Major Extensions to Cross-Impact Analysis

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ABSTRACT

In recent years Cross-Impact Analysis (CIA) has resurged as a powerful tool for forecasting the occurrence or not of a set of interrelated events in complex situations, such as emergencies. In this sense, CIA can be used for creating working models out of significant events and crisis scenarios. CIA has been combined with other methodological approaches in order to increase its functionality and improve its final outcome. This is the case of the merger of CIA and the technique called Interpretive Structural Modeling (ISM). The CIA-ISM approach aims at contributing to CIA with tools for detecting critical events and supporting graphical representation of scenarios. In this paper, major extensions to CIA-ISM are presented. These extensions are based on the inclusion of initial condition events and outcome events as two new event types that make CIA-ISM much richer in its potential span of application areas. The practical implications of these major extensions to CIA-ISM are illustrated with an example. The usefulness of this contribution to researchers and practitioners concerned with emergency planning and preparedness is also discussed.

Keywords

Cross-impact analysis (CIA), interpretive structural modeling (ISM), scenarios, emergency planning, emergency preparedness.

INTRODUCTION

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 it is difficult to create explicit relationships among the events. In the field of emergency management scenarios are frequently used, especially in the planning process. Scenario-based planning in the field of emergency management is also known as contingency planning (UNHCR, 1996). This mode of planning is a dynamic process under situations of uncertainty, where scenarios and objectives are evaluated. Basically the role of scenarios in this planning mode is to anticipate events that may happen in case of crisis and analyzing their effects. Based on these scenarios, managerial and technical actions and structures with possible response systems are defined in order to prevent or improve response to these emergencies. So, a well constructed set of scenarios for crisis can help to identify in advance the pressing needs in case of crisis, as well as supporting planning for mitigation of the possible negative consequences.

Bañuls, Turoff and Lopez-Silva (2010) introduced the CIA-ISM approach in order to cluster scenarios using cross-impact analysis. This approach aims at allowing researchers and practitioners to obtain a set of plausible snapshots of the future as well as to analyze interaction between critical events in the time horizon. The CIA-ISM approach can have several applications in emergency planning and preparedness, given that it (1) can be applied to any emergency (2) is oriented to supporting the planning rather than the response process (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 indirect effects of a fire or an earthquake), providing a broader view of events which could happen in emergency situations (Bañuls et al., 2010).

In this paper some major extensions to the CIA-ISM approach are provided. These extensions are based on the inclusion of initial condition events and outcome events as two new event types that make CIA-ISM much

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richer in its potential span of application areas[1]. It is thus possible to tailor a single general model to be able to examine very different situations with different initial properties and different outcome goals. This extension will be illustrated with an 18 event problem of predicting the outcome of software development projects in very different organizational situations. The practical implications of these extensions for emergency planners are analyzed at the end of the paper. But, firstly, the basics of the CIA and ISM merger will be presented and analyzed in the following section.

METHODOLOGICAL BACKGROUND

CIA is based on the idea that events may be unique in that they can only happen once (i.e. a particular disaster and/or emergency) (Turoff, 1972). 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 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. The basic concept of CIA or ISM is 'structural modeling' where professionals who are knowledgeable about at least some portion of the event set can estimate relationships and/or subjective probabilities. This allows the computer to establish a consistent model for one individual or for a group of individuals. In Figure 1, our proposal for the methodological merger between CIA and ISM is shown. This proposal can be contextualized along with recent developments and applications of CIA (Weimer-Jehle, 2006; Choi, et al., 2007; Bañuls and Salmeron, 2007) and ISM (Wanga, et al., 2008; Kannan, et al., 2009; Lee, et al. 2010) that can be found in recent literature. In this approach, the structural matrix model is obtained from processing the C_{ij} and G_i factors. That is, the input of the ISM is the output of the CIA.

