Clustering Scenarios using Cross-Impact Analysis

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ABSTRACT

Scenarios are frequently used in Emergency Planning and Preparedness. These scenarios are developed based on the hypothesis of occurrence or not of significant events. This is a complex process because of the interrelations between events. This fact, along with the uncertainty about the occurrence or non-occurrence of the events, makes the scenario generation process a challenging issue for emergency managers. In this work a new step-by-step model for clustering scenarios via cross-impact is proposed. The authors' proposal adds tools for detecting critical events and graphical representation to the previous scenario-generation methods based on Cross-Impact Analysis. Moreover, it allows working with large sets of events without using great computational infrastructures. These contributions are expected to be useful for supporting the analysis of critical events and risk assessment tasks in Emergency Planning and Preparedness. Operational issues and practical implications of the model are discussed by means of an example.

Keywords

Cross-Impact Analysis (CIA), Interpretive Structural Modeling (ISM), Scenarios, Emergency Preparedness, Risk Analysis.

INTRODUCTION

The idea that a crisis – whether a natural disaster or man-made – is unique and unpredictable is not entirely correct. Emergencies are composed of both foreseeable and unforeseeable events. Emergency managers are responsible for, among other tasks, (1) anticipating events that may happen in case of crisis (2) analyzing their effects and (3) making plans for mitigating the possible negative consequences. In order to support these planning tasks, scenarios are often used by emergency managers. A well-constructed set of scenarios for crisis can help to identify in advance the pressing needs in case of crisis. These scenarios are mostly narrative and based on previous experience of emergency managers. Despite the important role that these scenarios have in the emergency planning process, there is a lack of academic research aimed at developing future-oriented models to generate them. This fact impacts negatively on the thoroughness and objectivity of the scenarios-based analysis. This is because the narrative scenarios (1) do not support sensitivity analysis, (2) have no reliable indicators of the occurrence or of the events of the scenario and (3) do not supply measures about the relationships between events.

Several of the most recognized methodologies to generate scenarios are based on Cross-Impact Analysis (CIA) (Gordon and Hayward, 1968). CIA is a powerful tool for taking a set of binary future events and examining the potential causal impacts that the expectation or occurrence of each event may have on the others in the set. CIA was designed to calculate the basic impact of a political, social, or technological event on the occurrence probability of other events in the set. The success of the approach is mainly due to it being a flexible methodology that can be combined with other techniques such as Delphi (Linstone and Turoff, 1975; Bañuls and Salmeron, 2007) or Multi-criteria (Cho and Kwon, 2004; Bañuls and Salmeron, 2008) methods to allow true collaborative model building and scenario creation by groups.

In this paper, a new approach for building scenarios based on CIA is described. This method is an extension of Turoff's CIA approach (Turoff, 1972), one of the pioneering CIA approaches. This method is aimed at building

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scenarios and analyzing their key drivers. Specifically we propose combining CIA with the technique called Interpretive Structural Modeling (ISM) (Warfield, 1976). This new approach adds tools for detecting critical events and graphical representation to the previous scenario-generation methods based on CIA. Moreover, it allows working with large sets of events without using great computational infrastructures, bringing a graphical representation of complex systems following a quite structured process. This fact makes this methodology highly compatible with other complex systems analysis tools such as System Dynamics, Bayesian Networks and Fuzzy Cognitive Maps. These facts have several practical implications which are analyzed in the Conclusions section. In order to illustrate the CIA-ISM approach application, we use Turoff's original example (1972). This will allow others to check the consistency and mathematics of any effort to implement this process. Based on this example, operational and analytical issues are discussed. But, firstly, the basics of scenarios, CIA and ISM will be presented and analyzed in the following section.

