

Brownfield Development Selection Using Multiattribute Decision Making

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Abstract: Brownfields are potential development opportunities for the communities in which these old industrial sites sit. The Western Pennsylvania Brownfields Center at Carnegie Mellon University has developed and tested a multiattribute decision-making process for complex brownfield development selection. Local community organizers (in this case, Main and Elm Street managers) collected data on site attributes related to environmental conditions, demographics, development potential, infrastructure conditions, and market realities. Concurrently, decision makers [in this case, the Board of Directors of Keystone Community Oriented Real Estate (CORE) Services (KCS), a subsidiary of the Pennsylvania Downtown Center, with a mission to promote real estate development in Main and Elm Street neighborhoods and business districts] weighted the attributes consistent with their priorities and the availability of resources. Then, weights are applied to the attributes collected by the community organizers to estimate a total score for each property of interest. The result is a ranking of properties that can be used to guide investment decisions or public funding. This paper describes the process used and provides a guide for application elsewhere. DOI: 10.1061/(ASCE)UP.1943-5444.0000182. © 2013 American Society of Civil Engineers.

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Introduction

The complexity of decision making can stall the revitalization of brownfields. Brownfields are properties with the presence or suspected presence of hazardous contaminants (EPA 2009). Communities can be hesitant to proceed with development because of uncertainties about many issues, including the extent of contamination, ownership, and costs for remediation and infrastructure improvements. Within a community, the issues are often compounded by the existence of many brownfields (old commercial or industrial sites). Given limited resources, communities often face the problem of prioritizing the best sites for near term development. This observation is consistent with Wang et al. (2011), in which it is noted that the barriers to brownfield development stem from policy and planning problems as opposed to environmental conditions.

At the Western Pennsylvania Brownfields Center at Carnegie Mellon University, it was hypothesized that communities might benefit from a tool that could logically guide them through a decision-making process—one that would allow for transparent and rational decision making while meeting the needs of the community and accounting for limited resources. These efforts build on previous Carnegie Mellon research conducted by Lange and McNeil (2004a, b), wherein the attributes of development success and the lack of assessment tools are discussed.

Brownfields have many stakeholders, and the need for support tools that consider the intentions and attitudes of the decision makers is evident (Walker et al. 2010; Wang et al. 2011; Blokhuis et al. 2012; Yousefi et al. 2010). One solution is the use of a mathematical method to consider all aspects individually and make a decision that is logical and transparent to the public—a consideration that is especially important to government officials (Sunderpandian et al. 2005). Ideally, this solution would match the intuitive choices of the decision maker. One such mathematical method is the multiattribute decision-making process. The outcome of the applied process helps decision makers to allocate their resources (of time and money) to those sites that will have the greatest potential to succeed and catalyze additional development. Multiattribute decision making is also called multicriteria decision analysis or multiattribute utility theory, but in all cases, the methodology allows for the parsing of complex subjects (Belton and Stewart 2002).

Others are exploring the use of multiattribute decision making in the areas of sustainability (Wedding and Crawford-Brown 2007) and environmental management (Randhir and Shriver 2009). This paper reports on a multiattribute decision making tool developed at Carnegie Mellon for brownfield development selection. The method is presented in the following section, followed by an example application and a discussion of the overall process.

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Multiattribute Decision Making

Multiattribute decision making (MADM) usually involves complex decision problems—problems that are considered difficult by the decision maker and require careful elaboration and analysis (Bohanec 2008). Complex decision problems are usually characterized by

- Novelty: The decision maker is confronted with the problem for the first time and has insufficient knowledge or skills to address the problem;
- Confusion: Unclear understanding of the problem and its goals, unknown or incompletely defined options;

- Multiple and possibly conflicting goals;
- Group decision making: Involvement of different stakeholders or groups that have different and possibly conflicting goals;
- Important consequences of the decision; and
- Limited resources (time and expertise) to conduct the decision process.

A MADM process supports people in making decisions rather than making decisions itself. In MADM for brownfield development selection, the problem is primarily a problem of choice, which is defined as follows.

Given a set of optional brownfield properties, either

- Choose an option that best satisfies the goals and objectives of the decision maker; or
- Rank the options according to these goals and objectives.