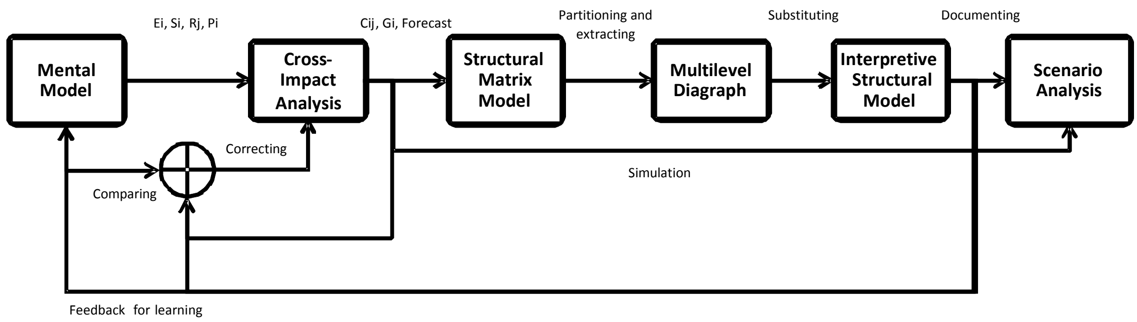

Figure 1. CIA-ISM process

For additional details please see (Turoff, 1972, Warfield, 1976; Bañuls, et al., 2010).

Some important factors allow us to extend this CIA-ISM approach to represent a much wider set of relationships than the original cross impact formalism:

- The Fermi Dirac distribution represents in Quantum Mechanics the distribution for whether an atom is in or is not in an excitation state. This is an event that occurs or does not occur. This is very analogous to the concept of whether an event occurs or does not occur in the future.
- The transformation allowed by this relationship converts a subjective probability estimate, a non linear parameter, to linear cross impact factors varying from plus infinity to minus infinity with the zero value reflecting a ".5" probability or an odds ratio of "1.0".
- The probability concepts in Quantum Mechanics reflect probability estimates of casual relationships that do not follow the probability calculus.

The result of the above is that we conceptually think about the C_{ij} and the G_i as linear influence factors that we may add and subtract to obtain additional measures of influences. What we have done is converted a non-linear

[1] Additional CIA-ISM issues are analyzed in Bañuls and Turoff (2011). This is a forthcoming paper that is going to be published in Technological Forecasting and Social Change, special issue on "The Delphi Technique" (summer 2011). This forthcoming paper gives more specifics on how to conduct related Delphi exercises and more on the theoretical and philosophical fundamentals of the CIA-ISM approach.

scale to a linear one. Not only does the above allow us to employ ISM to recognize meaningful scenarios among the original event set but it also allows us to view this method of CIA (Turoff, 1972) as scaling theory for subjective judgment in the sense that Torgerson (Torgerson, 1958) originally interpreted scaling theory.

A further observation in the classical probability literature is that the φ_i factors have been interpreted as "weight of evidence (WOE)" (Good, 1982), which implies an additive (linear) quality. Both probability and the measure of odds are highly non linear and they do not allow the easy visualization that the linear scale of the C_{ij} provided. If we accept the above viewpoints as the way to view this particular cross-impact approach, it becomes easy to conceptualize the following characteristics and extensions to the basic model. These are illustrated in the problem we have chosen as an example of these extensions.

- **Dynamic Events (E_i):** We have always assumed that the dynamic events could or could not occur during a certain time period. Within that time period, the factors we are estimating between E_i and E_j are measures that are valid during that time period. We also interpret the G_i as an expression of the influence on the *i*-th event of all the events we did not make explicit in the model we are creating.
- **Source Events (I_i):** One can also include source events, initial conditions, assumptions, or events that have already occurred for the problem being treated. In this case, all such source events are assumed to be .5 probabilities. When the model is applied to a given situation one can decide if the event has occurred or not occurred. No events in the set can influence the source events. Therefore if *k* is a source event all C_{ki}=0 for any other event type *i* as does G_k (to give the initial value of P_k = .5). Conversely, the estimator can judge the R_{ik} or S_{ik} for all the other events so that a C_{ik} can be determined (Turoff, 1972).
- **Outcome Events (O_i)**: These are events that occur at the end of the time period that measure the results of the system that is being modeled. For example, if one is measuring a conflict situation between two entities then one can define a probability of success for one entity which is one minus the probability of success of the other entity. In the example, we have chosen there will be a number of outcomes having to do with performance and cost measures. In this case, any of the source or dynamic events can influence these outcome events; however, the outcome events cannot influence the other events. If *k* is an outcome event all C_{ik}=0 for *i* events that are either source or dynamic. Conversely one can judge the R_{ki} or S_{ki} for *k* outcome events and *i* source or dynamic events.

