

Using Simplified Pattern Matching to Define Program Theory and Assess Program Effectiveness—Application to a Green Buildings Program

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ABSTRACT

Although efforts have increased to apply theory-based methods to evaluate energy-efficiency programs, implementation has been limited. One approach used in other fields is combining concept mapping and pattern matching to elicit and test program theories. This provides a means of comparing the program designers' program theory perceptions with those of targeted market actors. Concept mapping typically employs techniques to cluster either metric or non-metric data based on similarities, thus providing a map that groups concepts perceived to be similar. A program implementers' concept map can be used to reveal their perceptions about assumed linkages between program activities and expected outcomes (essentially the program theory). To test the theory, pattern matching is used to compare designer/implementer ratings of a program's expected effects on key outcomes with findings based on data from participants and differences observed between participants and non-participants.

This paper describes how we developed and applied a simplified version of this approach to articulate a program theory and provide insights on the theory's validity for a specific energy-efficient green building program. Program designer/implementer information was gathered from a one-day workshop, with follow-up submittals. The second step occurred during program evaluation when program participants were surveyed and asked to rate the barriers and the effectiveness of specific program services in reducing the barriers. These steps helped elucidate the program theory at project outset and provided the mechanism to compare anticipated program effects with actual outcomes and, therefore, test the consistency of the program theory against the reality of program outcomes.

Introduction

Although development of a program theory to assist the evaluation of energy-efficiency programs has been advocated for several years, a search of the IEPEC conference proceedings shows that the term was not even listed among the key words until the 2003 conference. Recent evaluation protocols have given new prominence to the need for and use of program theories in efficiency program evaluations. One such protocol (CPUC 2006), uses the term nearly 100 times within its recommendations for appropriate evaluation approaches.

Despite the growing emphasis on the need to develop and apply program theories as a component of energy-efficiency program evaluations, many methodological challenges remain. These include a lack of practical, well developed techniques for creating a program theory and causal models. One of the techniques that has been proposed for eliciting stakeholder program assumptions and explanations and then testing the articulated theory is concept mapping coupled with pattern matching (Marquart 1990).

When we designed our plan to evaluate Frontier Associates' Green Building Technical Support Services Program (the Program), we elected to apply the concept mapping/pattern matching approach to develop and test the program theory.¹ The Program was an information-only program intended to promote

¹ The results of Quantec's evaluation of this Program are presented in Lee et al. 2006.

fundamental market changes that would increase the adoption of residential green building practices. It employed a large number of activities targeted at a range of market barriers. Because of the complexity of the Program and its market transformation nature, it was especially useful to have a well articulated theory that could help guide the evaluation.

Concept Mapping and Pattern Matching

The concept mapping/pattern matching approach is based on extensive research and practical applications. The approach is offered by several firms as a service that can be implemented in real-time with in-person groups or through internet tools.²

Concept mapping

Concept mapping is an analytic approach to help groups develop a common framework for guiding and assessing their activities. It is commonly employed for strategic planning, program design, or performance improvement efforts. In the case of program evaluations, it can be a productive tool for facilitating the development of a consensus view by program designers and managers about what the outcomes of a program are expected to be and how the program components relate to those outcomes.

Concept mapping starts with the identification of relevant concepts. In a program evaluation application, the concepts are essentially the outcomes that are likely to be associated with the program. The evaluator can use a combination of literature, experience, the implementers' perceptions, or the perceptions of other stakeholders to identify the concept set. Next, the program implementers participate in the concept mapping process by sorting the concepts into groups based on their degree of similarity. This process is the basis for establishing the construct validity for the expected program outcomes. The implementers also provide their estimate of the causal effect of the program on each outcome.

The groups of sorted concepts provided by the implementers are then analyzed using a tool such as multidimensional scaling (MDS). MDS was developed more than 50 years ago (Torgerson 1952) as a way to help understand people's judgments about the similarity of members of a group of objects. When used to analyze judgments from multiple individuals it is a multivariate technique that takes account of the proportion of agreement among the individuals. Applied to concept groupings, each concept can be viewed as a point in a multidimensional space and the relationship between each pair of concepts is calculated as a distance representing their degree of similarity. There are several types of MDS, depending on whether the data are qualitative or quantitative, from one or multiple respondents, and weighted or unweighted. MDS can be used to generate a visual map showing how close the concepts are to each other and revealing concepts that cluster together because of their similarities. A common illustration of applying MDS is based on inputting the distance between various pairs of cities and then generating a two-dimensional map that typically closely matches the geographic relationships among the cities.

