Carnegie Mellon.
STEINBRENNER INSTITUTE
for Environmental Education & Research

Progress Report 6: October 1, 2011 – March 31, 2012
Accessing Brownfield Sustainability: Lifecycle Assessment and Carbon Footprinting
The Western Pennsylvania Brownfields Center at Carnegie Mellon, in collaboration with the Pennsylvania Downtown Center
US Environmental Protection Agency Brownfield Training Research and Technical Assistance Grant
Award: TR – 83417301 – 0
May 1, 2012

A. Background

The primary purpose of this project is to develop the methodology and subsequent tools that stakeholders can use to assess the sustainability of Brownfield development as measured through carbon footprinting, pollutant emissions and energy impacts. The research is intended to apply innovative analytical techniques (such as economic input-output life cycle analysis) to estimate the carbon emissions, pollutant emissions and energy impacts associated with Brownfield development; while documenting the drivers of these impacts given alternative Brownfield development scenarios.

Training and technical assistance efforts complement the primary research purpose. Through training, we intend to educate and disseminate information that will allow the members of the community to better understand the public health risks of unattended Brownfields and the benefits of alternative remediation strategies. Through technical assistance, we intend to provide targeted communities with a prioritization tool that will allow for fair, transparent and equitable Brownfield development decisions.

Per the scope of work in our original proposal, our work has been divided into 3 primary Activities[1]:

[1] Our original proposal reflected a scope of work that we based on a funding amount that will not be possible due do federal budget constraints. Therefore, fulfillment of some research tasks may not be achievable with reduced funding.

- *Activity 1: Training – Empowerment Through Knowledge.* Enhance Pennsylvania Downtown Center's (PDC) webpage for Brownfield relevant information, participate in annual PDC events to provide Brownfield related content, and conduct topic specific seminars. As the project proceeds, the target group for training will be expanded beyond PDC's current membership.

- *Activity 2: Research – Quantifying the Sustainable Brownfield.* Develop a life cycle assessment model, including footprinting, for comparison of Brownfield development relative to greenfield development, beta test the tool on sites (preferably) selected in cooperation with PDC members, finalize and validate the model, develop a computer based tool, train PDC members to use the tool, and coordinate with US Environmental Protection Agency to develop strategy for transferring the tool to other Brownfield stakeholders.

- *Activity 3: Technical Assistance – Site Selection Through Prioritization.* Assist PDC members in developing inventories of sites, beta test the Site Prioritization tool with select PDC members, finalize Site Prioritization tool, distribute Tool to remainder of PDC members, and coordinate with the Pennsylvania Department of Environmental Protections and the USEPA to develop strategy for transferring both tools to other Brownfield stakeholders.

B. Overall Progress

The official date of the award was March 12, 2009. Pre-award approval from the USEPA Project Officer allowed our work to commence in October 2008 and our first Progress Report was submitted on October 1, 2009. Progress Report 2 addressed the time period between October 2009 and March 2010. Progress Report 3 addressed the time period between April 1 and September 30, 2010. Progress Report 4 addressed the time period between October 1, 2010 and March 31, 2011. Progress Report 5 addressed the time period between April 1, 2011 and September 30, 2011. And, Progress Report 6 addresses the time period between October 1, 2011 and March 31, 2012.

Carnegie Mellon personnel working on technical aspects of the project during the period addressed in Progress Report 6 include Professor Chris Hendrickson, Dr. Deborah Lange, graduate students Amy Nagengast and Yeganeh Mashayekh, and undergraduate student Zhe (Mark) Zhuang. PDC personnel working on the project include Executive Director Bill Fontana and members of the Keystone CORE Services (KCS) group.

Overall progress with respect to each Activity is summarized as follows:

Activity 1: Training – Empowerment Through Knowledge – The Pennsylvania Downtown Center (PDC) provides education and technical assistance to local revitalization organizations and, as a result of the collaboration with Carnegie Mellon University, has developed a focus on real estate development through the creation of the Keystone CORE (Community Oriented Real Estate) Services (KCS) program. The board of CORE is comprised of private sector practitioners in disciplines such as urban planning, real estate law, and land development. PDC provides critical information to Main Street and Elm Street Managers while the KCS programs evaluates their success on the basis of projects implemented. PDC provides direct information to PDC program managers at the PDC annual managers meetings, annual conference, revitalization academy and indirectly through continuous upgrades to the brownfields section of the PDC web site. In addition, PDC continues to move toward the creation of sub-set of the larger PDC membership network that has come to express an interest in this topic and to impart more advanced information to this real estate/brownfields network. The PDC/Carnegie Mellon collaboration has resulted in PDC's success retention of State funding that was targeted for recapture due to reductions in the operating budget of the state of Pennsylvania.

Activity 2: Research – Quantifying the Sustainable Brownfield – A paper based on the comparison of 12 brownfield/greenfield pairs has been published (based on the research of Yeganeh Mashayekh) by the Journal of Urban Planning and Development, American Society of Civil Engineers in the February 2012 edition **(See Appendix A).** This research involved using travel demand models and traffic analysis zones to examine the effect of residential brownfield developments on the reduction of vehicle miles traveled (VMT) and the resulting costs (including the cost of driving time, fuel, and external air pollution costs). The ongoing research involves expanding the travel analysis to include retail facilities. The methodology used for retail travel analysis of brownfields will be discussed in the following section of this report under Section C, Activity 2.

Another paper has been written by Yeganeh Mashayekh on the analysis of residential brownfield developments if they are developed as LEED certified new developments (LEED ND) and their impact on travel patterns. This paper examines the cost effectiveness of the brownfield developments as VMT reduction strategy in comparison with other VMT reduction strategies. This paper (draft included as part of Progress Report 5) is going through major changes and revisions currently and will be submitted to Journal of Urban Planning and Development, American Society of Civil Engineers upon acceptance of the second paper. The paper will be presented at the International Symposium on Sustainable Systems and Technology (ISSST) conference in Boston, Massachusetts, May 2012.

Status of Tool Development: A summary spreadsheet tool has been developed to assess the environmental costs and cost savings associated with brownfield developments. We are in the process of fine-tuning the tool and adding sensitivity analysis to the spreadsheet. The summary spreadsheet provides a comprehensive tool allowing the user to compare all aspects (i.e. infrastructure, utility, construction, travel patterns) of residential brownfield developments with greenfield developments.

Activity 3: Technical Assistance – Site Selection Through Prioritization – During report Period 5, we worked with the Keystone CORE Services Group of PDC and engaged 79 communities in a beta test of the multi-attribute decision making (MADM) tool and evaluated the submissions for 23 pre-screened properties. For the subject Period 6, we made 'awards' to sites that received favorable scores through the MADM process. Additionally, we revised the data collection questionnaire to reduce ambiguity. On February 22, 2012, we presented the results of the MADM effort to Main and Elm Street Managers from across the state and responded to questions regarding future efforts to identify high potential projects using the MADM tool.

Additionally, Deborah Lange was invited to discuss the MADM process, and the collaboration with the Pennsylvania Downtown Center, at a brownfields conference hosted by the Technical

University of Ostrava (Czech Republic) and funded by the European Union, in early March. A copy of that presentation is included in **Appendix B.**

C. Efforts and Accomplishments by Activity

Activity 1: Training – Empowerment Through Knowledge

Managers' Meeting: On February 22, 2012, Carnegie Mellon Program Director Deborah Lange and Keystone CORE Services (KCS) Chairperson Chris Brown presented an update of the "Small Site Brownfield" Project to more than 100 community revitalization professionals from around Pennsylvania at the Pennsylvania Downtown Center's winter Managers' Meeting. The presentation included a review of the feasibility study conducted in Hamburg (Section C, See Activity 3) and an overview of "lessons learned" this far in developing the Site Attribute Questionnaire. The group was informed that these lessons will be incorporated into the next project round, which KCS envisions launching in the second quarter of 2012. As a result of that presentation, which was attended by the PA Department of Community and Economic Development's Deputy Secretary, a DCED decision requiring PDC to return funds from a previous loan program to DCED was reversed an PDC will now be allowed to retain any program income and reuse it as part of a "Pre-Development Loan Fund" which will include environmental analysis costs.

Revitalization Academy: PDC conducts an annual revitalization academy consisting of five (2) two-day sessions. Each session includes eight individual classes. PDC has devoted one of the eight classes specifically to brownfield and vacant land reclamation. The course is designed to provide new, first year revitalization professionals, many of whom lack any in-depth knowledge of brownfield and vacant property reclamation, with basic understanding of the laws, programs, processes and procedures involved in the reclamation and if necessary remediation of vacant, blighted and environmentally challenged properties. In the course of the current reporting period, this session was held on Wednesday, February 29, 2012. The session was attended by 26 new Main Street and Elm Street Managers.

Web Site: PDC continues to host a section on small site brownfield revitalization on its web site. Discussion on upgrading this site will take place in early May 2012 with PDC's web site consultant.

Real Estate – Brownfields Network: As a result of the Carnegie Mellon project and the interest express by those communities with a more intense organizational interest in the topic of small site brownfield and vacant property reclamation, PDC/KCS expects to establish a "network" of these communities and to deliver more focused education, technical assistance and training to those communities in the network. The educational sessions, technical assistance, and other network benefits will be developed and initial implementation take place during the upcoming program year.

Activity 2: Research – Quantifying the Sustainable Brownfield

As part of Activity 2 we are expanding the analysis of brownfield developments' travel patterns to include retail facilities. The selected retail facilities are all in Alleghany County and they include REI, Costco, Giant Eagle and Target. The goal of this study is to compare the residential driving distances of greenfield retail sites with those of brownfield retail sites within Allegheny County of the Commonwealth of Pennsylvania. This region was selected based on several factors including the availability of traffic and geographic data (TAZ maps, retail location information, knowledge of local transportation patterns), its large potential for urban brownfield development, and also because it is representative of many American cities, with dense urban development surrounded by less dense, rural communities. The motive for investigating residential travel savings between brownfield and greenfield developments is to relate external travel-related costs (travel time, roadway congestion, and air emissions) to the costs of brownfield development (remediation and liability).

The method used to calculate driving distances involves selecting a previously developed, centrally located retail site (the brownfield, which in this case is within the city of Pittsburgh) as well as one or more corresponding retail sites in previously undeveloped areas (the greenfield, located further from the urban center). To estimate the residential travel distances to both the modeled greenfield site and the modeled brownfield site, existing traffic analysis zones (TAZ) were used as areas with approximately equal population density. These TAZ areas, the location of which is approximated at their geographical centroids, act as discrete and additive nodes for the summation of calculated driving distances.

