A Decision Support Model for Risk Assessment in Communicable Disease Control in the United Kingdom

Dr. Chakib KARA-ZAITRI
Department of Industrial Technology
University of Bradford. Bradford.
The United Kingdom
Email: c.karazaitri@bradford.ac.uk

Keywords: Communicable Disease Control, Risk Assessment, Decision Support System, FMECA.

Abstract

This paper summarizes the development of a risk assessment model for Consultants in Communicable Disease Control (CsCDC) in the UK Health Service. The paper starts by reviewing the literature on generalised quantitative risk assessment tools and techniques. It next describes a structured and systematic methodology for capturing cognitive maps used by CsCDC for assessing risk in a given situation. The paper then presents a risk assessment model based on five key risk attributes that have been identified and defined using the Delphi Method. Each attribute is graded from 0 to 4 and a Risk Priority Number (RPN) is calculated by summing the five ratings. The RPN is used to prioritise appropriate interventions. The model developed is validated by direct simulations with twenty CsCDC. It is shown that the risk assessment model developed is systematic, quantifiable, objective, traceable, auditable, and appropriate for communicable disease control.

Introduction

Experience has shown that the risk assessment process carried out by a Consultant in Communicable Disease Control (CCDC) is based on a synthesis of scientific knowledge, subjective judgement, experience, intuition, and case law. The paper centres on four main objectives.

The first objective relates to a comprehensive literature review on quantitative risk assessment methodologies with a special emphasis on practical tools and techniques. The outcome of this first stage is the selection of Failure Modes Effects and Criticality Analysis (FMECA) as a suitable tool for Communicable Disease

Control. FMECA is the recognised tool for risk and reliability assessment in a plethora of applications in chemical, nuclear, aerospace and military systems.

The second objective relates to the development of a method for documenting the inherent reasoning process and identifying common factors of the decision-making process. Much of this knowledge is based on long experiences of CsCDC who inherently use varying ideologies or cognitive maps to reach a given decision. This knowledge and experience is extremely valuable but is, so far, stored in the minds of CsCDC members and is not effectively shared. The outcome of this second stage is a synthesised analysis of eight in-depth interviews with carefully selected CsCDC members and the identification of emerging issues.

The third objective focuses on the development of the risk assessment model, which is capable of handling the vagueness and uncertainty inherent in the decision process. The model is based on the reduction and pruning of emerging issues previously identified and consists of five key risk attributes that have been identified and defined using the Delphi Method. Each attribute is graded from 0 to 4. For a given scenario, the decision-making is facilitated by special and general rule protocols reflecting the risk assessment policy of the institution. General rules are based on the estimation of a Risk Priority Number calculated by summing the five ratings and comparing the resulting number with a categorised scale of appropriate interventions. Special rules indicate that the course for actions should one or more of the five attributes be graded as "high" regardless of the other attributes.

The final objective relates to the application, validation, and refinement of the model developed by direct simulations with twenty CsCDC. The scenarios cover a wide spectrum of events, with varying degrees of complexity and several communicable diseases.

Literature Review

The starting point of the literature review begins with two key publications. The first one is a study [1] by the Advisory Committee on Dangerous Pathogens aimed at addressing the scientific approaches to and the needs of risk assessment as applied to microbiological risks on a population / public health scale. Microbiological Risk Assessment (MRA) is a formal structured procedure for identifying and characterising microbiological hazard and determining the risk associated with it. The report reviews the current position, considers the information resources available for assessing and quantifying risks, and provides a system for information sources. It discusses available databases and examines modelling of disease and disease patterns. The second publication is a study [2] on the use of risk assessment in environmental toxicology, highlighting the advantages of applying quantitative methods.

Several reviews [3, 4, 5 and 6] have been carried out on the application of risk assessment in general health studies. The emerging factors from these reviews include the following:

1. The existence of several disparities in the practices of risk assessment and management.
2. The need to use a more systematic and structured risk assessment tool so as to minimise the reliance on default thinking.
3. The fact that infectious diseases have been managed ineffectively because of the lack of knowledge about the complexities of the diseases.
4. The ever-increasing "right-to-be-informed" by the general public.