A MADM is a process that can assist communities in making brownfield development decisions by promoting logical data collection and rational evaluation of options for moving forward. Specifically, MADM can be used to analyze brownfields by

- Structuring and breaking the problem down into more manageable parts;
- Explicitly considering the possible development alternatives, available information, and preferences of the decision maker (s); and
- Combining these to arrive at optimal or at least sufficiently good decisions.

To be suitable for multiattribute modeling, a decision problem must have some specific properties. Primarily, it should deal with options, which need to be evaluated, analyzed, and compared with one another. It is important that the decision problem can be understood as smaller, less complex subproblems, and that the options can be described by basic features. Brownfield development is multifaceted, as noted by Lange and McNeil (Kirkwood 2001), and is therefore a good candidate for such decision making. Considerations or properties of brownfield development include the existence (or not) of a champion, development potential, existing infrastructure, and the local real estate market. All of these considerations are presented and discussed in more detail subsequently.

MADM Method

The Western Pennsylvania Brownfields Center designed both of the data collection instruments and the methodology of assessing the priorities of the decision makers.

The principals in this process include the following:

- The decision maker—The keeper of the resources that can be selectively distributed to catalyze brownfield development;
- The data provider or community agent—Has familiarity with the many brownfield properties in the area and is not the property owner (to minimize bias and help to assure objectivity); and
- The facilitator—The independent agent that educates the data provider or community agent and works with the decision maker to establish priorities and associated weights.

Data is collected in two phases: site profile survey and site attribute questionnaire. Completion of the site profile survey by the data provider or community agent is the first step. The collection of individual site profile surveys allows the decision maker to sort the data and select sites that are readily comparable and are potentially feasible given available resources. Information to be addressed in the site profile is included in Table 1.

Data may be sorted on any of these criteria based on the focus of the decision maker. For instance, the decision maker might focus on sites that are less than 1 acre, or the decision maker might only want to look at sites with historical significance.

Table 1. Site Profile Survey

Section	Content
General information	Contact information for the person completing the survey
Property owner	Contact information for the property owner and his/her considerations for redevelopment
Site information	Location, property size, tax liens, existence of structures, historical value, regulatory actions

If after the decision maker has sorted the data a property is short-listed on the basis of information provided in the site profile survey, then the community agent (as defined previously) will complete the site attribute questionnaire (Table 2). Responses on the site attribute questionnaire were assigned a number to quantify the results and numerically score the property. Questions within each of the following four categories of data are to be completed for each site. Indicators refer to targeted questions within each category that guide the user to respond to specific criteria of interest in brownfield decision making. Indicator selection was based on previous research at Carnegie Mellon, with further revision by the board members of Keystone Community Oriented Real Estate (CORE) Services.

Concurrent to the data collection process (through both the survey and the questionnaire), the decision maker(s) determine the value or weight to be applied to each of the four categories and the weight of the indicator questions within each of those categories. The weights are intended to reflect the priorities of the decision makers. The final score, on the scale of 0–100%, for each property is then based on the following equation:

$$\text{Score} = \sum_c \left(W_c \times \sum_{ic} W_{ic} \times I_{ic} \right) \quad (1)$$

After all of the brownfield properties have been scored, the decision makers can then rank the sites based on the total score (or the scores for the individual categories) and determine those that are most consistent with their priorities, goals, and objectives.

In MADM, the conditions are weighed to reflect the interests of the decision makers. In this research, there are two levels of weighting: the four primary categories (as noted in Table 2) are weighted, then the indicators within each category are weighted. The products are then summed to attain an overall score for the property(ies) of interest. With this initial score and subsequent ranking (from high to low scores), the decision makers get a big picture of the sites and their relevance to the priorities of the group. The data can also be parsed to get more specific scores for each of the categories. With the parsing, one can then compare and evaluate the properties on the basis of any one of the four primary categories.