METHODOLOGICAL BACKGROUND

Scenarios

The use of scenarios to study the future is well-known as an approach to studying situations that can lead to extreme change and in which is difficult to create explicit relationships between the events. Examples are the merger of two companies, extreme disaster or risk situations, major political happenings and/or the long term impacts of new or changing regulations or policies. All the events in the set are of a binary nature: a merger will or will not occur; a new specific policy will be established or not; a company will or will not go bankrupt; a given technological breakthrough will occur or not, etc.

The term scenario has been mainly used in two senses. Firstly, to predict the occurrence or not of a set of events in time. Secondly, to describe a future story, from the present conditions to a set of plausible futures. In both cases, scenarios have been widely used for exploring the detection of future events together, as well as analysis of the path that leads to the desired future or prevents undesirable futures. In this sense, scenario-generation methods have often been used by decision-makers as an instrument to build landscapes of possible futures. Based on these future visions, decision-makers are able to explore different courses of action (Futures Group, 1994; Chermack, 2004). Scenario-generation methods combine a set of behaviors that mix qualitative and quantitative, subjective and objective methodologies in different layers (Harries, 2003). The number of potential scenario methods is increasing as researchers and consultants from different backgrounds use their particular expertise to create new variations (Chermack, 2007; Notten et al., 2003). One of the most commonly-used techniques for generating scenarios processes a CIA. This has been due to the ability of CIA to analyze complex contexts with various interactions.

Cross Impact Analysis

In recent years, CIA has resurged as a powerful tool for forecasting the occurrence or not of a set of interrelated events (Cho and Kwom, 2004; Weimer-Jehle, 2006; Choi et al. 2007; Bañuls and Salmeron, 2007, 2008). The main goal of CIA is to forecast events based on the principle that the occurrence of events is not independent. The analytical approach proposed by Turoff (1972) was developed specifically for restructuring the cross impact formalisms in a manner suitable for use on an interactive computer terminal. This requires users being able to modify or iterate their estimates until they feel the conclusions inferred from their estimates are consistent with their views. Moreover, Turoff's approach is based on the idea that an event may be unique in that it can only happen once (i.e., the development of a particular discovery or the outbreak of a particular war). Following Turoff, for this type of event there is usually no statistically-significant history of occurrence which would allow the inference of the probability of occurrence. So, the cross-impact problem is to infer casual relationships from some relationships among the different world views. This is established by perturbing the participant's initial view with assumed certain knowledge as the outcome of individual events. That is, subject estimates actually cause subjects to estimate causality. Analytically, the correlation coefficients (c_{ik}) can be calculated using a variation of the Fermi-Dirac distribution function by asking subjects about the probabilities (Pi) as determined by this relationship.

$$P_i = 1 / [1 + \exp(-G_i - \sum_{i \neq k} c_{ik} P_k)] \qquad (1)$$

Where:

P_i represents the probability of occurrence of the i-th event.

G_i (the gamma factor) is the effect of all (external) events not specified explicitly in the model.

c_{ik} represents the impact of the k-th event on the i-th event. Positive c_{ik} means it enhances the occurrence of the event and negative detracts from the occurrence.

For further details see (Turoff, 1972).

Interpretive Structural Modeling

The basic concept of CIA is "structural modeling" where professionals who are knowledgeable about at least some portion of the event set can estimate subjective probabilities. This allows the computer to establish a consistent model for one individual or for a group of individuals trying to arrive at a consistent model for the group. In this sense, ISM is a structural analysis-based technique that enables individuals or groups to develop a map of the relationships between the many elements involved in a complex situation (Warfield, 1976). ISM should be based on an interactive computer-based support system, because the inputs are obtained by means of human-computer interaction. From an analytical perspective, the starting point of ISM methodology is a system that is formed for a set of *n* elements of a set *S*.