There are three fundamental ways, not necessarily mutually exclusive, of estimating the risk of a given event--namely objective, subjective, and hybrid assessment methods. Objective methods use quantitative attributes of the risk and include the number of dead or infected, the resources and associated costs, and the time taken to finalise a given undesired event. Objective methods can be based on statistical analyses and probability distributions of outcomes. Subjective methods use qualitative assessments approaches of the risks involved and include pair-wise comparisons, base rate comparisons, and group judgements. Hybrid methods are based on objective and subjective methods and use numerical scores, indices, or ratings described by qualifiers or fuzzy linguistic variables. Hybrid methods are particularly useful in applications where both hard and soft data can be fused together to facilitate decision-making. The use of a single number to estimate the risk has advantages and disadvantages and has been the subject of extensive discussions and research [7]. The use of a single number is still the preferred option in many different applications.

The benefits of health risk assessment have long been recognised in the USA, Australia, New Zealand, Canada, the European Community, Germany, the Netherlands, Scandinavia, and the UK [8]. However, the applications have centred on mainly three broad areas: microbiological [1 and 2], cardiac, and other studies. A significant volume of literature can be found about communicable diseases in terms of description, symptoms, and necessary remedial actions. For example, comprehensive guidelines for the management of meningoccal disease clusters as well as associated rules and procedures can be found in References [9, 10, 11, 12, 13, 14, 15]. More specifically, information about the overuse and uncertain efficiency of the prophylaxis antibiotic for bacterial meningitis is studied in Reference [16]. Similarly, guidelines for preventing the transmission of tuberculosis can be found in Reference [17]. Other more practical guidelines [18], commissioned by the Infectious Disease Society of America, have been designed to provide assistance to clinicians when making decisions on when and how to best administer parental anti-microbial therapy. Interestingly, a standard ranking system is used for the strength of the recommendations and the quality of the evidence

cited in the literature reviewed. Apart from the computerised set of methods [19] for the risk assessment of infectious diseases in animals, very few references specifically addressing risk assessment in communicable disease control in humans could be found. Relevant quantitative risk assessment models in other areas include: auditing [20], financial systems [21], military decision-making [22], the Law [23] and asset management [24].

Journalists reporting on risk assessment matters [25] have to simplify the important information to readers and viewers--a task they find inherently difficult if it is not already done for them. They do not always explain the complexities, uncertainties, assumptions, and subtleties involved in assessing a given risk. Unfortunately, they sometimes tend to concentrate on the controversy caused by the disagreement of experts. Several relevant studies can be found in the literature [26], which have focused on such issues as: the kind of hazards the media report, the kind of information they present, the people deemed responsible for hazards and their prevention, and the accuracy of reported information.

A formalised and structured method that has helped analysts document their natural reasoning about what might go wrong, how and why it will go wrong, and the associated effects is Failure Modes Effects Analysis (FMEA). The widespread use of FMEA as a risk and reliability tool is probably due to its simplicity in terms of the documentation of the inherent analytical, logical, and natural reasoning process. For the purpose of this research, it is felt that the use of FMECA can be successfully adapted for the development of the risk assessment model required. The advantages and disadvantages of combining Severity, Occurrence, and Detection ratings into a single Risk Priority Number (RPN) and the difficulty in describing and interpreting the numerical ratings have been discussed at length in References [27] and [28].

It is concluded that the systematic, structured, qualitative, and quantitative approach used in the RPN methodology can be applied to develop the risk assessment model for communicable disease control. The decomposition of risk involved in individual key attributes or risk factors that are assessed individually and then combined into an overall index using a weighting system offers an effective solution to the problem under consideration.