Pennsylvania Downtown Center and Keystone CORE Services

Established in 1987, the Pennsylvania Downtown Center (PDC) promotes urban revitalization and reinvestment. The Main Street and Elm Street programs are two of PDC's initiatives. Main Street managers focus on economic restructuring, especially in the downtown business areas, and Elm Street managers are driven by the philosophy of neighbors and economy, with a focus on the residential areas. The Main Street and Elm Street programs have operated for years, but only recently (2009) was the Keystone CORE Services, Inc (KCS) formed as a subsidiary of PDC to provide additional support and incentives to the Main and Elm Street

Table 2. Site Attribute Questionnaire

Category	Indicators
Development driver—The champion is an entity, preferably an individual, who takes on the role of the organizer, the instigator, the cheerleader, and the connector. He or she drives the development effort. He or she might be part of a private sector developer, a community-based organization, or a local redevelopment authority.	Developer champion (private sector) Municipal or nongovernmental organization (NGO) interest
Development potential—This category assesses the likelihood that a site will be redeveloped. There are seven subindicators within development potential: end use, funding, time, labor market, property ownership, community support, and quality of life.	End use plans Funding availability Timeline Property ownership Community support Quality of life Contamination
Environmental—Environmental site conditions pose an uncertainty that can be prohibitive. It is important to define and understand the potential environment challenges because of the impact that those challenges might have on the projects' costs and schedule.	Previous use of site Public utilities
Market information—To better understand the surrounding community in which the brownfield site is located, this category of indicators helps to compare the site of interest with other (nonbrownfield) properties in the area with respect to property values and potential tax revenues.	Labor market Property and wage values Environmental justice Location Infrastructure indication

managers in the arena of complex land and real estate development matters. Working collaboratively with the private sector, the mission of the KCS is three-fold: combat community deterioration (by becoming an active and informed redevelopment partner), lessen the burden of government (by finding solutions to administrative hurdles), and promote historic preservation (by creative repurposing of architecturally significant structures).

The KSC was an appropriate partner for this project because of their mandate to find mechanisms to assist and expedite potentially catalytic development in the communities in Pennsylvania that are represented by either Main Street (170 communities) or Elm Street (71 communities) managers.

Data Collection and Analysis

The Western Pennsylvania Brownfields Center partnered with the Pennsylvania Downtown Center to perform a beta test of this spreadsheet-based tool. Main and Elm Street managers from across the state were encouraged to participate, and 79 site profile surveys were collected from 17 communities. The Board of Directors of KCS (the decision makers) shortlisted to 30 sites and received site attribute questionnaires from 23 sites. Shortlisting was generally based on the following criteria: size (smaller sites were preferred), geography (to obtain a representation of sites across the state), intuitive likelihood of success, whether or not a Phase I assessment (ASTM 2005) had been performed, the existence of a cooperative property owner, and whether or not the site was determined to be underutilized. The Keystone CORE Services was interested in this process because they possess resources (both funding and in-kind support and/or services) that can be strategically applied to initiate developments across the state.

Concurrently, Keystone CORE Services participated in a facilitated exercise to determine the weights of the four categories and the indicators within. Weighting is important because it reflects the priorities of the decision maker. An iterative process is necessary to achieve consensus among the members of the decision maker body. The weighting process followed a sequence of closed ballot reporting by each of the four directors, a discussion facilitated by the Western Pennsylvania Brownfields Center, a second closed ballot reporting, and finally a pairwise comparison. The results were for the main categories and the indicators as shown shown in Table 3.

A MS Office Excel spreadsheet was constructed and populated with the scores from the 23 returned questionnaires to perform the weighting calculation. Weights were applied to the data from the 23 finalists and the sites were ranked in order from highest to lowest scores. Final scores ranged from 27–70, with a distribution as shown in Table 4:

The relatively normal distribution of the results suggests that the properties should be evaluated further in terms of three groupings in terms of those that should be considered first, second, and last for development potential.

To assess the intuitive ranking of the sites, board members were asked to rank the sites before they were made aware of the results of the MADM process. The CORE board members and one PDC staff member listed their top six sites. With a total of 23 votes cast, 15 of those votes corresponded to the top 10 sites as determined through the MADM process. Eight votes went to sites that were ranked 11–20 in the MADM process. Although this was not a statistically rigorous exercise, the results indicate that the MADM-based ranking was generally consistent with the intuition of the decision makers. Comments by the decision makers might provide some insight into the differences. The MADM criteria were quite explicit, and the actors in the intuitive process attributed they ranked sites high if

- There was potential for a synergistic impact on the neighborhood;
- It was indicative of other sites and therefore the approach to development might be replicated;
- The development was consistent with the CORE's mission to intervene on distressed sites with high potential for success; or
- The development was consistent with the municipal comprehensive plan.

