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# Incorporating risk analysis and multi-criteria decision making in electricity distribution system asset management

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ABSTRACT: This paper discusses techniques for integrating risk and multi-criteria analysis in electricity distribution system asset management. The focus is on the tasks of the distribution company asset managers whose challenge is to incorporate the different company objectives and risk analysis into a structured decision framework when deciding how to handle the company physical assets.

## 1 INTRODUCTION

Electricity distribution networks are considered natural monopolies and therefore companies operating and maintaining these networks are under regulatory control. Although the regulatory practice is different in each country, the goal is generally the same: to assure good service quality, higher efficiency in using the network and lower costs/prices. Hence, when managing their physical assets, distribution companies are asked to increase reliability and use less human and financial resources. This presents a challenge for asset managers that are constrained in distributing the amount of resources available, on different maintenance and reinvestment actions (Yeddanapudi *et al.* 2008).

Distribution system asset management (DSAM) is a complex process comprising the lifecycle management of a large number of geographically distributed assets. The failure of one or several assets may cause system failures (power supply interruption), with negative consequences on company economy and reputation, personnel safety or the environment. However, not all assets pose the same risks given their failure and therefore, from a risk perspective, not all assets deserve the same level of attention. Proper identification and assessment of risks are keys factors in DSAM.

Generally, asset managers (AMs) in electricity distribution companies recognize the need and the challenge of adding structure and a higher degree of formal analysis into increasingly complex asset management decisions (Nordgård, 2008).

Examples of such decisions are: 'Maintain or replace a specific asset or asset group?'; 'Which (how many) assets to maintain and which (how many) assets to replace?'; 'How often to maintain?'; 'When to replace?' In almost all cases, the answer should be based on an assessment of the foreseeable risks associated with the assets and an evaluation of consequences a decision would have on company's economy and reputation, personnel safety or the environment.

This paper focuses on decision support tools for risk assessment and multi criteria analysis that can be used in DSAM decision making. We give a short overview of available theoretical methods and discuss some of the challenges of applying these methods in practice. A case study is presented for illustrating the use of risk and multiple criteria assessment in an integrated framework for designing maintenance and reinvestment strategies for 12 kV MV air insulated switch-disconnectors.

## 2 MULTIPLE CRITERIA AND UNCERTAINTY IN DISTRIBUTION SYSTEM ASSET MANAGEMENT

### 2.1 *Criteria in distribution system asset management*

DSAM decisions concerning specific assets or asset groups are, in general, of a multi-criteria nature. Because of the role electricity infrastructure has in the society, and because of regulatory pressure, distribution companies must balance economy (costs and profits) against reliability, quality of supply, personnel safety and other aspects. In other words an asset or network failure might lead to more or less critical incidents with consequences for the company and customers, personnel or third party safety, etc.

Asset management decisions must be in line with the company's overall objectives, and the role of the AM is to make these objectives operational at lower decision levels. The challenge is to balance the evaluation of consequences at company level with the evaluation of consequences of daily operational routine and maintenance decisions. In general, criteria at lower decision levels are easier to operationalize and measure than criteria at higher decision levels. For example, we can say that each component in the network operates in unique conditions and has an unique role and position with respect to the other assets in the network. It can be therefore difficult to generalize a set of rules to measure these criteria (performances) for all assets of a similar type, and even more difficult when it comes to the entire asset base. All these aspects have to be taken into consideration if a multi-criteria approach is to be used in asset management decisions.

### 2.2 *Uncertainty in distribution system asset management*

Many decision elements in DSAM are uncertain during a real decision making process: what can go wrong with an asset or within a distribution system, how likely is that a system or asset fails and what will be the consequences.

Many classifications exist for uncertainty and risk in decision making. For example Stewart (Stewart, 2005), differentiates between two uncertainty aspects: 'external' uncertainty and 'internal' uncertainty.