An important feature of the concept map is that it reveals which concepts fall into groups based on their similarities. Figure 1 presents a hypothetical concept map for an information/training energy-efficiency program based on nearly 100 concepts. In this illustrative case, the concepts fall into eight groups of similar outcomes.

For a program evaluation, a concept map can be developed as well for the population targeted by a program. This can be done through a survey of both participants and non-participants that gathers information on the characteristics or variables expected to be affected by the program. The correlations between the responses to questions on the different characteristics or variables can then be analyzed using MDS to develop a similar concept map.

² See, for example, <http://www.conceptsystems.com/ConceptMapping/ConceptSystem.cfm>

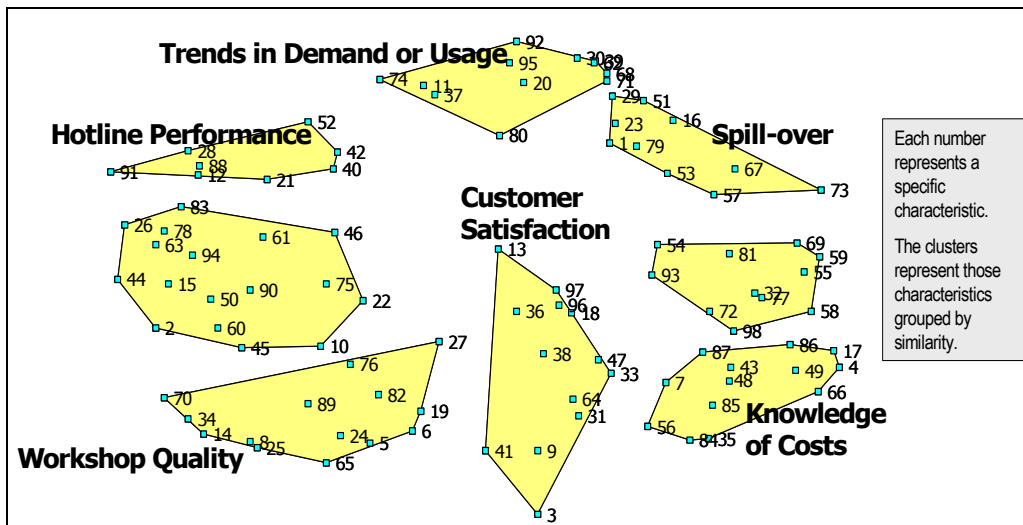


Figure 1. Hypothetical Concept Map for an Information/Training Program

Pattern matching

Pattern matching can be used in program evaluations to assess the program theory in two ways. First, the concept map produced by the program implementers can be compared with the one developed based on the information from program participants and non-participants. If the maps are displayed, an initial assessment of their correspondence can be made by visual inspection. A quantitative measure of their congruence can be calculated from the overall correlation coefficient based on the distances between concepts in the two maps. Individual pairs of concepts can be assessed also by comparing the correlations between the survey responses for each pair with the distances between them in the concept map generated by the implementers. In either case, high consistency between the implementers' assessment and the evaluation results suggests that the basic relationships underlying the program theory are reasonable.

The second step in assessing the program theory is to examine whether outcomes were influenced as expected by the program. This is accomplished by comparing the causal effect estimates derived from the implementers during the concept mapping data collection process with the outcomes based on the evaluation. For example, the implementers providing the data for Figure 1 might have given their program an average rating of 2 on a scale from 1 to 10 for its effect on one of the components of customer satisfaction. This rating can then be compared with the survey responses of program participants and non-participants. In this case, the low rating by the implementers would lead us to expect to see little difference between the responses of participants and non-participants to a question about this customer satisfaction element.