Using GIS mapping software in conjunction with the Google maps directions function, driving distances were estimated from each TAZ centroid (latitude, longitude) to street address of the nearest greenfield site, as well as from the TAZ centroid to the brownfield site. For consistency, the route with the shortest driving distance was chosen in cases where multiple travel routes were suggested by the directions tool. The driving distance to the nearest existing and substitutable retail location from each TAZ centroid was also found this way. Using these three values (distance to modeled brownfield, distance to modeled greenfield, and distance to the nearest existing site, all for each TAZ) travel savings were estimated.

$$d_{Bi} = driving\ distance\ from\ TAZ_i\ centroid\ to\ modeled\ brownfield\ site$$

$$d_{Gi} = driving\ distance\ from\ TAZ_i\ centroid\ to\ modeled\ to\ greenfield\ site$$

$$d_{Ei} = driving\ distance\ from\ TAZ_i\ centroid\ to\ nearest\ existing\ site$$

$$S_B = brownfield\ development\ travel\ savings$$
$$= \sum_i^n (d_{Ei} - d_{Bi}),\ for\ all\ i\ where (d_{Ei} > d_{Bi})$$

$$S_G = greenfield\ development\ travel\ savings$$
$$= \sum_i^n (d_{Ei} - d_{Gi}),\ for\ all\ i\ where (d_{Ei} > d_{Gi})$$

$$R_{total} = S_B - S_G$$

Where R_{total} is the estimated additional benefit (in residential TAZ*miles) of a brownfield development scenario when compared to a greenfield development scenario. In cases where the TAZ centroid was either at an equal driving distance or further from the site of interest than from an existing site (e.g. $d_{Ei} \leq d_{Bi}$) , there were no recorded travel savings for that TAZ. Due to this assumption, all residential trips to retail sites other than the closest retail site (that is, residential driving distances that were now greater than those before the addition of the new retail site) were not included in the model. This was assumed because it would introduce great uncertainty into the model if trips to the "newer" site, despite it being further from a given residence than an existing site, were included in the model. Also, it is assumed that no more additional residential trips are made due to the addition of the "newer" site.

The results of this analysis will be added to the spreadsheet tool currently working in progress. Furthermore, the results will be published as part of a summary paper the team has drafted to explain the summary spreadsheet tool.

Activity 3: Technical Assistance – Site Selection Through Prioritization

In collaboration with the Western Pennsylvania Brownfields Center at Carnegie Mellon, the Pennsylvania Downtown Center assembled the results of the 23 sites for which a Site Attribute Questionnaire was completed. The sites were then ranked according to 'overall' score as well as the scores earned in the 'environmental' and 'developer' categories. The results are presented in the following table.

Community	Project	Region			Overall	Environmental		Developer	
		W	C	E	Total Score	Score	Rank	Score	Rank
Greenboro	Lock House	√			69.91	4.22	1	0.67	7
Allentown (Hamilton St.)	Hotel Project			√	68.93	2.23	20	0.67	7
Ebensburg	Babcock Bldg	√			66.77	4.06	4	0.46	15
York	Woolworth Bldg		√		66.30	3.95	6	0.67	7
Philipsburg	Fire Site		√		65.19	3.74	10	0.67	7
Collegeville	Perkiomen Bridge Hotel			√	64.47	3.79	9	0.73	3
Boyertown	Getty Station			√	61.72	4.11	2	0.80	1
Boyertown	Boyertown Café			√	60.97	4.11	2	0.80	1
Harrisburg	Big Ugly Warehouse		√		60.39	3.63	11	0.40	16
Danville	Cotner Building		√		59.97	1.45	22	0.73	3
Sunbury	Bittner Building		√		58.20	2.73	16	0.67	7
Bradford	McCourt Building	√			56.94	2.75	15	0.60	13
Danville	Lemon Building		√		56.67	2.73	16	0.73	3
York			√		55.55	3.51	13	0.67	7
Bradford	Marsh's Bar	√			51.89	2.7	18	0.6	13
Hamburg	Balthasar Bldg			√	48.86	3.16	14	0.73	3
Beaver Falls		√			43.46	3.63	11	0.07	20
Uniontown	46 E. Main Street	√			37.14	2.43	19	0.27	18
Collegeville	Flag Factory Bldg			√	36.36	3.82	8	0.27	18
Harrisburg	Coca-Cola Bldg.		√		34.16	1.64	21	-0.17	23
Ebensburg	Middle School	√			33.10	1.37	23	0	21
Philipsburg	Gas Station Site		√		33.02	4.03	5	0.33	17
Uniontown	86 West Main St	√			27.50	3.85	7	0	22
		8	9	6	52.93	3.20		0.49	

PDC found the results to be very useful: not only for the benefit of the ranking, but also because of the discussions that were prompted by the detail that was provided for each site. PDC decided to 'reward' as many participants as possible to encourage future engagement with the MADM process (anticipating a second round for data collection).

Each community (seen in the summary table above) was asked to provide their most pressing technical assistance need as it related to their project. A list of program needs was developed and continues to be used as project control sheet. While Commonwealth of Pennsylvania funding was anticipated to support these technical assistance projects, budget cutbacks made this proposed funding unavailable. Having made a commitment to the communities participating in the project to provide some level of technical assistance, the Board of Directors of PDC decided to invest $25,000 of its own money in providing enhanced support to the communities. The communities that received an allocation of the funds and the status of their respective projects are as follows:

- Greensboro, Greene County: Greensboro's Lock House restoration project was the highest scoring project resulting form the use of the Site Attribute Questionnaire. A preliminary letter of request to the Pennsylvania Department of Economic Development (DCED) for Industrial Site Reuse funds was initially denied because of DCED's rejection of the lock house as an industrial site. With the assistance of Carnegie Mellon and the staff of KCS, additional information was provided to DCED that included Army Corps of Engineers background information on the nation's lock and dam system and North American Industrial Classification System (NAICS) information detailing the locks inclusion within the general industrial and transportation codes. By providing this information, DCED reversed its decision and Greensboro was invited to submit an application, which as of this writing, is still believed to be pending. In addition, if the application for $200,000 for Phase 2 environmental analysis and site mitigation activities is funded, the community will need to provide a $75,000 match. KCS and PDC have committed to providing $5,000 toward this requirement.

- Hamburg, Berks County: KCS provided technical assistance in the form of a site reuse charrette for the Balthaser Building, a former clothing manufacturing facility, and more recently a mixed use site, including a small market house in Hamburg. With $5,000 provided by PDC/KCS and a $5,000 match from the *Our Town Foundation* in Hamburg, KCS was able to contract with Place

Economics, a Washington D.C. based real estate consulting company specializing in historic preservation based economic development. A team of 25 community representatives and other revitalization professionals spent 2 ½ days in February 2012 in Hamburg learning about a broader based site reuse feasibility study methodology that included environmental concerns as part of the training process. The result was four alternative site development schemes that are now being considered by the owner of the property and the *Our Town Foundation.* KCS expects to provide additional technical assistance as this decision-making process progresses.

- Sunbury, Northumberland County: As in Hamburg, PDC/KCS provided similar technical assistance in March 2012 to the owner of the Bittner Building, in cooperation with Sunbury Revitalization Inc.(SRI) and Place Economics. Once again PDC/KCS provided a $5,000 grant that was matched by the property owner. The result of this study which also included both educational sessions and hands on feasibility work, resulted in four alternatives schemes. SRI is moving forward with the owner on a plan that envisions the introduction of an educational facility, perhaps a community college site of culinary institute into the formerly vacant five-story building. Once again, KCS expects to provide additional technical assistance as this decision-making process progresses.

- Philipsburg, Centre County: The Philipsburg site was the scene of a significant fire event several years ago that left five parcel on the town's main intersection vacant. Lack of any interest from the market place has been extremely frustrating to the community. The next project on the KCS list will be to solicit proposals from architectural and engineering firms to develop site concepts for the marketing of this location. The site development concept may include Phase I site analysis. This project will also involve a $5,000 PDC/KCS grant a $5,000 matching grant from the community. KCS has been in the process of defining the specifics of the work scope with the community over the last two months. The RFP will be issued in the second quarter of 2012.

D. Progress vs Proposed Milestones

The proposed milestones for Years 1, 2 and 3 (presented in our application package) are summarized in the following table. It is noted that our Year 3 funding will expire on May 31, 2012 so this Progress Report 6 provides a summary of our efforts (in essence) through Year 3.

Per our proposal, Year 3 was to be completed by September 30, 2011 and the Year 3 efforts were based on a budget of $200,000, not the actual receipt of $150,000. For the timing and funding reasons, our deliverables may be a bit off target but still on tract with the overall intent of our program. (Note that the next allocation of funding (defined as 'Year 4' in the amount of $75,000) will cover the time period between June 1 and December 31, 2012.

Completion YEAR	Activity 1: Training – Empowerment through Knowledge	Activity 2: Research – Quantifying a Sustainable Brownfield	Activity 3: Technical Assistance – Site Selection through Prioritization
1	.Participate in PDC regional events .Update PDC webpage with Brownfield related content .Nat'l Brownfields Conference (Fall 2009)	Develop framework and scope for life cycle assessment and carbon footprinting tool	Complete inventories in select Main Street/ Elm Street Communities
2	As above with webpage updates including additional case studies	Finalize transportation, building, electricity and water analysis modules	Initiate ranking process select Main Street/ Elm Street Communities
3	As above with webpage updates including additional case studies .Nat'l Brownfields Conference (Spring 2011)	Demonstrate, troubleshoot and validate model and tool	Complete ranking process select Main Street/ Elm Street Communities

Our progress to date (through the near completion of Year 3) can be summarized as follows: Activity 1: We continue to work with PDC is their regional events. PDC webpage is active and we will need to focus on assuring the accuracy of the information on the webpage and adding case studies. We note that we have also shared the results of our research in a number of publications and conferences, as noted above.

Activity 2: We continue to investigate the retail and commercial component of brownfield developments in our understanding of travel patterns. The Excel-based spreadsheet tool, used to compare brownfields and greenfield developments is ready to be beta-tested with our PDC partners. This discussion will be initiated in a May 7 meeting of the KCS board of directors.

Activity 3: The first round ranking process of brownfield sites, using the MADM tool, with PDC is complete and is in the 'award' phase. A second round is expected in the next few months. The process with PDC/KCS has helped to optimize the data collection process. Lessons learned from this effort are discussed in Section F.

E. Actual vs, Proposed Expenditures

As noted above, Year 3 funds expire on May 31, 2012, therefore this report reflects the near completion of our efforts through Year 3. Given the reduction in funding from the proposed 3-year total value of $500,000 to the actual allocation of $450,000, are expenditures have been optimized and will be used entirely during the term of the grant.