Data Capture and Synthesis

This second phase of the research is based on in-depth interviews with eight carefully selected CsCDC. The main objectives of this phase include the following:

1. To develop a simple way of documenting the reasoning process used by each CCDC selected in reaching decisions based on risk assessment. The data

acquisition is to include the intuitive approach, subjective judgement used, and cognitive factors used in the decision-making process.
2. To identify critical elements, components, or attributes of the risk assessment model for each CCDC and associated values.
3. To summarise identified risk assessment attributes and associated values in a synthesised model.

The methodology utilised during the two-hour interviews is based on the following main points:

1. The interview took the form of a brainstorming session with all its associated rules. The main aim and objectives of the research were explained to the Consultants at the beginning of the session. The Consultants then spoke freely and with little prompting about their practice, experiences and risk assessment approaches. All ideas given were recorded and checked verbally with the consultants.
2. Five minutes prior to the end of the interview, the Consultants were asked to list, in their opinion, the main attributes of their risk assessment approach as fast as they possibly could. The Consultants were not warned about this and the intention was an attempt to quickly reach for their subconscious cognitive reasoning approach.

During the interviews conducted, notes were taken by two individuals and compared immediately after the sessions. This procedure was used to maximise the quality of the data acquisition methodology. Tape recording was deliberately not used, as this normally results in extra effort and the possibility of inhibiting interviewees from speaking freely and openly. Instead, all issues, points, and comments deemed pertinent were recorded verbatim. Despite the fact that every effort was made, the author recognises the possibility that some of the views and opinions of the Consultants may have been misquoted, quoted in the wrong context, misunderstood, or unintentionally ignored. The main emphasis on this part of the research is the identification of the general issues.

The data capture process took place immediately after each session in order to keep the issues and points raised afresh. The name of each Consultant was arbitrarily coded with a letter. Each issue raised or comment made was given a number--in this case a line number. Each line refers specifically to the disease under discussion. The data coding methodology consisted of the following two steps:

1. Each verbatim comment was coded using a unique identification number and two keywords: a primary keyword used to store the name of the main issue, concept or attribute, and a secondary keyword used to store a descriptor of the main issue. The idea here was to initiate the compilation of an unbiased list of important issues--a list which kept changing as more and more interviews were carried out.

2. Issues began emerging as the data captured for all the Consultants interviewed were sorted according to the selected primary and secondary keywords. The list of emerging issues was subsequently analysed and pruned.

The Development of the Risk Assessment Model

This next phase relates to the identification and description of the key attributes and sub-attributes and associated ratings. The literature suggests that the dimensions or attributes of risk must be comprehensive, non-redundant, independent, and preferably measurable and minimal in number. A "minimal set" of attributes can consist of three categories: magnitude, dread, and context. The starting point here was the emerging issues identified in the previous phase. An intensive brainstorming session took place with eight Consultants including some already interviewed and others. Using the advantages of the Delphi method, the Consultants were asked to complete the following tasks:

1. Individually describe and then openly discuss the emerging issues and identify any common factors.
2. Individually and then collectively put some of the emerging issues into natural groupings.
3. Individually and then collectively finalise their thoughts by identifying key attributes, using a single word to describe each one.

The Consultants were then individually asked to describe each attribute, sub-attribute, and associated rating. A decision was made to use a 0 to 4 scale for each attribute. The five attributes of the Risk Model can be found in table 1.

Model Validation

The model was validated in a simulation exercise involving twenty CsCDC and covering a wide spectrum of scenarios of varying complexity and an important number of communicable diseases. The risk assessment used was based on general and special rules. The general rules were based on the interpretation of the calculated Risk Priority Number (RPN) for the scenario under consideration. The RPN is obtained by adding the ratings of each of the five attributes. For example, if the RPN were less that 6, the appropriate action would be to do nothing. On the other hand, if the RPN were more than say, 15, a full emergency was declared.

The simulations were therefore used to calibrate the whole process. Comparing risks is not always easy and can be prone to controversy. Hamlet's observation that "there is nothing either good nor bad, but thinking makes it so" is fully justified in this context. However, the calibration and ranking process has several advantages including:

1. Comparisons of the same risk at different times or comparisons with the expected risk.
2. Comparisons of alternative solutions to the same problem and comparisons with the same risk experienced at other places.
3. Comparisons of average risk with peak risk at a particular time or place.