The Green Building Technical Support Services Program

The 2004-2006 Program we evaluated built on the 2002–2003 version of the Program. It focused on primarily two market segments: residential market-rate new construction and remodeling; and affordable housing. For the market-rate component, it targeted both supply-side and demand-side market actors in the residential new construction and remodeling industries. For the affordable housing component, it directed efforts to the development and maturation of the Green Affordable Housing Coalition (GAHC) as a central source of information and resources for affordable housing developers and public agencies with housing-related functions.

Because of the nature of the Program, it extended beyond the direct promotion of energy efficiency to include resource-efficient building design and construction. Green building takes a holistic view of building design and construction by also considering other major energy issues, such as the energy used to deliver clean water; the energy and resources used in the production, transport, use, and disposal of building materials; and the relationships between the building's energy systems and indoor air quality. The Program promoted integrated design, which is a basic tenet of green building. Integrated design requires that all of the key players in the design, construction and operation of a building (client, architect, engineer, builder, subcontractors, consultants, etc.) work together from the beginning of a project to set and achieve common goals, design the building and its systems, and work through construction and maintenance issues as an integrated team. The objective of integrated design is to produce building systems that actually work together as a system, reduce construction problems and delays, and improve building quality and resource efficiency.

Green building market barriers

The Program identified a set of market barriers and established activities to address those barriers. On the supply side, the barriers included:

- Lack of information: There is a general lack of knowledge of green building techniques and products within the building industry.
- Risk aversion: Builders are resistant to using new products and new construction techniques if they think there is any risk that the changes will add to construction costs, delay construction delays, require new skills and experience, or generate additional call-backs.
- Organizational practices: Builders tend to select contractors based on their expected performance and knowledge, and experience with green building practices does not typically enter into the selection decision.
- Lack of coordination: Builders rarely apply an integrated design approach, which is an essential element of successful green building projects.
- Regulatory barriers: Green building may be in conflict with local codes or ordinances.
- Split incentives: Builders usually do not emphasize long-term ownership costs, and they perceive their customers to be uninterested in paying extra for green measures and especially for energy efficiency.

On the demand side, barriers identified included:

- Lack of awareness: Home buyers have relatively little awareness of the existence and nature of energy-efficient and green features in a home. They lack the information to recognize those features and to evaluate their potential costs and benefits.
- Inseparability of product features: Energy efficiency and green home features are rarely recognized for their distinct benefits.
- Asymmetric information: The costs and benefits of green and energy-efficient features are not usually well understood by buyers and must rely on the sales agent who may not be perceived to be a credible source.

Finally, a set of barriers is linked to local government issues, policies, and practices. Local governments (cities, counties, and special districts) are logical agents for promoting green and efficient buildings, but they face significant constraints in their funding, staffing, expertise, and other resources.

Program efforts to address barriers

The main thrust of the Program was on addressing supply-side and demand-side informational barriers. On the supply side, it emphasized training on how to apply green products and practices with

reduced risk to custom builders, remodelers, and affordable housing developers; evaluate and select qualified subcontractors who can build green; and achieve an integrated design and construction process. The desired outcome was a supply chain that was better equipped to deliver green-built homes and understood how to define and assess green building.

On the demand side, the Program was intended to address lack of awareness and information via aggressive home buyer education. One tactic was to link energy efficiency to more core concerns, particularly health, comfort, and maintenance considerations. The desired outcome was a set of home buyers and home owners who understood the value of green features, knew how to shop for and find what they wanted, and thereby push the marketplace to respond to their desires.

On the public-sector front, the Program partnered with local governments to take advantage of their long-standing relationships with the community and the construction industry. Local governments were enlisted to help communicate with residents and business groups. The Program also assisted them in reviewing their role in affordable housing projects to ensure that they were encouraging rather than discouraging green building.

