Examining Networks of Building Professionals, Developers, Owners and Contractors in the Commercial Building Sector

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Abstract

Social networks are the key to understanding the diffusion of ideas and products in the market place. However, there have been few studies that have employed network concepts and methods to study energy efficiency programs and energy markets.

In this paper, the history of network theory is briefly presented. Particular emphasis is placed on recent developments that have led to an increased interest in network science and a large amount of new work since 1998.

Two examples of the analysis of networks of players in the commercial buildings market are presented. These analyses are based on F. W. Dodge Players Data for New Jersey for 2000 and 2001. The preparation of the data and the use of UCINET6 and PAJEK, network analysis tools, are discussed. One set of results identifies the architect and engineering firms associated with Limited Brands, a national retailer, and illustrates the concept of "image architects" who do much of the design and implementation of buildings for national and regional chains. The second example identifies a cluster of local firms that deal with public buildings in New Jersey.

The application of network analysis has substantial potential for improving the effectiveness of program implementation efforts and the measurement of the effects of market transformation activities.

Introduction

Networks and their importance in social life have been discussed in the academic literature for more than 80 years. There are hundreds of studies of networks and their importance to the diffusion of new products and ideas. Even so, the "conventional wisdom" in modern life is that mass communication drives the penetration of ideas and products in the market place even though there is clear evidence to demonstrate otherwise (Rosen, 2000). Clearly, mass communication has its effects, but studies have consistently demonstrated that it is interpersonal ties and networks that are the key to the widespread acceptance of new ideas and products.

The importance of networks is amply documented. Klovdahl's (1985) study of the early spread of AIDS shows that AIDS spread from clusters in Los Angeles and San Francisco to New York. One airline attendant was a particularly important key to the spread of the disease. The current spread of SARS from China, to Hong Kong, to other Asian cities such as Singapore, and to Toronto, and of course the U.S. is strong testimony to how interconnected we are and the effects of networks. Infected travelers carry the disease and spread it through incidental contact.

Through the years, there has been a small but steady stream of research on networks mostly conducted by social scientists. There are a variety of reasons why the amount of research has not be greater but three important reasons are the difficulty of gathering network data, the lack of secondary data sources that are amenable to network analysis, and the availability of software tools and computing power to analyze networks. Recently, the study of networks has blossomed as data, tools, theoretical interest, and problems of important social significance have appeared (Watts, 2003; Barabasi, 2002; Johnson, 2001; Taylor, 2001).

The energy field has grown up somewhat in isolation from the social science literature on networks. As a result, very few of the ideas about the importance of networks have penetrated the field of energy efficiency studies. There have been isolated studies in the energy efficiency field that have focused on networks but no sustained tradition.

This paper has four purposes. The first is to provide an overview of network theory and to identify the uses of network analysis in the commercial building market. The second is to identify and discuss a secondary data source that can be used for network analysis in the commercial building sector. The third is to briefly acquaint energy analysts with tools that can be used for network analysis. The fourth is to present some preliminary results of a network analysis of players in the commercial building market to stimulate interest in using network analysis to understand markets.

The Power of Networks

In one of the earliest studies of diffusion, Ryan and Gross (1943) examined the spread of hybrid seed corn among farmers in Iowa between 1928 and 1941. During this 13-year period, the use of hybrid seeds spread to virtually 100 percent of the farmers in two farm communities. Ryan and Gross found that early adopters got their information from salesmen while later adopters got their information from neighbors. The findings from this study suggested that the interpersonal communications and social networks among farmers were central to the adoption of hybrid corn.

Ryan had come from Harvard where social network analysis was aborning. At about the time Ryan was there, Elton Mayo and W. Lloyd Warner were contemporaries at Harvard. Mayo initiated the now famous studies at the Western Electric Hawthorne Works. Using anthropological techniques, the Hawthorne team observed and recorded the behaviors and interactions of the workers. The team presented their findings about the structure of work groups using sociograms, a major innovation (Roethlisberger and Dickson, 1939).

Meanwhile, Warner was examining the social structure of Newburyport, immortalized in the Yankee City Series.[1] In discussing the groups and subgroups, he identified a type of subgroup he labeled the "clique," an informal association of 2 to 30 people who are socially intimate and share behavioral and cultural norms. Warner and colleagues argued that people are integrated in communities through informal family and clique membership as well as the more formal ties of the economic and political system. Persons may be members of several cliques and the overlapping nature of these memberships result in a web of relations that include nearly everyone in the community (Warner and Lunt, 1941). The idea of the clique was a significant contribution.

