SOCIAL NETWORK ANALYSIS: A DIAGNOSTIC TOOL FOR INFORMATION FLOW IN THE AEC INDUSTRY

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ABSTRACT

In the Arquitecture, Engineering, and Construction (AEC) industry, the ability to integrate and manage information is critical for organizational performance. Information networks are key for value generation, collaboration and continuous improvement, thus the great interest that they present for companies with a lean thinking approach.

It is essential for companies to recognize and understand these relationships in order to exploit them and be able to manage them as any other process in order to improve transparency, flow and seek perfection. Unfortunately, they often remain invisible, unidentified.

The hypothesis of this study is that a Social Network Analysis can be utilized as an effective diagnosis tool in order to make explicit an otherwise hidden flow of valuable information. The study begins with a literature review to support the analysis and understand the metrics, and the creation of a methodology for its use and application. It continues with a pilot implementation program in a mining company, enabling to test the methodology and to conclude with recommendations and possibilities of use of this tool.

Future studies should continue to develop this tool in order to provide recommendations, detect possible behavioural patterns and explore other applications in the project network.

KEYWORDS

Flow, collaboration, improvement, social network analysis, diagnostic tool, information flow, knowledge management

INTRODUCTION

In the Arquitecture, Engineering, and Construction (AEC) industry, the ability to integrate and manage information is critical for organizational performance. Phelps (2012) concludes that information management cannot rely on technological tools but

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requires progress in the understanding of the social phenomena related to information processing.

Davidson (2004) refers to the “'information problem”, the problem about information on the building sector. The AEC industry is highly fragmented and its participants work in contexts that are unfavourable for good communication and, above all, unfriendly to the systematic acquisition of information, even if it is recognized as necessary to support the many decisions that must be made.

The dynamic nature of a project oriented industry contributes to a higher need for collaboration and coordination between team members. In this context, information networks are key for value generation and continuous improvement, thus the great interest that they present for companies with a lean thinking approach.

BACKGROUND

PEOPLE, INFORMATION AND THE LEAN APPROACH

The importance of Transformation, Flow and Value (TFV) has been greatly discussed regarding its importance in Lean Production (Koskela 2000). One of the main flows in project management is the information flow and it affects all other resources significantly (Dave, Boddy and Koskela 2010). Production planning is traditionally focused on what consist in transformation without an explicit method to manage information flow. The Last Planner System has provided the Lean Construction community with an organized approach to manage many of these flows through a make-ready process and lookahead planning. However many information and communications among team members that are required for project completion and for enterprise development in general are not visible in a way that can make explicit structure, components or difficulties. It is essential for companies to discover these relationships in order to exploit them and be able to manage them as any other process in order to improve transparency, flow and seek perfection.

SOCIAL NETWORK ANALYSIS (SNA)

A social network analysis examines the structure of social relationships in a group in order to be able to detect the real connections between people, including informal connections. In these networks, each individual is represented by a node in the network, and there is a connection between two nodes if an interaction has occurred. An interaction can be formal information exchange such as approvals and monthly reports, or informal exchange of opinions, request for information, report of a problem, sharing of an improvement idea, etc. In companies with a lean thinking approach, some common problem solving interactions are 5 why and A3 exercises.

The information is obtained through the answers to a simple survey that is constructed according to the network that will be mapped: innovation network, trust network, problem solving network are just an example of the many possibilities.

The outcome of an SNA lets us see where collaboration is breaking down, where talent and expertise could be better leveraged, where decisions are getting bogged down, and where opportunities for diffusion and innovation are being lost (Ehrlich & Carboni 2005). Furthermore, the SNA provides a series of metrics: density, path lengths, centrality, etc. This enables the transformation into a metric of an otherwise invisible flow.

