Systems Theory Application to Risk Management in Environmental and Human Health Areas

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Many of the epistemological and methodological issues confronting risk assessment have been explored in the general systems theory, however, the use of systems theory and systems analysis tools is still not widespread in the risk management area. Therefore, in this study, the author proposes the application of the original two-stage multidisciplinary qualitative-comparative analysis and systems theory methods for the holistic assessment and management of risk in environmental and health issues.

INTRODUCTION

Risk assessment provides a systematic approach for characterising the nature and magnitude of the risks associated with environmental and health hazards, while risk management can be defined as implementing risk controls. All activities, processes and products of human activities have some degree of risk. The ultimate aim of risk assessment and management is to provide the best possible scientific, social, and practical information about the risks, so that the best decisions are made as to how to control them.

To manage something, however, one first needs to measure it. There is an old management axiom: You cannot manage what you do not measure. Yet many organizations and/or countries do a not very good job (or no job at all) of measuring the risk and therefore control of environment factors on human health. Traditional approaches tend to simplify the situation in order to isolate the main variables. In doing so, they lose many of the important interactions between variables that play a significant role in risk minimization efforts. By employing a consistent, repeatable, comprehensive methodology that measures projected risk value as well as the actual risk of countries, however, can signifcantly improve both the assessment and management of environmental and health risk in the complex world of developing nations. In this study, the author proposes the application of the original two-stage multidimensional Qualitative-Comparative Analysis (QCA) and Systems Theory Methods (STM) to better understand and manage risk in the developing country context.

- The first complementary method is Qualitative-Comparative Analysis (QCA) and its formal language, Boolean algebra, which can be used to develop the risk factors, followed by
- System Theory Methods (STM), which have the capacity to evaluate the complex and dynamic interactions between factors (found in the first QCA stage) within the organisation/society, users, and external environment contexts.

Environmental and human health in this context is understood as a complex adaptive system (CAS). A complex adaptive system is a collection of individual agents with freedom to act in ways that are not always totally predictable and whose actions are interconnected. Central to a complex adaptive system is the notion that groups of living beings or organizations, whether they are businesses or soccer clubs, can be described as complex adaptive systems.

To better understand the concept of complex adaptive systems, one can find the following evolutionary brief useful. The first transformation of this scientific revolution emerged in the early 1900's, when German physicist M. Planck noticed significant flaw in Newtonian physics by demonstrating that "*the electron in orbit around the nucleus accelerates. Acceleration means a changing electric field (the electron has charge), when means photons should be emitted. But, then the electron would lose energy and fall into the nucleus. Therefore, atoms shouldn't exist*!" This discovery was a turning point in the contemporary science which Einstein s described it as science (in Newtonian sense of word) losing its foothold. In fact, traditional physics has had no explanation for the atom's behaviour at the sub-atomic level. To resolve this problem, Planck made a wild assumption that energy, at the sub-atomic level, can only be transferred in small units, called quanta. The quantisation, or 'jumpiness' of action as depicted in quantum physics differs sharply from classical physics, which represented motion as smooth, continuous change (Skoko, 2006, p.9). In exploring the subatomic world, scientists discovered: matter is not the hard mass that operates from the principles of gravity and Newtonian physics. Indeed, at the subatomic level, matter can take varying forms, either waves or particles or both at the same time. And what determines whether an electron is a wave or a particle depends upon the electron's relationship with other subatomic particles (Capra 1982). Quantum theory determined that particles can only be understood in terms of their movements and the resulting dynamics that occur as molecules interact.

That astonishing far-reaching development of quanta physics was one of the most exciting periods in the human scientific history. It has had a great influence not only on scientific inquiry but also in all others areas of human exploration – art, architecture, music, philosophy, medicine, socio-economic development, etc. of the 20th century. These discoveries set the foundations for the development of kibernetics and complex system theory, as well.

One of the major contributors to complexity science was a seminal work of physicist, Ilya Prigogine, who identified that the second law of thermodynamics of inexorable decay and random disorder (Holden, 2005). Prigogine and others in the 1960s identified that in the real world atoms and molecules are almost never left to themselves; if enough energy flows from the outside, the tendency to degrade is partially reversed, and indeed, a new pattern of complex structures will spontaneously organize (Waldrop 1992, Capra 1996). Prigogine drew on the work of French physicist Henri Benard who discovered that heating a thin layer of liquid resulted in an organization of new structures. (Capra 1996). This process of increasing heat was described as moving the system far from equilibrium, meaning far from uniform temperature throughout the liquid, and into a '*critical point of instability, at which the ordered hexagonal pattern emerges*' (Capra 1996, p. 87). This process of self-organizing is not limited to laboratory experiments. Building on Prigogine's work on non-equilibrium thermodynamics and the principle of self-organization, other scientists have noted a particular characteristic of self organization (Holden, 2005). Cilliers (1998), philosopher and research engineer in computer modelling, explained self-organization from the biological perspective. He noted that a system not only must receive, process, and retain information; it also must respond and produce some form of output as well. This process can result in a form of internal structure that is the result of complex interactions between the environment and the system's history and present state.

The final scientific layer that provided the foundation of complexity science involved that of non-linear relationships and actions. In 1963, Edward Lorenz, meteorologist at the Massachusetts Institute of Technology, identified the impact of changing only a few decimals in weather modelling on the overall result. Lorenz ran his computer model of weather in the middle rather than at the beginning, and he used six decimals instead of three. These seemingly small changes had a large effect on the results and laid the groundwork for the mapping of chaos mathematically (Holden, 2005). The discovery was characterized as the fact that small changes in the initial characteristics of an active system can dramatically affect the long-term behaviour of that system. This is often referred to as the 'butterfly effect'. (Haigh, 2002).

This concept of non-linear relationships has been a large component of the application of this emerging science of complexity in economics, biology, meteorology, etc. However, although mathematical descriptions of non-linear relationships are quite valuable, they do not capture the structure and organization that is characteristic of complexity science in general and complex adaptive systems in particular. That was the rationale behind our proposal to apply the QCA and STM methodology to the particular case of environmental and human health in developing countries.

The attributes of a complex adaptive system are further elucidated by Cilliers (1998, p. 3–5) to include the following:

- A large number of elements interact in a dynamic way with large exchanges of information.
- These interactions are rich, non-linear, and have a limited range because there is no over-arching framework that controls the flow of information.
- Complex systems are open systems with feedback loops, both enhancing, stimulating (positive) or detracting, inhibiting (negative). Both kinds are necessary.
- Complex adaptive systems operate under conditions far from equilibrium, which means there is continual change and response to the constant flow of energy into the system. 'Equilibrium is another word for death' (p. 4).
- Complex systems are embedded in the context of their own histories, and no single element or agent can know, comprehend, or predict actions and effects that are operating within the system as a whole.
- Complexity in the system is as a result of the patterns of interaction between the elements.