$$S=\{s_1, s_2, s_3, \dots, s_n\} \tag{2}$$

The relationships between the elements in set *S* are binary. From these binary relations we can calculate de adjacency matrix *A*, defined as a binary $n \times n$ matrix where the entry 1 represents the direct connection from node s_i to node s_j. So, of all the paths length being 1 in adjacency matrix *A*, it indicates which is likely to be reached. The adjacency matrix is a means of representing which vertices of a graph are adjacent to which other vertices. From this matrix we can obtain the reachability matrix (*M*), which is a square, transitive, reflexive and binary matrix. Suppose s_i and s_j are elements of the set *S*. If $M(s_i, s_j)=1$, this indicates that node s_i and node s_j are connected. If $M(s_i, s_j)=0$, this indicates that it is impossible to go from node s_i to node s_j. Every element in set *S* can be considered as a node and solved by graph theory. For a further explanation see (Warfield, 1976; Lendaris 1980).

BULDING SCENARIOS WITH A CIA-ISM APPROACH

There are some antecedents about the application of structural analysis to CIA. Duval et al. (1974) suggest that a cross-impact matrix can be structurally analyzed and portrayed by a signed directed graph. Ishikawa et al. (1980) introduce a method for processing CIA outputs and building scenarios based on structural analysis concepts. Godet (1994) proposes structural analysis for forecasting the key variables which bear on the future dimension. On the other hand, Martino and Chen (1978) combine cluster techniques and CIA analysis in order to create 'typical' scenarios. Moreover, there is some previous research focused on using ISM in order to build scenarios and identify key drivers and actors (Saxena et al., 1992). In this paper we take these ideas and extend them by applying CIA-ISM for building scenarios.

Event number	Description
1	The U.S. gets into a trade war with one or more of its major trading partners (Japan, Canada, western European countries).
2	Comprehensive tax revisions enacted with most present exemptions and exclusions removed, but with rates lowered.
3	Rigorous anti-pollution standards are adopted and strictly enforced for both air and water.
4	The U.S. averages at least 4 percent per year growth rate of real GNP for the time frame.
5	Defence spending declines steadily as a percent of the federal government's administrative budget.
6	The U.S. experiences at least one major recession (GNP Decline is greater than 5 Percent for a duration greater than 2 quarters) during the ten-year period.
7	A federal income maintenance system (e.g., negative income tax) replaces essentially all current state and local welfare programs.
8	The oil import quota system is phased out and domestic oil prices allowed to fall to the world price.

9	The U.S. agricultural price support system is dismantled.
10	A federal-state and local revenue-sharing program is adopted which allocates at least 5 percent of federal revenues to state and local governments.

Table 1. Events

We illustrate the CIA-ISM approach step-by-step using Turoff's example (1972). In the original paper a single economist developed and estimated the cross impact factors for what he felt were the ten critical events for the U.S. economy in the decade following 1971 (Table 1). These ten events will be represented by their event numbers in the following analysis.

Setting up the Model

The first step is setting up the model. To reach this aim, an individual or a group must come up with a set of interrelated events that might occur in the future. This needs to be a balanced set in that the interrelated subset of events that influence one another is often matched by a subset of external events that are largely not influenced by the interrelated set. Often the analysis itself determines which events the group judges to be external. A pure brainstorming or simple Delphi approach might be used to generate candidates for the model. Actual use of the model can determine which events may turn out to be less relevant than others to a final scenario or outcome determination in an iterative process. Then, the subjective probability that each event will occur in some future time frame such as five years should be estimated. Then, perturb their judgments a maximum amount following this process:

1. For events that have a probability of less than .5 (being the occurrence of an event with .5 probability completely uncertain), ask the estimator to assume it will occur and to re-estimate the probability of the other events occurring under this hypothesis.
2. For events that have a probability of .5 or more, ask the estimator to assume that the event will not occur and to re-estimate the probability of the other events occurring.