F. Lessons Learned and Goals by Activity

Activity 1: Training – Empowerment Through Knowledge

We will continue to improve the webpage and participate in PDC regional and statewide events. Interest in brownfield development seems to be growing based on the interest exhibited in the regional and annual PDC events. Interest in the adoption of the MADM tools (part of Activity 3) is a clear sign of heightened awareness amongst the Main Street and Elm Street Managers.

Activity 2: Research – Quantifying the Sustainable Brownfield

Previous research has indicated that the environmental impact of a residential brownfield development may be less than that of a greenfield development at least in part due to the travel behavior of the residents. In this reporting period, we initiated the research to try to understand travel behavior of customers of retail operations. Specifically, we are trying to estimate whether or not a retail operation on a brownfield results in less traffic demand than a retail operation located on a greenfield. This study is based solely on publically available data without data provided by the retail operation and therefore requires certain assumptions about behavior. These uncertainties will be explored during the next reporting period.

Activity 3: Technical Assistance – Site Selection Through Prioritization

Energized discussions with the Keystone CORE board have prompted a restructuring of the Site Profile Survey as well as the Site Attribute Questionnaire. Specifically, questions related to environmental conditions as well have demographics have been moved from the 'Questionnaire' to the 'Profile' because it was determined that those factors were better addressed in the screening phase as opposed to the scoring and evaluation phase. In the process of reorganizing and optimizing to better reflect the decision-making process of developer, the 'Infrastructure' indicator was re-introduced and re-defined. The revised Site Profile Survey is included as **Appendix C** and the updated Site Attribute Questionnaire is included as **Appendix D**. This means that the 'new' indicators for scoring and weighting now include: Development/Drive Champion, Development Potential, Infrastructure, and Market Information. This new format will be used in the second round of solicitations soon to be implemented by the PDC.

We note that Progress Report 7 will include efforts performed between April 1, 2012 September 30, 2012.

Respectfully submitted,

Deborah D. Lange

Deborah Lange, Executive Director
Steinbrenner Institute and the Western Pennsylvania Brownfields Center
dlange@cmu.edu
(412) 268-7121

Journal of Urban Planning and Development. Submitted February 24, 2011; accepted January 30, 2012; posted ahead of print February 3, 2012. doi:10.1061/(ASCE)UP.1943-5444.0000113

APPENDIX A

The Role of Brownfield Developments in Reducing Household Vehicle Travel

Yeganeh Mashayekh[1], Chris Hendrickson[2] Hon. M. ASCE, and H. Scott Matthews A.M.ASCE[3]

Abstract

The transportation sector is the second largest source of GHG emissions in the U.S. Developing underutilized urban industrial sites with certain characteristics (i.e. close proximity to transit, job and services, low remediation cost and high density) can potentially reduce the transportation sector's impact on the environment by lowering vehicle kilometers traveled (VKT) and related GHG emissions.

This study examines the effect of residential brownfield developments on VKT reduction and the resulting costs (including the cost of driving time, fuel, and external air pollution costs) and further compares the resulting costs with the initial one-time cleanup cost of brownfield sites. Sixteen brownfield and conventional development sites were analyzed in Baltimore, Chicago, Minneapolis and Pittsburgh. Travel demand models were used to estimate VKT differences among the developments. Air pollution valuation data was used to estimate external environmental cost differences. On average, residential brownfield developments reduce VKT by 52% compared to conventional greenfield developments. Also on average, brownfield developments result in a time and fuel cost reduction of 60% and an external environmental cost saving of 66%. Comparing these cost savings with the initial one-time cleanup cost of brownfields, it is shown that

[1] Research Assistant, Department of Civil & Environmental Engineering, Department of Engineering & Public Policy, Carnegie Mellon University, Pittsburgh, PA 15213-3890
[2] Professor, Department of Civil & Environmental Engineering, Carnegie Mellon University, Pittsburgh, PA 15213-3890
[3] Professor, Department of Civil & Environmental Engineering and Department of Engineering & Public Policy, Carnegie Mellon University, Pittsburgh, PA 15213-3890

Journal of Urban Planning and Development. Submitted February 24, 2011; accepted January 30, 2012; posted ahead of print February 3, 2012. doi:10.1061/(ASCE)UP.1943-5444.0000113

development density and the cost of remediation significantly affect the number of years required for the VKT cost savings to offset the remediation cost.

Subject Headings

Remediation, Industrial Facilities, Vehicles, Air Pollution, Environmental Issues, Brownfields, Vehicle Kilometers Traveled

Introduction

Brownfields are properties for which expansion, redevelopment, or reuse may be complicated by the presence or potential presence of hazardous substances, pollutants, or contaminants (EPA 2009). According to the U.S. Environmental Protection Agency (EPA) and the U.S. Government Accountability Office (GAO) there are more than 450,000 brownfield sites in the U.S. (EPA 2009, US GAO 2004). These sites include former industrial or manufacturing plants, dry cleaners, gas stations, laboratories and residential buildings. Developing brownfields incurs initial assessment and remediation costs and involves barriers such as uncertainty about the presence and type of contamination, uncertainty over cleanup standards, limited cleanup resources, and potential liability issues (HUD 2010; OTA 1995). On the other hand, developing these underutilized lands can positively impact economic development and the environment (Lange 2004; De Souza 2002). Brownfield developments have been shown to revive communities (Kaufman 2006), increase employment (De Sousa 2005), generate local tax revenue (De Sousa 2005), and keep green spaces intact (GWU 2001)

To make a proper decision about developing a brownfield site, it is important that all environmental, economic and social benefits and costs are taken into account. In this paper however, we only analyze the impact of residential brownfield developments on travel activity reduction and the consequential costs including the cost of time and fuel as well as the external environmental costs. Examining contributing factors such as travel distance and number of trips generated by each of the brownfield and greenfield sites, we compare vehicle kilometers traveled (VKT) for a sample of brownfield and greenfield residential developments in four cities: Chicago, Pittsburgh, Baltimore and Minneapolis. Greenfields are undeveloped lands such as farmlands, woodlands, or fields located on the outskirts of urbanized areas (HUD 2010). In the absence of in-fill developments (e.g. brownfields) greenfield developments are where growth occurs. We also estimate the external air pollution costs of driving for each brownfield and greenfield site using air pollution valuation data (Muller 2007). In addition to the valuation of criteria air pollutants, we include CO_2 emission costs using existing literature values. Furthermore, we compare the VKT reduction cost with the initial one-time cost of brownfield remediation. While the VKT reduction benefits of brownfield developments have been evaluated by a number of studies in the U.S., as discussed in the next section, no study to date has performed a comparison between the environmental, time and fuel benefits of brownfield developments and the cost of remediation. Our goal is to determine if the environmental cost savings as well as time and fuel cost savings from VKT reductions offset the extra initial one-time cleanup cost of brownfield developments.

Vehicle Kilometers Traveled (VKT) and Brownfield Developments

From 1995 to 2008, VKT in the U.S. increased from about 3 trillion to approximately 4.8 trillion, with an average annual increase of about 2% (FHWA 2008). It is projected that VKT will continue to increase at an average annual rate of 1.6% over the next twenty years (DOE/EIA 2008), resulting in a VKT of 7 trillion by 2030. The projected impact from increasing VKT is expected to outpace gains from improved fuel economy and alternative fuels, resulting in an increase of GHG emissions (AASHTO 2008). As a result, the American Association of State Highway and Transportation Officials (AASHTO) has set a goal of reducing the VKT growth rate to that of population growth, approximately 1% per year, by 2030. In addition, the Federal Surface Transportation Policy and Planning Act of 2009 was introduced to reduce national per capita VKT on an annual basis and to reduce GHG emissions resulting from surface transportation by 40% by 2030 (US FSTP 2009).

Reducing VKT and the resulting GHG emissions can be accomplished by various strategies including but not limited to parking management, pricing alternatives, and public transit improvement as well as changing land use patterns. Changing land use patterns can be accomplished through smart growth concepts such as compact developments, mixed-used developments, walkable communities and transit-oriented developments (Johnston 2006). Compact urban development has been correlated to a reduction of 20%-40% in VKT compared to sprawl (Ewing 2008). A National Research Council study concluded that compact developments with a high density are likely to reduce VKT, energy consumption, and CO_2 emissions (NRC 2009). Handy (2005) and Shammin (2010) also support the benefits of compact developments with respect to reducing energy consumption and travel activity. On the other hand, critics of compact developments note the costly effects of increased traffic congestion, higher taxes, higher consumer costs and more intensive developments (O'Toole 2009; Gordon 1997).

Large brownfield developments are typically redeveloped as mixed-use or compact developments, which consist of residential, retail, offices, entertainment centers and

Journal of Urban Planning and Development. Submitted February 24, 2011; accepted January 30, 2012; posted ahead of print February 3, 2012. doi:10.1061/(ASCE)UP.1943-5444.0000113

community centers (DNR 2006). As Paull (2008) documents, increasing mixed-use and especially residential use of the brownfield sites meets smart growth objectives. A number of studies have documented that brownfield developments are mostly compact. Brownfield developments conserve land in a ratio of 1 acre per brownfield redeveloped to 4.5 acres per conventional greenfields (GWU 2001). De Sousa (2005) reports brownfield residential density of 59 households per acre in Chicago. In addition to density, distance to city centers, access to transit, diversity of land use within the developments, and the design of the mixed-use developments, both internally and in connection with the existing urban grids, are factors that can potentially influence the impact that compact brownfield developments might have on VKT reduction. Several studies show that brownfield developments lower VKT compared to conventional greenfield sites (USCM 2001; EPA 2006; EPA 2010a). Moreover, Nagengast (2011) compares commuting travel times between brownfields and greenfields in six cities and concludes that commuting travel time is less for brownfields compared to greenfields. A comparison of the results of this study and the previous figures is presented in the discussion section of this paper.

Remediation Cost of Brownfield Sites

To develop a brownfield site, a risk assessment generally followed by site remediation is necessary. The remediation solution largely depends on the types of contaminants found. The cost of remediation varies significantly depending on the type of contaminant, level of exposure, and procedures needed to clean up the contaminants (EPA 2001; Rast 1997). While several studies report the cost of brownfield cleanup as a percentage of public funds or total investment funds, the exact remediation costs are not reported in most cases. The Council of Urban Economic Development reports the median cleanup cost per acre is $57,000 (CUED 1999). The City of Chicago reports the remediation cost of multiple projects from $25,000 to $530,000 per acre (Chicago 2003). A complete list of remediation costs from multiple studies used in the analysis of this paper is presented in the methodology section. Furthermore, a wide range of remediation cost and its impact on the results of our comparison is analyzed in the uncertainty analysis section of the paper.