Given this feedback, future iterations of the MADM tool might seek to include such considerations.

Sample Results

As noted previously, total scores for the 23 properties completing the site attribute survey ranged from 70–27. Simply, a high score means that the property of interest is a good investment for the decision maker—in this case, Keystone CORE Services. A property with a low score may still be a good development candidate, but the investment is not consistent with the priorities

Table 3. Weights of Categories and Indicators as Determined by the Keystone CORE Board of Directors

Category	Weight of category (%)	Indicator	Weight of indicator (%)
Development driver	25	Developer champion	20
		Municipal/NGO interest	80
Development potential	40	End use	30
		Funding	14
		Time	3
		Property ownership	7
		Community support	26
Environmental	20	Quality of life	20
		Contamination	50
		Previous use of site	34
		Public utilities	16
Market information	15	Labor market	5
		Property and wage values	10
		Environmental justice	15
		Location	30
		Infrastructure indicator	40

of the decision maker. In this section of the paper, two brief case studies will be presented: high and low scoring properties.

The Greensboro Lock Power House received the highest property score of 70. The Lock Power House is located along the Monongahela River in Greensboro, Pennsylvania approximately 75 mi south of the confluence with the Allegheny River in downtown Pittsburgh. The Lock Power House was constructed by the U.S. Army Corps of Engineers around 1920 and was decommissioned (and the locks removed) in 1995. There are approximately 5,000 ft² of developable space. The town of Greensboro acquired ownership of the property (and all remaining mechanical equipment) in 1995. In the MADM process, the Greensboro Lock Power House had a high total score for the following reasons: there is an interested developer (having already invested in some remediation of the property), the development potential is high (there is good community support), and market conditions are favorable (for a destination boutique).

A former Coca-Cola bottling facility in the state capital of Harrisburg, Pennsylvania received a low score of 33. The 60,000 ft² building sits on 1.5 acres and there have been a number of development ideas, from a business incubator to a grocery store to a collaboration with the Hamilton Health Care Center. Although there seems to be a private developer that is championing the project, the revitalization of this property is not a priority for the municipality, and the funding for such a large project seems to be difficult to identify and secure.

Based on the final ranking of the 23 brownfield properties, the KCS Board of Directors elected to offer incentives to some communities for the advancement of specific properties. Some communities received \$5,000 grants. Others received technical

Table 4. Summary of Scores for the 23 Sites that Participated in the MADM Process

Score	Number of sites
Greater than 67	2
63–67	4
56–62	8
44–55	3
34–42	4
Less than 32	2

assistance or other consulting services. Three communities were offered partial support of a “Do It Yourself Feasibility Study” facilitated by Donovan Rypkema of Place Economics.

Observations and Lessons Learned

A MADM is a process that when applied can assist decision makers in sorting through tough choices. As noted previously, the primary outcome of the application should provide direction for the effective distribution of limited resources based on the overall ranking. However, the execution of the process also provided insights to the behavior of the data providers and insights into the priorities of the decision makers. In addition, although the primary objective was to determine the overall final scores, additional value was found in the subscores for each of the categories.

Application of the MADM tool is not an absolute process, but rather the application only provides guidance because the process includes risk and uncertainty. Uncertainty can be introduced at a number of steps in the process, including but not limited to accurate interpretation of the profile and questionnaire requests, completeness of the data and limitations of the data provider, and transparency in creating the weighting process with the members of the decision making team. For this reason, the results of the application of the MADM tool should be used to facilitate decision support discussions and not be the sole source of decision making.

In the beta testing of the MADM tool, Main Street and Elm Street managers (associated with the Pennsylvania Downtown Center) were the primary providers of property data. The managers were generally reluctant to participate in the beta testing of the MADM tool. Completion of the survey and questionnaire required additional work time, and the rewards for time spent were uncertain. Because their reluctance was unexpected, there was a need to clarify the process and simplify the instructions. Also, in response to this hesitancy, Keystone CORE Services implemented a small grant incentive program. With this incentive and with staff support to help complete the survey and questionnaire, the response rate greatly improved. The ensuing dialogue was beneficial in improving the data collection mechanisms, raising awareness, and providing a better appreciation of the baseline level of brownfield understanding in communities across the state.