Once this set of $n(n-1)$ estimates have been made for the n events, the computer can generate a complete working structural model that may be used. If a working model is available for each participant, it is desirable to let them use the model to reach consistency among their individual estimates. It is then possible to use the derived c_{ij} factors to carry out a more consistent averaging process to reach a collaborative result for a group version of the model. If the event set spans many different professional areas, then users are more likely to only want to estimate probabilities for those events and event interactions they are more familiar with. That has to be done as a facilitated process such as in a Delphi. The result of this process is a cross-impact matrix (Table 2). The rows and the columns of the matrix are the events, the cells are the influence factors c_{ij} (equation 1), the diagonal being the overall probabilities (OPV). Note that the cross-impact matrix is associated with the G vector[1]. The G vector (column) represents the influence of external events on each i event. The row for *Gi* is all zero since the explicit internal events do not influence the unknown external events.

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	G_i
1	OVP	-0.29	0.00	-0.81	-0.33	1.57	0.00	-0.25	-0.22	0.00	0.23
2	-0.50	OVP	-0.23	0.46	0.00	-0.77	0.90	0.29	0.25	0.42	-1.33
3	-0.41	0.31	OVP	0.43	0.74	-0.58	0.00	0.27	0.24	0.68	-0.30
4	-0.81	0.58	0.07	OVP	0.33	-1.21	0.33	0.25	0.22	0.33	-0.05
5	-0.88	0.58	-0.14	0.81	OVP	-0.31	0.74	0.00	0.00	0.36	-1.02
6	0.88	-0.36	0.00	-2.70	-0.42	OVP	-0.38	-0.31	-0.28	-0.38	0.88
7	-0.41	0.99	0.00	0.88	1.16	-0.29	OVP	0.00	0.00	0.68	-0.91
8	-1.62	-0.50	0.00	0.58	0.48	-1.16	0.00	OVP	0.60	0.58	-0.97
9	-1.49	0.00	0.00	0.93	0.00	-1.07	1.25	1.01	OVP	1.25	-3.29

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[1] Authors' note: There was an erratum in the original paper. The symbol of the gamma factor linked to the 10-th event appeared as positive.

10	-0.41	0.99	-0.14	0.88	1.16	-0.58	0.68	0.00	0.00	OVP	-0.74
G_i	0	0	0	0	0	0	0	0	0	0	OVP

Table 2. Cross-impact matrix and *G* vector

Scenario Mapping

Our starting point for the scenario mapping is the cross-impact matrix, obtained with the CIA (Table 2). With the aim of applying structural analysis, we need to process the adjacency matrix from the transposed cross-impact matrix. Firstly, in order to apply ISM methodology, we need a positive matrix; that is, a matrix with its entire elements equal or more than 0 (Table 3). This is the unfolding of the weighted directed graph cross impact factors (Table 2) into a positive definite matrix where the occurrence and non-occurrence of each event is now a separate node in the graph.

	Occurring events (*e*)	**Non-occurring events (-*e*)**
Occurring events (*e*)	$+ c_{ij}$	$- c_{ij}$
Non-occurring events (-*e*)	$- c_{ij}$	$+ c_{ij}$

Table 3. Transforming the cross-impact matrix

Secondly, we need to decide what the limit is to consider the c_{ij} as relevant. In our case we assume an arbitrary value (0.85) as the lower limit for reachability in order to illustrate the process. The result of this transformation is the adjacency matrix. From this adjacency matrix we can attain the reachability matrix as was previously mentioned. Then, we apply ISM in order to obtain the representation of the scenario. Due to our having two symmetric sets of events, we will obtain two symmetric graphs. In order to avoid duplication, we are going to represent a unique graph with two clusters of events. We will use the term "cluster of events" to denote a set of events with the same destiny of occurrence (or not). We have shaded the different clusters of events in order to differentiate them. So, the graph is in fact the representation of two scenarios which might be interpreted as the two sides of a coin (Figure 1).