In his efforts to build social theory from an understanding of the interactions of individuals, Homans (1950), another member of the Harvard faculty, reanalyzed data from "Old City" (Davis, et. al.), one of the books in the Yankee City series. He rearranged the rows and columns of data representing women and the events they attended to show the underlying social groupings. He states that the same techniques were used in analyzing the bank wiring room in the Hawthorne studies. His contribution was to demonstrate the value of matrix techniques in the analysis of social networks.

In what is now a classic, William H. Whyte, Jr. published a Fortune magazine article containing an aerial photograph showing row houses that had air conditioners marked with an "X". A theme of the article was that the purchase of air conditioners had spread through word of mouth along the lines of social networks in the suburb.

The concept of networks was central to the work of the diffusionists. Everett Rogers (1996), in his book *Diffusion of Innovations* first published in 1962 and now in its fifth edition, highlights the role of two communication processes, "broadcast" and "contagion," in the spread of innovation. Rogers argues that broadcast processes, that is one-to-many communications processes, are important for innovators and early adopters. However, later adopters are most effectively reached through contagion,

[1] For a brief history of the Yankee City series, see http://magazine.uchicago.edu/0108/features/

a one-to-one process. The first 15 percent of the adopters may be reached through broadcast methods but the remainder of the population is more effectively reached through contagion.

F. M. Bass (1969) and his student Vijay Mahajan (1986) helped to tie together the theoretical and mathematical underpinnings of the widely cited "S-Curve". Mahajan has made a career of studying models for the diffusion of innovation and in a recent year was awarded the American Marketing Association's most prestigious prize for his sustained efforts. His monograph with Robert Peterson documents mathematical models that demonstrate how broadcast and contagion communication can combine to achieve diffusion and how these models may be modified to account for incentives and other features of marketing. The models based on the "S-curve" neatly and often quite accurately predict the outcomes of diffusion processes. The problem is that a host of factors can be introduced to make models mimic reality, but the understanding of the underlying social processes is often left as a black box.

In the late 1980s and early 1990s, Geoffrey Moore (1991) coined the term "crossing the chasm." His phrase captured the idea that the process by which innovations spread is different in the early and the later stages. Innovators and early adopters get their information through broadcast sources but the early majority references other members of the early majority and not necessarily the innovators and early adopters. Thus, the spread of an innovation may stop dead in its tracks after a promising start because word of the innovation does not gain a foothold and spread beyond the social and professional networks of the earliest adopters.

In an age where mass media is so pervasive and where we take mass media so much for granted, the idea that one-to-one communication might be as effective or more effective than mass media seems counterintuitive. It seems improbable that ideas might spread much beyond the localized communities of interest. Yet, there is Milgram's (1967) experiment in which a group of people in Nebraska and Kansas were handed an envelope addressed to a person in Boston, given a description of the person to whom the envelope was addressed, and then asked to pass the envelope to a friend or acquaintance who was to be instructed to pass it to another person until it reached the intended party. It took less than four days for the first envelope to arrive and an average of just six links for the letters to reach the ultimate party.

In 1973, Mark Granovetter (1973 and 1974) published a study of job hunting that was of both immediate importance and of profound impact to the field of networks 25 years later. Granovetter found that job hunters do not acquire information systematically but accidentally and that the probability of making a job change was related to the proportion of work contacts outside the occupation of the person doing the job hunting. His concept of the "strength of weak ties" pointed to the fact that crucial information for job seekers was more likely to come from acquaintances at a distance that have different information rather than family or close friends whose information is already familiar. Key information comes through weak ties between networks rather than the strong ties of the intimate network. The reason Milgram's letter reached Cambridge so quickly was the "weak ties" that "connected" people to the intended respondent in Cambridge.