The 'external' uncertainty, according to Stewart, refers to the lack of knowledge about the consequences of a particular choice (decision). In this paper we consider that external uncertainty resides in the estimation of the problem 'data', e.g.: probabilities and consequences. In this category we would like to include two sub-types:

1. Uncertainty that arises because of natural, unpredictable variations associated with the system or the environmental – aleatory uncertainty. This type of uncertainty is outside the control of the decision maker, e.g. the 100 years big storm, variations in the material fatigue in specific system components, etc.
2. Uncertainties that stem from lack of knowledge about different phenomena – epistemic uncertainty. This uncertainty resides from the lack of data to characterize the system or component failure, the lack of understanding and proper modeling of asset deterioration processes, the poor understanding of failure interdependencies in the system (physical or other phenomena) or the poor understanding of initiating events.

The 'internal' uncertainty can be better described as ambiguity / imprecision in decision making and most of it is due to the uncertainty in problem 'data'. It reflects the imprecision in human judgements: preferences, values and risk attitudes. This uncertainty can stem from insufficient problem understanding, insufficient data, insufficient modelling, little acceptance of modelling assumptions, etc.

Under many circumstances a boundary between external and internal uncertainties is difficult (if not impossible) to draw, but this differentiation is necessary because each uncertainty aspect has in general different implications for the decision support process, and the designs of decision support tools as it will be discussed further.

## 3 THEORETICAL APPROACHES TO MULTI-CRITERIA DECISION MAKING UNDER UNCERTAINTY

The most common representation of a multi-criteria problem is in a matrix form, where the set of alternatives (A) is mapped against a set of criteria (C). Making a decision in this setting means choosing an alternative based on an evaluation of outcomes $a_{ik}$.

When there is no uncertainty about the outcomes there is a direct correspondence between alternatives and consequences in terms of the criteria – $a_{ik}$. Moreover, $a_{ik}$ are deterministic.

Essential in multi-criteria decision analysis (MCDA) is the assumption that when analysing such a multi-dimensional decision problem, the decision maker (DM) has a set of values, preferences, and that these values can somehow be modelled. One of the most used theories for this purpose is the multi-attribute value function theory (MAVT) (Belton & Stewart, 2002). MAVT provides the background for modelling preferences by constructing a value function $V(A_i)$ based on a comparison of outcomes in each criterion (scores) and a comparison of criteria (weights). In its simplest form, this value function is additive and can be written as in the following:

$$V(A_i) = \sum_{k=1}^{n} w_k v_k(a_{ik})$$

where $v_k(a_{ik})$ are the scores and $w_k$ are the weights.

Under uncertainty there may exist many possible values for the outcomes $a_{ik}$ at the time of decision (*external uncertainty*) and often the values (scores and weights) can be difficult to express (*internal uncertainty*). Under uncertainty outcomes can be described quantitatively (through probabilistic quantities), fuzzy, or quantitatively (through verbal descriptions) – when

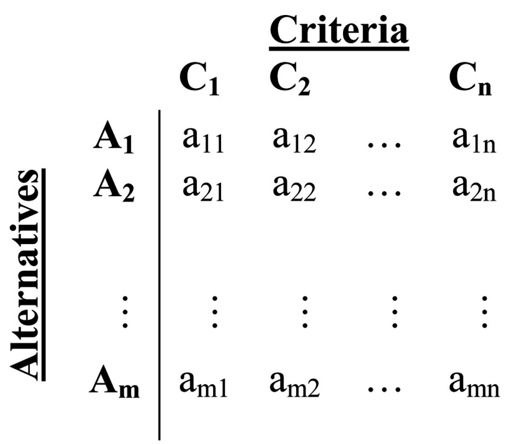


Figure 1. The decision matrix.

outcomes are not fully known or understood. Very often scenarios (future states of the world) are constructed in order to simulate the consequences (quantitative or qualitative) the decisions alternatives might have in terms of the different criteria. In the construction of scenarios, approaches like Bayesian Networks (BN) and influence diagrams or fault and events threes, are often used to understand and model random events and how they affect outcomes.