Table 1. The 5 attributes of Risk Assessment Model for CDC

1. Significance (Grading from 0 to 4) The seriousness of the event in terms of the intrinsic propensity of the disease to cause harm, and the size of the health impact (degree and extent) due to the infection on the case(s), and the implications for contacts and the wider population.
2. Confidence (Grading from 0 to 4) The level of confidence, epidemiologically, clinically, statistically and from laboratory evidence, that the diagnosis is correct and that cases are linked by person, time, place and organism. 2.1. Confidence in the diagnosis of each case 2.2. Confidence that cases are linked
3. Spread (Grading from 0 to 4) The intrinsic temporal and spatial potential for spread including the infective dose, the virulence of the organism, the availability of the route(s) of spread, and the susceptible population (e.g. lack of immunity). 3.1 Potential of the organism to spread 3.2. Susceptibility of population at risk 3.3. Observed spread
4. Interventions (Grading from 0 to 4) The ability and feasibility for an effective intervention to alter the course and influence the outcome of the disease in terms of containing, reducing, or eliminating the transmission of the organism. The ability and feasibility of delivering what is needed, to whom it is needed, and when and where it is needed. 4.1. Ability to do something useful 4.2. Feasibility of interventions
5. Context (Grading from 0 to 4) The broad environment, including public concern and attitudes, expectations, pressures, strength of professional knowledge, and the overall setting of external factors including politics, in which events are occurring and decisions on responses are being made. 5.1. Media, parents and local concern 5.2. Historical problems 5.3. Peer group practice 5.4. What is happening elsewhere

Conclusions

1. The data acquisition methodologies adopted have been successfully applied to acquire, capture, store, and document the intuitive reasoning process used in decision-making and associated risk assessment. The methodologies used have facilitated the mapping of the main cognitive attributes or factors of the risk assessment process for each Consultant interviewed. The structured methodology adopted has facilitated the synthesis of all the data captured and the identification of emerging issues of the risk assessment process.
2. The results of the work carried out so far have indicated consistencies as well as small discrepancies in the various approaches used by the Consultants in their risk assessment processes. The results shown on the synthesised framework have been successfully used to share, possibly for the first time, the various thinking models, and help build an integrated picture of current practice.
3. The results of the work carried out so far have also highlighted once again the significant volume of subjectivity and ambiguity inherent in the risk assessment process in terms of the main contributory attributes as well as associated elements and values. This finding reinforces the need for a more harmonised model based on best practice.
4. The reasoning process and the logic used can be documented, augmented, and shared. The quantitative methods adopted may be more easily defended in governmental committees, external parties, and the law.
5. All decisions, including complex ones, become easier to explain and justify at each stage of the decision process, either at the time of the event or some other time in the future when the main characteristics of the event will have been long forgotten.
6. The benefits brought in by the consistent approach will help standardise the approach and practice of risk assessment, will enable a more harmonised comparison between events, and facilitate the use of the methodology in other areas.
7. New lessons and data can be readily incorporated into the model as they become available, and the associated knowledge or the protocol of rules reflecting the organisation policy on risk assessment can mature and improve with time.

References

1. Advisory Committee on Dangerous Pathogens. Microbiological risk assessment: An interim report. London HMSO 1996.
2. Lammerding A. M. Paoli G. M. Quantitative risk assessment: an emerging tool for emerging foodborne pathogens. Emerging Infectious Diseases, Vol. 3, No.4, 1997.

3. Barnard R C. What is going on in Risk Assessment. Regulatory Toxicology and Pharmacology, 22, 295-299,1995.

4. Kamrin M. A. Environmental risk harmonisation: Federal/State approaches to risk assessment and management. Regulatory Toxicology and Pharmacology, 25, 158-165, 1997.

5. Exner M. Risk assessment and risk prevention in infectious diseases. WillZentra oflbl Hyg. Umweltmed 1996 Dec; 199 (2-4): 188-226.