Program objectives and implementation strategy

The stated objectives of the Program included:

1. Expand both the local supply of and demand for green building services and products
2. Create a broad awareness of the benefits of green building
3. Continue development of organizational frameworks to deliver green building education, services, and resources to local governments, building industry professionals, affordable housing developers, and the community
4. Maximize participation in the California ENERGY STAR® New Homes Program

The Program was essentially an information program based on a voluntary education and training model with a regional scope. It was intended to develop a consistent program design and market identity across multiple cities and counties, combined with local co-branding. The Program was planned to incorporate the following components:

- Continued organizational support for the GAHC
- Supply-side stimulus via technical training for the building and real estate industry
- Demand-side stimulus via aggressive public outreach and education regarding the benefits of building and buying “green”
- State-of-the-art green building website
- Local government support, including building inspector training and technical and programmatic support to local governments
- Project-specific technical support for home owners, builders, and contractors

Specific activities were set out in the implementers’ original proposal and Program Implementation Plan (PIP) to fulfill the Program objectives. As the Program progressed, however, its implementers responded to feedback from the targeted stakeholders and participants and made adjustments intended to increase effectiveness and efficiency.

Application of Concept Mapping/Pattern Matching

To investigate the program theory and test whether actual Program outcomes matched expectations, we used a simplified version of the concept mapping/pattern matching approach. Since the intent of the Program was to reduce the barriers identified in the green housing market, the concepts/outcomes considered in our application were changes in these market barriers. We implemented the following steps:

- An exercise was conducted, starting at the project initiation meeting, to solicit information

from the Program designers/implementers to identify the barriers addressed by the various Program activities. The implementers then assigned importance scores to perceived barriers and provided similar ratings of the expected effectiveness of specific Program activities to overcome the barriers.

- Through surveys and interviews with targeted audiences we obtained similar assessments of the significance of the barriers. This information was used to provide feedback on their perceptions about the barriers and Program effects.
- Participants provided ratings of the Program effects on the barriers; comparisons between the data from groups targeted by the Program and the responses of the Program designers/implementers provided a measure of how well the Program did in achieving the effects that the designers/implementers had intended.

Given the diversity of the audiences and Program activities, the pattern matching approach was applied selectively. We worked with Frontier to choose the most appropriate Program activities to evaluate with this methodology. The implementers' priorities and the suitability of the method were used to decide where and how to apply the technique.

Program theory

Because the Program consisted of numerous specific activities or services provided, more than in most programs, our approach in developing a testable program theory was not to identify a theory for the Program as a whole. We believed that, with the evaluation resources available, any theory developed for the overall Program would not provide enough information about the performance of individual Program components to help the implementers make effective improvements. Instead, we focused our study resources on specific Program components with the intent of developing theories specific to those components.

The basis for developing these program theories was a combination of primarily two elements. The first was the proposal Frontier submitted to receive funding (Frontier 2004) and the PIP, as mentioned above. The first section of the proposal, summarized earlier, lays out the implementers' rationale for the Program, market barriers to be addressed, and how the Program would tackle these barriers. The second element used to develop the specific theories was the process described below. Through this process we obtained the implementers' assessments of the Program barriers and how they thought each activity would influence the barriers. Together, these two elements provided us the key information for a program theory of each Program component studied. These fundamental program theories—activity description, stakeholders, market barriers, significance of the market barriers, and effect of activity on the barriers—became the pattern that we would compare with the outcomes and views of market actors.

Implementers' inputs

Quantec held an initial meeting with the implementation team to explain our approach and initiate data collection. Because of the nature of this Program—a large number of components and multiple target audiences—the data collection process was complex. We used a spreadsheet to obtain data from the implementers in which they provided their ratings on how important various green building barriers were to different target audiences (e.g., developers and homebuyers), and how effective they thought each of 14 Program components would be in mitigating each barrier for the specific target audience. The Program components analyzed ranged from technical consultation services to point-of-purchase displays. We explained the rating exercise during our first meeting and implementers were given several days to fill out the matrix and return it. To minimize confusion, a glossary of terms and directions were provided in the data entry spreadsheet.

Our process differed from the typical concept mapping approach because it was not essential to explicitly include a step to generate a concept map. The barriers identified were analogous to “concepts” in

the usual approach and the anticipated barriers were well identified by the implementers during Program design. Since the barriers for specific audiences were already identified, this reduced the need for a first step to map the concepts. We designed our approach to allow us to test the validity of the program-theory construct by requesting the implementers' assessment of the importance of each barrier. As described later, it was thus possible to compare the implementers' conceptual assessment of the market with the views of the targeted audiences and assess how consistent their perceptions were.