There are two main approaches to resolve uncertainty in MCDA (Stewart, 2005). One approach is to resolve first the uncertainty in outcomes by somehow reducing the set of possible $a_{ik}$ to single values and then solve the MCDA problem in a 'deterministic' setting. Uncertainty 'aggregation' can be done by using a decision paradigm such as: expected values, utilities, MaxMin, MinMax, MinRegret, etc. or to define risk as a separate criterion. The other approach is to define scenarios with associated probabilities of occurrence and evaluate alternatives in each scenario – however, the theoretical background for integrating MCDA and scenario planning is not yet fully developed (Stewart, 2005).

The 'main' method for modelling preferences under uncertainty is the Multi-Attribute Utility Theory (MAUT). In its simples (additive) form, a multi attribute utility function resembles a multi-attribute value function. The way to find parameters of a utility function is however different. While in the case of MAVT the scores and weights can be determined based on direct comparison of consequences, in the case of MAUT these components are found through lottery types of questions (Keeney & Raiffa, 1999).

MAUT measures 'complete' preferences under uncertainty. However, because preferences may not always be completely specified *(internal uncertainty*), methods have been developed to deal with value intervals, qualitative estimations and incompletes in judgements. Examples of such methods are: PRIME (Preference Ratios In Multi-attribute Evaluation) (Salo & Hämäläinenn, 2001) and ER (Evidential Reasoning) approach (Yang & Xu, 2002), among others.

Without going further into theory and method classifications, we summarize that dealing with uncertainty in multi-criteria analysis in practice requires methods to:

1) Represent and understand uncertainty in outcomes (data), and
2) Model preferences and risk attitudes.

## 4 CHALLENGES IN APPLYING MCDA AND RISK ANALYSIS TECHNIQUES IN PRACTICE

The successful application of multi-criteria approaches relies on effective facilitation by a decision analyst or on the ability and willingness of individual users to make an effective use of an approach, without becoming experts in the fields of MCDA or risk analysis. The main challenge in both cases is to make use in the best way, of:

1) the information available, and
2) the existing tools and personnel competences, i.e. to build upon the decisions support tools available in a decision situation in distribution system asset management.

An integrated MCDA and risk analysis may seem as the ultimate tool to gather all information available in a decision situation, and to obtain 'The' answer, but this is not the case. The advantages of using such an approach in real life decision support are:

1) a better problem understanding
2) a better understanding on how DM's judgments at a given moment in time, contribute to the final decision.

However, the decision must be important enough to justify the extra time and resources necessary in using such an approach. The approach is not better or worse than traditional ones and it does not replace fundamental analyses, but it can only improve it.

### 4.1 *Available information*

The amount, accuracy and relevance of information are crucial for problem understanding, modeling and the final decision. In distribution system asset management the following information is essential:

- Information about each equipment/asset: installation year, condition, historical failure rates, failure mechanisms, specific maintenance activities, etc.
- Information about the system: critical components, interdependencies, consequences of failure for the customers, the company and the environment.

In general, the easiest to access is information about: manufacturer equipment specifications, age and statistical failure rates, costs of repair and replacement.

However, some of this information is not always available in a format suitable to the problem at hand. For example, various sources of statistics exist for specific equipment, but often they are not in the right format for providing sufficient information in a specific situation. Companies may have specific practices and formats for recording failures, maintenance history, etc. Often, different databases and statistics must be compared and completed with expert evaluations.

Moreover the cost of repair and replacement for single components should be considered as evolving over time and as dependent on the existing spare parts in stock, available providers, technological advances, etc.

Then, the information must be structured and combined in order to provide further essential clues such as: equipment condition, failure modes and consequences, equipment criticality, environmental impact, etc.

### 4.2 *Existing tools for asset management in distribution networks*

Traditionally, electrical engineers have relied most on technical models/data, statistics and their own experience, and less on decision support models. However, because asset management decisions have become more complex, this trend is changing, and different types of models and tools used 'traditionally' decoupled are now being integrated in order to offer the best available decision support.