Although incurring initial remediation cost, brownfield developments might require lower initial construction investments as they are typically built compact and, in most cases, benefit from already existing infrastructures such as water pipelines, power supply, roadways and sewer systems (Burchell 2005, Leinberger 2009, Altshuler 1993)). Opponents of brownfield developments critique the lower initial brownfield construction investments and believe that for sites with higher density the existing infrastructure may not be properly sized or reusable, and due to brownfields' typical location within the urban core and scarcity of land in those areas development cost are higher (TCRP 1998, Greenberg 2002).

Methodology

Site Selection

Based on data availability, a sample of 16 U.S. brownfield and greenfield residential developments were selected in the four metropolitan areas of Baltimore, Chicago, Minneapolis and Pittsburgh. Our sample was restricted to metropolitan areas for which experienced and knowledgeable representatives could identify two brownfield developments and two comparable Greenfield developments. With the assistance oflocal representatives managing brownfield programs and local urban planners in each of the

Journal of Urban Planning and Development. Submitted February 24, 2011; accepted January 30, 2012; posted ahead of print February 3, 2012. doi:10.1061/(ASCE)UP.1943-5444.0000113

cities, two brownfield sites and two comparable Greenfield sites were identified in each of the four cities (total of eight brownfield and eight Greenfield sites) with the following two criteria (1) minimum of one hundred dwelling units within each development; and, (2) developments must have been completed within the past twenty years. The average distance between the selected brownfield sites and city centers is 6.4 km while the average distance from the selected greenfield sites to city centers is 34 km. Figure 1 illustrates the selected 16 sites used in this study, their approximate location as well as each of their distances to center cities.

Figure 1: Map of Brownfield and Greenfield Developments Analyzed in this Study and their Distances to Center Cities

While demographics of those living in various land uses (e.g. age, income) are important in the comparison of brownfield and greenfield developments, we did not include these factors in the site selection process. The methodology explained hereafter focuses on travel cost savings and its comparison with the cost of remediation for those who are already living at the aforementioned sites.

Vehicle Kilometer Travelled (VKT) Data Sources

To determine the average difference in travel activities between residential brownfield and greenfield developments, 2010 travel demand model (TDM) data including the number of home based work and non-work automobile trips and trip distances were obtained from the metropolitan planning organizations (MPO) for each city. Travel demand models simulate real world travel patterns. The model takes into account travel behaviors that influence drivers' choice of destination, mode of transportation and selected

Journal of Urban Planning and Development. Submitted February 24, 2011; accepted January 30, 2012; posted ahead of print February 3, 2012. doi:10.1061/(ASCE)UP.1943-5444.0000113

routes (Wang 2007). TDMs and Geographic Information Systems (GIS) were used to identify Traffic Analysis Zones (TAZ) containing the study sites. A Traffic Analysis Zone is the unit of geography, similar to census tracts, used in travel demand models (Harvey 2001). By analyzing trip productions and attractions (the number of trips produced and attracted to each TAZ), the number of home-based automobile trips and resulting VKTs generated and distributed by the study sites to all other TAZs were calculated. The trips were categorized into two groups: home-based work (HBW) trips and home-based non-work (HBNW) trips. To compare results among brownfield and greenfield sites, VKT estimates were normalized by the number of households. Specific information on each of the four MPOs involved in this study is provided in the Appendix. Due to the agreement with MPOs only the number of vehicular trips generated by each site within a TAZ as well as the distances were provided. Other relevant data had to be estimated. Texas Transportation Institute's (TTI) (explained in the next section) was used for speed and cost of time.

Direct Cost Analysis (Time and Fuel)

To compare costs of brownfield and greenfield developments, costs were categorized as direct (including cost of time and fuel) and indirect (external environmental) costs. Direct costs are typically those that are incurred by those occupying the development vs. indirect costs which are those that are incurred by the whole society.

To estimate the direct costs, VKTs associated with each brownfield and greenfield site were first converted to travel times and then to the cost of time. To determine travel times, the percentage of freeway and arterial kilometers for each site was investigated and speed of 97 km/h and 56 km/h was assumed for freeways and arterials respectively (TTI 2009).

Journal of Urban Planning and Development. Submitted February 24, 2011; accepted January 30, 2012; posted ahead of print February 3, 2012. doi:10.1061/(ASCE)UP.1943-5444.0000113

The average value of time was assumed to be $15.5 per hour for the base case, while a range of values were analyzed to account for uncertainties (TTI 2009).

To estimate the fuel energy and cost of fuel, vehicle emission factors were determined using EPA's Mobile 6.2 (MOBILE6) on-road emissions modeling tool. MOBILE6 determines emissions from fuel combustion, evaporative losses, brake wear and tire wear for light and heavy duty vehicles, trucks, buses and motorcycles (EPA 2003). Since only automobile travel data are analyzed, only light duty vehicles were included in the MOBILE6 analysis. Fuel energy in Megajoules (MJ) per km was calculated for the average speeds of 97 km/h and 56 km/h for freeway and arterial VKTs respectively. A Reid Vapor Pressure of 8.7 psi with July freeway conditions was assumed. The price of gasoline was assumed to be $2.8 per gallon. Fuel use (FU) is a function of fuel energy (FE) and daily vehicle kilometers traveled (DVKT) and fuel cost (FC) is a function of FU and the price of gasoline.

$$FU_{(a)} = (FE_i \times DVKT_{i(a)}) + (FE_j \times DVKT_{j(a)}) \quad (1)$$

$$FC_{(a)} = (FU_{(a)} \times P)/C \quad (2)$$

where:

$FU_{(a)}$ = Fuel use for site a (MJ/day);

FE = Fuel energy (MJ/km);

$FC_{(a)}$ = Fuel cost for site a ($/day);

P = Price of gas ($2.8/gallon);

C = 121.3 MJ/gallon of gasoline

$DVKT_{(a)}$ = Daily vehicle kilometer traveled for site a (km/day); and

i and j represent freeway and arterial respectively.

Indirect Cost Analysis (External Environmental Cost)

To calculate the cost of external air emissions, the Air Pollution Emission Experiments and Policy (APEEP) analysis model was used (Muller 2007). APEEP connects county-level emissions of air pollutants through air quality modeling to exposures, physical effects, and monetary damages (NRC 2010). For each county and pollutant, APEEP estimates mortality, morbidity, and environmental (e.g., crop loss, timber loss, materials depreciation, visibility, forest recreation) damages. A value of statistical life (VSL) of \$6M, in accordance with EPA's central VSL, is used for the APEEP analysis (Dockins 2004). The cost of CO was assumed to be \$520/t (Matthews 2000), as it was not provided by APEEP. Because CO and NO_x are both predominantly tropospheric ozone precursors, the CO value was scaled for each county analyzed using the ratios for NO_x observed in the APEEP data (Mashayekh 2010). A mean CO_2-eq cost of \$30/ton was used in this study (NRC 2010). To account for uncertainties, data ranges for the cost of CO, CO2, gas, time and APEEP costs are assumed and will be explained in the results section of this paper.

Joining APEEP specific county level results with the national MOBILE6 vehicle emission factors in grams per km, and freeway and arterial VKTs calculated for each site, the external environmental VKT cost for each of the brownfield and greenfield sites were calculated and compared. Carbon dioxide (CO_2), sulfur oxides (SO_X), nitrogen oxides (NO_X), particulates ($PM_{2.5}$), ammonia (NH_3) and carbon monoxide (CO) emissions were considered in this study based on the availability of pollution valuation data.

MOBILE6 fails to account for speed-specific fuel economy, emissions of SO_2, $PM_{2.5}$, and NH_3 or driving cycles specific to each metropolitan area (Mashayekh 2010). To capture the variation of fuel economy and CO_2 emissions with speed, the relationships

Journal of Urban Planning and Development. Submitted February 24, 2011; accepted January 30, 2012; posted ahead of print February 3, 2012. doi:10.1061/(ASCE)UP.1943-5444.0000113

developed by Ross (1994) were employed. The amount of fuel consumed by a vehicle and the resulting CO_2 emissions are the result of the power needed to overcome tire rolling resistance, air drag, vehicle acceleration, hill climbing, and vehicle accessory loads (Mashayekh 2010; Ross 1994). These factors in combination produce a fuel energy-to-speed profile that is used to adjust the MOBILE6 fuel economy and CO_2 emission baseline factors to develop speed-specific factors (Ross 1994).

To address the effects of fleet age, vehicle emission factors were increased by 4.9% annually for CO, 1.4% for NO_X, 4.5% for $PM_{2.5}$ and 5.9% for VOCs (Chester 2010). The average vehicle age is assumed to be 5 years (GREET 2008). Combining the cost of each pollutant from APEEP ($/kg) with emission factors from MOBILE 6 (gram/km) and daily VKTs (km/day), the external environmental cost of each pollutant was calculated for each development using the following equation:

$$C_{i(a)} = DVKT_{(a)} \times EF_i \times C_i \quad (3)$$

where:

$C_{i(a)}$ = Cost of pollutant i for development a ($/day);

$DVKT_{(a)}$ = Daily vehicle kilometers traveled for development a (km/day);

EF_i = Emission factor for pollutant i (gram/km); and

C_i = Cost factor for pollutant i ($/1000gram).

VKT and Remediation Cost Comparisons

After direct and indirect costs (costs incurred by the residents and costs incurred by the society) were calculated and compared between the brownfield and greenfield developments, brownfield cost savings from VKT reductions were also compared with the

Journal of Urban Planning and Development. Submitted February 24, 2011; accepted January 30, 2012;
posted ahead of print February 3, 2012. doi:10.1061/(ASCE)UP.1943-5444.0000113

initial remediation cost. The goal was to examine if the cost savings from VKT reductions offset the extra initial one-time cleanup cost of brownfield developments.

The remediation cost depends significantly on the type of contaminant and the level of exposure, both of which factored in selecting the strategy used to cleanup the site. The cost of cleanup includes direct costs, contractors' overhead and profits, and contingencies. Since these values vary significantly from site to site, a range of remediation costs from multiple studies and references was used:

Table 1: Remediation Cost Based on Various Documentations

To compare the one-time remediation cost with the cost savings from the VKT reductions calculated earlier, the average cost of $190,000 per acre was used for the base case and the 95th percentile cost of $550,000 per acre and 5th percentile cost of $24,000 per acre were used for the worst and best cases respectively.