Figure 2 provides an example of the results from the data collection exercise conducted with the implementers. In this case, Quantec asked implementers to provide their ratings regarding the builder/developer audience addressed by the Program. Six significant barriers are identified for this group in the figure, ranging from "regulatory" to "uncertainty" barriers. Their significance rating score is shown in the figure on the x-axis, on a scale from 0 to 10. For each barrier, the implementers' estimate of the effectiveness of each Program activity expected to affect that barrier for builders/developers is shown by a symbol in the figure. For example, the Program fact sheets are rated at approximately 6 on the scale in terms of their effectiveness in reducing "uncertainty." According to the implementers, the most effective Program activity for alleviating builder/developer uncertainty issues was expected to be in-depth consultations, which earned a rating of nearly 9. We analyzed the implementers' data for each of the Program activities and targeted stakeholders. Four key members of the implementation team provided their ratings.

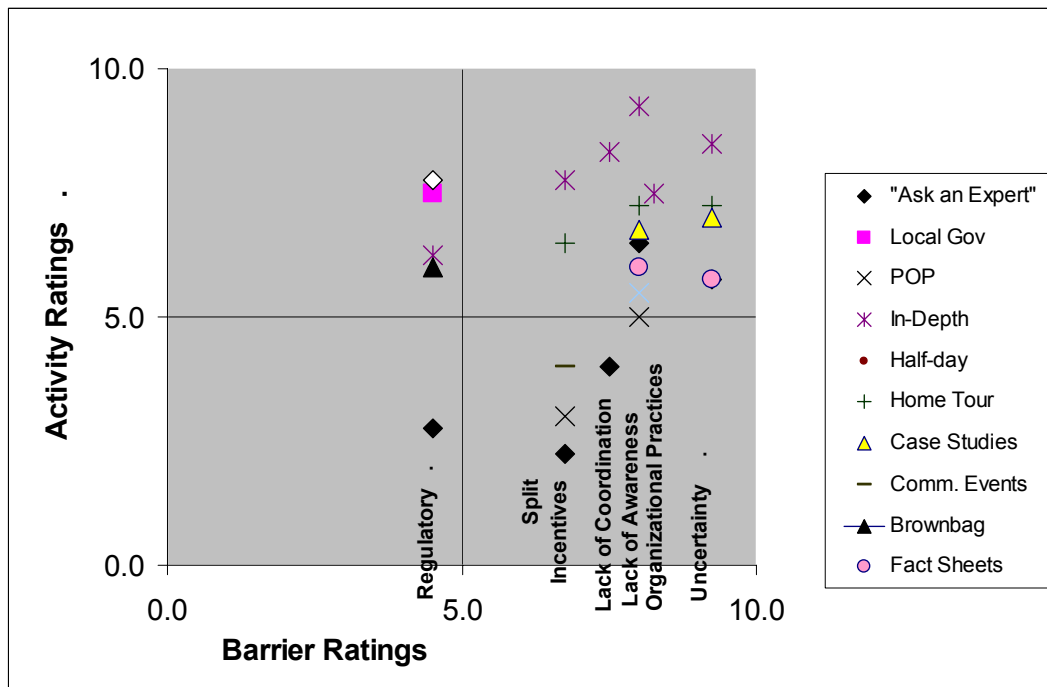


Figure 2. Implementers' Ratings for Builders/Developers

In general, there was a high level of consistency across the implementers' barrier ratings. Only four of the 25 market actor/barrier ratings they provided had a spread of five points or more (on the 10-point scale) between the highest and lowest respondents' rankings; none of these four was among those identified as the most significant barriers. Three of the four involved the split incentive barrier. The diversity in ratings for this barrier might be due as much to the difficulty of comprehending this barrier as genuine differences in perspectives. The ratings of Program activities also were very consistent, with a few exceptions. The exceptions helped identify areas where implementers differed in their views of how the Program would affect the market.

Market actors' data

Given the wide range of activities conducted in the Program, we employed several different techniques to obtain feedback from both Program participants and, in limited cases, non-participants. Besides helping to assess Program effectiveness, data collection from stakeholders was designed to be useful for comparing the Program implementers' perceptions about green building barriers and Program effectiveness with those of stakeholders affected by the Program.

