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Analyzing Stakeholders Using Fuzzy Cognitive Mapping

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Abstract

Stakeholder analysis was first explored as a methodology to assist business leaders with their strategic management functions. Stakeholder analysis has since expanded beyond the corporate arena. Stakeholders are a vital element in all complex systems problems; they are the customers, users, clients, suppliers, employees, regulators, and team members of a system. They fund a system, design it, build it, operate it, maintain it, and dispose of it. Each stakeholder contributes their own value-added perspective, as described by the systems principle known as complementarity. While many approaches exist for classifying and determining their attitudes, these approaches stop short of evaluating stakeholders in a holistic and dynamic manner. This paper closes this research gap by discussing an approach to managing stakeholders using fuzzy cognitive mapping, an approach which allows for qualitative and quantitative evaluation of stakeholders on a given problem. The developed approach extends previous work by the author to showcase how stakeholders may be mapped holistically and dynamically.

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Keywords: *Stakeholders; stakeholder analysis; fuzzy cognitive mapping*

1. Introduction

Shareholder theory, or the theory that corporations are strictly beholden to their shareholders and thus, driven entirely by financial objectives, was championed by Milton Friedman [1]. Seen by many as too myopic a viewpoint, this perspective was later broadened to include all stakeholders with the development of R. Edward Freeman's stakeholder theory [2]. Freeman's view was founded in corporate social responsibility, coupled with financial responsibility, as complementary perspectives to consider in running a business. This viewpoint has since broadened beyond the corporate arena and is now considered an essential part of many complex problem solving

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endeavors [e.g., 3]. Freeman's view of stakeholders includes customers, users, clients, suppliers, employers, regulators, and team members of a system. They represent those individuals and organizations that fund a system, design it, build it, operate it, maintain it, and dispose of it. The systems perspective of complementarity [4], stating that each individual brings a unique and value-added perspective to the analysis of a problem, supports Freeman's broader perspective. This paper first explores stakeholder analysis in the literature. It then discusses the mathematical technique of fuzzy cognitive mapping and how it may be applied to the analysis of stakeholders. Next, an illustrative example is presented to demonstrate the proposed approach. Finally, some conclusions are drawn about the proposed approach moving forward.

2. Stakeholder Analysis

Stakeholder analysis and management is essential to successful problem solving. In order to identify appropriate strategies for dealing with stakeholders, we must first consider "the principle of who or what really counts" [5]. From this principle, Mitchell, et al. [6] question, ". . . who (or what) are the stakeholders of the firm? And to whom (or what) do managers pay attention?" This is a brainstorming exercise that forces us to ask who the relevant stakeholders are for our problem. Once we've identified our stakeholders, we may analyze them. It is crucial that we understand stakeholder attitudes with respect to our problem. Stakeholders, of course, can be supportive, unsupportive, or indifferent, with respect to our effort. This is supported by Savage, Nix, Whitehead, and Blair [7], who discuss the importance of stakeholder attitudes and coordinating strategies for dealing with them based on their attitude. Failure to consider stakeholder attitudes poses the risk of over-involving individuals to the potential detriment of our project. Savage, Nix, Whitehead, and Blair [7] devote specific attention to this caution. They warn of converting previously supportive individuals to a non-supportive role. Further, practicality of resource constraints must be considered. We have limited resources in which to accomplish a project's goals. Efficient and effective use of stakeholder analysis and engagement will assist in this matter. Poor use of resources with respect to stakeholders runs the risk of derailing our entire project. Quantifying stakeholder attitudes for use in fuzzy cognitive maps can take the form of a scale similar to that shown in Table 1.

Table 1: Notional Scale for Attitude Evaluation

Attitude	Value
Extremely Non-Supportive	-1
Strongly Non-Supportive	-0.67
Mildly Non-Supportive	-0.33
Mixed or Marginal	0
Mildly Supportive	+0.33
Strongly Supportive	+0.67
Extremely Supportive	+1

Further complicating stakeholder analysis is the fact that stakeholders don't exist in a bubble. That is to say, they are part of a large network and the influence of each may be felt with respect to many others. As such, they must be considered more holistically, as in [8] using input-output modeling and in [3], using network theory. This paper proposes an alternative to previous methods for stakeholder analysis by exploring the use of fuzzy cognitive mapping as a mechanism for evaluating stakeholders in a manner that can account for the dynamic and network-centric behavior of stakeholders. Use of fuzzy cognitive mapping enhances limitations of previous stakeholder analysis work [e.g., 3 and 8] that did not capture the dynamic and holistic behavior of stakeholder interactions. We now turn to an introduction to fuzzy cognitive mapping.