The residential density of the eight selected brownfield sites studied in this paper ranges from 6 to 59 households per acre with the median of 12 households per acre. Great Communities Organization reports a range of 19 to 129 household per acre for compact developments (GCC 2009). Leading studies in compact developments report an average of 11 to 15 households per acre for compact developments (CSI 2009, Ewing 2008, and NRC 2010). In this study a base average of 12 households per acre was used to normalize the base remediation cost.

Results

VKT Comparison Results for Brownfield and Greenfield Sites

Journal of Urban Planning and Development. Submitted February 24, 2011; accepted January 30, 2012; posted ahead of print February 3, 2012. doi:10.1061/(ASCE)UP.1943-5444.0000113

VKTs were calculated for eight brownfield and eight greenfield sites within the four selected cities of Baltimore, Chicago, Minneapolis and Pittsburgh. Table 2 compares the estimated HBW automobile (i.e. light duty vehicle) VKTs, trip distance and the number of trips per household for brownfields and greenfields measured from the vehicle trips and distances provided by the MPOs for each city. The number of vehicle trips were based on TAZs that each site was located in.

Table 2: Brownfield and Greenfield Developments' Travel Pattern Comparisons – Daily Home Based Work (HBW) Auto Trips per Household

The results shown in Table 2 indicate that brownfield travelers drive fewer daily kilometers than those living in greenfields (60% less). This reduction is statistically significant at greater than 95% confidence (p=0.00004). The difference in VKTs is the result of the differences in the number of trips per household and the differences in the distance of those trips. Tables 2 and 3 also compare the daily VKTs, daily trips and distances with the national average data (NHTS 2009). In the case of HBW trips, the national average VKT falls in between brownfield and greenfield sites, perhaps due to an overall fewer number of trips per household in the nation.

The result of comparisons between HBNW trips shows that brownfield sites on average generate 42% less VKT than greenfield sites (Table 3).

Table 3: Brownfield and Greenfield Developments' Travel Pattern Comparisons – Daily Home-Based Non-Work (HBNW) Auto Trips per Household

Journal of Urban Planning and Development. Submitted February 24, 2011; accepted January 30, 2012; posted ahead of print February 3, 2012. doi:10.1061/(ASCE)UP.1943-5444.0000113

The reduction shown in Table 3 is statistically significant at greater than 95% confidence ($p=0.005$). Due to the general close proximity of shopping centers, schools and recreational sites to greenfields, the difference of VKTs between brownfield and greenfield developments in the case of HBNW trips is not as large as HBW trips.

In the case of HBNW trips the national average data are higher than both groups; perhaps because the national averages include rural areas in which people need to drive farther distances to get to non-work destinations compared to the urban areas used in this study.

The total annual weekday average VKT reduction associated with brownfield sites including work and non-work trips is 52%.

Direct and Indirect Travel Costs Results for Brownfield and Greenfield Sites

Table 4 shows a breakdown of the average daily direct and indirect costs of brownfield and greenfield sites per household and the percent reduction of each of these costs between greenfield and brownfield sites.

Table 4: Comparison of Direct and Indirect Average Daily Costs per Households between Brownfield and Greenfield Sites

Direct costs (those incurred by the residents of the sites including time and fuel) have higher magnitudes compared to the external environmental costs (incurred by society). Also, in the external environmental costs category, CO_2, VOC, CO and NH_3 costs have higher magnitudes than NO_x, SO_2 and particulates.

Based on the VKT calculations, the results of the cost analyses conducted for the four cities shows that the direct costs of brownfields including time and fuel are about 60%

Journal of Urban Planning and Development. Submitted February 24, 2011; accepted January 30, 2012; posted ahead of print February 3, 2012. doi:10.1061/(ASCE)UP.1943-5444.0000113

lower than greenfield sites, while the external environmental costs are reduced by about 67%.

Adding up the annual weekday costs for brownfields developments show an annual household direct (time and fuel) saving of $2,400 for the residents of the brownfield sites and indirect (external environmental) cost saving of $450 per household.

A percentage of those who live in brownfield developments will use transit, therefore they incur cost of transit plus cost of time. Also depending on the level of ridership increase, transportation authorities might increase the number of buses resulting in increased emissions and external environmental costs.

Comparison of VKT Costs and Remediation Costs for Brownfield Sites

To examine whether the benefits from the VKT reductions associated with brownfield sites makes up for the initial cost of brownfield sites, an average remediation cost of $190,000 per acre was assumed. For the remediation cost to offset the benefits from the VKT reduction ($2,900/household) in the first year, a development needs to have at least 65 housing units per acre. With the average density of 12 units per acre (CSI 2009), the benefit will offset the cost in about 6 years, assuming a discount rate of 7%. Figure 2 illustrates the net present value of various scenarios.

Figure 2: Net Present Value (NPV) for Various Remediation/Density Assumptions

Since the cost of remediation and the density of brownfield developments vary significantly as seen on Figure 2, sensitivity analysis, explained in the next section, was

Journal of Urban Planning and Development. Submitted February 24, 2011; accepted January 30, 2012; posted ahead of print February 3, 2012. doi:10.1061/(ASCE)UP.1943-5444.0000113

conducted to examine the effect of cost and density variances on the comparison between remediation costs and VKT reduction cost savings.

In addition in comparing the VKT costs and remediation costs it is important to realize that these costs are incurred by different groups. For instance while the direct cost savings of VKT reductions are incurred by the residents of brownfields, the indirect cost savings (external environmental cost savings) are a benefit to the society. Meanwhile, the remediation cost is typically paid by the developers, land owners or taxpayers through public agencies. Differentiating among these costs should help public agencies and policymakers to better incentivize and help with the cost of brownfield cleanups for the benefits of the society at large (De Souza 2002, Perskey 1996).

Uncertainty – Bounding Analysis

To examine the range of costs associated with the VKT reduction from brownfield developments and to compare the worst and best-case scenarios, a bounding analysis was conducted with the assumptions shown in Table 5. While county specific APEEP emissions costs were used for the base case, for the worst and best-case scenarios lowest and highest U.S. county costs were assumed. CO_2 unit costs are based on about 50 studies showing a mean cost of \$30/ton, and 5th and 95th percentile costs of \$1/ton and \$85/ton (NRC 2010). Cost of CO was assumed to be an average of \$520/ton, min of \$1/ton and max of \$1050/ton (Matthews 2000). Despite the large range of CO cost, the uncertainty analysis shows that cost savings are not sensitive to the cost of CO.

Journal of Urban Planning and Development. Submitted February 24, 2011; accepted January 30, 2012; posted ahead of print February 3, 2012. doi:10.1061/(ASCE)UP.1943-5444.0000113

Table 5: Uncertainty - Bounding Analysis Assumptions

The results show that the total cost savings of driving associated with brownfields ranges from $1,300 to $5,700 per household. Assuming a 7% discount rate, using the lowest remediation cost ($24,000/acre) and the highest density (100HH/acre), it will only take 1 year to offset the cost of remediation (even with the lowest cost saving of $1,300), while with the highest remediation cost ($550,000/acre) and lowest density (6HH/acre), the remediation cost is never covered by the annual cost savings even with the largest cost saving of $5,700. The highest remediation cost of $550,000 and the lowest cost saving of $1,300 require a density of 55 units per acre to make up for the cost in 10 years. Given the significant amount of uncertainty in the cost of remediation and the density of the development, to assure the highest amount of VKT reduction savings, both variables should be carefully considered when choosing a brownfield site.

Discussion

Comparison of VKT and GHG Reductions

Although methodologies to estimate VKT and GHG reduction are different between this study and some previous studies (i.e. TAZ level data vs. Census level data; valuation and accounting vs. life cycle assessments), the existing literature provides an opportunity to compare and validate the results of this study. Relevant existing reported VKT reductions are shown in Table 6:

Table 6: Comparison of VKT and GHG Reductions between Various Studies

Journal of Urban Planning and Development. Submitted February 24, 2011; accepted January 30, 2012; posted ahead of print February 3, 2012. doi:10.1061/(ASCE)UP.1943-5444.0000113

The variation observed in the estimates reported in Table 6 can be the result of many factors including methodology used, trip generation assumptions in different jurisdictions, vehicle emission profiles varying in different geographical boundaries, and uncertainties in estimating externalities. While these uncertainties and inconsistencies are inevitable, the literature results show a 43±38% reduction for VKT, which is consistent with the results of this study (38%-63%). Furthermore, the literature results show a 46±41% emissions reduction, which is consistent with the results of this study (35%-75%).

Travel times associated with brownfield sites are further compared to the national averages and census journey to work data in Table 7 (NHTS 2009; Census 2000).

Table 7: Brownfield Sites' Travel Time Comparisons with the National Averages

While the travel time estimates for HBNW trips used in this study are very similar to the National Household Travel Survey (NHTS) average, the HBW travel time is half of the other estimates, likely due to the close proximity of the small sample size to work and city centers. This difference implies that characteristics of brownfield developments (i.e. location) should be considered as they can impact travel patterns. The following section examines some of these characteristics.

Brownfield Developments Characteristics and VKT Reductions

As mentioned earlier, most urban brownfields are developed as mixed-use or compact developments. Compact development characteristics such as density, diversity, design and distance to city centers may all be affecting the reduction in VKT, number of trips and distance per trip. To examine if these characteristics are correlated with the reduction in VKT, using all 16 sites studied in this paper, some of the characteristics associated with compact developments were explored. Result of the correlation analysis shows that as distance to center cities increases, VKT increases; as access to transit improves, VKT decreases; and as walkability improves, VKT decreases. Also, brownfield developments show wider and higher range of density associated with less VKT, while greenfield developments show less dense developments (less than 3 HH/acre) with higher VKTs.

Brownfield Developments and Other Social and Economic Factors

Although time, fuel and environmental cost savings of brownfield developments are important factors when it comes to making decisions to move to urban areas, vacancy rates of the 16 study developments show the average vacancy rate of brownfield developments is higher (9%) than greenfield developments (1%). So the question is if moving to brownfield developments would save about 60% on the cost of fuel and time, why is the vacancy rate higher in urban cores? Factors such as income, age, home value, property taxes, crime rate and quality of schools are known to be among the most significant factors influencing vacancy rates. Examining the average home values and property taxes, it was concluded that for the 16 study sites examined in this paper, property tax and home values are not the major determining factors. Other factors such as crime rate or quality of schools may affect people's decision more significantly. Details on vacancy rates, home values and property taxes may be found in the Appendix.