Data were obtained from stakeholders on nine main types of Program activities. Point-of-purchase displays (POPs) were one of the early components of the Program implemented. They were information displays presenting basic information about green buildings and building practices. Our data collection for the POPs consisted of intercept interviews of shoppers at stores where the displays were present. As with most of the market actor data collection steps, our interviews of shoppers included questions about their view of the barriers to green building, as well as their response to the POPs.

Another Program service assessed was in-depth consultations provided by Program staff to members of builder/developer organizations. Quantec conducted two rounds of telephone interviews with members of organizations selected randomly. The purpose of these interviews was to evaluate awareness of the availability of Program in-depth consultation services, assess the delivery of services provided during consultations, and obtain opinions on the significance of market barriers and these consultations' impact on them.

A third activity we assessed was a green home tour conducted late in 2005. Quantec worked closely with the tour planners to develop and implement a written survey to which 347 participants responded. Over 50% of the attendees were homeowners or potential home buyers. The survey documented tour participation information (e.g., how many homes were visited) and provided evaluation data including views about how effective the tour was at reducing barriers to building green. Figure 3 summarizes the responses of homebuyers to questions about the effectiveness of the tour in reducing several key barriers.

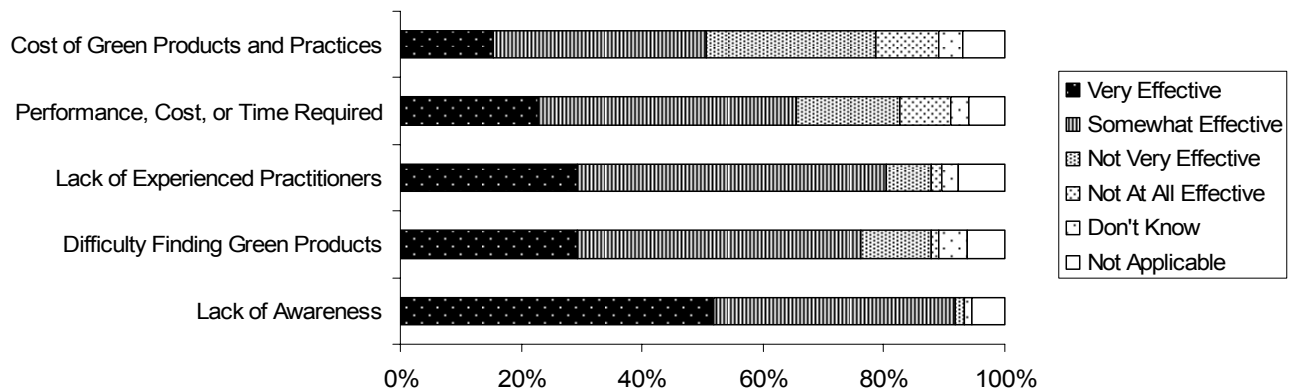


Figure 3. Effect of Home Tour on Green Barriers—Homebuyers

Because the Program activities were so diverse, the ways in which the data were collected and analyzed varied considerably. Generally, the detailed structure of the data obtained on Program outcomes was not completely consistent with data collected from the implementers. However, it was possible in general to satisfy the overall intent of collecting information on outcomes that could be compared with the perceptions and expectation of the designers/implementers to assess the degree of pattern matching.

Pattern matching and program theory testing

As noted earlier, we selectively tested the program theory for various Program components against outcomes. The choices were guided by the significance of the component, availability of data, and study

resources. One component that was both an important Program component and for which it was possible to collect sufficient data was the in-depth consultations provided by the Program team

The assessment of in-depth consultations was based on two sets of interviews Quantec conducted with members of organizations selected randomly from those that had received these services. The interviews were conducted in November 2004 and mid-April to mid-May 2006. In addition to typical process evaluation questions about satisfaction with the services received, participants were asked to rate both the significance of various green building barriers and the effect of the Program’s in-depth consultations on these barriers. Table 1 summarizes the results from these interviews .³