6. Lynn F. M. Public Participation in Risk Management Decisions: The Right to Define, the Right to Know, and the Right to Act. Risk Analysis, Vol.1, No.11, 1995.

7. Passchier W. F. & Reij W. C., Risk is More Than Just a Number. Risk Analysis, Vol.8, No.107, 1997.

8. Paustenbach D. J. Retrospective on U.S. Health Risk Assessment: How Others Can Benefit. Risk Analysis, Vol.6, No.283, 1995.

9. PHLS Meningococcal Infections Working Group and Public Health Medicine Environmental Group. Control of menigoccal disease: guidance for Consultants in communicable disease control. Communicable Disease Review. Vol.5, No.13, December 1995.

10. Kaczmarski E. B. and Cartwright K. A. V. Control of meningoccal disease. Guidance for microbiologists. Communicable Disease Report. Vol.5, No.5, R196-8, 1995.

11. Nadel S., Levin M. and Habibi P. Treatment of meningoccal disease in childhood. In: Cartwright K., editor. Meningoccal disease. Chichester: John Wiley, 207-43, 1995.

12. Stuart J. M., Monk P. N., Lewis D. A., Constantine C., Kaczmarski E. B. and Cartwright K. A. V. Management of clusters of meningoccal disease. Communicable Disease Control Report. Vol.7, No.1, 1997.

13. CDSC. Meningoccal disease in England and Wales. Communicable Disease Report. Vol.6, No.17, 1996.

14. The Department of Health. Control of communicable disease notes for guidance on the conduct of reviews of regional arrangements. 1989.

15. The Department of Health. Review of law on communicable disease control. 1989.

16. Pearson N, Gunnell D. J, Dunn C., Beswick T., Hill A. and Ley B. Antibiotic prophylaxis for bacterial meningitis: overuse and uncertain efficiency. Journal of Publich Health medicine 17 (4): 455 -8, 1995.

17. Guidelines for Preventing the Transmission of Tuberculosis in Canadian Health Care Facilities and Other Institutional Settings. Canada Communicable Disease Report. Supplement - April 1996 Vol. 22.

18. Williams D. N., Craig W. A., Kind A. C., Bradley J. C. Tice A. D. Hehm S. J. Practice guidelines for community based parental anti-infectivetherapy. Clinical Infectious Diseases 1997 Oct; 25 (4): 787 - 801.

19. Kouba v. Computerized methods for animal health risk assessment using the EPIZOO program. Rev. Sci. Tech, 16 (3): 793-799, 1997.

20. Boritz J. E. Consultants Limited. 1993. Toronto. Canada. auditMASTERPLAN®, Risk Alert:The Business Condition Analyst™.

21. Demery P. Why risk managers expect more. Credit card management, 34-35 (ISSN: 08969329). New York, May 1998.

22. Vertzberger Y. I. Making and taking risky decisions. Cooperation and Conflict, 33:1, 5-34, 1998.

23. Rodricks J. V. & Rieth S. H. Toxicological risk assessment in the Courtroom: Are available methodologies suitable for evaluating toxic tort and product liability claims?. Regulatory Toxicology and Pharmacology. 27, 21-31, 1998.

24. Jablonowski M. Automating the risk assessment process. Society of chartered property and Casualty Underwriters Journal. Vol. 51 (2), 101-105, 1998.

25. Friedman S. M. The Media, Risk Assessment and Numbers: They Don't Add Up. Risk Analysis, Vol.5, No.203, 1994.

26. Singer E & Endreny P. M. Reporting on Risk: How the Mass Media Portray Accidents, Diseases, Disasters and Other Hazards. Risk Analysis, Vol.5, No.26, 1994.

27. C.Kara-Zaitri, A. Z. Keller, P. V. Fleming. A smart Failure Modes and Effects Analysis package. IEEE Proc. Reliability and Maintainability, pp 414-421, 1992.

28. C. Kara-Zaitri. Advanced FMEA modelling. 4th International Congress of Industrial Engineering. Marseille, France, December 1993.