More recent research has proposed going beyond the static analysis and to consider evolutionary patterns in dynamic networks, providing insight into the underlying behaviour of the network (e.g. Mansoureh, Sangi, Fagnan, & Zaine, 2011). Chauvet, Chollet, Soda & Huault (2011) identify the conditions under which the contribution of a network research can be made in five areas: knowledge management, firm governance, career, entrepreneurship and team management. In the mentioned areas, SNA has been considered as a descriptive tool but it is proposed that it can and should be studied as a management tool. Social networks can be created and managed; this is the motivation for the research performed in this paper.

THE METHODOLOGY

The objective of the methodology is to effectively model the information flow in an organization by using the social network analysis framework, giving leverage for the improvement of the flow to further enhance LEAN implementation.

A key element of the proposed methodology is the data used to model the networks and how it´s obtained. Information flow within a team has numerous expressions: part of the information flow is represented through email exchange, document approvals or revision. These are all commonly used to model what is more commonly known as social networks, but the complete information flow cannot be described with these physical available sources. Information flow, such as a face to face conversation or a phone conversation, is harder to quantify.

In order to obtain the complete range of information flow, it is suggested to conduct a survey asking each member who he exchanges information with, instead of relying on the available information such as email exchange. This approach allows the identification of the complete spectrum of interactions, the expected formally identified interactions and the informal interactions that develop naturally. The complete process is defined with 6 basic steps as shown in Figure 1.

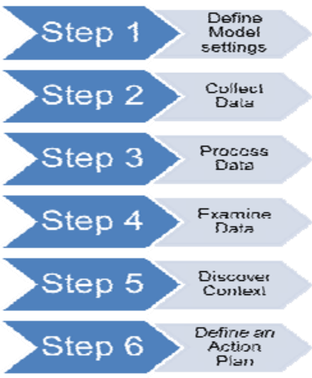

Figure 1: The Methodology

STEP 1: DEFINE MODEL SETTINGS

The following questions must be answered at this step to set the objectives and scope of the process.

- Which group of people will participate? It could be a specific business unit, a particular team, a community, the people at the company that dedicate to the same task, etc.

- What are the hypotheses to be explored and tested? The analysis will help to learn about unexplored areas but may also help support and test previous intuitions to leverage actions. These need to be identified and made visible. For example, a company might want to check if last planners are effectively being included on planning sessions, or if problem solving is occurring collaboratively.
- What networks will be modelled to prove or deny the hypothesis? The nature of the relationships and knowledge flow to be modelled will vary according to the reasons that motivate the study. Possible ties or relationships that could be modelled are: information exchange, problem solving, planning, trust, etc. Choosing a collection of networks to be identified will give a range of analysis possibilities and will describe the general information flow from different points of view.

STEP 2: COLLECT DATA; SURVEY

Obtain data about the knowledge and information flow patterns in an organization, using a survey. Some benefits of acquiring the data with the aid of a survey are:

- It will allow for a more complete data base, by acquiring not only the physical information exchanges but also the harder to get exchanges (face to face conversations) that are often the more critical exchanges to achieve project success (i.e.for problem solving).
- It's highly flexible; the survey can be adapted to fit the analysis, whilst using existing data limits the analysis.
- It enables a higher level of detail, depending on the survey used (information exchange can be asked to be classified).

There are some disadvantages that must be dealt with:

- The information is not previously available, requiring the survey to be short and user-friendly to facilitate the process. A web-based survey allows customization to shorten the survey, and flexibility for the respondents. Previous test runs done by GEPUC showed that a moderately complex survey could be answered in 15-25 minutes, and a week should be sufficient time to get most responses from 20-40 people.
- A complete sample is required and could be difficult to get. Strong management involvement and support is needed to ensure all surveys are answered.
- Answers are based on individual perception and memory. A strong conceptual framework is needed to ensure a common baseline between individuals.

Attribute information from the people that will be surveyed can be collected from the company database or asked directly with the survey. This data is important to explore and understand the networks, identifying possible patterns related to the attributes.