3. Fuzzy Cognitive Mapping

Fuzzy cognitive mapping was introduced by Kosko [9], based on the work of Axelrod [10] as a way to visually and logically capture the relationships between elements in a problem. Fuzzy cognitive maps (FCMs) are network-based collections of concepts (represented as nodes) and causal relationships (represented as arcs between the concepts). Arcs have weights that indicate both the strength and direction of a causal relationship; thus, a given relationship can be increasing or decreasing (i.e., A increases B or A decreases B).

Concepts can represent variables in a system [see, e.g., 11], with concept values defined on [0,1] as their value relative to the defined range for the given variable (i.e., 50% for a valve status means 50% open) and arc weights can be defined on [-1,1] to represent direction (positive weights are reinforcing; negative are decreasing) and magnitude of influence (a weight of one means complete influence of one concept over another, whereas a weight of zero indicates no connection between two concepts). Concepts can also represent system performance measures [see, e.g., 11], where causal relationships show the effect of increasing or decreasing a given performance measure on others.

Mathematically, the concepts within a FCM can be represent by a matrix C, the relative activation level of each concept can be represented by a matrix A, and W can represent the matrix of weights where each element w_{ij} represents the influence of concept i on j. Within the context of stakeholder analysis, C represents relevant stakeholder's attitudes, W the relative influence of each stakeholder on one another (quantified using Table 1), and A represents initial conditions (i.e., attitudes) spurred by "what-if" scenarios intended to be explored by the analyst. "An FCM can be considered as a type of recurrent artificial neural network" [11]. Thus, FCMs evolve over time and can be analyzed relative to this evolution. Time step t+1 can be evaluated using information from the previous time step, t, as:

$$A(t+1) = f(A(t)W) \quad (1)$$

where f is known as a transfer function used to evolve the FCM from one time stamp to the next. This transfer function typically takes on one of the following three forms: 1) binary, 2) trivalent, or 3) sigmoid. Tsadiras [11] provides additional details on each of the three transfer functions as well as the following guidance on the appropriateness of each:

"(i) Binary FCMs are suitable for highly qualitative problems where only representation of increase or stability of a concept is required.
(ii) Trivalent FCMs are suitable for qualitative problems where representation of increase, decrease or stability of a concept is required.
(iii) Sigmoid FCMs are suitable for qualitative and quantitative problems where representation of a degree of increase, a degree of decrease or stability of a concept is required and strategic planning scenarios are going to be introduced." [11]

While it is beyond the scope of this paper to illustrate use of the various transfer functions, the reader is referred to Tsadiras [11] for guidance on the implementation of each. This paper uses a sigmoid transfer function in order to capture the richness of relationships between stakeholders. That is to say, they are able to capture the highest level of detail and thus, provide the most feedback to the individual using them, when compared with either the binary or trivalent functions.

The following section will illustrate this approach on a sample real estate example first introduced in [6].

4. Illustrative Example

This example extends the example presented in [6] and continued in [3]. It concerns a real estate developer's desire to rezone a parcel of land from single family homes to condominiums. The main conflict resides in the opposition of nine local communities, who oppose the rezoning due to perceived loss of property values, as well as general inconvenience of the project. The analysis is undertaken from the perspective of the developer, who is seeking to analyze the support of relevant stakeholders. The influence matrix, W, developed in [3], is recreated here as Table 2 with signs added to demonstrate direction of influence (i.e., positive or negative).

Table 2: Weight Matrix for Stakeholder Problem

	The real estate developer	City Staff	City Planning Commission	City Council	Local media	Nine local communities
The real estate developer	0	0	0.25	0.25	0	-0.25
City Staff	0	0	0	0	0	0
City Planning Commission	1	0	0	0.5	0	0
City Council	0.5	0.5	0.25	0	0	0
Local media	0	0.25	0	0.25	0	0
Nine local communities	-0.5	0	-0.5	-0.5	-0.25	0

We can undertake some interesting "what-if" analyses using FCM. As the developer, we can first explore answers to the question, what if the only support we can garner is from ourselves? Couple this with the perceived lack of support from the nine local communities and these results are shown in Figure 1. Of note is the fact that seeking only support from the real estate developer may be problematic, given that they may have identified the nine local communities' support as crucial to the success of their project and their support alone is not enough to persuade the nine local communities to change their mind. This is not suprising as the communities opposed the project on the ground of decreased property values and increased noise, pollution, and general nuisance, elements the developer would likely ignore in trying to persuade the communities to support their efforts.

