Discussion Paper

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A Method for Linkage Analysis

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Abstract

This paper introduces a simple method to characterize linkages among organizations in a system. Data required are collected by a questionnaire with scaled answers. This method can be applied to determine dominant and subordinate organizations, identify weak linkages among them, and give insights into linkage mechanisms to be established. Having accomplished these, decision makers will be in a position to design formal rules and procedures that facilitate the growth of desired linkages.

Key words: Linkage analysis, survey evaluation, graph theory, organizational hierarchies

Introduction[1]

This paper introduces a simple method to characterize linkages among organizations in a system. Data required are collected by a questionnaire with scaled answers. This method can be applied to determine dominant and subordinate organizations, identify weak and/or strong linkages among them, and give insights into linkage mechanisms to be established. Having accomplished these, decision makers will be in a position to design formal rules and procedures that facilitate the growth of desired linkages.[2] Below, the method is described and then the questionnaire for data collection is presented. Finally, the paper is concluded.

The method[3]

Below, a total of seven concepts are introduced, each of which will be used in the evaluation of the questionnaire that fallows.

Concept 1. A linkage matrix **L**

Let the system at hand aim to develop, diffuse, and apply new or improved technologies, and further let it consist of 5 components, each of which is a group of organizations with similar objectives. The matrix **L** below represents this system and maps all the one-to-one linkages between these components: policy (P), Research and Education (R), Extension and Information (I), Farm production (F), and External assistance (X). The components are placed in the diagonal cells, and following clock-wise convention, their linkages are placed in the off-diagonal cells of **L**:

$$\mathbf{L} = \begin{bmatrix} \mathrm{P} & PR & PI & PF & PX \\ RP & \mathrm{R} & RI & RF & RX \\ IP & IR & \mathrm{I} & IF & IX \\ FP & FR & FI & \mathrm{F} & FX \\ XP & XR & XI & XF & \mathrm{X} \end{bmatrix}.$$

The term PR in the 1st row – 2nd column of **L** represents the linkage that representatives of organizations within P commonly express to have had linkages with those organizations within R. Likewise, the term RP in the 2nd row – 1st column of **L** represents the linkage that representatives of organizations within R commonly express to have had with those organizations within P. The terms placed in the off-diagonal cells of **L** are one-to-one (or one-edge) linkages, meaning that the two components are linked with no intermediary linkages, like

[1] Special thanks go to Prof. John A. Hudson, who acquainted the author with the graph theoretical concepts, which are the building blocks of the method. Many thanks also go to Thomas Braunschweig and Doug Horton for their comments on the earlier version of the paper. Needless to say, the author is responsible for the content of the paper.

[2] A system is defined to be a set of organizations organized around a common objective. The term "institutions" is used to mean rules and regulations governing activities of all the organizations in the system.

[3] The reader is referred to Shrum (1997), Scott (2000), Freeman (1997, 2000) for the application of social network concepts in the analysis of organizational linkages.

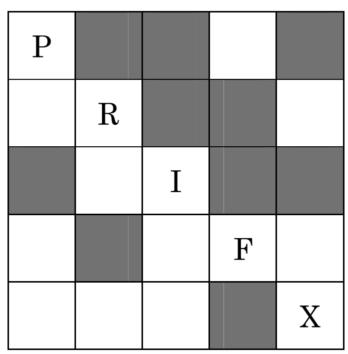
P→R. The linkage between P and R can also be established through a pathway, like P→I→F→R, which is called a three-edge pathway of linkages. The maximum number of edges is equal to (n-1)=4, where n denotes the number of components in **L**.

