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Scenario construction via Delphi and cross-impact analysis

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ABSTRACT

Since its origins, decision makers have broadly used the Delphi method as a collaborative technique for generating important events and scenarios about what may happen in the future. This is a complex process because of the different interrelations and the potential synergetic effects among the relevant events related to a decision. This fact, along with the uncertainty about the occurrence or non-occurrence of the events, makes the scenario generation task a challenging issue in Delphi processes. In the 1960's, Cross-Impact Analysis (CIA) appeared as a methodological tool for dealing with this complexity. CIA can be used for creating a working model out from a set of significant events. CIA has been combined with other methodological approaches in order to increase its functionality and improve its final outcome. In this paper, the authors propose a new step-by-step model for scenario-analysis based on a merger of Turoff's alternative approach to CIA and the technique called Interpretive Structural Modeling (ISM). The authors' proposal adds tools for detecting critical events and for producing a graphical representation to the previous scenario-generation methods based on CIA. Moreover, it allows working with large sets of events without using large computational infrastructures. The authors present sufficient information and data so that anyone who wishes to may duplicate the implementation of the process. Additionally they make explicit a set of requirements for carrying out a Delphi process for a group to develop a set of significant events, collectively make the estimations of cross impacts, and to support a continuous planning process within an organization. They use two examples to discuss operational issues and practical implications of the model.

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"Born, troubled, died."
This was their history of Everyman.
"Give me next for my people," spoke the head man,
"in one word the inside kernel of all you know,
the knowledge of your ten thousand books
with a forecast of what will happen next—
this for my people in one word."
And again they sat into the peep of dawn
and the arguments raged
and the glass prisms of the chandeliers shook
and at last they came to a unanimous verdict
and brought the head man one word:
"Maybe."
—from Poem 49 in "The People, Yes" by Carl Sandburg

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1. Introduction

The use of scenarios to study the future is well known as an approach to studying situations that can lead to important changes and in which it is difficult to create explicit relationships among 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. By means of scenario generation methods, forecasters make predictions about the occurrence or not of a set of events in time and/or 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. That is what we call scenario analysis. 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 [1,2].

Scenario-generation methods combine a set of behaviors that mix qualitative and quantitative, subjective and objective methodologies in different layers [3]. The number of potential scenario methods is increasing as researchers and consultants from different backgrounds use their particular expertise to create new variations [4,5]. The Delphi method is one of the most used techniques for foresight [6–8]. By means of Delphi method forecasters, based on the input provided by an expert panel, can make hypotheses about the occurrence or not of singular events. This success is mainly due to two of the main characteristics of the Delphi method: controlled feedback and anonymous interaction among experts. These characteristics help forecasters to avoid several limitations of traditional face-to-face experts' panels, such as unwanted leadership and high time cost [9]. Nevertheless, the inability of the Delphi method to make complex forecasts in which events are not isolated but interrelated is a limitation for scenario analysis. In a basic Delphi process the occurrence or not of an event was usually considered as if it had no effect on the rest of the event set.

Cross-Impact Analysis (CIA) [10] was developed to address this limitation. 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. Due to this ability of CIA to analyze complex contexts with various interactions, CIA is one of the most commonly-used techniques for generating and analyzing scenarios. Another success factor of the approach in scenario analysis is that it is a flexible methodology that can be combined with other techniques such as Delphi [11,12], Fuzzy [13] or Multi-criteria [14,15] methods to allow true collaborative model building and scenario creation by groups.

CIA is based on cross-impact questions that allow individuals to easily estimate the relationships among n events taken two at a time ($n(n\text{-}1)/2$ comparisons). It is an approximation to the real world where we do in fact recognize the further possibility of relationships among three, four, etc. events. This same approximation assumption is used in many other modeling areas such as measures of association and payoff matrices. For ten events a complete description among all possible interactions into the future of their occurrence would require gathering approximately ten million estimates [16]. This is calculated by following all possible occurrence sequences in a tree-like expansion for all possible sequences of events. No expert, manager, or team of judges would ever be able to undertake such an estimation process by Delphi or any other collaborative methods to do this. Many different approximation approaches to analyzing the more limited matrix model have been proposed such as an approximated Bayesian model [17] and an approximated systems dynamic representation [18]. There are even some very simplified approaches that directly solicit from experts the degree of impact between each interaction on an arbitrary scale (i.e. ++, +, 0, -, - -) and treat this as the degree of impact. Further discussions about different approximations approaches can be found in [12]. At the moment the method proposed by Turoff [16] is the only one that changes nonlinear probability measurement scales to linear interval measurement scales which makes it much easier for humans to view and understand the degree of influence one event has on other events as a consequence of their estimates. We observe that even for interactions among as few as ten events it is very unlikely that a single human can stay consistent when there is no feedback to show the consequences of the individual's estimates of impacts. To then combine the individual's judgments with the input from other estimators is not an activity that will lead to a trusted model of the situation. The need for improved visualization methods of all forms of complex data intended for supporting human decision processes is currently a major field of Information Systems and Science.

In this paper, a new method for building scenarios based on CIA is described. This method is an extension of Turoff's CIA approach [16]. We focus on this CIA approach because of its previously mentioned capability of transforming the nonlinear probability measures to linear interval variables, among other advantages:

1. The estimator supplies a set of probabilities for the n events which are indicative of the non-linear nature of the future occurrence of the events. The estimator is then told to assume the opposite of the initial estimate about each event (i.e. if he or she thinks it is likely, they assume it will not occur) and to indicate how the probabilities of all the other events would change.
2. Among other properties of Turoff's model of cross-impact is the result that all the n equations relating the probabilities to one another are solved for a single consistent set of factors that produces an equation for the outcome of each event based upon the values of all the other events. This provides an inferred consistency from the solution method and allows individuals to see the consequences of their model before it is merged with the data of others.
3. The most critical property is that these equations take the non-linear probability factors between 0 and 1 and convert them to linear factors between each event pair that vary from plus infinity to minus infinity for each pair of events, i and j. This

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