The concurrent effort to weight the categories of data forced an interesting dialogue between the members of the KCS Board of Directors. Members of the Board come from disciplines such as real estate development, real estate law, and urban planning. However, until the facilitated weighting discussion, they were not unified in their priorities for the organization. The discussion forced them to vocalize their respective expectations for their organization and their role in benefitting the Main and Elm Street

Table 5. Modified Site Profile Survey

Section	Content
General information	Contact information for the person completing the survey
Property owner	Contact information for the property owner and his/her considerations for redevelopment
Site information	Location, property size, tax liens, existence of structures, historical value, regulatory actions
Environmental information	Existence of any environmental contamination and proximity to sensitive areas
Local demographics	Unemployment and education levels

Table 6. Modified Site Attribute Questionnaire

Category	Indicators
Development driver—The champion is an entity, preferably an individual, who takes on the role of the organizer, the instigator, the cheerleader, and the connector. He or she drives the development effort. He or she might be part of a private sector developer, a community-based organization, or a local redevelopment authority.	Developer champion (private sector) Municipal or nongovernmental organization (NGO) interest
Potential—This category assesses the likelihood that a site will be redeveloped. There are seven subindicators within development potential: end use, funding, time, labor market, property ownership, community support, and quality of life.	End use plans Funding availability Timeline Property ownership Community support Quality of life Public utilities Transportation
Infrastructure —The infrastructure indicator estimates the availability of infrastructure adjacent to a site. The infrastructure can be a strength or weakness of a project based on conditions and capacity. A great benefit of redeveloping brownfields instead of greenfields is that brownfields will often have existing infrastructure. The required resources for creating new infrastructure on a greenfield may be saved and used to improve other areas of a brownfield.	
Market information—To better understand the surrounding community in which the brownfield site is located, this category of indicators helps to compare the site of interest with other (nonbrownfield) properties in the area with respect to property values and potential tax revenues.	Property values Tax revenue Liens

communities. This type of feedback is important for negotiation (Walker et al. 2010) that should result in consensus.

The MADM process is intended to assign a final score to each property of interest with the potential to then rank the score and identify those properties that collectively embody the mission and priorities of the decision makers. In addition, however, it was realized that subscores associated with the four primary categories of data were also useful in making decisions, especially decisions related to allocation of resources. For instance, funding that might be available from alternate sources, such as environmental protection or community development funding from the Department of Community and Economic Development. Also, technical resources might be targeted based on expressed needs within the categories of development potential or real estate market information.

Based on the PDC-KCS effort, the site profile survey and the site attribute questionnaire have been modified. The modifications are summarized in the following tables. Modifications are currently being tested by the PDC, and the results are forthcoming.

In Table 5, the bold text indicates that those sections (environmental information and local demographics) have been moved from the site attribute questionnaire to the site profile survey. These changes were based on the determination that the environmental and demographic indicators are difficult to score (in terms of what is good and what is bad) and are therefore more useful in the sorting process.

In Table 6, the bold text denotes those categories that have been modified in the site attribute questionnaire. As suggested previously, the primary change was to move the environmental information and the demographic information to the site profile survey while giving more emphasis to infrastructure.

Conclusions

Brownfield development can play an important role in helping to revitalize communities, but the process is complex with many stakeholders and often uncertain conditions. The MADM process for brownfield decision making, developed by the Western Pennsylvania Brownfields Center at Carnegie Mellon, is a decision

support tool that can parse the intentions of the stakeholders and help to clarify the barriers to site development. The MADM tool was first beta tested with the Redevelopment Authority of the county of Washington (Pennsylvania), and the process of working with the Pennsylvania Downtown Center allowed for a more refined and robust tool—one that better suits the decision-making processes of the development community. Participation in the decision process helps both the decision makers (in this case, PDC-KCS) and the community development organizations (in this case, Main and Elm Street managers). Both groups gained transparency in their thought processes while understanding uncertainty surrounding the brownfields in communities of interest. The tool was tested on 79 properties, and the final ranking of the sites (in terms of development potential) was generally consistent with the intuitive decision-making process of the development professionals that were members of the KCS Board of Directors. At a minimum, the MADM tool allows for the creation of a complete database of brownfield properties. When used to its full potential, the MADM tool can help to facilitate rational decision making, which is particularly important for communities with limited resources.

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