CASE STUDY APLICATION

Since this will be a one person model rather than a composite by experts, we resort to a topic one of the authors has familiarity with, having taught it for a considerable number of years. The choice of events and the estimates for those events are by Dr. Turoff. Even today, there is considerable error in the predictions of the cost and performance of a software development process. A large percentage of software development projects end up to be failures in either the non-performance of the desired results for the users or in the much higher than estimated costs.

Events

The events of the model reflect a series of lectures to a graduate course in the Management of Information Systems. However, the model presented here does reduce a somewhat larger set of potential events to a set of 4 source events, 10 dynamic events, and 4 outcome events. This represents about 196 consistent estimates that must be made by a single estimator and is about twice the number needed for the original 1972 ten-event set. The problem of collaboratively treating the estimation of a larger set will be taken up after this example. We will only give a few explanations to illustrate the thinking that goes into such an event set. Our major goal here is to illustrate the expanded cross-impact modeling capability. The events below have a short title to be used in listing the analytical results.

Source Events

The Source events or the initial conditions that can be judged, usually to be true or false, at the beginning of the time period are:

- I1. Evaluation Organization: An evaluation unit exists outside of the existing computer services organization(s) (indicates a time in the past when the computer operation ran amuck and a formal control group had to be established).

- I2. Minimal Internal Development: The organization has a general management policy of using off the shelf software where possible (indicates limited ability to develop new applications internally).
- I3. Management Computer Literacy: Management is expected to be computer literate in Decision Support Applications (indicates some significant degree of computer literacy for all levels of management).
- I4. Technology oriented: The organization deals with technological products and/or services (indicates some significant degree of computer literacy for most types of professionals).

The degree to which each of the above is true or false about the organization gives some much needed background about what types of problems can or cannot occur. By knowing the organization one can reset the .5 probability in the final model to higher or lower values and see the impact upon the results.

Dynamic Events

The dynamic events are the core of the modeling process and their initial values are chosen to reflect current wisdom about their likelihood. They are also chosen to provide a balanced model where possible negative influences as well as positive influence events are somewhat equally represented. A good cross impact model should reflect a range of outcomes from desirable to undesirable, depending to some extent on choices available to the management of the organization being modeled.

- E1: Requirements by Management: A management Committee decides on the final requirements for the system.
- E2: Requirements by computing professional: A professional software engineer decides on the final requirements for the system.
- E3: Requirements by users: A sizable requirements study effort involving significant user participation determines the requirements.
- E4: Modification of existing software by organization: An existing application package is purchased and modified by the organization to meet the requirements.
- E5: Modification of existing software by supplier: An existing application package is purchased and modified by the supplier to meet the requirements.
- E6: Prototype first: A prototype is developed and tested by the users in parallel with the existing system.
- E7: Evolutionary Development: An evolutionary or incremental approach is taken for the development of the system.
- E8: Upfront Cost-Benefit study: A detailed cost-benefit study is undertaken before requirements are fully developed.
- E9: Cost-Benefit after requirements: A detailed cost-benefit study is done after the requirements are specified.
- E10: Evaluation of Existing Applications: Regular evaluation and modification studies are typical of existing software applications in this organization.

Clearly this is a top level set of some of the most important and obvious considerations that affect the outcome of a software development process. There are many more factors that can be brought in but it would really require collaboration where different contributors would focus on the estimates that represent the factors that they feel confident in dealing with.

Outcome Events

We have specified two typical negative outcomes followed by two positive ones. These reflect both the effectiveness vs. efficiency paradox and the difference between long and short term considerations.

- O1: Development Costs: Development costs significantly exceed original estimates.
- O2: Maintenance Costs: Maintenance costs significantly exceed original estimates.
- O3: Effectiveness: System is considered a success by both the direct and indirect users of the system's outputs.
- O4: Low Life Cycle costs: The life cycle costs are low for this type of application.

In most cases the first two are more likely Pi =.6 than the latter two Pi =.4 and you will note the initial values for those reflect that difference.

Cross-Impact Analysis

Once we obtain the subjective probabilities, we are able to build the cross-impact matrix (Table 1).