Concept 2. A coded linkage matrix **L**[c]

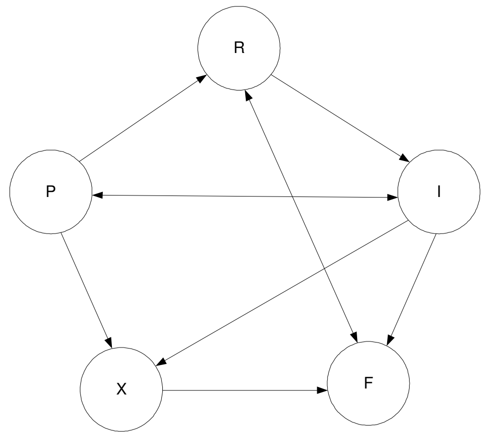
L[c] is defined as a matrix with binary codes: 0 for absent and 1 for existing linkages. For illustrative purposes,

$$\mathbf{L}[c] = \begin{bmatrix} P & 1 & 1 & 0 & 1 \\ 0 & R & 1 & 1 & 0 \\ 1 & 0 & I & 1 & 1 \\ 0 & 1 & 0 & F & 0 \\ 0 & 0 & 0 & 1 & X \end{bmatrix}$$

where P expresses a linkage with R, I, and X; and R expresses a linkage with I and F but not with P and not with X. Notice that PR exists but RP, which is manifested by 1 in the 1^{st} row – 2^{nd} column and 0 in the 2^{nd} row – 1^{st} column of **L**[c], respectively. This coding convention shows that links are directional and not necessarily symmetric. Below, **L**[c] is shown in a different format that can be used for visual detection of patterns, where black (white) cells indicate the existing (nonexistent) links:



Another format to represent **L**[c] is to define it as a *digraph* (i.e., *directed graph*). The digraph consists of five vertices, P, R, I, F, X, and assumes an implicit function that translates the linkages into real values {0, 1}. Although it is difficult to immediately recognize patterns in the following diagram, this format has its own advantages (Murota 1987; Pearl 1995; Richardson 1999; Freeman 2000; Scott 2000).



<u>Concept 3. The refinement of **L**[c]</u>

L[c] is refined using questionnaires like the one in Appendix, and the resulting matrix is denoted by **L**[r]. The person completing the questionnaire would provide his/her opinion about the nature of linkages that his/her organization has developed with the rest of the organizations in the system. Since the answers to the questions in the questionnaire are all expressed in scales, like none, weak, medium, and strong, we can assign to each scale a value, 0 for a nonexistent, 1 for a weak, 2 for a medium, and 3 for a strong linkage.[4] This procedure would yield a vector of values representing the degree of linkages between the interviewed organization and the rest of the organizations in the system. Repeating the same procedure for each organization would result in as many vectors as organizations. Next, the components are defined as subsets of the organizations already characterized, and the vectors of values assigned to the organizations in each subset are reduced to an average vector. Suppose that repeating this procedure for each component yields,

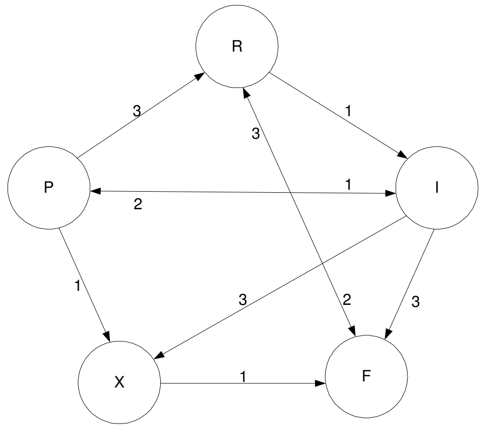
$$\mathbf{L}[\mathrm{r}] = \begin{bmatrix} \mathrm{P} & 3 & 1 & 0 & 1 \\ 0 & \mathrm{R} & 1 & 2 & 0 \\ 2 & 0 & \mathrm{I} & 3 & 3 \\ 0 & 3 & 0 & \mathrm{F} & 0 \\ 0 & 0 & 0 & 1 & \mathrm{X} \end{bmatrix}.$$