Table 1. Ratings of Barriers and Effectiveness of In-Depth Consultations

Green Building Barrier	Significance of Barrier	Effectiveness of Consultations at Addressing Barrier*	No. Respondents Rating Barriers
Lack of awareness and knowledge about green products or practices	3.8	4.0	6
Difficulty finding green products	2.8	2.0	5
Difficulty finding experienced practitioners	3.7	4.0	5
Uncertainty about performance or time required to apply green products or practices	3.0	3.0	5
Cost of green products and practices	3.1	3.3	5
Added coordination required during design and construction	2.8	3.5	5
Need to change how design/construction are done	3.3	3.5	4
Reduced profit margin	1.0	N/A	5
Confusion or conflicts with local codes	0.8	N/A	4

Note: 4=Very Significant/Effective, 1=Not At All Significant/Effective

* Only one of the three 2006 respondents was able to respond to the question of the effectiveness of consultation services

According to the average ratings, the most significant barriers were the “lack of awareness/knowledge” and “difficulty finding experience practitioners.” “Reduced profit margin” and “conflicts with local codes” were rated as the least significant barriers. The effectiveness of the in-depth consultations received high marks overall and was rated the highest for addressing the two barriers considered to be the most significant.

It is interesting to note that there appeared to be trends in the responses about the barriers. In 2004, the builders/developers rated “lack of awareness/knowledge” and “difficulty finding practitioners” to be considerably more significant barriers than the 2006 respondents did. Since the in-depth consultations received high ratings for effectiveness addressing these barriers, it is reasonable to conclude that the consultations, over time, were helping alleviate these barriers.

³ Not all participants expressed views on all barriers. Some were not applicable to the services they had received or their personal involvement with the Program.

The pattern-matching consisted of a comparison of these results with those from the original exercise conducted with implementers. Figure 4 shows the implementers' ratings for in-depth consultations provided to builders/developers. As before, the x-axis shows how significant the barriers were judged to be and the y-axis shows how effective in-depth consultations were expected to be at reducing each barrier.

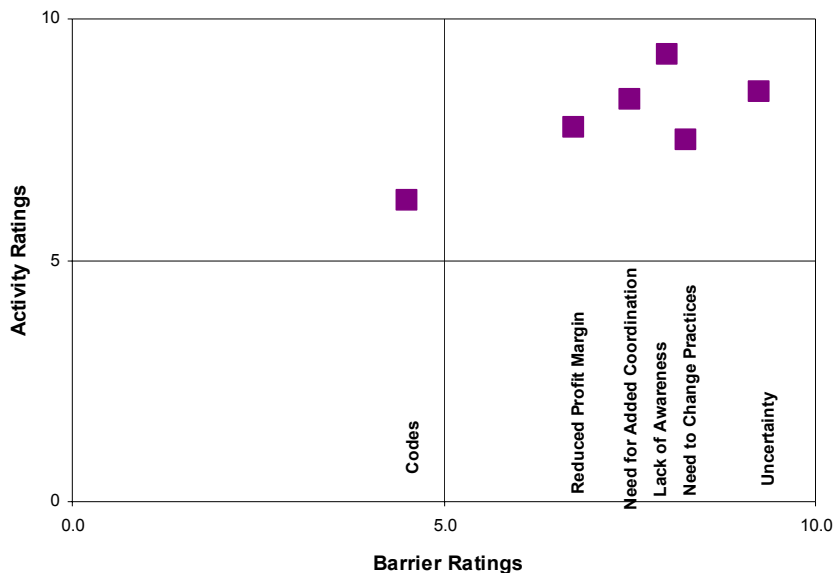


Figure 4. Implementers' Ratings: In-depth Consultations for Builders/Developers

When these results were compared with those from the builder/developer interviews, they agreed in terms of what barriers were rated as least significant: “code conflicts” and “reduced profit margin.” However, the implementers rated “uncertainty about the performance of green products and the time required to apply them” as the most significant barrier, while the builders/developers rated several barriers as more significant than uncertainty.⁴

Though the importance ratings differed to an extent, the effectiveness of in-depth consultations at reducing the barriers received quite similar ratings from both the implementers and the builders/developers. This suggested that the expectations of the implementers were fairly accurate about how effective the in-depth consultations would be.