Based on the above, the author build a complex adaptive model - a general risk factors model, with empirical validity and relevance for the environmental and human health risk management being tested by the Systems Theory Methods.

In the model I recognise that human participants are an integral part of the system having no 'system's value attributes' per se, but only through their interaction with other factors. Therefore, many aspects of risk need to be assessed not just as isolated factors but also as a nexus of interaction with other parts of the system and the society itself to fully understand how they influence individual risk factors and the complex system as a whole. Thus, this research method and applying a holistic/systemic approach (STM) on a case study, would enable practitioners to comprehensively answer the following questions:

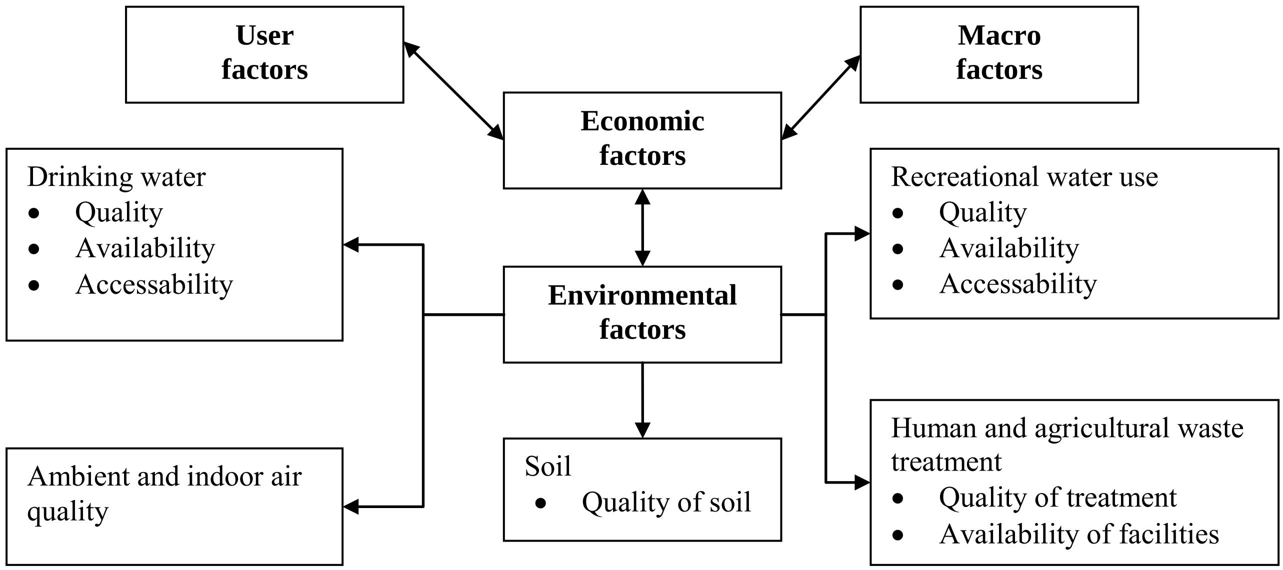
- How do the interactions between risk factors impact environmental and human health, and
- What are the outcomes of a particular system created by these interactions?

CONCEPTUAL FRAMEWORK

The most recent literature examining risk assessment and control factors forms the basis for the conceptual component of this study (see Figure 1).

Environmental and human health can be impacted on three different levels: individualistic or user/participant level, macro level and environmental level. In addition, the economic context is of great importance in facilitating macro decision regarding which management strategy to adopt, and how to implement it. Therefore, influencing risk factors examined across a range of contexts suggested by the literature can be organised within four contexts: Environmental (Drinking Water, Soil, Recreational Water, Human and Agricultural Waste Treatment, Ambient and Indor Air Quality), Users, Macro and Economic context.

FIGURE 1
FACTORS AND CONTEXTS OF ENVIRONMENTAL AND HUMAN HEALTH



Using this model as a departure point, I extend the investigation process of finding the risk factors to exploring interactions among them and their causal outcomes. That means that the risk factors must be evaluated and considered as a dynamic part of a complex system, which can be characterised as non-linear, co-evolving, self-organising and which is on the edge of chaos. That is, considering environmental and human health, as a complex adaptive system requires mixed, multidimensional, multi-stakeholder, explicitly value-based assessment approaches which are provided by the QCA and STM. Environmental and human health depends on many factors and their effects are different for every society, since the system is socially constructed. As a result, the system (environmental and human health) needs to be taken into account together with its interactions with people, organization/society and processes. Hence, many authors argue that the only way to consider its effects is to use systemic approach. Following this lead, I employ the QCA first, then systemic approach with their tools as outlined in the following sections.

QUALITATIVE COMPARATIVE ANALYSIS (QCA)

This section (based on Krivokapic-Skoko, 2002 and 2003) outlines the basic features of the Qualitative Comparative Analysis (QCA) and its formal language - Boolean algebra. The purpose is to present the epistemological and technical features of the method.

The Qualitative Comparative Analysis (QCA) is a relatively new method for providing causal explanations in social science. It is essentially case-oriented comparative research that provides a systematic, holistic analysis of a moderate number of cases. The method is designed to draw causal inferences from comparing configurations of the selected causal variables across cases included in an analysis. QCA holistically compares these configurations to discover necessary and sufficient conditions for the emergence of an outcome. In terms of technical procedure, QCA systematises and transforms empirical evidence into algebraic forms, and then uses Boolean algebra to do comparisons. Moreover, QCA is based on an epistemology that allows for evaluating theoretical propositions, particularly contextual, or combinatorial causal arguments.

Charles Ragin introduced the QCA in 1987 as a bridge between qualitative and quantitative research strategies in comparative research in social science. Typically, qualitative research methods discuss many features of a relatively small number of cases. Quantitative methods on the other hand analyse the variations of small numbers of features across many cases. While qualitative methods see cases as complex configurations of elements and structures, quantitative methods examine relationships among variables and patterns of variation across cases, rather than how different features fit together within a particular case. Ragin argued that features of both strategies could be combined in a complementary way. Introduced by Ragin as a synthetic strategy, QCA combined some of the features of the case-oriented modes of research that are typically intensive, holistic and deterministic, and some features of the variable-oriented, extensive and probabilistic research strategy in comparative social science.

In the view of Ragin (1987) and other authors who applied QCA (Hicks, 1994; Biggert, 1997; Coverdill et al., 1994, Krivokapic-Skoko, 2002 and 2003), this method complements qualitative and quantitative analyses by providing a more complex approach than most quantitative research methods, and by being more systematic than most qualitative research methods. QCA also brings additional rigour and a variable concept of quantitative methods to qualitative ones, and also some of the causal complexity and in-depth analysis of qualitative to quantitative research methods.