	I1	I2	I3	I4	E1	E2	E3	E4	E5	E6	E7	E8	E9	E10	O1	O2	O3	O4
I1	OVP	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
I2	0.00	OVP	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
I3	0.00	0.00	OVP	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
I4	0.00	0.00	0.00	OVP	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
E1	-1.08	4.47	-2.70	-1.08	OVP	-0.39	-3.44	0.74	0.59	-2.63	-2.79	2.26	0.98	-2.48	0.00	0.00	0.00	0.00
E2	-0.46	-0.96	-1.53	-1.53	-1.10	OVP	-3.09	2.86	-0.64	0.56	-1.28	1.37	0.42	0.85	0.00	0.00	0.00	0.00
E3	1.53	-0.43	3.16	1.53	-1.46	-1.26	OVP	0.00	0.00	3.31	3.52	-2.67	1.13	2.62	0.00	0.00	0.00	0.00
E4	-1.39	3.58	0.00	4.28	0.00	-0.68	-1.25	OVP	0.00	-2.11	0.00	-0.59	-2.28	-1.39	0.00	0.00	0.00	0.00
E5	-0.58	6.59	0.96	1.80	0.00	-1.69	-3.82	0.00	OVP	-2.92	-3.54	0.34	-3.54	-2.16	0.00	0.00	0.00	0.00
E6	2.42	-1.27	0.93	0.93	-1.90	0.71	3.29	0.00	0.00	OVP	2.68	-3.44	3.15	0.99	0.00	0.00	0.00	0.00
E7	1.62	-1.96	3.12	1.62	-0.77	1.25	3.44	-1.63	0.00	3.26	OVP	-4.78	1.78	3.98	0.00	0.00	0.00	0.00
E8	0.00	0.96	1.39	0.96	0.36	0.74	-5.07	0.80	0.00	-2.29	-3.11	OVP	-5.99	-2.76	0.00	0.00	0.00	0.00
E9	1.29	-0.80	1.80	0.84	-1.17	1.38	0.00	0.70	0.00	1.23	-0.81	-0.81	OVP	-1.32	0.00	0.00	0.00	0.00
E10	-1.62	-2.70	1.49	1.49	-3.72	1.15	5.07	-1.35	0.00	4.22	6.43	-3.47	3.26	OVP	0.00	0.00	0.00	0.00
O1	-0.88	1.62	-1.96	-0.88	0.58	-1.51	0.68	0.00	1.08	0.52	-2.24	0.54	-1.47	-1.39	OVP	0.00	0.00	0.00
O2	-1.96	3.58	-1.96	-1.96	0.58	-1.51	-1.25	1.35	1.08	-1.47	-2.24	0.54	0.00	-1.39	0.00	OVP	0.00	0.00
O3	1.96	-1.62	1.96	3.58	-0.58	0.68	2.76	-1.35	-1.08	2.11	2.24	-0.54	1.47	1.99	0.00	0.00	OVP	0.00
O4	3.58	-1.62	1.96	3.58	-0.58	0.68	2.76	-1.35	0.00	1.47	3.25	-0.54	0.00	1.99	0.00	0.00	0.00	OVP
Gi	0.00	0.00	0.00	0.00	0.68	2.35	-1.64	-0.03	1.85	-2.99	-2.19	3.95	-1.54	-1.42	1.75	1.35	-3.95	-5.01

Table 1. Cross Impact Matrix and *G* vector

In order to get a numerical estimate of the total variability in the matrix of influence factors we examine the following linear sums of C_{ij} for the original C_{ij} matrix

$$|\text{Source Events Influences}| = \sum|C_{iI}| = 103.53 \quad (1)$$

$$|\text{Dynamic Events}| = \sum|C_{ij}| - \sum|C_{iI}| = 213.83 \quad (2)$$

$$|\text{External (unspecified) Event influences}| = \sum|G_i| = 30.69 \quad (3)$$

In the original model the total of all influences is

$$|\text{Total Impacts}| = \sum|C_{ij}| + \sum|G_i| = 348.07 \quad (4)$$

This allows us to calculate the relative fractions or percentages of the impacts due to each type of event.

$$|\text{Source events impact}| \,/\, |\text{Total Impacts}| = 0.30 = 30\% \quad (5)$$

$$|\text{External events Impacts}| \,/\, |\text{Total Impacts}| = \sum|G_i| \,/\, (\sum|C_{ij}| + \sum|G_i|) = 0.09 = 9\% \quad (6)$$

Therefore, only 9% of the influences are due to the events we did not specify. The dynamic events make up 61% of the influences. We see that the source and the unknown external events account for 39% of the influence and the dynamic events of the model account for 61% of the influence.

Scenario Analysis

By applying the CIA-ISM approach described in the section 3 we can represent the forecasted scenario by means of a diagraph (Figure 1). The limit of this forecasted scenario is $|C_{ij}|=1.69$, so it includes the 42.77% of the C_{ij} and the 61.97% of the linear sums of C_{ij}.