Conclusions

In this paper, we have estimated and compared VKTs and their resulting costs of time, fuel and emissions for eight brownfield and eight greenfield sites in Baltimore, Chicago, Minneapolis and Pittsburgh, showing that residential brownfields generate significant

VKT reduction and cost savings. Brownfield developments studies in this paper on average result in about $2,900 cost savings per household ($2,400/HH from time and fuel savings and $450 form the external environmental cost savings). These estimates can be used in benefit-cost studies to assess the benefits of travel reduction through land use changes and specifically brownfield developments. Comparing the cost savings from travel reductions with the initial cleanup cost, new development densities and the cost of remediation are important in choosing the optimal brownfield site. This study should help policymakers and public agencies involved in the process of brownfield developments to make efforts in selecting the sites that assures the best solution given the amount of remediation needed and their proximity to services such as transit. The study further should encourage policymakers to incentivize the selected brownfield sites by providing remediation funding to the developers/landowners for the environmental benefits of the society. In the process, those who choose to live in the correctly selected and developed brownfield sites (those with close proximity to services and at a higher density) incur annual time and fuel cost savings that can improve other aspects of their lives.

Acknowledgements

The authors wish to thank colleagues Dr. Deborah Lange and Amy Nagengast and two anonymous referees for helpful comments. This material is based upon work supported by the National Science Foundation (Grant No. *0755672) and the U.S. Environmental Protection Agency (Brownfield Training Research and Technical Assistance Grant).* Any *opinions, findings, and conclusions or recommendations expressed in this material are those of the author and do not necessarily reflect the views of the Environmental Protection Agency or the National Science Foundation.*

References

(AASHTO 2008). The American Association of State Highway and Transportation Officials. Primer on Transportation and Climate Change. <http://downloads.transportation.org/ClimateChange.pdf> (August 2011)

(Altshuler 1993) Altshuler, A., Gomez Ibanez, J. (1993). "Regulation for Revenue: The Political Economy of Land Use Exactions" Washington, DC: Brookings Institutions.

(Auld 2010) Auld, R., Hendrickson, C., and Lange, D. (2010). "A Life Cycle Assessment Case Study of a Brownfield and a Greenfield Development: Cranberry Heights and Summerset Pennsylvania." Carnegie Mellon University. Business of Brownfields Conferences Proceeding.

(Burchell 2005) Burchell, R., et. al. (2005). "Sprawl Costs: Economic Impacts of Unchecked Developments." Island Press, Washington D.C. ISBN 1559635304

(Census 2009) United States Census Bureau (2009). 2000 Decennial Census, <http://factfinder.census.gov/home/saff/main.html?_lang=en> (December 2010)

(Chester 2010) Chester, M. and Horvath, A. (2010). "Comparison of Life-cycle Energy and Emissions Footprints of Passenger Transportation in Metropolitan Regions." *Atmospheric Environment*, 44(8), pp.1071-1079, DOI:10.1016/j.atmosenv.2009.12.012.

(Chicago. 2003) Chicago Brownfields Initiative (2003). "Recycling Our Past, Investing in Our Future." <http://www.csu.edu/cerc/documents/ChicagoBrownfieldsInitiativeRecyclingOurPastInvestinginOurFuture.pdf> (August 2011)

(CSI 2009) Cambridge Systematics, Inc. (2009). "Moving Cooler: An Analysis of Transportation Strategies for Reducing Greenhouse Gas Emissions." Washington, D.C. Urban Land Institute.

(CUED 1999) The Council of Urban Economic Development. (1999). "Brownfields Redevelopment: Performance Evaluation." Washington DC

(De Sousa 2002) De Sousa, C. (2002). "Measuring the public costs and benefits of brownfield versus greenfield development in the Greater Toronto Area." Environment and Planning B, 29 (2): 251-280

(De Sousa 2005) De Sousa, C. (2005). "Policy Performance and Brownfield Redevelopment in Milwaukee, Wisconsin." *The Professional Geographer*, 57(2), pp. 312-327.

(DNR 2006) Missouri Department of Natural Resources. (2006). "Hidden Treasures:Value in Brownfields."

(Dockins 2004) Dockins, C., Maguire, K., Simon, N., Sullivan, M. (2004). "Value of Statistical Life Analysis and Environmental Policy: A White Paper." <http://yosemite.epa.gov/ee/epa/eerm.nsf/vwAN/EE-0483-01.pdf/$file/EE-0483-01.pdf> (December 2010)

(DOE/EIA 2008) U.S. Department of Energy/Energy Information Agency. (2008). "Annual Energy Outlook Report # DOE/EIA-0383." <http://www.eia.doe.gov/oiaf/aeo/pdf/0383%282010%29.pdf]. (December 2010)

(DOT 2010) Department of Transportation. (2010). "Transportation's role in reducing US. Greenhouse Gas Emissions Volume I Synthesis Report to Congress." <http://ntl.bts.gov/lib/32000/32700/32779/DOT_Climate_Change_Report_-_April_2010_-_Volume_1_and_2.pdf]> (August 2010)

(EPA 1999) Hagler Bailly Services, Inc. and Criterion Planners/Engineers (1999). "The Transportation and Environmental Impacts of Infill Versus Greenfield Development:A Comparative Case Study Analysis." U.S. Department of Energy

(EPA 2001a) Environmental Protection Agency (2001). "Comparing Methodologies to Assess Transportation and Air Quality Impacts of Brownfield's and Infill Development, Development, Community, and Environment Division," EPA 231-R-01-001.

(EPA 2001) Environmental Protection Agency (2001). IEC and Cambridge Systematics, Inc. "EPA Remediation Technology Cost Compendium Year 2000."

(EPA 2002) Environmental Protection Agency (2002). "Quantifying Emissions Impacts of Brownfields and Infill Development."

(EPA 2003) Environmental Protection Agency. (2003). "MOBILE6 Vehicle Emission. Modeling Software." <http://www.epa.gov/otaq/m6.htm.> (December 2010)

(EPA 2006) Environmental Protection Agency (2006). "Solving Environmental Problems through Collaboration: the Atlantic Steel Case Study."

(EPA 2009) Environmental Protection Agency. (2009). "Brownfields and Land Revitalization." < http://epa.gov/brownfields/about.htm > (August 2011)

(EPA (2010a) Environmental Protection Agency. (2010). "Air and Water Quality Impacts of Brownfields Redevelopment (Draft)."

(Ewing 2008) Ewing, R. Bartholomew, K., Winkelman, S., Walters, J., and Chen, D. (2008). "Growing Cooler: The Evidence on Urban Development and Climate Change." Washington, D.C. Urban Land Institute.

Journal of Urban Planning and Development. Submitted February 24, 2011; accepted January 30, 2012; posted ahead of print February 3, 2012. doi:10.1061/(ASCE)UP.1943-5444.0000113

(FHWA 2008) Federal Highway Administration (2008). "Highway Statistics." <http://www.fhwa.dot.gov/policy/ohpi/hss/index.htm> (August 2010)

(GCC 2009) Great Communities Collaborative. (2009). "The Benefits of Compact Development. < http://greatcommunities.org/intranet/library/sites-tools/greatcommunities-toolkit/density.pdf> (December 2010)

(Gordon 1997) Gordon, P., and Richardson, H. (1997). "Are Compact Cities a Desirable Planning Goal?" Journal of the American Planning Association, 63(1), pp. 95-106. DOI: 10.1080/01944369708975727.

(Greenberg 2002) Greenberg, M., (2002). "Should Housing be Built on Former Brownfield Site?" American Journal of Public Health, 92(5): 703–705.

(GREET 2008) U.S. Department of Energy, Argonne National Laboratory (2008). "The Greenhouse Gas, Regulated Emissions, and Energy Use in Transportation (GREET) Model." <http://www.transportation.anl.gov/modeling_simulation/GREET> (August 2010)

(GWU 2001) The George Washington University (2001). "Public Policies and Private Decisions Affecting the Redevelopment of Brownfields: An Analysis of Critical Factors, Relative Weights and Areal Differentials." <http://www.gwu.edu/~eem/Brownfields> (August 2010)

(Handy 2005) Handy, S., Cao, X., and Mokhtarian, P. (2005). "Correlation or causality between the built environment and travel behavior? Evidence from Northern California." Transportation Research Part D: Transport and Environmen.10(6), pp. 427-444. DOI: 10.1016/j.trd.2005.05.002.

(Harvey 2001) Miller, Harvey J. & Shih-Lung Shaw (2001). "Geographic Information Systems for Transportation." Oxford University Press US. p. 248. ISBN 0-19-512394-8

(Hoehner 2005) Hoehner, C.M., Brennan Ramirez, L.K., Elliott, M.B., Handy, S.L., and Brownson, R.C. (2005). "Perceived and objective environmental measures and physical activity among urban adults." American journal of preventive medicine. 28(2), pp. 105-116. DOI: 10.1016/j.amepre.2004.10.023

(HUD 2010) US Department of Housing and Urban Development (2010). "HUD Aggregated USPS Administrative Data On Address Vacancies." <http://www.huduser.org/portal/datasets/usps.html> (December 2010)

(IEC 2003) Industrial Economics, Inc. (2003). "Analysis of Environmental and Infrastructure Costs Associated with Development in the Berkeley Charleston Dorchester Region." BCD, SC area

(Johnston 2006) Johnston, R. (2006). "Review of U.S. and European Regional Modeling Studies of Policies Intended to Reduce Motorized Travel, Fuel Use, and Emissions."

Department Environmental Science and Policy. University of California - Davis. Victoria Transport Policy Institute. Victoria, BC.

(Kaufman 2006) Kaufman, D., and Cloutier, N. (2006). "The Impact of Small Brownfields and Greenspaces on Residential Property Values." Journal of Real Estate Finance and Economics, 33, pp. 19-30.

(Lange 2004) Lange, D., and McNeil, S. (2004). "Clean It and They Will Come? Defining Successful Brownfield Development." Journal of Urban Planning and Development, 130(2), pp. 101. DOI: 10.1061/(ASCE)0733-9488(2004)130:2(101).

(Lehr 2004) Lehr, J.H. (1997). "Wiley's Remediation Technologies Handbook." Chicago, IL: The Heartland Institute.

(Leinberger 2009) Leinberger, C. (2009), The Option of Urbanism: Investing in a New American Dream. Island Press, Washington, D.C. ISBN 1597261378

(Mashayekh 2011) Mashayekh, Y., Chester, M., Hendrickson C.T., Weber, C.L. (2010). "External Environmental Costs of Congestion in the U.S. Metropolitan Areas." Transportation Research Records, Transportation Research Board. In Press.

(Matthews 2000) Matthews, H.S., and Lave, L.B., (2000). "Applications of Environmental Valuation for Determining Externality Costs." Environmental Science and Technology, 34, pp. 1390-1395. DOI:10.1021/es9907313.

