A Fuzzy Logic Approach to evaluate Health Care Liability and Risk of Medical Malpractice

BORDONI STEFANO
Dep. of Political Economics - Faculty of Economics
University of Modena and Reggio Emilia
via Berengario, 51 – 41100 Modena
ITALY

Abstract:- One of the main problem that all the Healthcare systems have been called to handle in the last decades is how transposing to health structures the rules and concepts that usually supervise the productive system and companies, such as the typical form of control and responsibility.

Despite the efforts in terms of standardization and control of health care activity, what Health structures and Insurance Companies still look to miss is a well and commonly defined concept of risk in a medical environment, probably due to the presence of quantitative as well qualitative significant aspects.

What follows is a bad modelling of the complex nature of the problem, unable to provide meaningful results to describe health outcome and medical practice riskness by the usage of simple score cards dealing with the quantitative aspects only.

The aim of this paper is providing an original alternative solution based on a fuzzy inference system to better define and study the imprecise nature who links qualitative and quantitative variables of the subject, in order to evaluate and rank the risk of error connected to health practice (Malpractice).

The same technology, here implemented to evaluate a risk index concerning organisational and activity figures of a single ward of an hospital, could probably find useful application if extended to the whole health structure or to monitor in progress the riskness of the single treatment procedure, through the combined analysis of structural data and clinical figures of the patient.

Keywords: fuzzy expert system, healthcare liability, medical malpractice

1. Malpractice

In a very general definition we can say that Malpractice concerns all the diagnostic, therapeutic and organizational errors done by physician to their patients.

The error in health involves serious and sometimes irreversible damages to the patients and correspond to a third part of the all general expenditure of Italian Healthcare system.

Despite that, medical errors often lie undeclared and hidden, because of fear or fraud, under the risk that none of the actors involved can teach from what happened.

The study of Malpractice aim to discern, suggest, implement and keep under control procedures, guidelines, managerial models and activities to reduce to as little as possible the unavoidable error.

The most part of patients' complaints do not depend from the gravity of the damage, but rather from the misbehaviour of physicians (lack of attention, care and responsibility). In the last years citizens showed an increasing sensibility and attention to Malpractice, due to the raising scientific and technological progress, the introduction of the DRG lines, an higher level of information and a growing will to make their own rights to be respected in order to obtain an unexceptionable service.

In order to avoid and/or to limit the cases of Malpractice, many authors stressed the importance to identify as first the quality and risk factors of health outcome to make possible a reporting activity of adverse clinical incidents as well as the near misses cases, but the lack of a clear definition of the medical error and the shortage and inconsistency of data has seriously complicated any attempts to study Malpractice and gather data on this subject.

The clear definition of consistent indicators makes possible to collect data in an adverse events database, which can be used to assist event recognition, monitor reporting and sentinel events

or deviations from protocols, so to reduce potential errors at every stage of development of the system.
Though a worldwide effort, there is no clear evidence at the moment from existing systems of what data to collect or whether reporting and score cards programmes are effective in reducing errors.
The only available data and statistics, like the ones used in this paper as risk benchmark of the single medical specialization, often come from ex post analysis, showed the reported cases only and for this reason are scarcely legitimate to be representative of the real size of the problem.
The lack of data and quantitative models able to evaluate consistent risk indicators of adverse events has also obvious implications in terms of pricing models and insurance policies of Insurance Companies. On one side the rising of claims against physicians and hospitals determined sensible raise of insurance premium who provoked strikes of the physicians, withdrawals from the profession or anticipates retirements. On the other, the difficulties to calculate and apply a correct politics of pricing, drove Insurance companies to strong losses or the renunciation of the premium.

2. The fuzzy Malpractice risk index

The quantitative models who deal with health liability and health malpractice suffer the lack of a global overview to study the problem. There is no general acceptance on which indicator affect the risk of medical practice and a consequent difficulty to collect consistent data.
What existing model usually do is trying to evaluate the few main quantitative variables with simple score card system or other traditional approach, often ignoring the qualitative aspects of health practice.
This paper proposes a new evaluation model which uses fuzzy set theory to calculate a risk index of a single hospital ward, through the analysis of its technical and organizational aspects.
This model has been developed using a Fuzzy Logic approach, as a natural environment to consider the partial membership to vague classes and to better manage the complexity of imprecise relations of dependency between the quantitative and qualitative variables, with no need to a precise formulation of the mathematical relation who link the variables.
A fuzzy expert system allows to implement this set of relations with a set of fuzzy rules, to supply the lack of a mathematical formulation of the problem.
This kind of index can be properly used by:

- Health structures (to check their aptitude to provide interventions in an effective and efficient context, with the aim to understand in which step of the distribution process errors or obstacles can rise that can then carry a damage to the patient)
- Insurance Companies (a risk index of an healthcare structure can be used like reference index for a correct pricing policy)