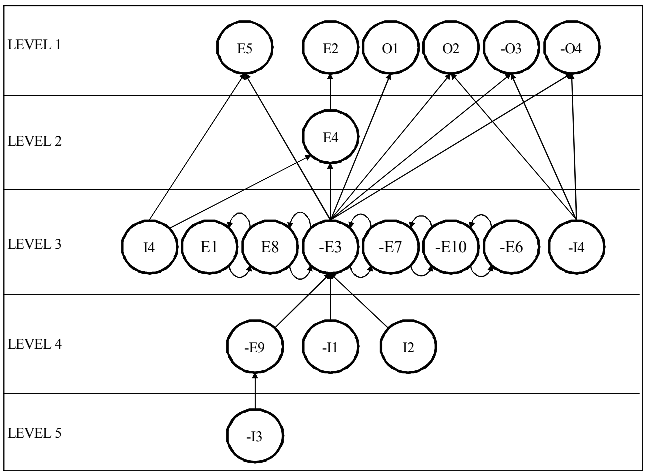

Figure 1. Diagraph for $|C_{ij}|$ >1.69

We obtain the same result by means of the simulation when we make the probability of the source events I1=0.01, I2=0.99 and I3=0.01 (Table 2). Regarding the source event I4, we obtain the same result when probability is I4=0.99 (Table 2) or I4=0.01 (Table 3). That is, we obtain the same result of the graphical resolution. This seems to verify the perturbation approach as providing a valid analysis of the influence implications for final outcomes.

EVENTS	Pi	STEP1	STEP2	STEP3	STEP4	STEP5	STEP6	STEP7	STEP8	STEP9	STEP10	STEP11	STEP12	STEP13	STEP14
I1	0.010	0	0	0	0	0	0	0	0	0	0	0	0	0	0
I2	0.990	1	1	1	1	1	1	1	1	1	1	1	1	1	**1**
I3	0.010	0	0	0	0	0	0	0	0	0	0	0	0	0	0
I4	0.010	0	0	0	0	0	0	0	0	0	0	0	0	0	0
E1	0.700	0.997	0.999	1	1	1	1	1	1	1	1	1	1	1	**1**
E2	0.650	0.876	0.929	0.975	0.974	0.973	0.973	0.973	0.973	0.973	0.974	0.974	1	1	**1**
E3	0.350	0.011	0.002	0.001	0.001	0.001	0.001	0	0	0	0	0	0	0	0
E4	0.600	0.696	0.914	0.894	0.892	0.891	0.891	0.891	0.891	0.891	0.891	0.891	0.889	0.907	**1**
E5	0.750	0.972	0.999	0.999	0.999	0.999	0.999	0.999	0.999	1	1	1	1	1	**1**
E6	0.150	0.007	0.001	0	0	0	0	0	0	0	0	0	0	0	0
E7	0.200	0.002	0	0	0	0	0	0	0	0	0	0	0	0	0
E8	0.850	0.664	0.997	0.998	0.998	0.998	0.998	0.998	0.998	0.998	1	1	1	1	**1**
E9	0.450	0.075	0.087	0.083	0.087	0.086	0.086	0.086	0.086	0.086	0.086	0.086	0.089	0	0
E10	0.010	0	0	0	0	0	0	0	0	0	0	0	0	0	0
O1	0.600	0.964	0.981	0.983	0.982	0.982	0.982	0.982	0.982	0.982	0.982	1	1	1	**1**
O2	0.600	0.995	0.999	0.999	0.999	0.999	0.999	0.999	1	1	1	1	1	1	**1**
O3	0.400	0.005	0	0	0	0	0	0	0	0	0	0	0	0	0
O4	0.400	0.002	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 2. Forecasted Scenario – Simulation for I1=0.01, I2=0.99, I3=0.01 and I4=0.01

Occuring Events Summary: I2 -> E1, E2, E4, E5, E8 -> O1, O2 (7)