(Muller 2007) Muller, N.Z., Mendelsohn, R., (2007). "Measuring the Damages from Air Pollution in the U.S." Journal of Environmental Economics and Management, 54, pp. 1-14.

(Nagengast 2011) Nagengast, A. (2011). "Commuting from US Brownfield and Greenfield Residential Development Neighborhoods." ASCE, 1-32. <http://www.eswp.com/brownfields/Present/Nagengast%205B.pdf> (August 2011)

(NHTS 2009) National Household Travel Survey (2009) <http://nhts.ornl.gov> (August 2011)

(NRC 2009) The National Research Council of the National Academies (2009)."Driving and the Built Environment: The Effects of Compact Development on Motorized Travel, Energy Use, and CO2 Emissions." Transportation Research, Special Report 298.

(NRC 2010) The National Research Council of the National Academies (2010). "Committee on Health, Environmental, and Other External Costs and Benefits of Energy Production and Consumption; National Research Council, Hidden Cost of Energy: Unpriced Consequences of Energy Production and Use." National Academies Press.

(NRDC 2003) Allen, E., Benfield, F.K., (2003). "Environmental Characteristics of Smart Growth Neighborhoods, Phase II: Two Nashville Neighborhoods." Natural Resources Defense Council. <http://www.nrdc.org/cities/smartgrowth/char/charnash.pdf> (August 2010)

(OTA 1995) U.S. Congress, Office of Technology Assessment. (1995). "The Technological Reshaping of Metropolitan America, OTA-ETI- 643." Washington, DC: U.S. Government Printing Office.

(O'Toole 2009) O'Toole, R. "The Myth of the Compact City Why Compact Development Is Not the Way to Reduce Carbon Dioxide Emissions." Policy Analysis 653. <http://www.cato.org/pubs/pas/pa653.pdf> (August 2011)

(Persky 1996) Persky J, Wiewel W. (1996). "Central City and Suburban Development: Who Pays and Who Benefits?" Great Cities Institute, University of Illinois at Chicago, Chicago, IL.

(Paull 2008) Paul E. (2008). "The Environmental and Economic Impacts of Brownfields Redevelopment." Northeast-Midwest Institute. <http://www.nemw.org/images/stories/documents/EnvironEconImpactsBFRedev.pdf> (December 2010)

(Rast 1997) Rast, R.R. (1997). "Environmental Remediation Estimating Methods." Kingston, MA:R.S.Means.

(Ross 1994) Ross M. (1994). "Automobile Fuel Consumption and Emissions: Effects of Vehicle and Driving Characteristics." Annual Review of Energy and the Environment, 19. pp.75-112,

(RS Means 2010) RS Means (2010). "RS Means Cost Estimation Tools." <http://rsmeans.reedconstructiondata.com/MeansCostWorks.aspx> (August 2010)

(Schroeer 1999) Schroeer, W., (1999). "Transportation and Environmental Analysis of the Atlantic Steel Development Proposal." Prepared for U. S. Environmental Protection Agency, Urban and Economic Development Division.

(Shammin 2010) Shammin, M. R., Herendeen, R. a, Hanson, M. J., and Wilson, E. J. H. (2010). "A Multivariate Analysis Of The Energy Intensity of Sprawl Versus Compact Living in The U.S. For 2003." Ecological Economics, 69(12), 2363-2373. Elsevier B.V. DOI: 10.1016/j.ecolecon.2010.07.003.

(TCRP 1998) Transit Cooperative Research Program (1998). "TCRP Report 39. The Costs of Sprawl - Revisited." Transportation Research Board. Washington D.C.

(Terry 1999) Terry, N., and Banuelos, G. (1999). "Phytoremediation of Contaminated Soil and Water." Boca Raton,FL:Lewis Publication.

Journal of Urban Planning and Development. Submitted February 24, 2011; accepted January 30, 2012; posted ahead of print February 3, 2012. doi:10.1061/(ASCE)UP.1943-5444.0000113

(TF 2009) Tax Foundation. (2009). "Tax Foundation website." <http://www.Taxfoundation.org> (December 2010)

(TTI 2009) Texas Transportation Institute, Lomax, T. (2009). "Urban Mobility Report."Texas Transportation Institute.

(USCM 2001) The US Conference of Mayors (2001) "Clean Air/Brownfields Report. Environmental Protection Agency." <http://usmayors.org/brownfields/CleanAirBrownfields02.pdf> (December 2010)

(US FSTP 2009) Federal Surface Transportation Policy and Planning Act of 2009. <http://www.govtrack.us/congress/bill.xpd?bill=s111-1036> (August 2010)

(US GAO 2004) The government Accountability Office. (2004). "Brownfield Redevelopment. Stakeholders Report That EPA's Program Helps to Redevelop Sites, but Additional Measures Could Complement Agency Efforts." <http://www.gao.gov/new.items/d0594.pdf> (August 2010)

(Wang 2007) Wange, X., and Hofe, Rainer Vom, (2007). "Research Methods in Urban and Regional Planning." Tsinghua University Press, Beijing and Springer. ISBN 978-3-540-49657-1.

Journal of Urban Planning and Development. Submitted February 24, 2011; accepted January 30, 2012; posted ahead of print February 3, 2012. doi:10.1061/(ASCE)UP.1943-5444.0000113

List of Figure Captions

Figure 1: Map of Brownfield and Greenfield Developments Analyzed in this Study and their Distances to Center Cities

Figure 2: Net Present Value (NPV) for Various Remediation/Density Assumptions

Journal of Urban Planning and Development. Submitted February 24, 2011; accepted January 30, 2012; posted ahead of print February 3, 2012. doi:10.1061/(ASCE)UP.1943-5444.0000113

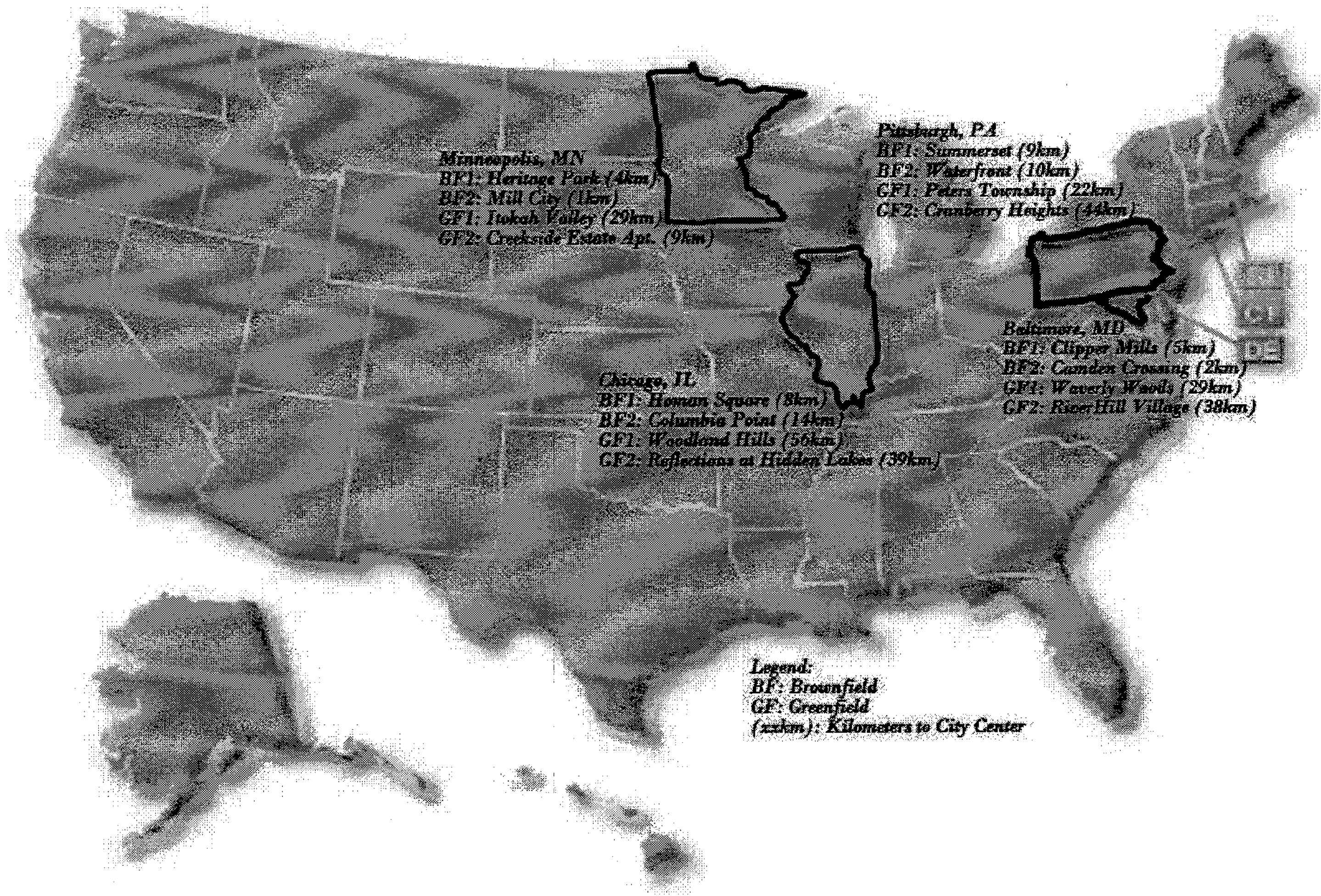
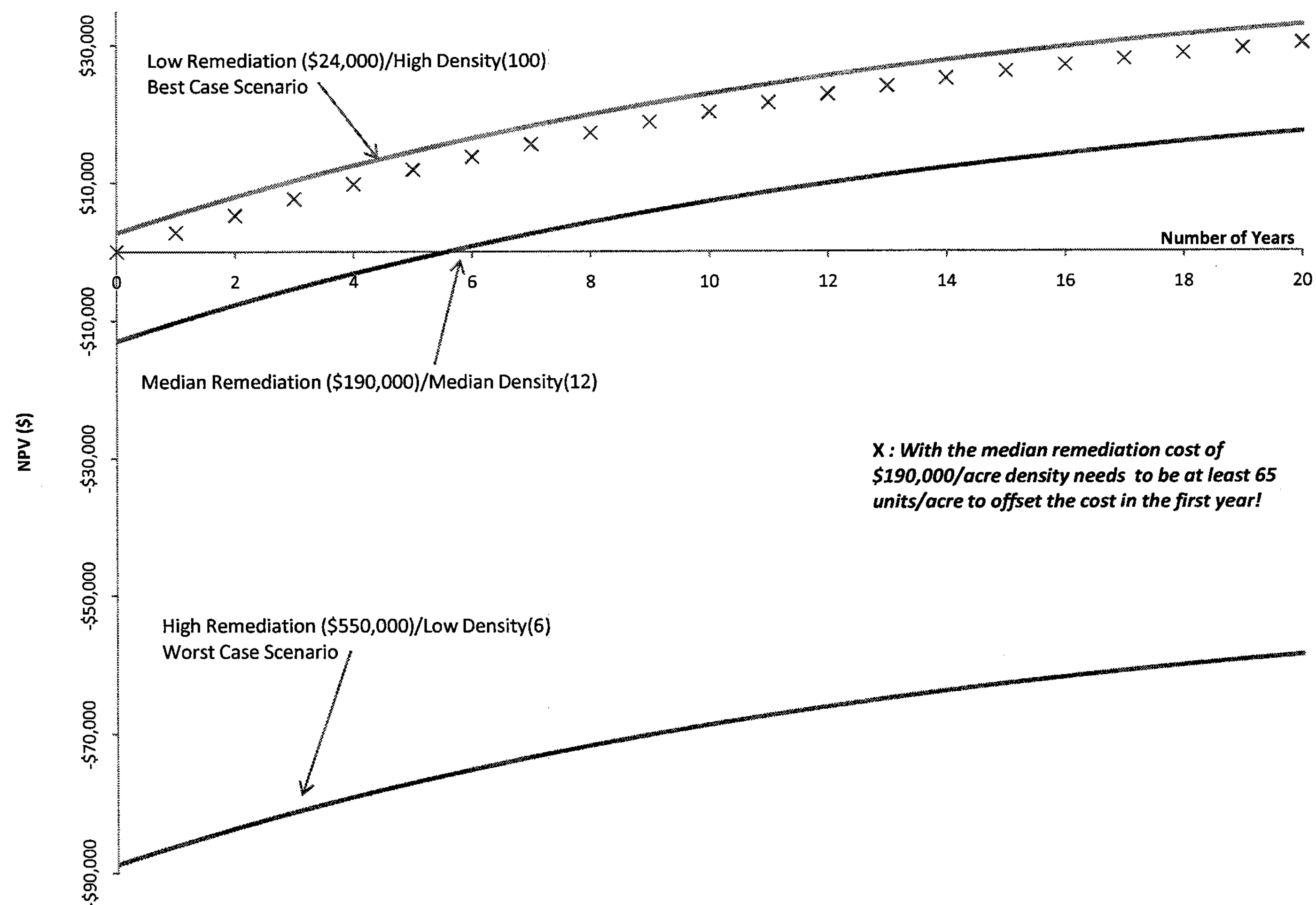