The 'tools' available and used by AMs in electricity distribution companies can be classified as following:

- databases for recording asset information, faults, damages, system operation and maintenance practice
- software used for a complete distribution system representation, power flow and reliability modeling
- management tools used at higher decision levels: economic calculations, balance scorecards, or risk matrices.

Generally, AMs recognize the need and the challenge of adding structure and a higher degree of formal analysis into increasingly complex asset management decisions (Nordgård, 2008). One example is the way risk matrices are used in practice. Undesired events are placed in a risk matrix based on an overall expert evaluation of probability and consequences. There is very little practical use of tools for understanding and modeling equipment condition, aging, and failure modes and how this information (if available) could be used further in risk assessment, completion of risk matrices and asset management decisions.

## 5 INTEGRATING RISK AND MCDA ANALYISIS IN ASSET MANAGEMENT DECISION MAKING

This chapter offers an example of how an integrated framework for risk and MCDA analysis can be used in designing asset maintenance strategies for 12 kV MV air-insulated switch-disconnectors.

The scope of this study is to illustrate how a maintenance and reinvestment strategy can be designed in order to manage the risks and costs associated with these assets. A strategy is considered to be a set of rules about what to do with different types of assets, e.g. whether to maintain or replace them. The case is built upon previous research reported in (Nordgård, 2008; Nordgård & Sand 2008) and has as focus on *personnel injury caused by malfunction of manually operated switch with a burning electric arc as a result.*

### 5.1 *Description of the case*

There are 12 kV MV air-insulated switch-disconnectors in electricity distribution networks. These assets are located in MV/LV sub-stations and their function is to break the load current when sectioning the MV grid. In general, these assets are not particularly critical or important from a system/security of power supply perspective. However, the operation and maintenance of specific types of switch-disconnectors in specific conditions may pose non-negligible personnel safety risks.

Factors such as equipment type, condition and operation environment may lead to switch pole stuck or slow operation thus incorrect breaking of the current and personnel injuries. In the transient period after the opening of the switch – when there is no longer physical contact between the switches' poles – the current will continue to flow through an electric arc until the natural zero-crossing of the alternating current. Normally the electric arc will then extinguish in a controlled manner, and the breaking of the current is successful. However, in some cases, when there is a slow movement of the switch during operation, the arc will re-ignite and current will continue to flow through, generating energy dispersion through heat (with accompanying pressure rise) and creating stable burning conditions. This will pose a safety risk for the operator.

In this study we consider a distribution network having in its structure the following types of switch-disconnectors:

- full encapsulated switches (*steel plate covered cubicles, with pressure relieving outlets in safe directions*)
- semi encapsulated switches (*steel plated cubicle fronts, but the top and bottom of the cubicle is open*)
- wire fence switch cubicles (*only wire fences – supplies little protection from electric arcs coming from the switchgear*).

The reason for different encapsulations is that the substations have been built over quite a long period of time, during which the technical solutions have improved from the wire fence solution to the full encapsulations.

### 5.2 *Risk analysis and modeling*

The first step in the analysis was to clarify whether all assets pose the same risk or if different asset groups can be identified based on risk differentiation.

A Bayesian Network (BN) modeling approach has been used to analyze the safety risk (expressed as PLL – Potential Loss of Life) associated with different asset groups, considering today's condition of components and maintenance practice.

The BN model is illustrated in Figure 2 and has been developed in (Nordgård & Sand 2008). This reference paper contains all details about the data and assumptions made.

Several factors have been identified by experts in the field, as being relevant for differentiating the population of the switches: switch type (encapsulation), age and operating environment.