Overall, the pattern matching showed that the theory for this component of the Program was quite accurate in terms of how the in-depth consultations would perform. The theory was less accurate about the relative significance of the major barriers. It is necessary to qualify this finding, however, for two reasons. First, the number of builder/developer respondents was not very large. Second, the participants who sought in-depth consultations may not have been totally representative of all builders/developers targeted by the Program. When the implementers did their ratings, their assessment was probably based more on the typical builder/developer than those self-selected ones who requested the consultations.

For each of the stakeholder groups for which we had sufficient data, the group's ratings of green building barriers were compared with those generated by the implementers. A figure was created to compare these ratings. The comparison for homebuyers is shown as an example in Figure 5. If the agreement were perfect, the barriers would all appear in the cells along the diagonal from the bottom left to top right. In

⁴ Note that not all the barriers rated by the two groups were the same so there were not ratings from both groups for a few barriers.

general, the agreement was relatively close for all the groups. Similarly, Quantec compared how the implementers and stakeholders rated the effectiveness of Program components. Again, the agreement between the implementers' and stakeholder groups' ratings was generally quite close.

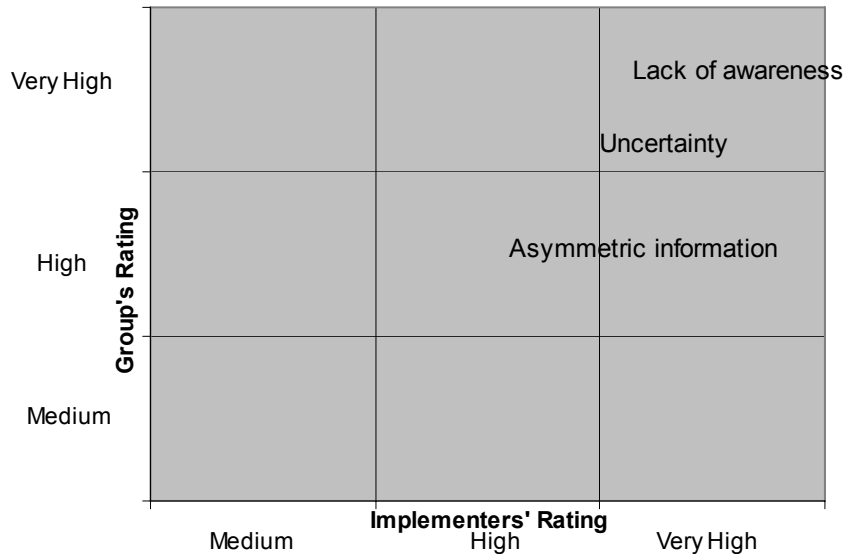


Figure 5. Ratings of Barriers: Homebuyers

Conclusions

Based on the comparisons between the implementers' and market actors' responses regarding the significance of market barriers and the effects of the various Program components, we concluded that the program theory proposed by the implementers matched quite closely the actual functioning of the Program. The barriers anticipated by the implementers were basically consistent with those experienced by the various market actors. Similarly, the activities and services delivered by the Program were about as effective at addressing these barriers as the implementers expected when designing the Program.

Our conclusion about how well the program theory matched reality, however, must be tempered somewhat. Data collection, sample sizes, and the scope of the study did not permit a comprehensive review of all the Program activities, barriers, and Program effects. Consequently, there were several gaps in the comparisons presented above. Nevertheless, for those cases where we were able to make direct comparisons, the program theory matched the empirical data from our study and confirmed the theory.

With regard to the use of concept mapping and pattern matching, applying the approach was challenging in this case because of the large number of separate Program components. Most programs consist of fewer activities and a smaller number of outcomes to be assessed.

Given our experience in this study, we believe that concept mapping/pattern matching is a very useful technique for generating and testing program theories. In this evaluation, the approach provided a process for getting the implementers to articulate their theories of what the Program components were designed to do, how they would accomplish their objectives, and how effective they would be. Since using program theories as the basis for program evaluations has gained broader recognition, the authors recommend wider and more systematic applications of the concept mapping/pattern matching approach as a way to develop a program theory and use it to guide evaluation design and test the match between intentions and outcomes.

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