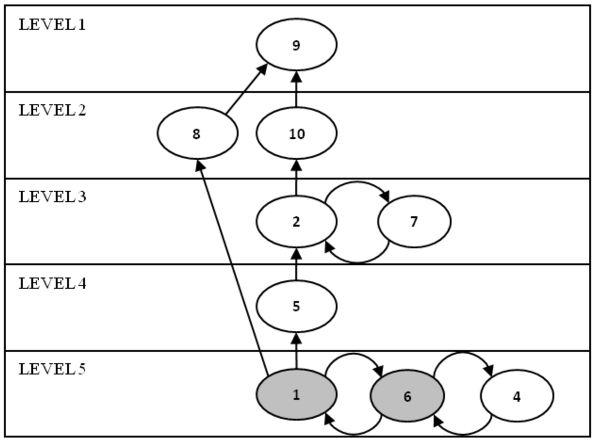

Figure 1. Sets for $|c_{ij}|$>0.85

The graph expressed in Figure 1 includes all events except for event 3. This failure of the method to forecast the occurrence or not of event 3 is because all impacts related to event 3 are less than the arbitrary value 0.85. Note that we need to discard information when we take the c_{ij} weights and convert them to zero or one. We are going to avoid this limitation by treating the adjacency matrix determination as a sensitivity analysis.

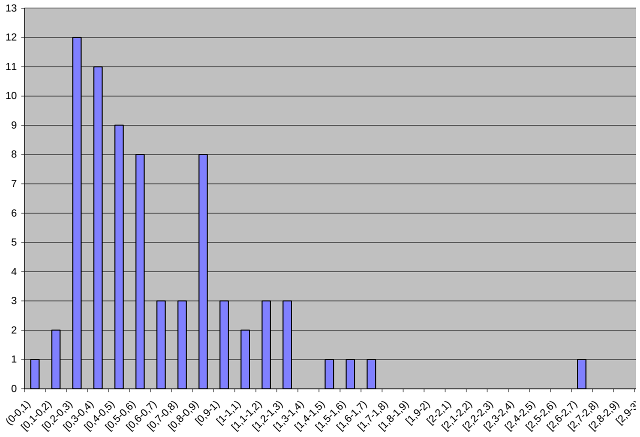

Figure 2. c_{ij} distribution histogram

Percentile 90	1.1581
Percentile 80	0.9198
Percentile 70	0.8109
Percentile 60	0.6450
Percentile 50	0.5389
Percentile 40	0.4132
Percentile 30	0.3409
Percentile 20	0.2950
Percentile 10	0.2508

Table 4. $|c_{ij}|$ distribution

By means of the sensitivity analysis, the collapse as it occurs from the first macro event occurring until the final one can be represented. The users should choose how far down they want to go. This sensitivity analysis starts with the analysis of the c_{ij} distribution. Applying the K-S test, we can find that the c_{ij} follows a Normal distribution with a reliability of 99% (p value= 0.308). If we take the non-zero c_{ij} values and plot the number of them as a histogram from zero to the largest absolute value, we have the $|c_{ij}|$ distribution. Now we are going to apply the structural analysis by taking the k% largest absolute values for c_{ij}. We will stop when we find a scenario with a graphic representation of all events.