EVENTS	Pi	STEP1	STEP2	STEP3	STEP4	STEP5	STEP6	STEP7	STEP8	STEP9	STEP10	STEP11	STEP12	STEP13	STEP14
I1	0.010	0	0	0	0	0	0	0	0	0	0	0	0	0	0
I2	0.990	1	1	1	1	1	1	1	1	1	1	1	1	1	1
I3	0.010	0	0	0	0	0	0	0	0	0	0	0	0	0	0
I4	0.990	1	1	1	1	1	1	1	1	1	1	1	1	1	1
E1	0.700	0.993	0.999	0.999	0.999	1	1	1	1	1	1	1	1	1	1
E2	0.650	0.603	0.883	0.915	0.917	0.917	0.917	0.917	0.918	0.918	0.918	0.918	0.918	1	1
E3	0.350	0.050	0.009	0.004	0.004	0.004	0.004	0.004	0	0	0	0	0	0	0
E4	0.600	0.994	0.998	0.998	0.998	0.998	0.998	1	1	1	1	1	1	1	1
E5	0.750	0.995	1	1	1	1	1	1	1	1	1	1	1	1	1
E6	0.150	0.018	0.001	0.001	0	0	0	0	0	0	0	0	0	0	0
E7	0.200	0.008	0	0	0	0	0	0	0	0	0	0	0	0	0
E8	0.850	0.838	0.998	0.999	0.999	0.999	1	1	1	1	1	1	1	1	1
E9	0.450	0.157	0.141	0.172	0.178	0.179	0.178	0.179	0.179	0.179	0.179	0.179	0.179	0.196	0
E10	0.010	0	0	0	0	0	0	0	0	0	0	0	0	0	0
O1	0.600	0.916	0.970	0.959	0.955	0.955	0.955	0.955	0.955	0.954	0.954	0.954	1	1	1
O2	0.600	0.967	0.996	0.994	0.994	0.994	0.994	0.994	0.994	1	1	1	1	1	1
O3	0.400	0.163	0.010	0.009	0.009	0.010	0.010	0.010	0.009	0.009	0.009	0	0	0	0
O4	0.400	0.079	0.008	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0	0	0	0	0

Table 3. Forecasted Scenario – Simulation for I1=0.01, I2=0.99, I3=0.01 and I4=0.99

Ocurring Events Summary I2, I4 -> E1, E2, E3, E4, E5, E8 -> O1, O2 (8)

Table 4 is useful for understanding the graphical results and also for the estimator to understand better the implications and consistency of his or her estimates. In this case, it makes quite clear what the estimator thought. Having management set the requirements is clearly not a good thing in the view of the estimator.

J Event ID	Short title E_j	C_{ij}	$C_{ij}*P_j$
I2	Minimal Internal Development	4.47	2.23
E8	Upfront Cost-Benefit study	2.26	1.69
E9	Cost-Benefit after requirements	0.98	0.44
E4	Modification of existing software by organization	0.74	0.44
E5	Modification of existing software by supplier	0.59	0.44
E2	Requirements by computing profesional	-0.39	-0.25
I1	Evaluation Organization	-1.08	-0.54
I4	Technology oriented	-1.08	-0.54
E10	Evaluation of Existing Applications	-2.48	-0.25
E6	Prototype first	-2.63	-0.39
I3	Management Computer Literacy	-2.70	-1.35
E7	Evolutionary Development	-2.79	-0.56
E3	Requirements by users	-3.44	-1.20

Table 4. E1- Requirements by Management (Ordered Influences Table)

He (in this case) feels that a company that does little internal development is likely to use this approach to such an extent that the initial condition I2 is about twice the influence weight (4.47) as the second most important factor, that of doing a Cost-Benefit Study before there are any user or detailed requirements (2.26). The next three positive influences are all less than 1/2 the magnitude of this.

The negative influence factors start with E3 (-3.44) which is clearly contradictory to E1 and is followed by many items that would influence alternatives to develop requirements. Note the only events not involved, by definition, are the outcome variables which have zero influence factors on all the other events, as indicated by blanks for values to allow better visualization. The second column shows the actual weight applied because of the values for P_j multiplying the influence factors. This does not change the relative amounts much for the positive influences but makes the third negative influence most important. The idea is that computer literacy on the part of management might change their minds about designing the requirements without inputs from the employees that are going to actually use the system.

The next example shows the analysis of the relationship between the outcome of very large maintenance costs (O2) being highly influenced by the initial condition (I2) of minimal internal developments. This is so powerful that the first three graphs, which represent 30% of the largest C_{ij} factors, show no interaction with any of the internal events for this singular influence of I2 on O2.