<u>Concept 4. The cause-effect structure of **L**[r]</u>

Cause (C) is defined as the influence of a single component on the rest of the components in **L**[r], and *Effect* (E) as the influence of the rest of the components on that single component. These definitions, together with the clock-wise convention that was followed in the construction of **L**[r], imply that rows (columns) in **L**[r] represent cause (effect). For example, the 2nd row indicates R's

[4] Note that if the scale consists of such categories as "very harmful", "harmful", "neutral", "useful", and "very useful", then an appropriate set of values to be assigned to these categories would be –2, -1, 0, 1, and 2, respectively. For more reading on measurement techniques for surveys with scaled questions, the reader is referred to Miller (1956) and Tull and Hwakins (1984).

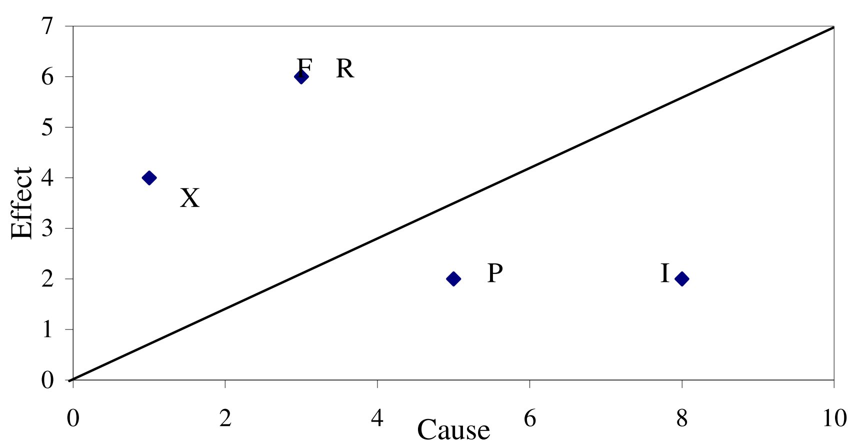
influence on P, I, F, and X, while the 2nd column indicates others' influence on R. This also means that the one-to-one linkages represent directional relations shown in the following directed graph:



With a value of 1 the arrow from R to I indicates R's influence on I, and similarly, with a value of 3 the arrow from P to R indicates P's influence on R.

Applying the above definitions, one can calculate the (C, E)-coordinates of **L**[r]: (5, 2) for P, (3, 6) for R, (8, 2) for I, (3, 6) for F, and (1, 4) for X. And one can also detect dominant and subordinate components of the system. Figure 1 shows the underlying cause-effect structure, where I is the most dominant component, and F and R are the most subordinate components of the system **L**[r].

Figure 1. The Cause-Effect structure of L[r]



Concept 5. Adjusted **L**[r]

During the interview questions are asked about how strongly the interviewed organization influences the others in the system. And, depending on the degree of perceived influence scaled as none (n=0), weak (w=0.33), medium (m=0.66), and strong (s=1), **L**[r] is adjusted to determine the adjusted cause-effect structure of the system. Below is an example of the influence-adjusted linkage matrix denoted by **L**[a]:

$$\mathbf{L}[\mathrm{a}] = \begin{bmatrix} \mathrm{P} & 3.s & 1.w & 0.n & 1.w \\ 0.n & \mathrm{R} & 1.w & 2.m & 0.n \\ 2.m & 0.n & \mathrm{I} & 3.s & 3.s \\ 0.n & 3.s & 0.n & \mathrm{F} & 0.n \\ 0.n & 0.n & 0.n & 1.w & \mathrm{X} \end{bmatrix} = \begin{bmatrix} \mathrm{P} & 3 & 0.33 & 0 & 0.33 \\ 0 & \mathrm{R} & 0.33 & 1.32 & 0 \\ 1.32 & 0 & \mathrm{I} & 3 & 3 \\ 0 & 3 & 0 & \mathrm{F} & 0 \\ 0 & 0 & 0 & 0.33 & \mathrm{X} \end{bmatrix}.$$

Obviously, the structure in Figure 1 is a special case in which all of the linkages are strongly influence-oriented.