In 1998, Duncan J. Watts and Steven Strogatz published a very short paper in *Nature* that unleashed flurry of interest in the science of networks. In that paper they created a model explaining the power of weak ties. They represented all members of a population as points on a circle. Each member was connected to the nearest member, as illustrated by the AC link in Figure 1A, and the two nearest neighbors as illustrated by the dashed BC link. Thus, the members A, B, C, D, E form a small network in which the next nearest neighbors are joined by three links, AE, AD, and BC. Now in a world of billions, where people are connected in small networks like these, it would take billions of links to move from one side of the circle to the other. However, if you add cross-links as shown in Figure 1B, the network distances decline rapidly. For example, to get from A to J in Figure 2 is two links. To get from A to J by moving around the circle in Figure 1 requires five links. The insight of Watts and Strogatz enabled network scientists to begin to analyze the power of networks, for example, by examining the effects of increasing the number of weak links.

Why wasn't more done with the science of networks in the 25 years between the Granovetter and Watts and Strogatz papers? At least for social scientists, there was a data problem. The analysis of networks requires data that links members of networks with each other. In order to get that data one has to ask people who they reference or one has to observe and record with whom people interact. In large-scale settings this task is very tedious and almost impossible to accomplish. Thus, it is not surprising that network studies emerged in small community and laboratory based psychological studies where observation and anthropological techniques could be used and where the size of populations was limited. Studies of networks among scientists emerged because the Science Citation Index permitted those interested in the study of scientific networks to manipulate large amounts of data to see who cited whom.

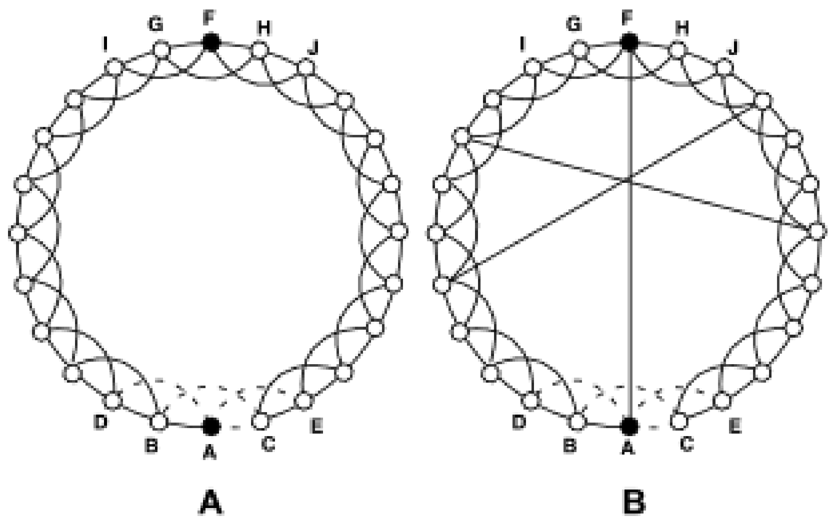

Figure 1 Small-world networks per Duncan and Watts

The appearance of the Watts and Strogatz paper also coincided with the realization that artifacts of the use of e-mail and the worldwide web represented a significant treasure trove of data for studying networks. Here was a source of almost endless data that made it feasible to study the operation of networks. Further, from the early inception of electronic networks, researchers had been concerned with the potential for disruption of the networks. Network scientists demonstrated that the more that "weak ties" exist, the less vulnerable networks are to disruption. They also realized that the more a network depends upon a few super nodes the more vulnerable it becomes if the node is lost.

Now, what does any of this have to do with promoting energy efficiency and making commercial buildings or any other set of buildings more energy efficient?

- Building professionals and developers are clearly linked in social and professional networks.
- If we believe the literature, those networks are potentially among of the most effective channels for communicating with building professionals.
- Our communications with building professionals and owners have tended to rely on broadcast methods.
- If we understand how building professionals and developers are linked and how communications flow, we can switch from broadcast methods to the more effective methods of spreading information by contagion.
- If we understand the linkages and how communications flow among building professionals, we can identify the need for and create additional weak ties to increase the flow of information.

Data for Analyzing the Social and Professional Networks of Building Professionals

Our understanding of the commercial buildings market would be greatly enhanced if we could analyze networks of building professionals and developers to see who interacts with whom and what the structure of the market might be. A critical issue is data. In its Players database, F. W. Dodge records the names of the key players involved in projects including architects, engineers, owner/developers, and contractors. The Players data is analogous to the Science Citation Index data that is used to analyze connections among scientists. The Players data can be used in much the same way to analyze connections among the participants in the commercial buildings market. The data tells us who works with whom. In addition to knowing who works with whom, it is important to know how building professionals influence each other outside of contractual settings. Unfortunately, the Dodge data do not tell us this and other sources of information for this type are not known to us.