QCA systematises empirical evidence are usually gathered from intensive case studies. This systematisation is based on data reduction logic rooted in Boolean algebra, the algebra of logic and sets. Based on Boolean algebra, QCA measures and transforms both independent and dependent variables into dichotomous forms. QCA uses what social scientists would call presence-absence dichotomies. This means that causal conditions and outcomes are either present or absent in each case.

Configurations of selected causal conditions or independent variables are first presented as nominal data with a yes/no or presence/absent dichotomy, and then holistically compared by using Boolean procedures. Put simply, these procedures involve comparing groups of cases based on the presence or absence of an outcome and the presence or absence of theoretically or empirically derived causal factors. In comparing the cases, the point is to identify the similarities among the cases with the same outcome and differences between cases conforming to different outcomes.

QCA appears to be of a substantial utility in research sites with contextual and multiple causal relations. The method assumes that causal variables are effective only when operating in conjunction with each other, and consequently the impact of each causal variable should be discussed only in a particular context. QCA also accepts that more than one configuration of causal variables may generate the same outcome. Accordingly, QCA locates different paths to the emergence of an outcome and therefore enables the analyst to classify the outcomes based on different configurations of the causal variables. Apart from deriving the patterns of causal factors leading towards the emergence of outcomes, QCA also identifies the causal conditions related to the ‘negative outcomes’, thus to the absence of the phenomena of interest.

In conclusion, QCA may be summarised in the following key points.

QCA:

1. Is a comparative analysis with an explicit goal to explain
2. Is a case-oriented approach
3. Focuses on the cases as wholes
4. Examines cases as the configuration of selected causal/independent variables and outcomes/ dependent variables
5. Works with the presence/absence dichotomy, and presents it in the algebra forms of presence (1) and absence (0)
6. Considers both causes (independent variables) and outcomes (dependent variables) as qualitative phenomena, such as the presence or absence of events, processes or structures
7. Focuses on the combination and the interaction amongst the various factors as responsible for the emergence of outcome
8. Assumes that different combinations of causes may produce a single outcome

9. Explains both positive and negative outcomes and considers them equally important for causal analysis
10. Employs a concept of necessary and sufficient causal conditions
11. Offers deterministic, not probabilistic explanations for the emergence of an outcome.

There are certain steps and analytic tools in using QCA. The analytic tools in carrying out QCA are: truth tables, primitive equations, prime implicants, and logically minimal Boolean functions.

The actual implementation of the method starts from selecting causal variables. The method requires considerable care in deciding on the number of causal variables to be included and how to choose those variables. Selecting causal variables is followed by the operationalisation of the outcome using the existing theoretical perspectives and empirical literature on the topic. As Boolean algebra operates only with dichotomous measures an analyst has to specify all causal variables and the outcomes using a presence/absence dichotomy. What is needed in this data reduction phase of the method implementation are very clear criteria in the categorisation of variables. Furthermore, the coding system and the procedure should be outlined before the data gathering process actually starts.

After selecting causal and outcome variables and deciding upon coding procedure, the analyst starts with building a truth table. A truth table is a raw data matrix, which comprises causal conditions and outcomes across a number of cases. Each row in a truth table represents either a logical or a real combination of values of causal variables. Each row of a truth table also sets an output value on the dependent variable. The truth table is completed when all the cases and codes on the causal and outcome conditions are displayed using binary mathematical forms.

This matrix of binary data (presence/absence dichotomies) is then subjected to a procedure of Boolean minimisation. The procedure involves comparing groups of the cases based on the presence/absence of the outcome conditions and the presence/absence of the selected causal conditions. These combinations are compared with each other and then logically simplified through a bottom-up process of paired combinations. In carrying out a bottom-up comparison, through two steps of minimisation, the comparison ends up with a logically minimal Boolean expression as an output of the analysis. This provides logically minimal configurations which account for the emergence of particular outcomes.

QCA provides additional features for carrying out causal analyses. As the logically minimal Boolean expression may locate different paths to the emergence of an outcome, it becomes possible to do a classification of the outcomes based on different configurations of the causes. Accordingly, the analyst may carry out a further interpretation using a more detailed account of the phenomenon in question. Furthermore, by factoring Boolean equations it is possible to interpret results in terms of necessary and sufficient causal conditions. One aspect of the method's utility is the possibility of writing down final equations with a negative outcome that can help in explaining the conditions accounting for failure of a particular event.

There are some specific issues and additional steps in using QCA to evaluate theoretical arguments. These are outlined below.

In evaluating theoretical arguments, QCA maps the areas of agreement and disagreement between the theoretical propositions (T) and the results of minimisation of the truth table (R). In assessing theories by using QCA it is not appropriate to make a strict parallel with the classical approach in testing hypotheses. QCA does not, as a rule, reject theories in the same way that classical statistical analysis does. Typically, the end result of QCA is a statement of the explanatory limits of the causal variables identified with different theories, not their mechanical rejection or acceptance.

In introducing QCA, Ragin (1987, Chapter 7) outlined how theoretical arguments about causal combinations may be incorporated into QCA and also showed the compatibility of the method with the goals of theory testing. Ragin also illustrated how to evaluate theoretical models/arguments by calculating the intersection between the final Boolean equation (R) and the hypotheses formulated in Boolean terms (T). By calculating these intersections it is possible to derive three subsets of causal combinations: both hypothesised and empirically confirmed, hypothesised but not detected within the empirical evidence, and finally causal configurations empirically found but not hypothesised. Ragin also argued that this third intersection of theoretical explanations and empirical evidence would demonstrate shortcomings of a theory/model.

Thus, the steps in using QCA for evaluating theoretical arguments are:

Step 1: To express theoretical arguments in Boolean terms and to write down Boolean equations that explain the concept of the proposed composite/combinatorial models;
Step 2: To select and define causal conditions and outcome variables;
Step 3: To decide upon coding systems to transform both outcomes and causal conditions into the presence-absence dichotomy;
Step 4: To systematise empirical evidence and to construct the 'real' truth table;
Step 5: To address the problem of contradictions (if appropriate), and then to check if there are too many cases with the same causal configurations and different outcomes;
Step 6: To address diversity of causal combinations (if appropriate) and to decide on how to treat non-existent combinations of causal conditions;
Step 7: To write down primitive equations emerging from every row of the truth table and accordingly the 'sums of the products';
Step 8: To carry out the process of Boolean minimisation, and to write down prime implicants and a prime implicants chart (if appropriate) showing the convergence of primitive equations towards the final minimal equation;
Step 9: To calculate the Boolean intersections (if appropriate) between the function representing theoretical expectations and the functions derived from the truth table;
Step 10: To derive three types of causal combinations (both hypothesised and found in empirical evidence; hypothesised but not found in empirical evidence; found in empirical evidence but not hypothesised) and to outline possible shortcomings of the proposed model.