Asset's age, operating environment and maintenance practice are important in the estimation of different failure modes (burning electric arc). Two age

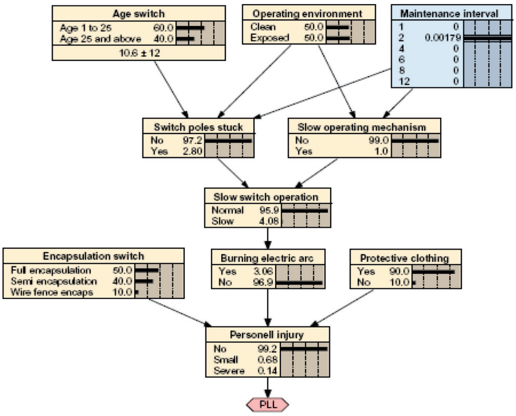


Figure 2. Bayesian network for modeling safety risk (Nordgård & Sand, 2008).

groups have been considered: assets 'younger' and 'older' than 25 years. The operating environment can be characterized as clean (C) or exposed (E). The failure probability is supposed to be larger in an exposed environment (containing more dust and dirt) in than in a clean environment. The switch encapsulation and other personnel related factors (for example the use of protective clothing) are also considered as risk factors.

The BN model is used to estimate the probability of personnel injury and the potential loss of life associated with one component (12 kV MV air insulated switch-disconnector) with specific characteristics: age, operating environment, maintenance practice, and encapsulation.

### 5.3 *Risk-based categorization of assets*

Using the BN model, the entire population of switches can be characterized in terms of safety risk. By varying some of the parameters (age, operating environment and encapsulation) several categories of switches can be defined ((F,E) – to (W,C)[1]).

In this example, the different types of assets were further placed into a risk matrix (illustrated in Figure 3), according to the estimated safety risk using the BN model. Probability and consequence levels for the assets plotted in the risk matrix were estimated based on the same assumptions used in the BN model.

For simplification, the asset age does not come into the picture in this risk matrix, but it will be considered in further analyses. Tables 2 and 3 show the probability and consequence scales used in the risk matrix.

This risk mapping shows that at least three asset categories ((W, E), (S, E) and (W, C)) contain elements with medium to high safety risk. Using company's asset information, a total number of approximately 5000 switch-disconnectors are analysed. Table 3 and Figure 4 show the distribution of the total number of assets on different asset categories defined based on asset type, age, and operating environment.

The moderate and high risk asset groups are marked with red respectively yellow patterns in Figure 4.

The decision is how different assets categories should be maintained, considering the safety risk, the maintenance and reinvestment costs.

[1] F = Full encapsulation, S = Semi-encapsulation, W = wire-fence encapsulation, E = Exposed operating environment, C = Clean operating environment

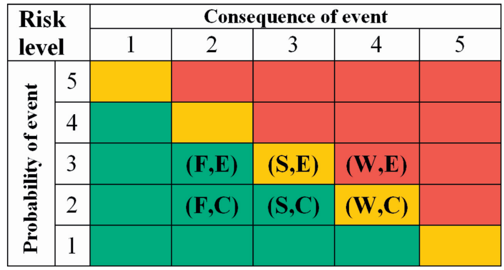


Figure 3. Risk matrix illustrating the safety risk for different assets.

Table 1. Probability scale.

| Scale | Description | Frequency |
|---|---|---|
| 1 | Improbable | less than once in 10 000 switchings |
| 2 | Less probable | every 1 000–10 000 switchings |
| 3 | Probable | every 100–1 000 switchings |
| 4 | Very Probable | every 10–100 switchings |
| 5 | Highly Probable | every 1–10 switchings |

Table 2. Consequence scale.

| Scale | Description | Consequence |
|---|---|---|
| 1 | Insignificant | *no injuries* |
| 2 | Small | *minor injuries* |
| 3 | Medium | *medium to serious injuries* |
| 4 | Very serious | *more than one person with serious injury* |
| 5 | Catastrophic | *one or more deaths/10 or more injuries* |

Table 3. Number of 12 kV MV, air-insulated switches.