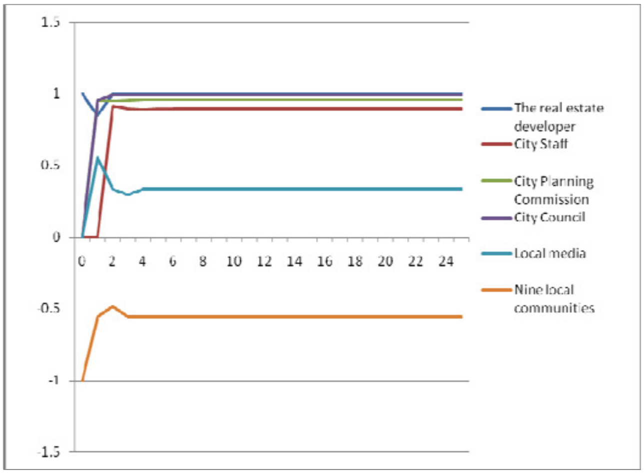

Figure 1: Results of Developer-Only Support Scenario

What if the developer works to ensure the nine local communities are supportive? These results are shown in Figure 2. This has an unanticipated negative effect. Garnering the support of the communities, while ignoring the other stakeholders, leads to an environment in which only the communities are supportive and all other stakeholders are not. This is due to the relationship between the communities and the other stakeholders, with the communities having a negative effect on its fellow stakeholders, as shown in Table 2. This is clearly not an enviable scenario either.

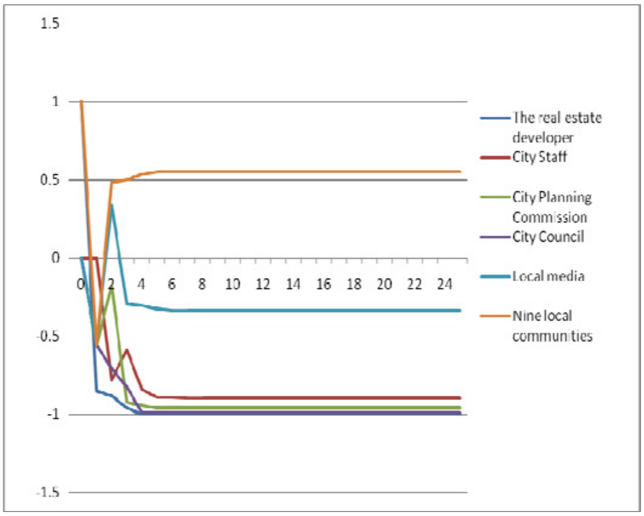

Figure 2: Results of Developer and Community Support Scenario

Exploring any one of a number of other candidate scenarios yields only those steady states shown in either Figure 1 or Figure 2. Even garnering complete support from everyone at the outset does not ensure all stakeholders remain supportive; given the relationship between stakeholders, this is not a surprise. The only way in which the nine local communities can remain neutral without disturbing the support of others is to change the underlying relationships between the stakeholders. That is, we must change the W matrix (and of course, change the actual nature of this relationship). If we can improve the influence of the real estate developer on the communities to neutral (rather than a negative relationship), then the nine local communities will remain neutral, which is a marked improvement from their current state of opposition to the development effort. This scenario is shown in Figure 3. At least in this scenario, with the nine local communities not seeing the developer as a negative influence, they remain neutral in the development project; this is a start toward improved relations and project success.

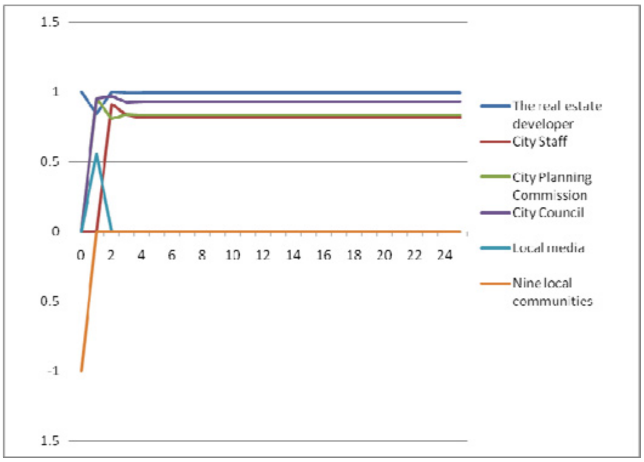

Figure 3: Results of Neutral Influence Scenario

These scenarios illustrate the breadth of stakeholder analysis possible with FCM. FCM allows for the developer to perform numerous "what-if" scenarios and explore potential situations in an effort to ensure the best chance of success for this effort. This allows for the developer to focus on what is really important to the success of this project, namely, improving the nature of their relationship with the nine local communities.

5. Conclusions

Because stakeholders are the engine that drives our system development efforts, we must formally consider them during the analysis of our problem solving efforts. It is not enough, however, to merely consider their behaviors and relationships at a snapshot-in-time; rather, we must consider them dynamically. To this end, this paper developed a fuzzy cognitive mapping-based approach to stakeholder analysis. This approach allows for "what-if" analysis to be conducted in a manner that supports stakeholder analysis for problem solution efforts.

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