STEP 3: PROCESS DATA

Use computer tools to create a network map from the data and to produce statistical analyses of the patterns in the data. Numerous software is available, open source and paid.

Network Maps can be significant tools for analysis if information is added to them. Some mapping software have additional mapping capabilities such as algorithms for locating the nodes. Using algorithms such as Force Atlas (Jacomy et al. 2009) highlights the existing relationships among groups, making holes and clusters easily recognizable.

STEP 4: EXAMINE DATA

Examine the results to look for gaps, or junctures, between individuals and groups. It´s important to remember that the results of analysis give us no answers, just tell us where to ask questions. The data will act as an indicator and guide for the questions to be performed on the analysis.

Gephi is an open source software that facilitates exploring and understanding the graphs. The user interacts with the representation; manipulates the structures, shapes and colors to reveal hidden properties. The goal is to help data analysts to make hypothesis, intuitively discover patterns, and isolate structure singularities or faults during data sourcing (Jacomy et al. 2009).

The proposed metrics to be analysed are; density, diameter, average degree and average path length, as detailed on Table 1.

Table 1: Proposed Network Metrics

Metric	Definition	Proposed analysis or use
Density	Percentage of actual connections within a network as a proportion of the number of possible connections.	Could help balance the benefits of connectivity vs. the expense of building and maintaining ties.
Diameter	The largest of the shortest paths between every pair of nodes.	Shows the less effective chain or channel on the network.
Average Path Length	Average number of steps that it takes all of the nodes in the network to reach each other.	Could help monitor the effectiveness of the channels on a network.
Average Degree	Average number of connections that each node has within each network.	Shows the direct network that the average node has.

Many additional metrics with interesting interpretation exist for the network as a whole; reciprocity, transitivity, clustering, efficiency, hierarchy, among others. The nodes also have descriptive metrics that could aid the analysis, the centrality metrics are particularly interesting, both betweenness and closeness centralities. These should be analysed and included if they are considered to aid the testing of the hypothesis.

STEP 5: DISCOVER THE CONTEXT

Use consultative interviews to understand the context that is behind the data and the diagnostics.The work in an SNA project is less about the actual diagrams and charts than about the dialogue that ensues from their examination and the insight and action that emerge from the dialogue. The interviews will allow understanding the context behind the data and the diagnosis.

For example, in companies with lean thinking approach, problem solving is expected to cross boundaries and be highly collaborative. If the data showed low density and isolated groups, the root causes should be discovered on this step. Some questions to be explored could be: Are communication channels available for the isolated groups? Should additional efforts be made to connect these areas with key problem solvers? Should additional problem solving instances be planned?

STEP 6: DEFINE AN ACTION PLAN

Check if your initial hypotheses are reassured. Target areas where insufficient knowledge flow has a serious impact on the business and design organizational interventions to create the environment that will enable social capital to grow. Anklam (2003) suggests three types of interventions:

- Structural/organizational: An analysis may indicate the need to modify the organization or to introduce people into new, specific roles to assist the knowledge transfer.
- Knowledge-network development: Frequently, the SNA may provide confirmation of prior intuition, but in a way that overcomes previous resistance to action.
- Individual/leadership: Most individuals, and especially leaders, will rapidly correlate the map to their own perceptions and intuitions about the context behind the map and take their own actions, either publicly or privately.

PILOT APPLICATION

The Methodology exposed was applied to a specific management group (MG) of a large Mining Company. The Centre of Excellence in Production Management, GEPUC, had an ongoing Project Management Improvement implementation with the mentioned company that was driven by LEAN philosophy. GEPUC applied the proposed Social Network Analysis with two objectives: First, to test the methodology and tool to prove the stated hypothesis, and second, to support the on-going Project Management Improvement program.