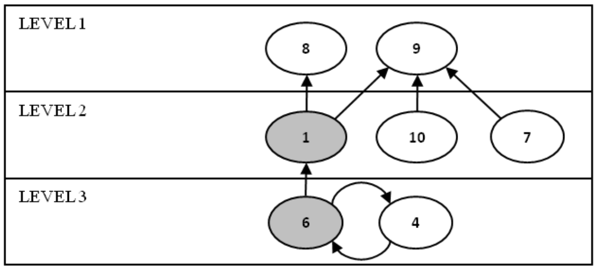

Figure 3. Graph for percentile 90

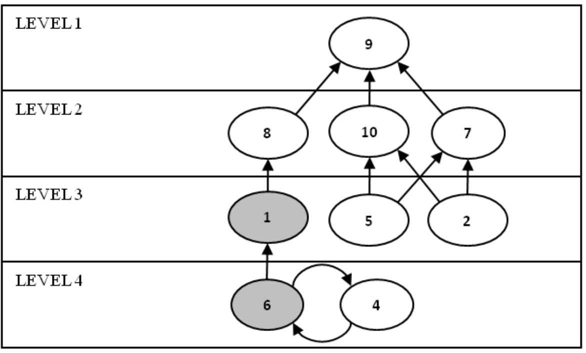

Figure 4. Graph for percentile 80

Figure 3 shows the graph for percentile 90. This is a scenario that only includes the high impacts between events. That is, in this scenario events 2, 3, and 5 are not in the representation. Figure 4 illustrates the ISM analysis for percentile 80. At this level of analysis, we represent the events 5 and 2 in the scenario, but not event 3. The analysis of the percentile 70 is the same as the initial example (Figure 1), so we go through the ISM analysis for percentile 60 (Figure 5).

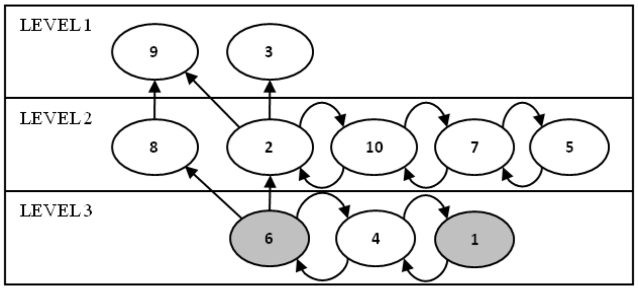

Figure 5. Graph for percentile 60

Analyzing the output of the CIA-ISM analysis for percentile 60, we can symbolize a complete scenario.

Limit of the Forecasted Scenario

The forecasted scenario obtained in the previous section might have a limit. This limit expresses the c_{ij} in which the solution of the forecasted scenario changes. In our example, the limit for the forecasted scenario shown in Figure 6 is 0.4975. We have obtained this value following the same procedure shown in the sensitivity analysis.

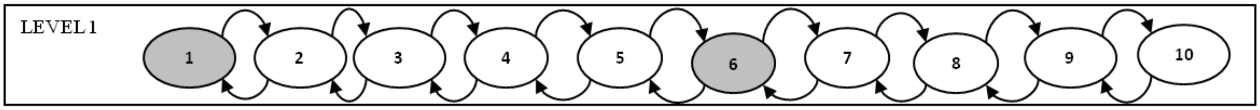

Figure 6. Graph for the limit

If we take a value lesser than the limit, for instance the first quartile of the c_{ij} distribution 0.3294, we find that we have several sets that have, at the same time, as antecessor or successor the occurrence and non-occurrence of an event. This is because of the inclusion of weak c_{ij} impacts at the same level of larger c_{ij} impacts. This fact makes an indirect impact hide the real sense of the larger direct impact. This is something possible in complex systems, in which direct impacts are not always in the same direction as indirect impacts. The solution for the limit of the forecasted scenario can be reached by calculating the collapsed cross-impact matrix and the new G_i values for the forecasted scenario.

Scenario Clusters

The scenario clustering process is based on the interpretations of the scenario mapping. In Table 5, it can be seen that we have we have four scenarios: one forecasted scenario and three alternative scenarios. Each scenario is represented by two clusters of events.

		Forecasted Scenario	**Alternative Scenario I**	**Alternative Scenario II**	**Alternative Scenario III**
Limits		(|∞|, |0.4975|)	[|0.4975|, |0.3804|]	(|0.3804|, |0.2318|)	[|0.2318|, 0)
Interval of reliability		0.5253	0.1019	0.1400	0.2327
c_{ij} sum		35.2527	4.6881	5.3805	1.0224
Event	**P_i**	**Clusters of Events**			
1	**0.5**	A	A	A	A
2	**0.3**	B	B	B	A
3	**0.6**	B	B	B	B
4	**0.5**	B	B	B	B
5	**0.4**	B	A	B	A