To demonstrate the potential of network analysis, we used the F. W. Dodge Player's data for 2000 and 2001 for the State of New Jersey. The Player's data contains active projects in various stages of completion. Projects range from those that have just been permitted to those that are in the final stages of completion. The Dodge data capture all projects over $100,000 and as many projects under $100,000 as are identified. According to McGraw Hill, the Census Bureau audited the projects in the Players database and found that the data capture 95 percent of the value of projects. McGraw Hill claims that the actual captured value is closer to 98 percent.

For a network analysis, the Dodge data is not without its problems. Dodge assigns an identification number to each player. Because the names of the players are not always captured consistently, some players may have more than one identification number. This is not a major problem but it does mean the data require cleaning.

The data also reflect the fact that developers frequently create a company for each project they do. Thus, there may be many projects with different names belonging to the same developer. By analyzing addresses and telephone numbers we were able to connect projects with different firm names. Because the companies are co-located we assumed for this analysis that the same staff is managing them. We assigned these to a single developer.

Another problem arises when firms have multiple offices or multiple addresses. An engineering firm may have more than one office in "New Jersey," for example, a Princeton office and a Philadelphia office (Philadelphia sits on the border with New Jersey). These branches are represented separately in the F. W. Dodge Data.

A basic issue is how to deal with the separate entities. A key question is whether the offices work together on projects or whether they operate separately and perhaps even compete with one another. If different offices work together and more or less act as a unit, then the data for these offices should probably be combined for the network analysis. From various interviews we have done for other projects, we know that a branch of a firm may farm out work to other branches in order to distribute the load, although the branches receiving the work may not be the branch in closest proximity.

If the offices act somewhat independently, the practices in one office may not be the same as in another and ideas and practices may or may not be communicated between branches. In this case, the analysis should be done separately. For the current analysis, we treated branches of the same firm as a single entity although we are not necessarily convinced that that is always the correct approach. We really need more data than is available to make this determination.

The Analysis

After cleaning and combining the data for 2000 and 2001, there were 8292 "unique" players in New Jersey. Using this information, we created an "edgelist." An edgelist is a data stack in which each row contains a pair of identification numbers indicating that a pair of firms work together. For three firms, A, B, and C, if A and B and A and C work on at least one project together but B and C do not, the edgelist would contain two records, A and C and B and C.[2]

Once the edgelists were created, we used two tools to do the network analysis, UCINET and PAJEK. In order to do the analysis, it is necessary to create an 8,300 by 8,300 matrix indicating the relationships between all players. We started with UCINET but quickly discovered that it was unable to handle the very large number of nodes. We then switched to PAJEK, which is capable of handling larger datasets. Utilizing PAJEK, we were able to complete the network analysis. Once we completed the clique analysis, we subdivided the problem and reverted to UCINET to produce the visual outputs provided in this paper.

General Results

Using PAJEK we identified 2,100 cliques of three or more. A clique is made up of people, or in this case firms, who reference or work with one another. Table 1 shows the size and count of cliques greater than three. The actual network diagram for these players is so dense that it is not possible to reproduce it here. Further, it would not be possible to discuss the results in sufficient detail to be meaningful. To provide some idea of the results, two examples are presented, one for the Limited Retail Brands and one for a group of companies that work together on local public projects.

Table 1 Number of cliques and number of players in the clique

Number of players in clique	Number of cliques by size
14	1
13	1
12	1
11	1
10	1
9	3
8	13
7	30
6	75
5	145
4	321
3	1500
Total	2092

The Limited Brands Example

Most readers are familiar with the Limited family of companies: Limited, Limited Express, Limited Bath and Body Works, Victoria's Secret, Lerner New York, Lane Bryant, and Aura.[3] Retail stores for these companies are found in many mid to upscale shopping centers and malls in this country.

The analysis of the Limited Brands is constrained by the fact that we are using data for New Jersey in 2000 and 2001. Analysis of data for another geographic region or larger area might result in a slightly different picture because the local players might change or because additional architectural or engineering firms might be identified. Nonetheless, we believe that the basic configuration is correct.