| | Age | | *Total* |
|---|---|---|---|
| Type /Operation environ. | < 25 yr. | > 25 yr. | |
| *Full encapsulated switches* | *1800* | *700* | *2500* |
| Clean | 1140 | 210 | |
| Exposed | 360 | 490 | |
| *Semi encapsulated switches* | *1050* | *800* | *1850* |
| Clean | 580 | 400 | |
| Exposed | 470 | 400 | |
| *Wire fence switch cubicles* | *150* | *500* | *650* |
| Clean | 120 | 250 | |
| Exposed | 30 | 250 | |

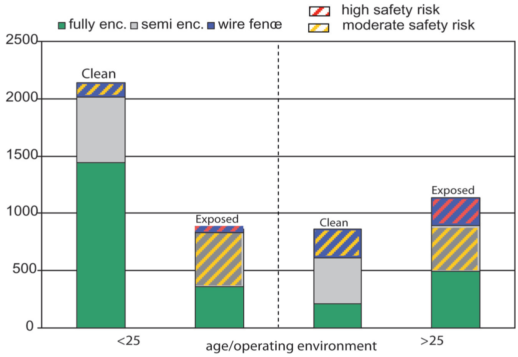


Figure 4. The number of assets in each risk category.

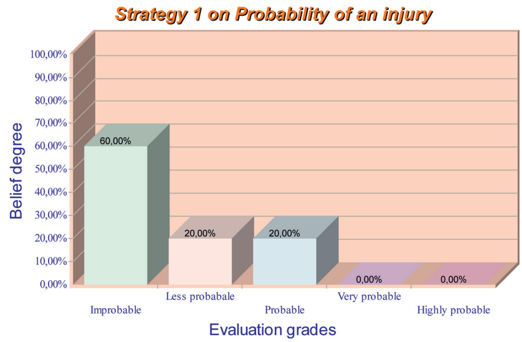


Figure 5. Degrees of belief for 'probability of injury' given strategy 1.

## 5.4 *Identifying maintenance strategies*

A closer look into the number of components in each group reveals that considering today's maintenance practice, a significant number of switches (5%) are of the type (W,E) – high risk, and even more components (25%) are in the medium risk zone (S,E) and (W,C). This situation may require the redesign of today's maintenance strategy for 12 kV MV air-insulated switch-disconnectors in order to reduce the total risk.

The analysis is further focused more on new technical solutions rather than discussing current maintenance activities and practice. Thus, in order to reduce the total risk associated with the switch-disconnectors, the following technical solutions are considered:

1) for the wire fence switches (W), accounting for 13% of the population: *reconstruct the encapsulation* or *replace them with new* $SF_6$ *switches*.
2) for the semi-encapsulated switches (S) accounting for 37% of the population: *improve the maintenance* (cleaning, lubrication, etc.).

The following maintenance strategies have been considered for further analysis:

Strategy 1: Maintain as usual.
Strategy 2:
- a) Replace all wire fence switches with SF6 switches (650 pieces)
- b) Improve the maintenance of semi-encapsulated switches, in exposed environment, older than 25 years (400 pieces).

Strategy 3:
- a) Replace all wire fence switches in an exposed environment (280 pieces)
- b) Redesign all wire fence switches in a clean environment (370 pieces)
- c) Improve the maintenance of all semi-encapsulated switches in an exposed environment (380 pieces).

## 5.5 *Choosing a maintenance strategy*

The choice of a maintenance strategy is based on an evaluation of potential for risk reduction associated with each strategy and the maintenance and reinvestment costs necessary to achieve this risk reduction. In this example we illustrate the use of multi-criteria software – IDS Multi-Criteria Assessor[2] as decision support in choosing a maintenance strategy.

IDS is a general-purpose multi-criteria decision analysis tool based on the methodology called the Evidential Reasoning (ER) approach (Yang & Xu, 2002). The software was developed to deal with multi-criteria problems having both quantitative and qualitative information with uncertainties and subjectivity – thus IDS can be used to resolve both the external uncertainty (in data) and internal uncertainty (imprecision in judgments) as discussed in Chapter 2 of this paper.