6	**0.3**	A	B	A	-
7	**0.6**	B	B	B	-
8	**0.2**	B	A	B	-
9	**0.1**	B	-	B	B
10	**0.6**	B	B	B	A

Table 5. Summary of Results

Each cluster is marked with an A or B. If we have not information about the occurrence of an event, we leave the cell unmarked. Due to the c_{ij} following a normal distribution, we can determine the reliability interval of each scenario. This reliability interval expresses the quantity of the c_{ij} population included in each scenario. As well as this measure, we show in table 6 the c_{ij} sum as indicators of the information included in the scenario. The analysis shows that, in terms of reliability, the forecasted scenario is the item with better indicators. Moreover, it can be easily seen that the clusters of the alternative scenario II are the same as the forecasted scenario. So, the alternative scenario II supports the clusters of the forecasted scenario.

Scenario Forecasting

To estimate the occurrence or not of the two clusters of events we have to go through the sensitivity analysis and see how the final scenario has been made up and which are its key drivers. The macro event 6 and 4 (-6, 4; 6, -4) is clearly one of them. This fact can be seen graphically in Figures 2 and 3, where the macro event (-6, 4; 6, -4) is a high-level event. Through the analysis of the set of probabilities P_i (Table 5) we have not a clear idea about the occurrence or not of the macro event due to their probabilities being close to 0.5. It can also be done analytically as the execution model in the original paper (Turoff 1972, p. 354). Following this method we have events 1 and 6 as being supposed to occur and the rest are not. This scenario is also supported by the alternative scenario II. So the main forecast contains over 65% of the impacts of the model and over 87% of the coefficients of these impacts. The key driver of the scenario is the macro event (6, -4) in the first instance and events 1, -10 and -7 in the second. Moreover, there is a key relationship between events 8, 5, and 6 that would change the forecast to the alternative scenario I. Nevertheless, analyzing the indicators of alternative scenario I, this fact is not very probable. Finally, we have a large set of weak impacts, included in the alternative scenario III, that are not supposed to affect the forecast due to their low coefficient level in the model.

Interaction

Once a model has been established for the group or for an individual it is possible to vary the initial probabilities of individual events and see the degree of influence that this has on the occurrence of the other events by means of computer interaction. There are also internal measures that quantifiably express to what degree a given event is controlled externally to the set. This indicates either that it is truly external or that events might be missing that should have been included. One can also quickly list which events have the most influence on which other events.

Due to the ladder nature of the model, it is possible to build subsets of multi-event mini scenarios of which two, three, or four events always seem to happen or not happen in a combination. One can then create a new event set made up of compound events and in fact reduce the complexity of the problem from *n* different events to a much smaller number of multi-event scenarios including the extreme result of one scenario made up of all the events. However, this should be done with the help of someone who knows the internals of the CIA model well enough to be able to use the internal parameters to present a sensitivity analysis for the user group as a whole. Since probabilities are highly non-linear variables, and understanding of the model's consequences and the estimations by those without a good understanding of the mathematical properties does require some guidance for most user groups. This is at least the case the first time they go though using the model as an input to planning. The most powerful benefit in the long run is to reduce very complex situations to simpler ones by developing summary scenarios that express the most likely futures. This is based on some of the decision options and actions that are contained in the initial event set.

USING CROSS IMPACT WITH GROUPS

The first objective in a group cross impact exercise is the creation of an event set. This is a collaborative process and it is best done in a Delphi process which allows a large number of possible events to be generated and then evaluated to try to come up with the most important ones. A problem-solving dynamic Delphi process, such as the one developed by White and Turoff (2007), is a good example of what is needed. It uses Thurstone's Law of Comparative Judgment to convert the rank orders of the individual participants into a single group interval scale. This allows one to observe the most important clusters of events so that a subset can be chosen for applying the cross-impact approach by the same group or a related group. The version of this technique described in the prior paper allows the process to proceed without everyone voting on all the events and to change their votes based upon the discussion.