Having sketched the steps in using QCA, the next section provides a short review of the Boolean Algebra and the QCA formal language.

Ragin (1987, 1994a) identified ten aspects of Boolean logic that are essential to use in social science. These are as follows.

1. Use of binary data

   There are two conditions or states in Boolean logic, and these are generally referred as 1 indicating presence, and 0 indicating absence. Thus, in Boolean logic all variables, independent and dependent, are dichotomous forms and hence presented by nominal-scale measurements. There is also the convention that upper-case letters indicate the presence of a condition and lower-case letters indicate the absence of condition.

2. Boolean addition

   In Boolean logic addition is equivalent to the logical operation 'or'.

3. Boolean multiplication

   In Boolean logic multiplication is equivalent to the logical operator 'and' , where a product is a specific combination of causal conditions. For instance, Boolean expression Abc => Y means that the presence of variable A, combined with the absence of variable B and the absence of variable C produces the presence of the outcome Y.

4. Use of truth table to represent data

   A truth table is a data matrix where each row represents a logical combination of values on causal conditions and outcomes. Each row gets an output value of either 1 or 0. In Boolean logic a number of causal conditions determine the number of combinations of causal condition that are logically possible. Accordingly, the number of the rows in the truth tables is an exponential function of a number of independent variables (2n).

Table 1 is a representative truth table with three independent variables (n =3, 8 rows in the truth table). Each case is described as a joint influence of independent variables (A, B, C) with the logical operator ‘and’ marked as ‘x’ to produce the outcome variable Y. Again, upper-case letters indicate the presence of a causal condition of outcome, and lower-case letters indicate the absence of a causal condition or outcome. The table includes all logically possible combinations of causal factors, which may or may not occur in reality.

TABLE 1
REPRESENTATIVE TRUTH TABLE

Row No. (type of cases)	No. of Cases	Variables Independent/Causal		Dependent/Outcome
1	3	A x B x C	=	Y
2	3	A x B x c	=	Y
3	2	a x B x C	=	Y
4	1	a x b x C	=	Y
5	6	A x b x C	=	y
6	8	A x b x c	=	y
7	3	a x B x c	=	y
8	4	a x b x c	=	y

5. Combinatorial logic
   Boolean logic gives the same status to the absence and the presence of causal conditions/variables. Thus, the absence of a cause has the same logical status as the presence of a cause. Moreover, a cause is not viewed in isolation but always within the contexts of the presence/ absence of other causal factors.
6. Boolean minimisation
   The rule of Boolean minimisation is: if two Boolean primitive expressions, i.e. one of the lines in the truth table differ only in one causal condition, yet produce the same outcome, we can remove the condition that is different, accepting it as irrelevant. This minimisation is based on two subsequent procedures. First, all rows of a truth table having the same value of X for the dependent variable are combined into one equation but joined with the logical operator ‘or’ as marked with ‘+’ . Correspondingly, the first four original configurations, or primitive equations as taken from a representative truth table (Table A2.1), may be simplified using Boolean minimisation as:

Original causal configurations: A x B x c + A x B x C + a x B x C + a x b x C => Y

Minimised causal configurations: A x B + B x C + a x C => Y

Minimised causal configurations are also referred to as prime implicants, which is the last line illustrated above, and the second minimisation procedure involves a construction of prime implicant chart map.

7. The use of ‘prime implicants’
   Boolean logic uses prime implicant chart map as a link between primitive, original equations, and prime implicants as obtained after the first phase of minimisation. The point is to write down a chart showing convergence of primitive equations towards the final minimal equation.

TABLE 2
PRIME IMPLICANTS

Primitive Expressions /Original Configurations

Prime Implicants/ Minimised Configurations	Abc	ABC	aBC	abC
AB	x	x		
BC	x		x	
aC			x	x

Thus, in two causal configuration - AB and aC, prime implicants cover all four original configurations, and the logically minimal Boolean equation is AB + a C => Y.

A prime implicant chart is a table of rows, columns and cells that shows the relationship between prime implicants and the configurations from which they were derived. QCA displays a prime implicant chart by listing configurations across the top of the table (columns in the table) and prime implicants down the left hand side of the table (rows of the chart). An 'x' symbol in a cell of the chart indicates that the prime implicant in the row covers the configurations in the column. The basic goal of the chart is to select the minimum number of prime implicants needed to cover all configurations in the chart. QCA further simplifies a prime implicant chart to arrive at the final Boolean minimal function.

Furthermore, there are some optional steps involved in carrying out QCA. These are:

8. Use of De Morgan's law
   It is possible to write a minimal Boolean expression for the presence (1) of an outcome, and its logical compliment for the absence (0) of an outcome using De Morgan's Law. Thus, applying De Morgan's Law to the Boolean equation derived for the positive outcome, that is AB + aC = Y, it is possible to derive a Boolean equation for negative outcome, that is A b + a c + b c = y.
9. Necessary and sufficient conditions
   The results of Boolean analysis may be interpreted in terms of necessary conditions (must be present for a certain phenomenon to occur) and sufficient conditions (by itself can produce a certain phenomena). Some patterns of necessary and sufficient causation expressed in Boolean equations are: AC + BC (C is necessary but not sufficient causal factor); A + Bc (A is sufficient but not necessary) , B (B is both necessary and sufficient).
10. Factoring Boolean expressions
    In Boolean logic it is possible to do factoring in order to find which causal conditions are necessary and which are causally equivalent. A hypothetical Boolean equation AB+ AC + AD = Y can be factored to show that A is necessary condition A (B + C + D) = Y and that B, C, and D are causally equivalent (in combination with A) with respect to outcome Y.

In conclusion, as noted elsewhere QCA is seen as a suitable method to establish risk factors, especially those derived from combinatorial models. QCA is considered to be the appropriate method to empirically prove specified, deterministic relations between a set of hypothesised causal variables (risk factors conceptualised in the framework Figure 1) and possible outcomes. Upon applying QCA and its formal language – Boolean Algebra, one finds risk factors and possible outcomes by conducting in-depth interviews in the field making it possible to compare the hypothesised with factors derived from the 'truth table'. The next step would be to evaluate interaction intenstities amongst established factors and outcomes to create the Map of Interactions to develop the risk management strategy. This can be done by applying the Systems Theory Methods (STMs) explained in the following section.

SYSTEMS THEORY METHODS (STMs)

Once the risk factors are identified and their causal outcomes established by applying QCA, systems theory methods can be used to assess factor interactions intensity. That is, STM can be used for assessing risk and implementing risk management. This section describes systems theory method and its tools, as the second stage in assessing the risk factors and their interactions and control.