The first step in using this software is the definition of the decision problem, i.e. the definition of alternatives and their achievements in three main criteria: *safety*, *maintenance cost*, *investment cost*. This is equivalent with the matrix in Chapter 3, only that IDS allows the definition of a *belief decision matrix*, of which the conventional decision matrix is a special case.

For example, the criterion *safety risk* is a qualitative measure that cumulates AM's beliefs regarding the probability and possible consequences of an injury, given a strategy. For Strategy 1 (status quo), an evaluation of the risks associated with different asset categories (see the risk matrix in Figure 3) can lead to a total risk perception as illustrated in Figures 5 and 6. Note that while the risk matrix was developed for one generic asset in each category, the total risk evaluation of a strategy (involving all asset groups) is a qualitative measure that can be defined as in the following. The probability of injury, considering Strategy 1 can be modeled through the 'belief' distribution: {[Improbable, 60%], [Less probable, 20%], [Probable, 20%]}; the impact of safety given Strategy 1 can be evaluated as: {[Small, 70%], [Medium, 20%], [Very serious, 10%]}.

IDS allows the combination of these beliefs into a total safety risk evaluation for each strategy, as shown in Figure 7. This figure is an equivalent of the risk

[2] A free version of IDS is available at www.e-ids.co.uk.

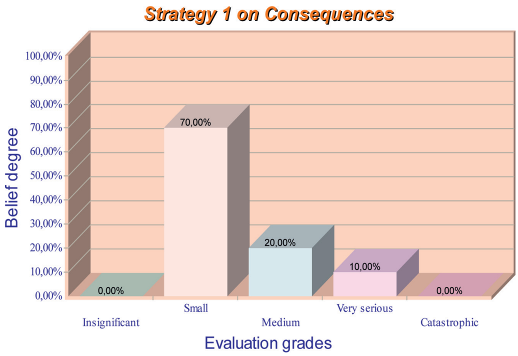


Figure 6. Degrees of beliefs for 'consequences' (in terms of personnel injuries) given strategy 1.

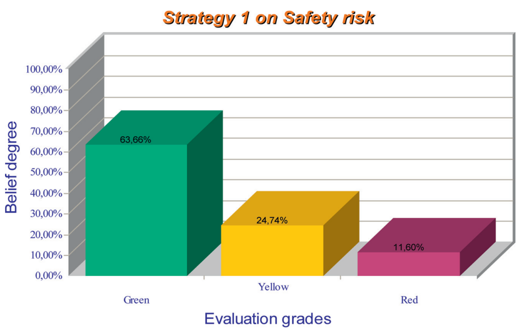


Figure 7. Degrees of beliefs for 'safety risk' given strategy 1.

Table 4. Cost estimates for different maintenance strategies.

| Criteria | Increase in maintenance cost | Investment cost |
|---|---|---|
| | K NOK | k NOK |
| Strategy 1 | 0 | 0 |
| Strategy 2 | 800 | 52 000 |
| Strategy 3 | 1745 | 29 800 |

*NOK – Norwegian krone

matrix in Figure 3, but showing the 'cumulated' risk perception for all asset groups, given Strategy 1.

In the same way, the total safety risk picture for alternatives 2 and 3 can be described.

The advantage of using IDS is that such qualitative evaluations or 'degrees of belief' can be included in a formal analysis, together other, quantitative criteria.

Reinvestment in large amounts of assets requires significant economic efforts for a distribution company whose annual costs and profits are under regulatory control. Table 4 shows a rough estimation of the increase in maintenance costs and investment costs associated with each strategy.

These cost figures are defined as quantitative, certain values into IDS.

Up to now we have described how to define evaluation grades for the three criteria considered for the analysis of the three maintenance strategies. In addition to this, rules have to be defined in IDS, to show how each criterion grade may contribute to the overall objective – the *potential for risk reduction*- based on which the alternatives will be ranked. For example, an investment cost of 0 NOK is likely to induce *higher risk exposure* while and investment cost of 52 000 is likely to contribute to a *lower risk exposure*.