Once we have an event set it should be given to a group to apply the cross-impact modeling. Each individual should have access to develop their own model and examine the consequence. The consistencies and inconsistencies the model can provide the individual with can allow them to change their initial inputs to make them more consistent with the inferences the model provides as they modify their estimates of the individual event probabilities and see alternative outcomes for which events occur or do not occur. Once the individuals feel they have done the best they could for creating their world view of the future, the results can be averaged to produce a group model. This can be done in the following way:

1. Average each c_{ij} and each G_i for the group as a whole. Plotting these in terms of the frequencies of estimates for values along the x axis around 0 in the plus and minus direction gives a good description of how consistent the group is. One would hope that there is agreement about the direction of influence of the j-th event upon the i-th event. If this is not the case one needs to engage in a decision among the participants upon about why there is such a significant disagreement. Having to resolve this can send the participants back to their individual models to change the associated estimates.
2. At this point one can apply ISM and start reducing the number of events by the formation of tightly coupled doublets of events and, at some stage, decide on how far to go in reducing the initial n independent events into a smaller total number of events and scenarios. This can bring about a significant reduction in the complexity of the results.
3. After the choice of reducing the event set complexity, one can ask the same set or a new set of participants to re-estimate a new set of probabilities to develop a new model for the reduced event set.
4. An alternative option is to recalculate averages of the probabilities using the theory of least squares via the geometric mean, or using the Bayesian formula given in Dalkey's 1975 paper for averaging probability estimates among a group of experts (page 255, formula 14)
5. A final option is to use the calculated cross impact factors to set up a game by assuming initial probabilities of .5 for all events, adding event sinks which are goals and objectives that are influenced only by the internal explicit events and do not in turn influence any of them. In this case, the model determined by the factors reflects the choice of different options by two players or teams who use resources to buy improvements in a subset of events by buying an improvement in a given event having a higher probability of occurrence. This is viewed as a learning game in that the players should, from repeated plays of the game, get a feel for the impact of the internal structure of the model which was developed by the collaboration of a group of experts in that field (Hendela and Turoff, 2010).

The collaborative development of models is still a major challenge in the Delphi area and the various options described above deserve further exploration and experimentation.

CONCLUSIONS

In this paper, a new scenario generation methodology has been proposed. The CIA-ISM approach aims at allowing researchers and practitioners to (1) handle complex systems; (2) obtain a set of plausible snapshots of the future; (3) analyze interaction between events; (4) detect critical events. This scenario-generation method can have several applications in Emergency Planning and Preparedness that (1) can be applied to any emergency, (2) is oriented at supporting the planning rather that the response process and (3) is oriented to analyzing social factors rather than technical estimates. In addition, these scenario-generation models can be integrated with other predictive models designed to estimate the evolution of a particular disaster (such as the direct effects of a fire or an earthquake), providing a broader view of events which could happen in emergency situations.

The main strong points of the authors' proposal are: (a) a strong theoretical background for the techniques on which the authors' proposal is based; (b) the possibility of working with large sets of events; (c) tools for analyzing the key drivers of the scenarios; (d) specific software is not needed for making the calculations; (e) a graphic output that gives a clear representation about the forecast; (f) it is strongly compatible with other techniques such as the Delphi or multi-criteria methods. Additionally, the introduction of the merger of cross impact with ISM is a major extension in allowing the collaborative development of scenarios out of much larger event sets and this ultimately reduces the complexity for estimating a working model. In the typical large scale event sets approaching a hundred events or more, estimation by groups will usually result in the need to subdivide the estimation process among different areas of expertise. It is generally true in Delphi that one should encourage participants to estimate or judge only those areas they feel confident in judging. We have provided an intelligent approach to the evolution of scenarios from event sets which augments human judgment in an integrated manner for the direct construction of a structural relationship model through the use of a computer in a true direct augmentation process without the need for intermediaries to implement computer programs (Lendaris, 1980; Warfield, 1976).

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