According to Buerki, 2006, the systems theory methods consists of five stages each with two sub - stages (Table 3).

TABLE 3
METHODS FOR EACH STAGE USED FOR THE FIVE-STAGE SYSTEMS THEORY METHODS

<table>
<tr><td>Stages</td><td>Methods</td><td>Description</td></tr>
<tr><td>Stage 1 A</td><td>Brainstorming, ‘brain writing’, method 635, rich picture, PAT-mirror, Synectic, progressive abstraction</td><td rowspan="2">Stage 1 (a and b): Discover and identify opportunities and problems
The first contact with a complex phenomenon is done by first describing fuzzy statements or set of factors (1a and b). In this stage different roles and different key players are identified. There are no solutions or interpretations in this stage.</td></tr>
<tr><td>Stage 1 B</td><td>Concentrate data to cluster and clear statements: Mindmap, set of factor, role settings, syntegration, dialoguing</td></tr>
<tr><td>Stage 2 A</td><td>Holistic test, holistic potential test, holistic environmental turbulence score, gap-analysis</td><td rowspan="2">Stage 2 (a and b): Reflect wholeness, analyse interactions and tensions
The goal in this stage is to test the data on wholeness (2a), and then to define and analyse the interactions between the factors (2b). Different tests (from holistic test to double-cross-impact analysis) are completed in order to find the interactions which are normally not seen and therefore left out.</td></tr>
<tr><td>Stage 2 B</td><td>Double-cross-impact analysis, loop diagrams, family constellations</td></tr>
<tr><td>Stage 3 A</td><td>Interpretation of systems dynamic, critical systems heuristics, systemics goal definition, Presencing</td><td rowspan="2">Stage 3 (a and b): Work out possibilities of design and steering, understand dynamics
In this stage information that transforms into knowledge is reflected. Double-cross-impact analysis is interpreted, results are reflected and the goal is (re)defined (3a). From dynamic interpretation to four drive method we achieve a generic playground for new solutions. It is important to stay open for new information in this stage and to ask in order to make statements.</td></tr>
<tr><td>Stage 3 B</td><td>10 points for viability, sensitivity analysis, risk analysis, Neuro-Linguistic programming (NLP), four drive method</td></tr>
<tr><td>Stage 4 A</td><td>Synectic, morphology, the six thinking Hats method, precise destroying, Osborn-Checklist</td><td rowspan="2">Stage 4 (a and b): Develop causal solutions and sustainable decisions
In this stage new knowledge is produced for solutions (4a) and making decisions (4b). These insights are crucial for recognising that all scientific concepts and theories are limited and approximate. Solutions are seen as emerging opportunities.</td></tr>
<tr><td>Stage 4 B</td><td>Simulation, scenario technique, holistic value-benefit analysis, four force field reflection</td></tr>
<tr><td>Stage 5 A</td><td>Project management, process couching, balanced scorecard, consultancy, coaching, portfolio of activities</td><td rowspan="2">Stage 5 (a and b): Consolidate commitment and realise viable processes
In this stage action is being taken (5a), followed by the feedback from the environment. Shift from isolated positions to networks as a metaphor for sustainable solutions: there is no signal “right thing to do”, as the strategy includes a network of parallel processing.</td></tr>
<tr><td>Stage 5 B</td><td>Micro-article, knowledge management, Network, Lessons learned, EFQM quality model, reflecting groups</td></tr>
</table>

Adopted from Buerki 2006

TABLE 4
TOOLS OF STMS

Tool	Description	
Holistic structure test	Using the holistic structure test enables a quick holistic check of any description or analysis by pointing out the blind spots. The distribution of the factors gives valuable information about the structure of the system and reveals the blind spots.	
Holistic potential test – four basic drives	Following Buerki, 2006, factors are tested by four drives: drive to acquire; to bond; to learn; and to defend. This test is basically grouping the factors under appropriate drivers, according to the content of the factor that strengthens specific drives (D1, D2, D3 or D4).	
Holistic environmental turbulence score	This test measures turbulence in the relevant environment to indicate how fast and how much the system needs to change its strategy or products.	
Systemic gap-analysis	At this stage, factors should be described in relation to the real situation in the company. Then they are evaluated on a scale from 1–5 and the variation from the line which present the holistic environmental turbulence score is measured	
Double-cross-impact analysis	After factors for ICT adoption are established from the literature, and tested with holistic tests, their impact on the company in the post-adoption period will be evaluated. The tool for evaluation of those factors on company's goals and performance is called the double-cross-impact analysis. It was developed by Vester and Hesler (1980) in order to analyse dynamic systems, and was successful in evaluating key factors for explaining and improving all variety of systems. Double-cross-impact analysis consists of assessing all interrelations between the different factors for ICT adoption. It is based on ADVIAN (Advanced Input Analysis) method developed by Messerli, 2000, were the impact factors are identified and connected. The impact strength of each factor on each other factor is estimated. (see figure 2)	
	The basic steps of the Double-cross-impact analysis are	Firstly, the system was reduced to a set of relevant key factors for ICT adoption (conceptual framework), An assessment of interrelations between selected key factors was carried out by means of matrices in order to understand the influence exerted and received by each key factor, and Interpretation and discussion of each key factor to identify its potential to influence the entire system. In fact the double-cross-impact analysis is a matrix that facilitates systematic assessment of every single interrelation and of its intensity. In order to take into account the positive and negative interrelations, two matrices are used - one for all the stimulating interrelations and one for the inhibiting interrelations. The interrelations are assessed qualitatively.
	In addition, double-cross-impact analysis provides other important information	The active sum - the sum of each line of each key factor. It represents the total influence the factor exerts on the system (stimulation or inhibition). The passive sum - the sum of each column of each key factor. It represents the total influence of the system on the factor (stimulation or inhibition). The degree of interrelation which is the product of the active sum multiplied by the passive sum. The higher the value, the more the factor is interrelated within the system. The degree of activity of each factor - the quotient that is the result of dividing the active sum by the passive sum. A small quotient means that the influence the factor undergoes is greater than the influence the factor exerts on other components. The opposite applies for high quotients. (see figure 2 Impact Matrix).

Adopted from Buerki 2006

Tools of the five-stage systemic approach are explained in the next table (4). Those tools can be used to check the relevance of the conceptual framework factors in influencing risk management, as well as the interaction of the factors. Following the STM rules and its tools, as well as applying systemic data gathering strategies [focus group meetings, the landscape of the mind (LoM), reflect back workshops, in-depth semi-structured interviews, mapping of email connectivity (NetMap), and participant observation].

With adjusted factors it is possible to construct the stimulating and inhibiting interrelations (respectively) impact matrices of factors for risk factor interaction intensities as presented below.