The network diagram for the Limited Brands is shown in Figure 2. Limited Brands has a vice-president for store design and construction. In this diagram, the Limited Brands is identified as node 27 in the middle of the network. The Limited Brands is defined as any of the retail firms under the Limited Brands umbrella that developed retail space in New Jersey. Node 27 is the "center" of a series of nodes 24, 25, 26, 28, 29, 30, 31, 35, and 36 that represent the architects, engineers, and contractors who supported construction for Limited Brands in New Jersey. The names, node numbers, and locations of these firms are found in Table 2. The firms highlighted in gray form the "Limited Brands" clique.

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[2] For a good discussion of the history and methods of network analysis see John Scott, *Social Network Analysis: A Handbook*.

[3] Limited Brands sold Lerner New York in 2002 and Lane Bryant in 2001. Since this analysis was based on 2000 and 2001 data, stores built for Lerner and Lane Bryant would still have been associated with Limited Brands. Limited Too was a spin-off from the Limited Brands in 1999 and appears to continue to use the same architect and engineering firms that it used while part of Limited Brands.

Nodes 35 and 36 appear to be "local" contractors. The remainder of the players in the clique is architects, engineers, and retail engineering groups who do the design for the "Limited Brands" in its store development efforts. For the most part, these firms are physically located geographically close to the Limited Brands' headquarters in Ohio.

In other studies (Reed, 2002; Reed, 2000; Reed, 1998), the term "image architects" has been used to designate architects and engineers who are closely allied with retail chains and franchises. These firms provide the consistent standard of design that is applied in stores throughout the country and the world. The cluster of firms in Ohio represents the image architects for the Limited Brands.

Additional nodes have been included in Figure 2 to illustrate the degree of "interlinkage" among retail firms as a result of their use of some of the same building professionals. Consider node 31, HBK, which is linked to the Limited Brands, but also forms another cluster with nodes 9, 34, and 6. While HBK is not linked to node 22, Kravco Developers, Kravco is clearly linked with nodes 34 and 6. Remember that we treated all offices of the same company as part of the same entity, so that the HBK