Once the description of each alternative in terms of the three criteria is done, criteria weights must be defined. Figure 8 below shows the normalized weights used in this example. Safety is considered the most important criterion, followed by maintenance and reinvestment costs.

The results from IDS consist in a ranking of strategies based on the *potential for risk reduction* as shown in Figure 9. This figure shows that Strategy 3 has the highest potential of risk reduction. The ranking is based on average degree of beliefs (utilities) calculated based on preference and belief information about criteria and weights.

These results indicate that Strategies 2 and 3 can reduce the possibility (belief) of having higher personnel risk exposure. The results can be used to justify how assets on 'red' in the risk matrix in Figure 3 may move towards 'yellow' or 'green' zones by applying one of Strategies 2 and 3. While the safety risk is still

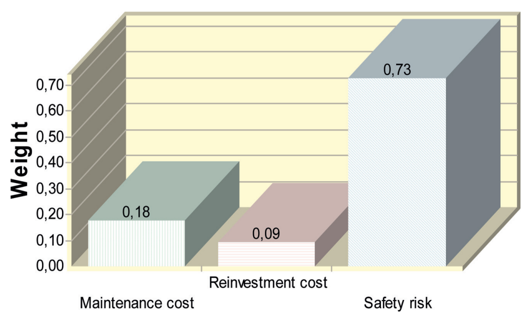


Figure 8. Criteria weights.

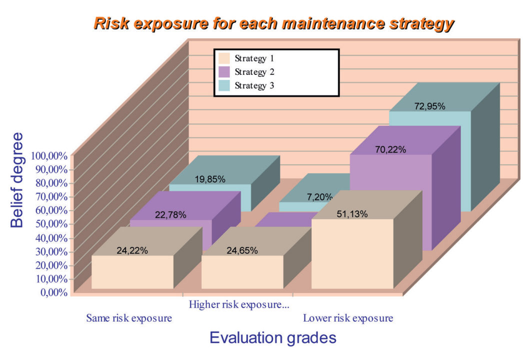


Figure 9. The ranking of strategies in terms of risk exposure.

'qualitatively' assessed, the costs of different strategies for reducing the risk exposure are however supposed to be known.

### 5.6 *Concluding remarks*

This case study was used to illustrate how BN models can be used as basis for constructing risk matrices, and how this information may be used further in (multiple criteria) decision making using the ER approach and IDS Multi-Criteria Assessor.

This link between different tools for risk analysis and the final decision is often missing in real life decision making in distribution companies. While risk matrices are often used by asset managers, justifications for how the matrices are built and how they are used further in decision making are often missing. The IDS software, as an integrated tool for risk and multi-criteria analysis and visualization, has a good application potential in DSAM.

## 6 CONCLUSIONS

This paper addresses the challenges in adding structure and a higher degree of formal analysis into increasingly complex distribution system asset management decision making. It discusses the available theoretical approaches for multi-criteria decision making under uncertainty and the tools and information asset managers already have at their disposal.

A case study was used to illustrate how to use available theoretical methods as Bayesian Networks to improve the usability of risk matrices – tools that AMs in electricity distribution companies already use.

A multi-criteria decision analysis tool – IDS Multi-criteria Assessor is further used to deal with the multi-criteria decision of choosing among several strategies for managing 12 kV MV air insulated switch-disconnectors. The software allows for both quantitative and qualitative information with uncertainties and subjectivity – thus uncertainty in data and imprecision in judgments.

An integrated MCDA and risk analysis may seem as the ultimate tool to gather all information available in a decision situation, and to obtain 'The' answer, but this is not the case. The advantages of using such an approach in real life decision support are: 1) a better problem understanding, and 2) a better understanding on how decision maker's judgments at a given moment in time, contribute to the final decision. In general, the decision must be important enough to justify the extra time and resources necessary in using such an approach. The approach is not better or worse than traditional tools in DSAM and it does not replace fundamental analyses, but it can only improve it.

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