TABLE 5
IMPACT MATRIX

	impact	on IF1	on IF2	on IF3	on IF4	on IF5	activity direct sum
	of IF1	**0**	1	0	0	0	**1**
	of IF2	0	**0**	1	0	0	**1**
	of IF3	0	0	**0**	1	0	**1**
	of IF4	0	0	0	**0**	1	**1**
	of IF5	0	0	0	0	**0**	**0**
passivity	direct sum	**0**	**1**	**1**	**1**	**1**	

After constructing two matrices (for inhibiting and enabling factors) of interactions and their intensities it is possible to construct the Map of Interactions.

This map's (of interactions) goal is to transform the highly concentrated knowledge of the 'Double-cross-impact analysis' to the right brain-hemisphere's way of thinking, in order to create a picture of different dimensions of the system.

The horizontal axis of the map of interactions represents the degree of activity of risk factors in the system while the vertical axis represents the degree of dynamics (interactions). For the interpretation purposes this map can be also divided into four quadrants.

TABLE 6
QUADRANTS OF THE MAP OF INTERACTION

Passive and highly interactive factors These factors are influenced by and interact with the rest of the system	**Active and highly interactive factors** These factors influence and interact with the rest of the system
Passive and less interactive factors These factors are influenced by and are less interactive with the rest of the system	**Active and less interactive factors** These factors influence but have less interaction with the rest of the system

ILLUSTRATIVE EXAMPLE

In this section I will illustrate an application of STMs. First, by applying the QCA I have found the following dissagregated risk factors:

TABLE 7
RISKS FACTORS

Factor 1	Environmental factors: Drinking water - quality
Factor 2	Environmental factors: Drinking water - availability
Factor 3	Environmental factors: Drinking water - access
Factor 4	Environmental factors: Recreational water use - quality
Factor 5	Environmental factors: Recreational water use - availability
Factor 6	Environmental factors: Recreational water use - access
Factor 7	Environmental factors: Ambient and indoor air quality
Factor 8	Environmental factors: Human and agri waste treatment - availability
Factor 9	Environmental factors: Human and agri waste treatment - quality
Factor 10	Environmental factors: Soil - quality
Factor 11	User factors - Education
Factor 12	User factors - Culture
Factor 13	User factors - Tradition
Factor 14	Economic factors - Costs
Factor 15	Economic factors - Human resources
Factor 16	Economic factors - Infrastructure
Factor 17	Macro factors - Political stability
Factor 18	Macro factors - Economic development
Factor 19	Macro factors - Educational policy
Factor 20	Macro factors - Health policy
Factor 21	Macro factors - Environmental policy
Factor 22	Other
Factor 23	Other
Factor 24	Other

Further let’s assume that by applying STMs tools we have established interactions intensities amongst factors represented by the following impact matrices:

FIGURE 2
STIMULATING FACTORS IMPACT MATRIX

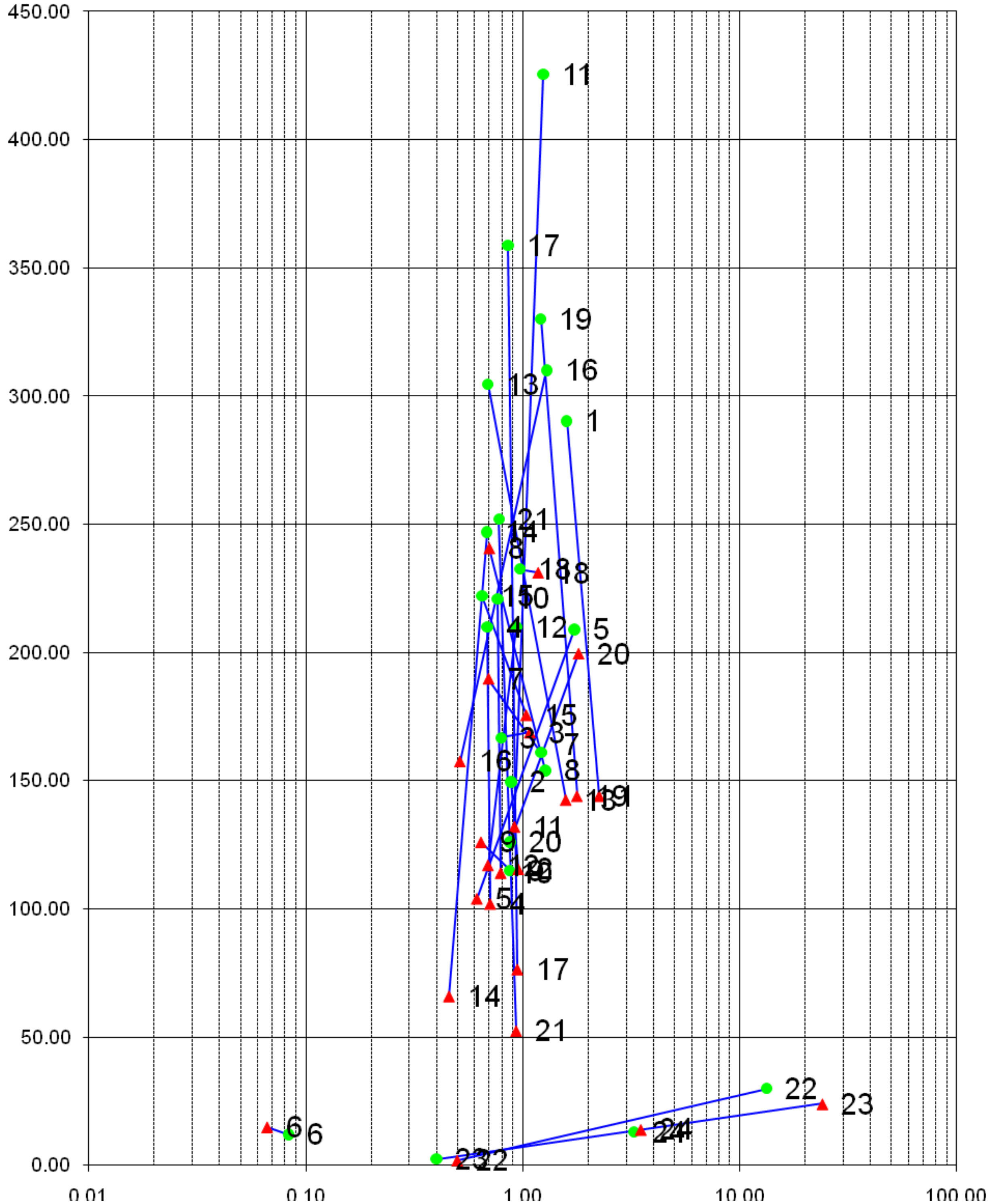
		Wirkungsmatrix - fördernde Wechselwirkungen																								Aktiv-	Fördernd	
		Wirkung auf Variable —>						Wirkung auf Variable —>						Wirkung auf Variable —>						Wirkung auf Variable —>						summe	Quotient	Produkt
Wirkung von Variable		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	AS	Q = AS/PS	P = AS*PS
Enviromental factors: Drinking water - quality	1	1.0	1.0	0.5	2.0	1.0	0.5	1.0	0.5	0.5	1.0	1.0	1.0	2.0	0.5	1.0	0.5	1.0	2.0	1.0	0.5	2.0				21.5	1.59	290.25
Enviromental factors: Drinking water - availability	2	1.0	1.0	1.0				1.0	1.0			1.0			1.0	2.0		2.0			0.5					11.5	0.88	149.50
Enviromental factors: Drinking water - access	3	0.5		1.0			1.0				2.0		0.5	1.0	0.5	1.0	1.0	1.0	1.0		1.0					11.5	0.79	166.75
Enviromental factors: Rekreational water use - qu	4		1.0		1.0	1.0	1.0	0.5			0.5		0.5	1.0	1.0	1.0	2.0			1.0		0.5				12.0	0.69	210.00
Enviromental factors: Rekreational water use - av	5	1.0	1.0	1.0	1.0	1.0			0.5	2.0	0.5	1.0	1.0	1.0	2.0	1.0		2.0		1.0	1.0	1.0				19.0	1.73	209.00
Enviromental factors: Rekreational water use - ac	6						1.0																			1.0	0.08	12.00
Enviromental factors: Ambient and indoor air qual	7	1.0	1.0	2.0	2.0			1.0			1.0	1.0	1.0	1.0				1.0	1.0		0.5	0.5				14.0	1.22	161.00
Enviromental factors: Human and agri waste treat	8	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0		1.0			2.0	2.0					1.0						14.0	1.27	154.00
Enviromental factors: Human and agri waste treat	9			1.0	1.0	1.0	1.0			1.0		0.5	0.5	0.5	0.5			1.0		1.0		1.0				10.0	0.87	115.00
Enviromental factors: Soil - quality	10	1.0	1.0	2.0	2.0	0.5	0.5	0.5			1.0		0.5		0.5	0.5		0.5	0.5			2.0				13.0	0.76	221.00
Users faktors - Education	11	1.0	1.0	1.0	2.0	2.0	2.0		2.0		1.0	1.0		2.0		1.0		2.0	2.0	2.0	1.0					23.0	1.24	425.50
Users faktors - Culture	12											2.0	1.0	2.0	2.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0				14.0	0.93	210.00
Users faktors - Tradition	13	2.0	2.0				2.0				1.0	1.0	1.0	1.0			2.0	1.0		0.5	0.5	0.5				14.5	0.69	304.50
Economic factors - Costs	14				0.5	0.5	0.5	0.5				1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0				13.0	0.68	247.00
Economic factors - Human resources	15	1.0						2.0	2.0	2.0	2.0					1.0	1.0				0.5	0.5				12.0	0.65	222.00
Economic factors - Infrastructure	16							1.0	1.0	1.0	1.0	1.0	1.0	1.0	2.0	2.0	1.0	2.0	2.0	2.0		2.0				20.0	1.29	310.00
Macro factors - Political stability	17		1.0	1.0	2.0			2.0		1.0	1.0	1.0	1.0	0.5		1.0	1.0	1.0	1.0	0.5	0.5	2.0				17.5	0.85	358.75
Macro factors - Economic development	18								2.0	2.0	2.0	2.0	2.0	1.0	1.0	1.0			1.0		0.5	0.5				15.0	0.97	232.50
Macro factors - Educational policy	19	1.0	1.0	1.0	1.0					1.0	1.0	1.0		2.0	2.0	1.0	2.0	2.0	1.0	1.0	1.0	1.0				20.0	1.21	330.00
Macro factors - Health policy	20	0.5	0.5	0.5	0.5	0.5						2.0	1.0		1.0	1.0	1.0			1.0	1.0					10.5	0.88	126.00
Macro factors - Enviromental policy	21	1.0		1.0	1.0	1.0						1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0		1.0				14.0	0.78	252.00
Other	22					1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	20.0	13.33	30.00
Other	23																							1.0		1.0	0.40	2.50
Other	24	0.5	0.5	0.5	0.5	0.5	0.5													0.5	0.5	0.5	0.5	0.5	1.0	6.5	3.25	13.00
Passivsumme PS:		13.5	13.0	14.5	17.5	11.0	12.0	11.5	11.0	11.5	17.0	18.5	15.0	21.0	19.0	18.5	15.5	20.5	15.5	16.5	12.0	18.0	1.5	2.5	2.0	328.5		