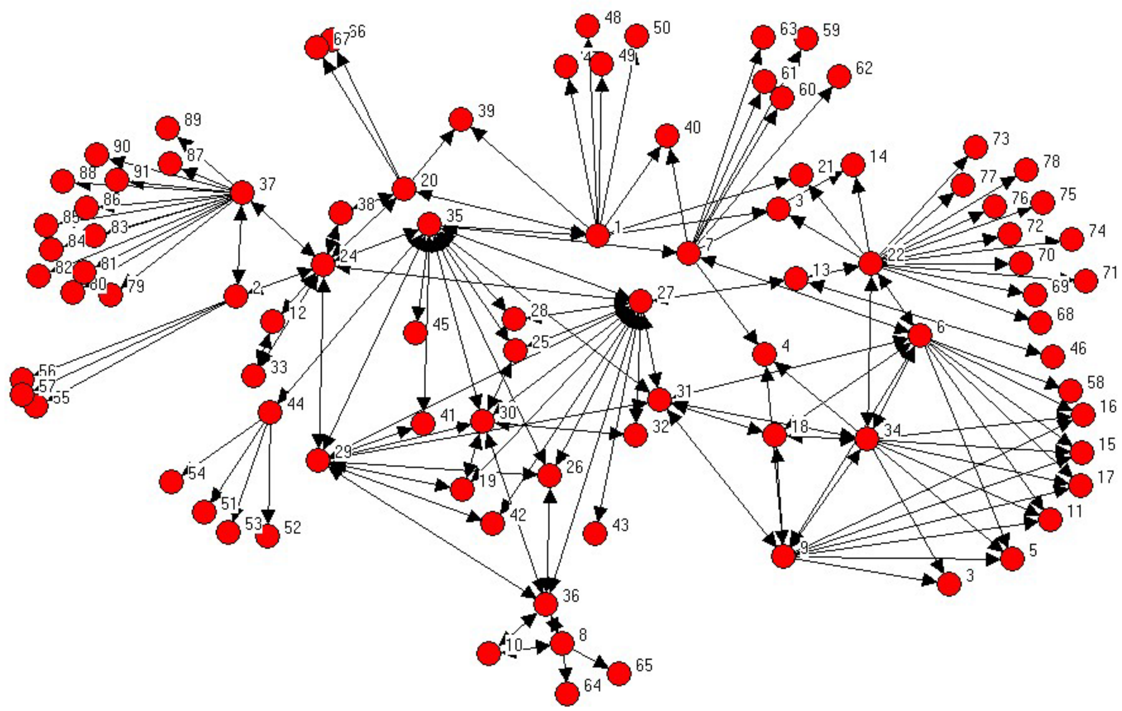

Figure 2 Network Analysis of the Limited Brands based on 2000 - 2001 New Jersey data

office(s) involved with node 34 may not be the same as the one that is involved with the "Limited." Nonetheless, HBK is linked to both the Limited Brands and the Gap (node 34). The important point is that firms of building professionals may influence multiple chains and retailers. Thus, these firms of building professionals are potentially important in efforts to market energy efficiency.

If one wants to work with the Limited Brands on energy efficiency, it is important to target the key support firms in Ohio. This probably implies the need for a national rather than a local strategy for chains because the design standards set in Ohio are likely to be used throughout the country. The standards may be adjusted to meet the requirements of local codes or to respond to incentives at the local level. It also means that the target audience is professionals in design firms rather than each store that is being developed.

Table 2 Identifiers for selected nodes in the "Limited Brands" network

Node number	Company	Company type	Location
6	Fisher	Developer	NY
7	Simon Property Group	Developer	IN
8	Highland	Engineer	NY
9	Eipel	Engineer	NY
13	Oliveri	Contractor	OH
19	Elite Retail Services	Contractor	FL
22	Kravco	Developer	PA/NJ
24	Doerschlag	Architect	OH
25	Retail Design	Design	OH
26	Engineering Support Services	Engineer	OH
27	Limited Brand	Retailer	OH
28	Cline	Architect	OH
29	Shremshock	Architect	OH
30	M Retail	Engineer	OH
31	HBK	Engineer	OH
34	Gap	Retailer	CA
35	Valco	Contractor	PA
36	Provini	Contractor	NJ
37	Designline	Construction services	NJ

A "Public Building" Cluster

The cluster with the largest number of nodes identified by the PAJEK analysis was subsequently identified as a "public building" cluster. This cluster is shown in Figure 3. It contains 14 highly interconnected nodes. The nodes are identified in Table 3. Node 14 is at the center of this cluster. Node 14 is an architectural/engineering firm, Remington and Vernick. The single arrows emanating from node 14 are largely projects such as schools, colleges, public housing, hospitals, and other public facilities. Many of these also connect to the other nodes within the diagram but theses linkages were suppressed in this diagram to make it more readable.

With one exception, an architectural firm, all of the firms in the clique are construction, construction management, engineering firms, and owner agents. There is a high level of interaction among these firms in terms of the work they do in New Jersey. These players appear to have a local and regional base although they may have national or international bases as well. Clearly, this is a group of firms to target if the goal is to upgrade energy efficiency in the public sector.

