered building; non-combustible structures; 1990s construction

Onsite reviews were conducted for each site. A visual inspection of the principle areas was performed, to determine the general conditions at the sites, and to confirm the general

Fig. 5. Relative risk results.

accuracy of the descriptions provided. The knowledge gained during the surveys was used in the risk modeling process.

Overall, the locations reviewed had similar physical characteristics, i.e. non-combustible construction, building management programs, multiple tenants, and protective systems. The closest similarities for these areas were between the Locations 1 and 2. The most notable differences were between the Locations 1, 2, and 3 related to the potential for using the below ground operations for operations. The Location 3 county also weighted favorable for reduced risk, due to less exposure from hurricanes, subsidence, population, and hazardous exposure. Other dominant factors weighting for less risk included the physical separation of mission critical and non-critical operations and activities, removing third party and non-essential personnel from mission critical operations, which would be conducted in the below ground bunkered area. The physical separation of the mission critical operations from the physical above ground exposure to natural hazards provides a significant risk reduction for the Location 3. Slight favorable risk conditions existed for Location 2, when compared to Location 1, in that Location 2 appeared to have an advantage in the area of formalization of management in maintenance and security. Results demonstrate that Location 1 represented the greatest and Location 3 the least weighted risk exposure of the three locations for loss of business operations from both large and small losses when exposed to the factors evaluated (Fig. 5).

The risk factors having the highest weighted influence were as follows:

Loss of business operations—small (minutes/hours) to large (days/weeks) exposure events:

1. Human error;
2. Evacuation;
3. Windstorm/tropical storms/lighting;
4. Third party.

Loss of business operations—large exposure events:

1. Human error;
2. Third party;
3. Building system failure;
4. Windstorm/tropical storms/lighting.

The location characteristics, which had the greatest influence on the comparisons in the analysis, were attributed to separation of mission critical operations from non-critical operations; geographic location, with respect to proximity to weather and population of third party exposures.

4. Conclusions

Multi-criteria decision making techniques such as AHP in combination with risk scoring/indexing are methods for quantifying subjective and objective judgments, and work on the principle that experience and knowledge possessed by people is at least as valuable as the data itself. These techniques are especially useful in the early stages of a risk analysis when attempting to determine which risk issues are critical and may require a more intensive analysis technique. Other underlying reasons for using methods such as these stem from the lack of consistency between data on different risk and hazards, which may be difficult to apply when subjected to a broader scale of scientific style risk review.

This risk analysis process facilitates taking a complex problem and reducing it into simpler, more manageable portions which proceed downward from more general to more concrete, and from the less controllable to the more controllable.

Other advantages to the use of MCDM techniques due to lack of data or its quality include:

- Few incident loss estimates demonstrated similar quality data, with respect to the risk factors. Documentation for conclusions related to the data are either absent or based on assumptions that would require further and timely review, without warranty of determining objective facts or accuracy.
- Cost and frequency of large events and incidents are not well documented. They are often based on inconclusive evidence and in some cased extrapolated.
- Documentation for many incidents do not account for a root cause and in many cases the actual event is categorized as an after effect, i.e. reporting loss of power as the cause, which actually resulted from lightning strike, or in poor planning, or miss design for a specific occurrence.
- Many data conclusions do not differentiate between industry and residential. In some cases, geographic and specific large events biases dominated data sources, i.e. major earthquakes affecting the west coast mixed in with overall U.S. business disruption impacts used for a particular data set.
- Many data sources are presented by publications (newspapers/magazines) which are generated on relative day-to-day, or week-to-week format which might infer the lack of quality control of the information collection and accuracy.
- In some cases, data sources claim conflicting views for the same incidents. This may be attributed to their point of reference, industry, or marketing approach.

Risk assessment does not have to be a calculation-intensive exercise in probabilistic theory. Such calculations are, after all, based upon probabilities that are of questionable benefit in rare-occurrence scenarios. A false precision is often assigned to numbers that are the result of detailed calculations. In reality, the margin of uncertainty is quite high because of the large number of assumptions required in such analyses.

The most sophisticated analysis that is studied once and then filed away is at best only a means to satisfy an intellectual curiosity. An easy-to-understand, easy-to-modify system of risk assessment can become a part of everyday design, business, and operations risk decision.While we will most likely never be able to accurately predict which risks will lead to a loss, we can pick out what we believe to be important factors that may be risk contributors resulting in conditions leading to a loss. Analyzing these factors and their interactions provides insight into the relative potential for a loss and ultimately in their prevention.

References

[1] T.L. Saaty, The Brain, Unraveling the Mystery of How It Works: The Neural Network Process, RWS Publications, 4922 Ellsworth Avenue, Pittsburgh, PA 2000. p. 15213, 13–22.

[2] W. Fine, Mathematical evaluation for controlling hazard, J. Safety Res. 40 (1971) 157–166.

[3] S.S. Gupta, P.K. Dey, Risk-based model aids selection of pipeline inspection & maintenance strategies Oil Gas J. (July 9, 2001), 54–60.

[4] S. Rodentis, Disaster Recovery, Can Your Business Survive the Unexpected? American Institute of Certified Public Accountants, J. Account. 187 (February 1999), www.aicpa.org/pubs/jofa/feb1999/rodetis.htm.

[5] FM Global Website, Various Human Factor Documents, www.fmglobal.com, 2002.