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Determining Stakeholder Influence Using Input-Output Modeling

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Abstract

Stakeholders are a vital element in all complex systems problems. They are customers, users, clients, suppliers, employees, and team members. They fund the system, design it, build it, operate it, use it, maintain it, and dispose of it. While many approaches exist for classifying and determining their attitudes, these approaches stop short of evaluating stakeholders in a holistic manner. This paper closes this research gap by developing the metric of stakeholder situation influence, a measure which allows for quantitative evaluation of stakeholder influence on a given problem. This measure is derived from Leontief Input-Output analysis. The developed approach extends previous work by the authors to showcase how stakeholders may be mapped holistically in a manner that serves to improve scenario situational awareness and support resource allocation decisions.

Keywords: Stakeholders, stakeholder influence, stakeholder mapping, Leontief Input-Output model

1. Introduction

Stakeholder analysis was first explored by Freeman [1] as a methodology to assist business leaders with strategic management functions. Stakeholder analysis has since expanded beyond the corporate arena. Stakeholders exist at the center of any complex problem solving effort and holistic consideration of them is a key element of analyzing a problem systemically. Stakeholders 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 [2].

Appropriate stakeholder analysis and management is essential is to understanding complex systems. In order to determine our strategies for dealing with stakeholders, we must undertake a proper stakeholder analysis, by first considering "the principle of who or what really counts" [3]. From this principle, Mitchell, et al. [4] question, ". . . who (or what) are the stakeholders of the firm? And to whom (or what) do managers pay attention?". That is, how can we identify our stakeholders and how do we decide on strategies to engage these stakeholders in support of problem solution strategies? Answering these questions involves classifying and determining stakeholder attitudes in order to help determine who important stakeholders are and what their attitude is with respect to a particular endeavor. This analysis leads to a set of stakeholder strategies as discussed in Hester, et al. [5]. This analysis is insufficient, however. It fails to address what we should do in the event of multiple stakeholders who share the same attitude and classification. In this case, and given resource constraints encountered by modern systems, we must be careful as to which stakeholders we choose to engage with and to what extent. In order to discern between these varying cases of stakeholders, the authors propose the metric of

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stakeholder situation influence, based on input-output (I-O) analysis. This metric is developed in the following section and demonstrated on a case example. Implications of this work as well as future work are then presented.

2. Determine Stakeholder Situation Influence

Stakeholder influence on a given situation is crucially important as we must determine the relationships between stakeholders such that we may prioritize organizational resources in an effort to achieve our objectives. The model proposed in this paper is derived from the Leontief [6] Input-Output model. This model, in general terms, relates a number of interacting industry sectors, each of which consumes and produces commodities, to one another. The model takes the general matrix form of:

$$\mathbf{x} = \mathbf{A}\mathbf{x} + \mathbf{c} \qquad (1)$$

- where **x** is the matrix of industry inputs,
- **A** is known as the Leontief coefficient matrix relating intermediate consumption between industries,
- **c** is the final demand (or final consumption) matrix for the industries

Equivalently, (1) can be written in scalar form, for *n* industries, as:

$$\{x_i = \sum_j a_{ij} x_j + c_i\} \forall i \qquad (2)$$

- where x_i and x_j are the total input of industries i and j, respectively
- a_{ij} is the proportion of industry i's input to industry j, with respect to total production output of industry j
- c_i is the final demand (or final consumption) for industry i's output
- where $i,j = 1,2...n$

This model has been adapted for use extensively in determining infrastructure inoperability [7-10]. This reformulation is written as:

$$\boldsymbol{q} = \boldsymbol{A}^{*}\boldsymbol{q} + \boldsymbol{c}^{*} \ (3)$$

- where $\boldsymbol{c}^{*}$ is a demand-based perturbation vector expressed in terms of normalized degraded final demand (i.e., 0.20 represents a 20% loss in demand);
- $\boldsymbol{A}^{*}$ is the interdependency matrix for the demand-based model which describes the extent to which the sectors are interconnected; and
- $\boldsymbol{q}$ is the demand-based inoperability vector expressed in terms of normalized production loss, where elements represent unrealized production (i.e., 0.20 represents 20% unrealized production with respect to "as-planned" levels).