Extending the approach, the ward risk model can be used in order to analyze:

- A whole hospital structure in its complex (macrostructure)
- One single therapeutic activity (microstructure)

2.1 Fuzzy Inference System basics

Any Fuzzy Inference System is based on the concept of Fuzzy set, related to a membership function defined as

$$A = \{(x, m_A(x)) : x \in A, m_A(x) \in [0,1]\}$$

who determine the degree of membership to A of the generic input value x_i.
Any inference system include usually two or more input and one output variables. For each input variable x_i (i=1…m) and output variable y we define their fuzzy values by some linguistic terms:

$$A^i = \{A^i_1, A^i_2, .., A^i_{j_i}, .., A^i_{n_i}\},$$

$$B = \{B_1, B_2, ..., B_k, ..., B_r\}$$

where $A^i_{j_i}$, $j_i \in [1, n_i]$, $n_i \in [1, \hat{n}]$ and

$B_k, \forall k = 1..r$ are fuzzy numbers:

$$A^i_{j_i} = \left\{(x, m_{A^i_j}) : x \in X, m_{A^i_j} : X \to [0,1]\right\}, \text{ and}$$

$$B_k = \left\{(y, m_{B_k}) : y \in Y, m_{B_k} : Y \to [0,1]\right\}.$$

The relation between the fuzzy numbers of A^i and B express the fuzzy, imprecise relation who links inputs and output of the problem.
The number and the shape of the fuzzy numbers as well as the sets of rules implemented in the model by the experts determine the end result of the inference process and replace the mathematical formulation of the problem.

In a general form we define the set fuzzy rules as

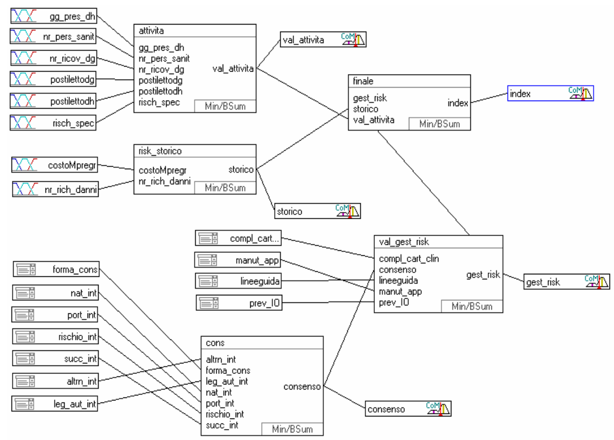
IF (x_1 is $A^1_{j_1}$) $\otimes$ (x_2 is $A^2_{j_2}$) $\otimes \ldots \otimes$ (x_m is $A^m_{j_m}$) (1)

THEN (y is B_k), (2)

The relation (1) is called "precondition", the relation (2) is called "aggregation" and the symbol $\otimes$ represents one of the possible aggregation operators, where the MIN and the MAX operators are usually preferred for these kind of applications.
The IF (1) part can consist of more than one precondition linked together by linguistic conjunctions like AND and OR.
The THEN (2) part computes the condition (the left side) of each rule. This intermediate result is used in the next step of rule composition computation who determine the result aggregation.
If more than one fuzzy rule fires the same term, the result aggregation defines how to compute the final result over all rules for this term. We can choose between a MAX operator which uses the maximum firing degree of all rules matching the term or BSUM who sum in the evaluation process all firing degrees within a bound of 1.0.
The BSUM method, used in this model, involves any element of decisional logic (any rule) to provide the calculation of the final result.
The result of fuzzy rule inference is, of course, fuzzy. Membership functions are used to retranslate the fuzzy output into a crisp value.
This retranslation is known as defuzzification and can be performed using several methods.
The Center of Maximum (CoM) defuzzification method is here used as compromise between different results of valid output term. and computes a crisp output as a weighted mean of the term membership maxima, weighted by the inference results.
In brief, these are the operators of the model:

Input Variables	19
Output Variables	5
Rule Blocks	5
Rules	51
Membership Functions	72
Aggregation:	MINMAX
Result Aggregation:	BSUM

2.2 Logic of the model. I/O variables



Var. Name	Var. meaning	Type
Gg_pres_dh	Day of presence as day hospital	Quantitative
Nr_pers_sanit	Total number of medical personell	Quantitative
Nr_ricov_dg	Total number of admission in hospital	Quantitative
Postilettodg	Total number of beds	Quantitative
Postilettodh	Total number of beds as day hospital	Quantitative
Risch_spec	Risk of medical specialization	Quantitative
Costompregr	Average cost of earlier cases of malpractice	Quantitative
Nr_rich_danni	Number of cases in the past 5 years	Quantitative
Forma_cons	Nature of consent	Qualitative
Nat_int	Nature of the intervention	Qualitative
Port_int	Location of the intervention	Qualitative
Rischio_int	Risk of the intervention	Qualitative
Altrn_int	Possible alternative solution to the intervention	Qualitative
Leg_aut_int	Legitimacy of the approval	Qualitative
Compl_cart_clin	Completeness of the case sheet	Qualitative