FIGURE 3
INHIBITING FACTORS IMPACT MATRIX

		Wirkungsmatrix - hemmende Wechselwirkungen																								Aktiv-	Hemmend	
		Wirkung auf Variable —>						Wirkung auf Variable —>						Wirkung auf Variable —>						Wirkung auf Variable —>						summe	Quotient	Produkt
Wirkung von Variable		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	AS	Q = AS/PS	P = AS*PS
Enviromental factors: Drinking water - quality	1	1.0	0.5	1.0	1.0	0.5	0.5	0.5	1.0	0.5	1.0	0.5	1.0	1.0	2.0	1.0	1.0	1.0	1.0	0.5	1.0	0.5				18.0	2.25	144.00
Enviromental factors: Drinking water - availability	2	1.0	1.0			1.0			1.0				1.0		1.0		2.0			2.0		0.5				10.5	0.95	115.50
Enviromental factors: Drinking water - access	3		1.0	1.0	1.0			2.0	2.0			1.0	1.0	0.5					1.0	1.0		2.0				13.5	1.08	168.75
Enviromental factors: Rekreational water use - qu	4	0.5		2.0	1.0				0.5	0.5		0.5		0.5				1.0	1.0		1.0					8.5	0.71	102.00
Enviromental factors: Rekreational water use - av	5					1.0	0.5	0.5		0.5	0.5			2.0			2.0		1.0							8.0	0.62	104.00
Enviromental factors: Rekreational water use - ac	6						1.0																			1.0	0.07	15.00
Enviromental factors: Ambient and indoor air qual	7					2.0	2.0	1.0	2.0	0.5	0.5				1.0	1.0	1.0			0.5						11.5	0.70	189.75
Enviromental factors: Human and agri waste treat	8								1.0		1.0	1.0	1.0			2.0	2.0	2.0	2.0		0.5	0.5				13.0	0.70	240.50
Enviromental factors: Human and agri waste treat	9	1.0	1.0	1.0			0.5	0.5	0.5	1.0	0.5					0.5	0.5		1.0		1.0					9.0	0.64	126.00
Enviromental factors: Soil - quality	10								0.5	0.5	1.0	0.5		0.5			0.5		2.0	2.0	2.0					9.5	0.79	114.00
Users faktors - Education	11						1.0	1.0		2.0		1.0	1.0		2.0		2.0					1.0				11.0	0.92	132.00
Users faktors - Culture	12							2.0	2.0	2.0	2.0		1.0													9.0	0.69	117.00
Users faktors - Tradition	13			2.0	2.0	2.0		1.0	1.0	1.0				1.0	2.0	2.0			1.0							15.0	1.58	142.50
Economic factors - Costs	14	0.5	0.5	0.5					1.0	1.0	1.0				1.0											5.5	0.46	66.00
Economic factors - Human resources	15		1.0	1.0	1.0	1.0	1.0					2.0	2.0	1.0	1.0	1.0		0.5	0.5	0.5						13.5	1.04	175.50
Economic factors - Infrastructure	16	1.0	1.0	1.0	1.0	1.0	1.0										1.0				2.0					9.0	0.51	157.50
Macro factors - Political stability	17				2.0	0.5	0.5	0.5	0.5				0.5	0.5	0.5	1.0	1.0	1.0								8.5	0.94	76.50
Macro factors - Economic development	18		2.0	2.0	2.0	2.0	2.0	2.0								1.0	1.0	1.0	1.0	0.5						16.5	1.18	231.00
Macro factors - Educational policy	19	2.0	2.0			1.0	1.0	1.0	1.0			2.0	2.0			2.0	1.0			1.0						16.0	1.78	144.00
Macro factors - Health policy	20						2.0	2.0	2.0	2.0	2.0	2.0	1.0	1.0			1.0	1.0	1.0		1.0	1.0				19.0	1.81	199.50
Macro factors - Enviromental policy	21						1.0	1.0	1.0	1.0	1.0										1.0	1.0				7.0	0.93	52.50
Other	22																						1.0			1.0	0.50	2.00
Other	23	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	24.0	24.00	24.00
Other	24							0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5						1.0	7.0	3.50	14.00
Passivsumme PS:		8.0	11.0	12.5	12.0	13.0	15.0	16.5	18.5	14.0	12.0	12.0	13.0	9.5	12.0	13.0	17.5	9.0	14.0	9.0	10.5	7.5	2.0	1.0	2.0	264.5		

The results of the systemic analysis of this example are presented in the following ‘Map of Interaction’.

FIGURE 4
MAP OF INTERACTION



As earlier mentioned, the horizontal axis of the map of interactions represents the degree of activity of risk factors in the system while the vertical axis represents the degree of dynamics (interactions). This map is then divided into four quadrants (see Table 6 above) to easy its interpretation.

INTERPRETATION OF THE EXAMPLE'S RESULT

In our double cross impact analysis, factors in the top circle of the map of interaction factors 1, 13, 16, 17, and 19 are the components that are the most connected factors in the system. The majority of factors in the middle circle are less interactive factors within the system. The rest of the analysed factors interact very little. They have still roles in the system, although they are 'moving slower', particularly factors 22, 23, and 24.

The striking characteristic of the double-cross-impact analysis is that there is actually the only one real activating factor for creating a positive dynamic in the system – factor (11) – ,which should be given priority in a efforts facilitate the problem solving process.

An innovative approach to the system would be to pay attention to the factors in the middle circle. To achieve that goal, one would have to find solutions to influence the activities of factors 12 and 20. In doing so, the degree of interaction would be reduced and the system would become more passive. In that case factor (12) would 'move' into the field of 'goals' (the middle circle), (goals depend on firm's goals and/or society's goal; for example if a firm's goal is improved performance then the goal would be to impact factors driving changes). In reality that could mean that the influence of culture, in my example, could become less intensive, e.g. culture could become subject to 'other influences'. Similarly, factor (20) would change from a 'transformation key player' that policy makers rely on to a 'quality indicator', which can be steered and supported.

In the Map of Interaction I can look at different areas of interactions between the risk factors, which can be summarised in the following six points.

Factors grouped around the axis 150 describe the system as a whole, which is well differentiated by the degree of interaction. However, it is less differentiated in the degree of transformation. It means that I have identified the key factors in the system. Apparently, the system has only a small negative feedback, meaning the system is a dynamic one – it can be influenced either by enforcing the positive development or lowering the negative one.

The most recognised factors in the system – passive outcome or symptom – are factors (11, 17, and 19). These factors could be fields of actions for the fast solutions and achieving results. However, those factors would be only an indication of success, since they do not really change the system as whole. I can use those factors for 'symptomatic solutions', only in the case of 'crisis' or if the system needs to get recognition in order to continue to operate and to survive. Therefore, I should not be tempted to act upon those kinds of factors. Instead, the management should focus on factors that are stable in the active part in the system. However, those three factors should be measured and controlled regularly, as the best indicators of transformation processes.

Factors that are maintaining the processes of transformation are: (1, 13, 16, 18, and 8); having them in the system would mean that they could be problematic in transforming new ideas into new solutions. However, without that transformation area any initiative would not succeed in the way it is expected.

The only fast driver within the system is factor (11). This factor (Education) is absolutely crucial and has to be part of the solutions in all scenarios. However, as with all dominant factors, factor (11) could foster good, as well as bad developments. Fortunately for the system it is possible to find other factors in the system that can be acted upon for long term solutions, like factors (12, 18 and 19).

The challenge to develop sustainable solutions is therefore to put factor (11) in a creative and adaptive interaction with (13), (16), (18) and (8) in order to get more successful solutions of the project.

The actual identified structure – without changing factors and interactions – is focused on the goals or to foster 'Other" factors (22, 23 and 24), whatever, they might be in the real case study.

The final reflection on our illustrative system is almost a 'painting of dynamical information'. For example, if the system/organisation/country wants to change the 'field of goals' then it would have to change the structure in the both active and the passive parts of the system. Or, if the firm would want to make the system more sensitive to changes, then they must find new ways of interactions of factor (12 - Culture) with other factors in the system.

The final principal participant observations and recommendations would be to the system/organisation/country to build on a high commitment with all involved in the project in this example. So, the management/policy makers should be more creative and not fixed on the 'actual structure' of the system, for what it necessary to understand the wholeness and decide on what to keep and what to change in the actual situation.

CONCLUDING REMARKS

In this section, the authors have used STMs and its tools to identify the key factors and their interactions and influence on the system. The results of the double cross impact analysis revealed six dimensions that can influence the performance of the system. Although those dimensions were for illustrative purposes and thus kept at a very general level, they still can be instructive for an organisation wanting to utilise better control and risk management and consequently improve the performance of the system.

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