We adapt this model to analyze stakeholders by creating an analogous model for stakeholders as:

$$\boldsymbol{q}^{S} = \boldsymbol{A}^{S*}\boldsymbol{q}^{S} + \boldsymbol{c}^{S*} \ (4)$$

- where $\boldsymbol{c}^{S*}$ is a perturbation vector expressed in terms of loss of stakeholder functionality in the scenario (i.e., 1 represents that the stakeholder is removed from the scenario, 0 represents that their functionality remains intact);
- $\boldsymbol{A}^{S*}$ is the interdependency matrix for the stakeholder network which describes the interconnectedness (i.e., influence) of the stakeholders with one another. This matrix is unidirectional such that a_{ij}^{S*} represents the influence that stakeholder i has on stakeholder j according to Table 1; and
- $\boldsymbol{q}^{S}$ is the reduction in stakeholder ineffectiveness (akin to inoperability) vector expressed in terms of normalized ineffectiveness (i.e., 0.20 represents 20% ineffectiveness with respect to "as-capable" levels).

Table 1. Stakeholder Influence

Influence i exerts on j	a_{ij}
High	0.75
Medium	0.5
Low	0.25
None (no arc between *i* and *j*)	0

Eq. (4) can be reformulated to isolate $\boldsymbol{q}^S$ as:

$$\boldsymbol{q}^S = (\boldsymbol{I} - \boldsymbol{A}^{S*})^{-1}\boldsymbol{c}^{S*} \quad (5)$$

Solving for $\boldsymbol{q}^S$ provides us a normalized effect that removing a particular stakeholder has on the network. We can also extend this effect to include the relative attitude and classification of a given stakeholder [see 5] as defined in Tables 2 and 3,

Table 2. Stakeholder Classification

Classification	C_j
Definitive	1
Expectant	2/3
Latent	1/3
Non-stakeholder	0

Table 3. Stakeholder Attitudes

Attitude	A_j
Non-supportive	1
Marginal	2/3
Mixed	1/3
Supportive	0

These quantities can be multiplied together to calculate $\boldsymbol{l}$, the matrix of "as-capable" capacities of the stakeholders. Combining this value $\boldsymbol{q}^S$ gives us a comprehensive evaluation of the effect of neutralizing a particular stakeholder (i.e., their stakeholder influence, ***SI***) as:

$$\boldsymbol{SI} = \boldsymbol{q}^S \boldsymbol{l} \quad (6)$$

We are now able to assess each stakeholder's relative contribution to the problem in a concise and efficient manner. We now turn to a problem to illustrate use of this proposed approach.

3. Illustrative Example

A simple illustrative example shows the determination of situation influence. This analysis is being conducted by an outside company who is trying to convince a small manufacturing company to expand its offerings by carrying its product. Table 4 shows six stakeholders associated with the analysis and their respective classification and attitude. While determining these quantities is outside the scope of this paper, the reader is referred to Hester, et al. [5] for further information on these concepts. They are used to generate *Cj* and *Aj* values for quantification in Eq. 5.

Table 4. Stakeholder Attitudes

Stakeholder	*Stakeholder Classification*	*Stakeholder Attitude*
CEO	Definitive	Supportive
VP of Production	Definitive	Non-supportive
VP of Sales	Latent	Supportive
VP of R&D	Latent	Mixed
VP of Engineering	Expectant	Mixed
VP of Finance	Expectant	Mixed

This set of relationships is shown graphically in Fig. 1.