The primary objective of the original project was to generate positive impacts on Project Management in order to secure the objectives of each project, the efficient and effective administration of the portfolio and the strengthening of the team, through knowledge transference on various topics, such as LEAN, waste identification, last planner, leadership, team building, effective communication, and others, as well as monitoring and support. After several months of implementation with positive results, a strong relationship was developed between GEPUC and the company, giving GEPUC leverage to suggest different and new courses of action, specifically a SNA as described in this paper, to diagnose and support the organizational challenges related to integration and collaboration among the teams.

METHODOLOGY APPLICATION

The first step was to define the model settings, the networks that were characterized during this pilot application were: interaction network, information flow network, problem solving network, planning network, and trust network. This set of networks described the information flow in the organization from different points of view and took under consideration the specific challenges of the company.

The survey to collect the necessary data, step 2 of the methodology, was applied during a period of 2 weeks to the complete MG, 99 team members, with 100% responses. Web-based survey software, with advanced piping capabilities, was used to allow the customization and to facilitate the answering process. The analysis was done with the aid of open source tools to generate the diagrams, manipulate the data and calculate the metrics.

RESULTS

The results of processing the data were the selected metrics for each network (as displayed on Table 2), and the network diagrams. The examination of the metrics gave valuable data about the information flow in the company and fed step 5 of the methodology; discovering the context making the correct questions.

Table 2: Pilot SNA Network Metrics

Network Metrics	Interaction	Information Flow	Problem Solving	Planning	Trust
Nodes	99	99	99	99	99
Connections	1518	1191	1169	1059	841
Density	16%	12%	12%	11%	9%
Diameter	5	6	7	6	7
Average Path Length	2.4	2.6	2.7	2.8	2.9
Average Degree	15.3	12.0	11.8	10.7	8.5

The analysis possibilities for the metrics are numerous; in this paper we give some examples of interpretation of each metric on different networks. All the networks that were identified describe the same group of people, the MG, thus each network has the same number of nodes or people. The amount of connections of each network changes according to the number of relationships that the group declared on the survey.

The interaction network was the first question on the survey, it represents who people interact with, but it doesn’t specify the kind of interactions (it could be to exchange information, solve a problem, or other reasons). All the other networks are subgroups of this network, specific kinds of interactions.

The densest network is naturally the interaction network, with 16% of possible connections occurring. Information flow is the second densest, followed closely by problem solving. This is very interesting since it suggests that problem solving can be done with almost as much people that you transfer information within the group. The trust networks density is the lowest, only 9%. This would indicate that, information transference, problem solving and planning is, on some cases, done between people that don’t trust each other. These findings generate many questions that must be asked on an additional step, discovering the context, after the examination of the results.

The diameter of the information flow network is six, meaning that if you wanted everyone in the group to be able to reach all the information, it would take up to that amount of connections to do so, six people would have to pass the information. If everyone used the shortest existing path to transfer information, it would have to go through an average of 2.6 people. Both metrics, diameter and average path length, describe the effectiveness of the information transference channels and could be used to monitor them. Reducing the average path length to 2 would mean that the average amount of people that need to pass on information for it to reach another is 2.

The average degree represents how many connections people have on average on the networks. For example, the average degree on the planning network shows that people plan with an average of 10.7 people, but, as seen on the trust network, they only trust an average of 8.5 people. These people are not necessarily a subgroup of each other, but they do represent subgroups of the interaction network, which as an average degree of 15.3. People on the MG, on average, plan with 70% of the people they interact with, but they only trust 56% of them. Additional analysis can be made by examining the visual diagrams that represent the networks.

Figure 2 shows the information flow network diagram. Colors are set to represent different areas of the company and the node size represents de degree (amount of connections) of each person.