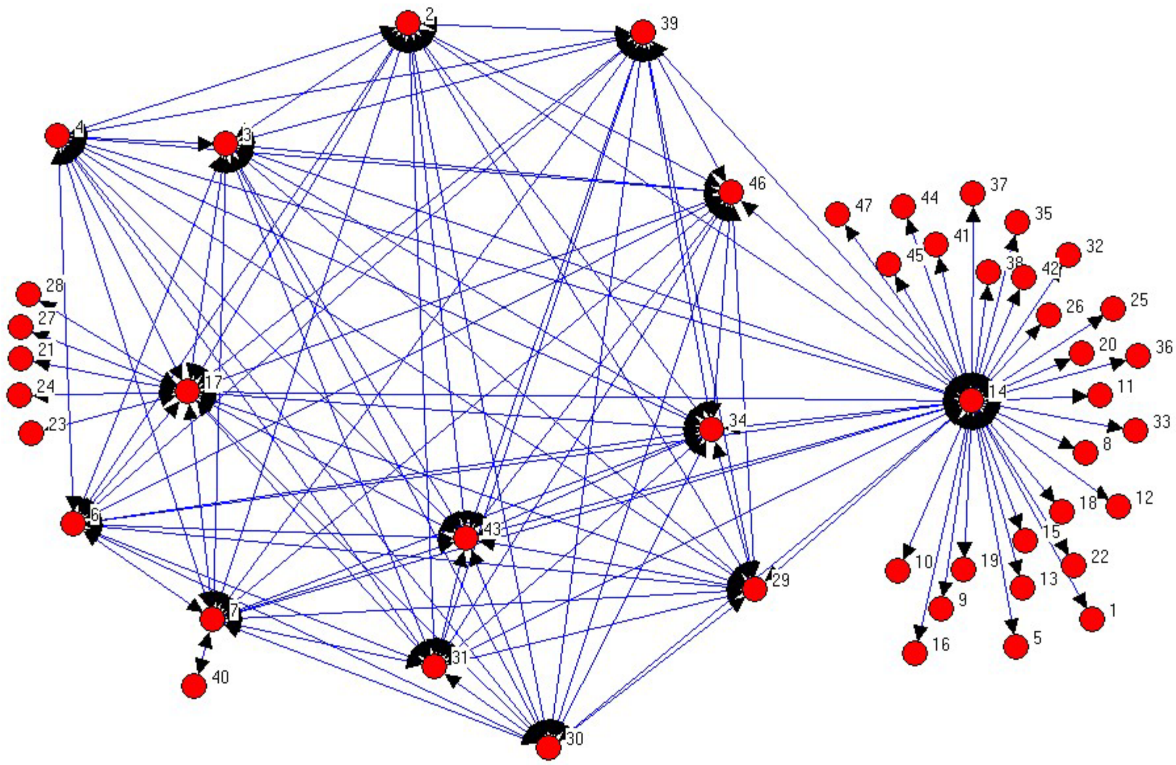

Figure 3 Network analysis of contractors working in public sector

Table 3 Identification of selected nodes in the "public building" network

Node number	Company	Company type	Location
14	Remington and Vernick	Engineer	NJ
2	Gibbs and Cox	Engineer	NY
3	AMSEC M. Rosenblatt and Sons	Architect	NY
4	Han-Padron	Engineering	NY
6	Pennoni Associates	Engineer	NJ/PA
7	Anvil	Contractor	PA
17	Hill International	Construction Management	NJ
29	Envision	Contractor	NJ
30	Damiano Long	Engineer	NJ
31	AP Construction	Contractor	NJ
34	Hudson	Engineer	NJ
39	Creative Computer Solutions	Engineer / owner agent	NJ
42	Cooper Ferry	Owner agent	NJ
46	Weeks Marine	General contractor	NJ

Summary and Conclusions

Network analysis has not been widely used in the energy efficiency field. However, review of the literature on network analysis suggests that interpersonal communication through networks is the most effective way to reach about 85 percent of the target audience in a population such as professionals in the commercial building sector. The keys to effective use of networks are to understand the structure of networks, to create linkages that shorten the communication distances between people and firms, and to use the weak ties.

One of the reasons that network analysis may not have been widely used in the field of energy efficiency has been the lack of data that is amenable to network analysis. This paper shows how the F. W. Dodge Players data can be prepared and used in a network analysis of who works with whom. The paper identifies issues that arise in preparing the data such as the way in which commercial operators structure and name their companies and problems in dealing with the multiple branches of companies. Nonetheless, the data are still quite usable and the analysis produces interesting and actionable results.

The paper also presents two tools that are used in the analysis of networks. UCINET and PAJEK. PAJEK is more capable for the analysis of large data sets.

The analysis of two networks is presented. The first is the analysis the Limited Brands of retail companies that are based in Ohio. The analysis identifies firms of building professionals who work with the group and also local contractors. These firms are likely to be the “image architects” that have been discussed in other publications. The analysis also shows the linkages of firms of building professionals across retailers. The second network shows a more local or regional group of building professionals who provide professional services to the public sector.

Potentially these network analyses can be used to more effectively promote energy efficiency in the building sector. Program implementers can use the results of network analyses to plan marketing efforts and to make marketing efforts in the commercial sector more efficient and effective. Network analyses can be used to assess the penetration of products and ideas by examining whether they have entered and spread through networks.

This paper just begins to show the potential of network analysis. Hopefully this foray into network analysis will encourage others to explore its potential.

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