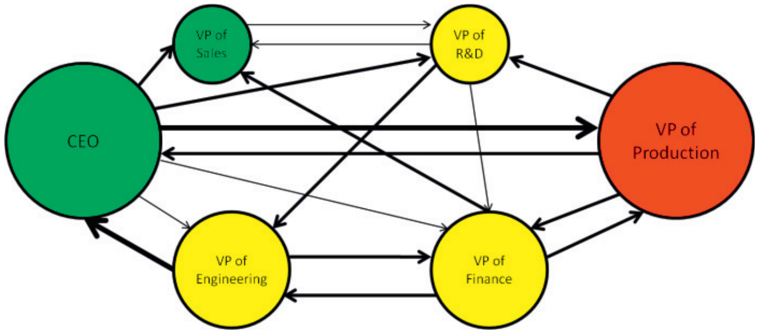

Fig. 1. Illustration of Stakeholder Network

Three keys are necessary to truly understanding this map. They include attitude, classification, and influence and are presented together in Fig. 2.

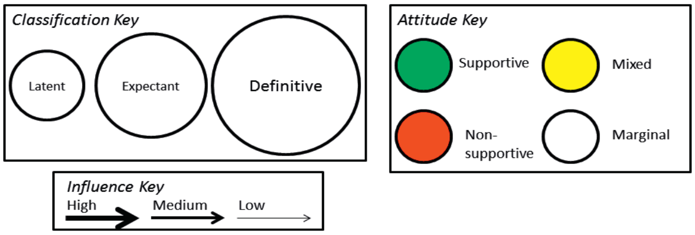

Fig. 2. Keys for Stakeholder Relationship Map

The interdependency matrix, $A^{S}*$, for the problem is shown in Table 5.

Table 5. Interdependency Matrix

	CEO	VP of Sales	VP of Engineering	VP of Finance	VP of R&D	VP of Production
CEO	0	0.5	0.25	0.25	0.5	0.75
VP of Sales	0	0	0	0	0.25	0
VP of Engineering	0.75	0	0	0.5	0	0
VP of Finance	0	0.5	0.5	0	0	0.5
VP of R&D	0	0.25	0.5	0.25	0	0
VP of Production	0.5	0	0	0.5	0.5	0.5

Given this mapping between stakeholders, we can now compute the stakeholder influence for all the stakeholders using Eq. 6. Table 6 shows the various stakeholders and their influence with respect to this particular problem, sorted in descending order of influence.

Table 6. Example Stakeholder Influence

Stakeholder	*SI*
VP of Production	1.0291
VP of Engineering	0.3140
VP of R&D	0.2572
VP of Sales	0.1842
CEO	0.0913
VP of Finance	0.0321

The results of this analysis may not be intuitively obvious and thus, require some explanation. The VP of Production has the largest ***SI*** value. This is because the VP of Production is a definitive stakeholder and exhibits large influence (much like the CEO). However, unlike the CEO, the VP for Production is non-supportive. Thus, this connection is quite influential within the network. If the VP for Production is removed from the network, no one stands in direct opposition to the effort. Thus, it would be wise for the outside company to develop a strategy which sways the VP of Production to a supportive role. The outside company could utilize the ***SI*** values to further prioritize strategies determined by using the methodology presented in Hester, et al. [5]. On the other end of the spectrum, the VP of Finance has the least influence in this network. Thus, the production company would be wise to avoid wasting scarce resources in developing approval from the VP for Finance.

4. Conclusions

Because stakeholders exist at the center of all systems problems and serve as the principal contributors to the solution of these problems, we must formally address them as part of the solution to any systems problem. In this paper, we developed an approach to evaluating stakeholder influence in a situation using a Leontief-derived Input-Output model. Results of this analysis should be used to prioritize scarce organizational resources in order to resolve complex problems. Those stakeholders that have larger influence values demand greater organizational attention. This technique is an important discriminator enabling systems practitioners with an effective method for dealing with stakeholders appropriately.

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