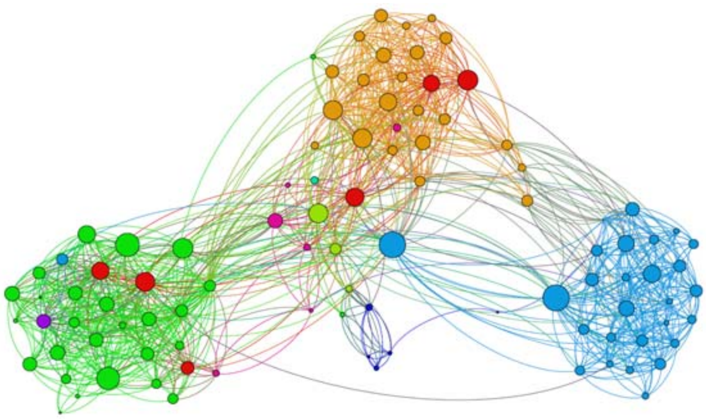

Figure 2: Information Network

The spatial distribution of the nodes was performed with the Force Atlas 2 algorithm. This algorithm simulates a physical system in which nodes repel (like magnets) while connections are attracted (like springs), creating a movement that converges to a state of balance. The final configuration can help the interpretation of the data; it shows visually proximity and remoteness of communities of nodes.

This diagram shows three distinct groups within the MG, the group on the left is made up from people of the same area (A), but the group of the right is composed by people of different areas. Area A could be isolated from the rest of the company since only two nodes of the area are “outside” of the cluster. These nodes would be critical to keep area A connected to the rest of the group.

Some central and large nodes can be immediately identified. Common sense would lead to believe they should be leaders, or in the case of information flow networks, secretaries (they tend to manage a lot of the information on a company), but analysing if this is true or not can help identify natural leaders or knowledge centres.

Some nodes are directly between two clusters; these might be very important links, or may be bottlenecks. What kind of information these nodes manage and who they connect the information with will be interesting questions to be analysed. Much more analysis can be made with these diagrams for each network. Some specific analysis was done to understand the impact of LEAN implementation:

- There were instances of training and monitoring of planning such as Last Planner Workshops, Last Planner Follow-up and Interactive Planning Workshops. People with greater participation in these activities have higher degrees on the Planning Network.
- During the Waste Identification Workshops conducted at the beginning of the project a number of ideas were raised. People who were working on the implementation of these ideas are also highly referred to as "problem solvers" on the Problem Solving Network.
- During the project, a practical implementation and follow up of interpersonal skills was conducted as well as various workshops: LEAN Leadership, Team Building, Effective Communication and Time Management. The higher the level of participation in this implementation, the greater the number of people who rely on the person to share personal issues.

CONCLUSIONS

The final steps of the methodology, discovering the context and creating and action plan, were done by the company independently. Nevertheless, follow up has been done to gather the company´s impressions.

The general feeling of the board of directors was that the tool was enlightening, both supporting their previous intuitions and generating interesting questions to explore. The Social Network Analysis results reflected the efforts made during the Project Management Improvement implementation; the cohesiveness of the teams that participated directly on the implementation, the planning patterns according to what was expected for projects that implemented Last Planner System, and a significant difference on the level of participation on innovation of the people directly involved on the project. However, the analysis also highlighted opportunities of improvement, such as a highly hierarchical working environment that generated bottlenecks, unbalanced work load related to information transference, and some informal leadership that weren't recognized. Suggestions to achieve improvement included; balancing work load of specific bottlenecks, arranging meetings between key areas, empowerment of informal leaders, transferring best practices of highly connected areas with good performance to other areas.

Overall, the tool proved valuable to diagnose the current information flow patterns among people in the organization:

- To gain a general understanding of the information flows and interactions.
- To sustain and communicate pre conceived perception of management, allowing a call for action.

- To discover unknown patterns such as bottlenecks, clusters, isolated areas, among others.

FUTURE DEVELOPMENT

The present case study unfolds the potential of SNA and some promising uses opening numerous possibilities for future development. Future studies should continue to develop this tool in order to:

- Provide recommendations to improve information flow through the analysis of the networks.
- Explore additional analysis opportunities.
- Detect possible behavioural patterns and their link with project performance.
- Explore other applications in the project network.

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