J Event ID	Short title E_j	C_{ij}	$C_{ij}*P_j$
I2	Minimal Internal Development	3.58	1.79
E4	Modification of existing software by organization	1.35	0.81
E5	Modification of existing software by supplier	1.08	0.81
E1	Requirements by Management	0.58	0.41
E8	Upfront Cost-Benefit study	0.54	0.41
E9	Cost-Benefit after requirements (No Impact)	0.00	0.00
E3	Requirements by users	-1.25	-0.44
E10	Evaluation of Existing Applications	-1.39	-0.14
E6	Prototype first	-1.47	-0.22
E2	Requirements by computing profesional	-1.51	-0.98
I1	Evaluation Organization	-1.96	-0.98
I3	Management Computer Literacy	-1.96	-0.98
I4	Technology oriented	-1.96	-0.98
E7	Evolutionary Development	-2.24	-0.45

Table 5. O2 - Large Maintenance Costs (Ordered Influences Table)

Classically, when an organization does not do internal development it becomes fully dependent on an outside supplier for the software and for any changes that need to be made to that software. Such suppliers, once they capture such a customer, will tend to increase the cost of 'fixes' over time.

This is likely especially if there is no talent in the company to carefully investigate and determine the design changes needed and how they would be implemented so that a well specified technical request could be sent to other suppliers. We see here the influence factor for I2 has a large positive impact on O2 relative to all the other factors, negative or positive. In addition, when one multiplies by the initial P_j's the contrast is even larger, given the much lower negative factors.

Clustering Summary

Looking at the figure 1, we have the following cluster possibilities:

$$(((E8, E1), (-E10, -E7)), (-E3, -E6)) \quad (9)$$

If one is trying to replace the original 10 internal events with a simpler model, then one can choose to cluster any of the three doublets, one 4 event inner model and a doublet, or all six events into one mini-scenario. The decision to do this in the case of this management problem should depend on the following:

- Are any of the possible mini scenarios independent of management control or actions? If so, there is no reason not to create the mini scenario to reduce the complexity of the overall problem.
- Are any of the possible mini scenarios influenced by the same influencing events? If so, they can also be turned into mini scenarios.
- Management can decide to take actions that make the events in the chosen mini scenarios to be true, whether the events consistently occur or don't occur according the combined scenario.

Note that in the final model and the forecasted model the only dynamic event influencing the full scenario above is E9 (Cost benefit after requirements). The other influencing factors are three of the Initial Conditions. I3 does influence E9. Changing initial conditions is usually a strategic decision that may take more time and effort than the internal events that are controllable.

If a new reduced cross impact model is to be composed it will treat each chosen mini-scenario as a single event. It may also be that the user or users of this model decide they need to create some new events to describe potential increased control over the outcomes of the model. This would be normal in terms of any use of the model in a continuous planning process.

Outcome Events Analysis

We use the process of the perturbation simulation to calculate the outcome of all the events. We take each source or internal event and set each one in turn to a value of .01 and then to a value of .99. In the perturbation model approach (Turoff, 1972) this causes that event to either occur or not occur first in the sequence, causing the other events affected to change their values and then take the one closest to 0 or 1 to next occur. The process continues until all the outcomes are determined.

The outcome events are divided into two bad outcomes (O1 and O2) where development costs and maintenance costs greatly exceed the forecast amounts. The good outcomes (O3 and O4) are user acceptance and low life cycle costs. The following table shows for each event whether the occurrence or non occurrence of that event cause the good outcome or the bad outcome to occur. This is a summary of a large number of different runs of the model. Note that certain events do not matter and these are E2, E4, and E5. Reviewing figure 1 helps to understand the specific influence paths and underlying logical clusters or mini-scenarios leading to this result.

We note from the final diagrams that E2, E4, and E5 are essentially behaving as a set of three outcome variables, so that it is not strange that they do not behave in the same manner as the other variables. They have no direct influence on the outcome variables.