<u>Concept 6. Density of the cause-effect structure</u>

The density, d, of the C-E structure is calculated as $d=b/[n(n-1)]$ with $1\geq d \geq 0$, where b denotes the total number of existing binary interactions, and n is the number of dimensions in **L**[r]. Thus, **L**[r] has a density of 0.5, where b=10 and n=5. Fully identified structures will have d=1, implying that all components are linked to each other.

<u>Concept 7. Clusters</u>

A cluster is a subset of components concentrated around a (C, E)-coordinate. The C-E structure is a useful tool for detecting clusters in the system. This concept, useful especially in a system with a large number of components, helps identify subsystems and examine their characteristics.

The questionnaire

The questionnaire consists of three parts. In the first part, the interviewee is asked to choose from Table 1 those linkage mechanisms that his/her organization uses in its interaction with other organizations. In the second part, the mechanisms chosen were assigned across organizations in Table 2. Lastly, the interviewee is asked to rank the mechanisms employed according to their degree of strength.

Table 1. Linkage types and mechanisms

Types	Mechanisms	Codes
A. Planning & Review	Joint problem diagnosis	1
	Joint priority setting and planning	2
	Joint program development	3
	Joint review and evaluation	4
B. Program Activities	Joint technology development	5
	Joint technology evaluation	6
	Joint technology demonstration	7
	Joint technology diffusion	8
C. Resource Use	Exchange of personnel/staff rotation	9
	Joint use of facilities (e.g., laboratories)	10
	Sharing of financial resources & materials	11
D. Information	Sharing of information	12
	Joint use of information sources like library and Internet	13
	Joint reporting	14
	Joint publication of documents	15
	Joint seminars and workshops	16
E. Training	Joint training of students	17
	Joint training of staff (short-term)	18

Table 2. Linkage mechanisms used by your organization

Components	Agents	Codes					
Policy **(P)**	Parliament's Agr. Committee						
	Cabinet of Ministers Agr. Com.						
	Ministry of Agriculture						
	Ministry of Science & Education						
	MOA Div. of Agr. Sci., Ed Ext.						
Research and Education **(R)**	Agricultural research council						
	Agricultural research institutes						
	Research dept at institutes						
	Agricultural universities						
	Researchers at research inst./univ.						
Extension and Information **(I)**	Agricultural extension offices						
	Extension program leaders						
	Extension specialists or agents						
	Agricultural communications unit						
Farm production **(F)**	Large farmer organizations						
	Small farmer organization						
	Large farms						
	Small commercial farmers						
External assistance **(X)**	Development agencies						
	International ARCs, NGOs, PVOs						
	International networks						

Table 3. Strength of linkages with other agents

Components	Agents	Strength			
		N	**W**	**M**	**S**
Policy **(P)**	Parliament's Agr. Committee				
	Cabinet of Ministers Agr. Com.				
	Ministry of Agriculture				
	Ministry of Science & Education				
	MOA Div. of Agr. Sci., Ed Ext.				
Research and Education **(R)**	Agricultural research council				
	Agricultural research institutes				
	Research dept at institutes				
	Agricultural universities				
	Researchers at research inst./univ.				
Extension and Information **(I)**	Agricultural extension offices				
	Extension program leaders				
	Extension specialists or agents				
	Agricultural communications unit				
Farm production **(F)**	Large farmer organizations				
	Small farmer organization				
	Large farms				
	Small commercial farmers				
External assistance **(X)**	Development agencies				
	International ARCs, NGOs, PVOs				
	International networks				

Strength: S = Strong; M = Medium; W = Weak, N = None

Conclusion

This study introduces a method for characterizing linkages between components of a system. A questionnaire with scaled answers is also presented to be used in gathering data required for this characterization. One unique feature of this method is that it can be applied to any situation that concerns the analysis of organizational interactions or interactions among people organized around a common goal.

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