Var. Name	Var. meaning	Type
Lineeguida	Presence of guidelines	Qualitative
Manut_app	Hardware maintenance	Qualitative
Prev_IO	Prevention of hospital infections	Qualitative
Succ_int	Probability of success	Qualitative

As shown in the inputs list, only 8 variables are quantitative, while the residual 11 try to include the linguistic expression who represent the qualitative aspects of the ward activity.
Differently from traditional score card method, this model return the joint evaluation of both different sets of variables.
The 19 indicators used as input variables are grouped in 4 different sets, in relation to their membership to specific features or activities of the ward. The decision logic applied to any group of inputs provides an (intermediate) output variable to appraise that specific area of activity. The joint analysis of the 4 intermediate output computes a global risk index.

- Attività del reparto (Ward activity)
- Rischiosità pregressa (Historical risk)
- Politica di gestione del rischio (Politics of risk management)
- Trattamento del consenso informato (Treatment of the informed consent)

3 Results and comments

This model tries, as first, to identify all the key variables who determine the quality of the medical performance in a ward activity. Then means to resolve the limits of score cards and other traditional quantitative models to study and evaluate a problem affected by variables of different nature.
At last, it aims to provide the health structure a tool to evaluate ex ante the quality of its activity in order to prevent errors and damages to patients.
The model has been tested using the wards data gently provided by Hospital "C. Poma "of Mantova, and referring to year 2001.
The data supplied by the hospital of Mantova deal with the 5 main input variables only (concerning structural-organizational aspects) on 19 requested by the model in order to obtain consistent results.

To properly test the model, we considered the average results coming from several simulations based on sensitivity analysis of lacking input data.
The model results have been compared with the figures declared by the Tribunale per i Diritti del Malato (TDM) on national scale to stress possible divergences of efficiency from the national statistics (Tab. 1). Actually, the TDM ward risk index is included as one of the input variables of the fuzzy model and corrected from the combined appraisal of the residual 18 variable. Any difference shows the impact of the added qualitative and quantitative real aspects of that specific ward and provides a more complete and coherent result of the real riskness of the unit.

Tab. 1 (Comparison with data coming from Tribunale per i Diritti del Malato)

Reparto (anno 2001)	Tribunale del malato	FLC Index
Ortopedia e traumatologia	16,5%	11,78%
Oncologia	13,0%	13,89%
Ostetricia e ginecologia	10,8%	9,57%
Chirurgia generale	10,6%	10,15%
Odontoiatria	6,5%	3,05%
Oculistica	6,4%	3,07%
Malattie del s. Circolatorio	5,0%	5,09%
Chirurgia cardiovascolare	4,6%	5,73%
Neurologia	4,2%	4,94%
Otorinolaringoiatria	3,5%	4,94%
Medicina generale	3,4%	4,98%
Urologia	3,0%	5,65%

This difference between the national benchmark and the results of the model for any single medical area is the main result of our analysis and accomplish the purpose to provide health structure an instrument to evaluate their specific situation against the national ex post figures.

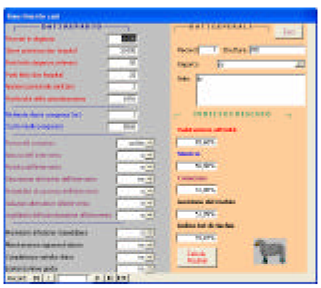
4. Conclusione and remarks.

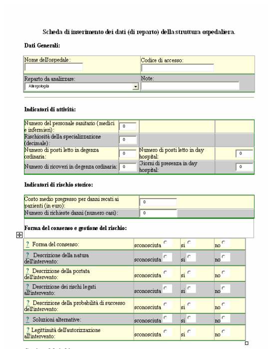
Though not affecting the utility of the model, the results obtained through the analysis of the Hospital of Mantova data are scarcely meaningful, because of:

- Lack of input data (missing and/or confidential)

- Lack of a feedback comment by the human experts of the hospital to validate the model results
- Lack of real data on malpractice cases effectively happened in the considered period

The lack of so many input and output values, as well as many important information from the hospital, made impossible to optimize the model with manual or artificial neural nets techniques.
In order to support the development and the optimization of the model through the collection of complete set of data from interested users, a local as well as a remote application have been implemented and currently available on the Web.





To test the decision logic through the web application, see:
http://informatica.economia.unimo.it/reparto/repartoinsdativbs.asp

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