Event	Good Outcome +O3 and +O4 -O1 and –O2	Bad Outcome +O1 and +O2 -O3 and –O4
Source/Initial Events		
I1. Evaluation Organizations	+I1	-I1
I2. Minimal Internal Development	-I2	+I2
I3. Management Computer Literacy	+I3	-I3
I4. Technology Oriented	+I4	-I4
Internal Events		
E1. Requirements by Management	-E1	+E1
E2. Requirements by Computer Professional		+E2 –E2
E3. Requirements by Users	+E3	-E3
E4. Modification of Existing Software by organization		–E4+E4
E5. Modification of Existing Software by Supplier		+E5 –E5
E6. Prototype first	+E6	-E6
E7. Evolutionary Development	+E7	-E7
E8. Upfront Cost Benefit Study	-E8	+E8
E9. Cost-Benefit after requirements	+E9	-E9
E10. Evaluation of Existing Applications	+E10	-E10

Table 6. Outcome Events Analysis

CONCLUSIONS

The days of discrete, periodic long term plans and short term plans are numbered. Planning today for the emergency manager has to be made a continuous process. One needs to integrate the type of model described here into a complete planning environment. In this sense, planning should not be a discrete event in emergency management. Planning must also be a highly participative process by all the actors involved in emergencies. The CIA-ISM approach aims at contributing to this goal through allowing the collaborative development of scenarios out of much larger event sets, and this ultimately reduces the complexity for estimating a working model. The authors' proposal aims at providing 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.

This contribution is especially relevant in the field of emergency planning and preparedness. This is because of there is a lack of foresight methods developments in these fields aimed at supporting scenario generation and analysis. In emergency management, the existing scenario simulation methodologies are focused on simulate the effect of a specific natural (i.e. earthquakes, floods) or man-made (industrial crisis) disaster. Nevertheless these approaches do not include expert estimations about other factors that cannot be measured quantitatively (human and societal factors). The integration of these non quantitative factors is critical in the emergency plans. In this sense, this research aims at addressing the growing necessity for foresight tools that allows emergency planners to detect and mitigate a wider scope of risks and threats.

Currently CIA-ISM research is being applied in several research areas, some of them in the Emergency Management field. This is the case for TIPEx, a collaborative research project among three universities in Spain. The main purpose of this project is to study different information technology techniques, and their use in prototypes, in order to facilitate the definition of and training for the implementation of emergency plans, based on the use of realistic scenarios. At this point we are studying with the practitioners different realistic scenarios in order to know and understand the different factors which are involved in the definition of the plan and how different actors participate in it. We are trying is to demonstrate the ability to create a working model of the scenario, based on CIA-ISM, that may be used to examine the consequences of various assumptions about preparedness, plans, and the actions taken during the event. It may be used as either a planning tool and/or a training tool. It is based upon the judgments and estimates of knowledgeable people in creating the interacting elements and judging the relative impact they have upon one another to influence the probability of a degree of truth about assumptions, actions, events, and/or outcomes. There are specific events that deal with public reactions and their degree of trust in the leadership as part of our current model.

On the other hand we are focusing our current research in how using dynamic scenarios as collaborative tool to help emergency planners to understand the needs of specific emergency situations that include teams, roles, situations, and actions. A dynamic scenario exercise is one in which an initial scenario is presented describing a possible situation, and then various assumptions are specified as being relatively true or false. This triggers the inference of the impact of these on the relationships in the model to determine which situations and actions are likely to occur and the resulting impact on various outcomes. In this sense we are applying CIA-ISM methodology to develop dynamic emergency scenarios based upon soliciting inputs for the interactions so we can provide a working example to encourage emergency planners to develop their own models for the risks they are most concerned about. In table 7 examples of the definition of the different kinds of events (source, dynamic and outcome events) could be found. These events are taken from a hypothetic dirty bomb attack scenario that we are currently designing along with Professor Starr Roxanne Hiltz and Dr. Alvaro Pemartin.

Event type	**Name of the Event**	**Description** (from a total of 34 events (8SE 20DI 6OE)
Source Event	Detection Preparedness	There are at least one hundred radiation detectors and trained people that can be supplied quickly to check people for contamination.
	Public Trust	The public trusts the decisions of the local leadership and will follow their requests for behavior in emergencies.
Dynamic Event	Bomb recognition	A fireman with training recognizes bomb fragments within the first hour after the explosion.
	Public Panic	There is a rush to leave the city by any means possible as public panic sets in.
Outcome Event	Income Loss	The short term (including loss of income) costs of this event to the national economy are estimated to be more than ten billion Euros.
	Public Trust	The public is extremely cooperative and trusting in the advice and directions of the city leadership.

Table 7. Dirty bomb scenario events

This application is aimed at sensitizing responders and decision makers to the details that would mean the difference between a successful and a non successful response as well as providing emergency planners a model that that allows them to test different conditions and decisions in terms of their consequences for outcomes.

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