Figure 2.pdf

Journal of Urban Planning and Development. Submitted February 24, 2011; accepted January 30, 2012; posted ahead of print February 3, 2012. doi:10.1061/(ASCE)UP.1943-5444.0000113



Journal of Urban Planning and Development. Submitted February 24, 2011; accepted January 30, 2012;
posted ahead of print February 3, 2012. doi:10.1061/(ASCE)UP.1943-5444.0000113

Table 1: Remediation Cost Based on Various Documentations

Study	Remediation Cost ($/acre)	Note
Chicago 2003	25,000-530,000	Various Projects
Auld 2010	580,000	Pittsburgh
Lehr 2004	250,000-500,000	Capping
CUED 1999	57,000	-
R.S. Mean 2010	45,000	Capping (18")
Terry 1999	22,000	Phytostabilization
Terry 1999	56,000	Soil Capping
Terry 1999	65,000	Asphalt Capping

Journal of Urban Planning and Development. Submitted February 24, 2011; accepted January 30, 2012; posted ahead of print February 3, 2012. doi:10.1061/(ASCE)UP.1943-5444.0000113

Table 2: Brownfield and Greenfield Developments' Travel Pattern Comparisons – Daily Home Based Work (HBW) Auto Trips per Household

Type	Average VKT (Km/HH)	Average Distance (Km/trip)	Average # of Trips/HH
Brownfield (BF)	10.0	11.0	0.9
Greenfield (GF)	24.0	18.0	1.7
National	19.0	21.0	1.0
Reduction (GF to BF)	60%	36%	47%

*HH: household, BF: Brownfield, GF: Greenfield, Km: Kilometer.

Journal of Urban Planning and Development. Submitted February 24, 2011; accepted January 30, 2012; posted ahead of print February 3, 2012. doi:10.1061/(ASCE)UP.1943-5444.0000113

Table 3: Brownfield and Greenfield Developments' Travel Pattern Comparisons – Daily Home-Based Non-Work (HBNW) Auto Trips per Household

Type	Average VKT (Km/HH)	Average Distance (Km/trip)	Average # of Trips/HH
Brownfield (BF)	18.0	7.0	2.5
Greenfield (GF)	31.0	10.0	3.0
National	40.0	15.0	3.0
Reduction (GF to BF)	42%	33%	17%

*HH: household, BF: Brownfield, GF: Greenfield, Km: Kilometer.

Journal of Urban Planning and Development. Submitted February 24, 2011; accepted January 30, 2012; posted ahead of print February 3, 2012. doi:10.1061/(ASCE)UP.1943-5444.0000113

Table 4: Comparison of Direct and Indirect Average Daily Costs per Households between Brownfield and Greenfield Sites

	Average Direct Costs ($/Day)		Average Indirect External Environmental Costs ($/Day)							
Area	**Time**	**Fuel**	**CO_2**	**NO_x**	**VOC**	**CO**	**SO_2**	**PM**	**NH_3**	**Total**
Brownfield (BF)	5.0	1.1	0.1	0.06	0.2	0.2	0.002	0.02	0.4	0.9
Greenfield (GF)	12.0	2.8	0.3	0.09	0.5	0.3	0.005	0.06	1.4	2.6
% Reduction (GF to BF)	60	60	60	40	70	40	60	70	75	67

Journal of Urban Planning and Development. Submitted February 24, 2011; accepted January 30, 2012; posted ahead of print February 3, 2012. doi:10.1061/(ASCE)UP.1943-5444.0000113

Table 5: Uncertainty - Bounding Analysis Assumptions

	Base	**Best Case**	**Worst Case**
APEEP Emission Costs	County Specific	Lowest County Costs	Highest County Costs
CO_2 Value ($/ton)	30	1	85
Cost of fuel($/Gallon)	2.80	Min (2008-2010)	Max (2008-2010)
Cost of CO ($/t)	520	1	1050
Cost of Time ($/hr)*	15.5	8.25	30.0
Remediation Cost ($/acre)	190,000	24,000	550,000
Density (HH/acre)	12	100	6

*Based on minimum wage and annual salaries.

Journal of Urban Planning and Development. Submitted February 24, 2011; accepted January 30, 2012; posted ahead of print February 3, 2012. doi:10.1061/(ASCE)UP.1943-5444.0000113

Table 6: Comparison of VKT and GHG Reductions between Various Studies

Study	Geographic Area	Type of Land-Use	Average Reduction in VKT	Range of Reduction in VKT	Range of Reduction in GHG & Air Pollutants
This Study	Baltimore, Pittsburgh, Chicago, Minneapolis	Brownfield	52%	38% - 63%	35%- 75%
EPA 2010a	Seattle, Minneapolis, St. Paul, Emeryville, Baltimore, Dallas	Brownfield	47%	32% - 57%	32% - 57%
EPA 2001a, EPA 2002, EPA 1999, NRDC 2003, Schroeer 1999, IEC 2003	12 cities: Atlanta, Baltimore, Boston, Charlotte, Denver, Dallas, Nashville, Sacramento, San Diego, Montgomery, Wes Palm Beach, BCD	Brownfield	61%	39% - 81%	-
US Conference of Mayors (USCM), 2001	Baltimore and Dallas	Brownfield	-	23% - 55%	36%-87%*
EPA 2006	Atlantic Station, Atlanta	Brownfield	73%**	14%-52%	-
CSI 2009,	U.S.	Compact	40%	20%-60%	20%-60%
NCR 2010	U.S.	Compact	-	5%-25%	5%-25%
Ewing 2008,	U.S.	Compact	30%	20%-40%	18%-36%
Nagengast, 2011	Minneapolis, Baltimore, Chicago, St. Louis, Pittsburgh, Milwaukee,	Brownfield	***	***	36%

*Actual number reported is 73%. The range was from pre-development model.

** The range is only showing the reduction of VOC and NOx.

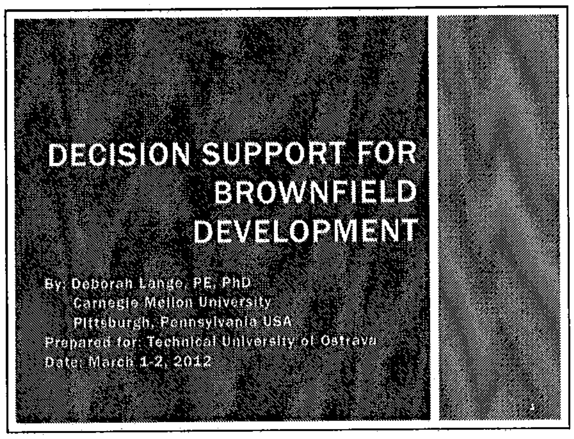
*** Nagengast does not directly calculate VKT, but rather focuses on travel time for commuting only and concludes that travel time for brownfields is only 3 minutes less than greenfields for all modes. Modal shares differed between the brownfield and greenfield developments, with transit share higher for brownfields.

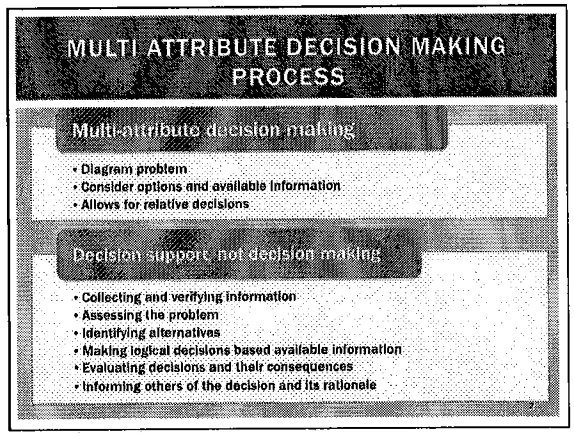
Journal of Urban Planning and Development. Submitted February 24, 2011; accepted January 30, 2012;
posted ahead of print February 3, 2012. doi:10.1061/(ASCE)UP.1943-5444.0000113

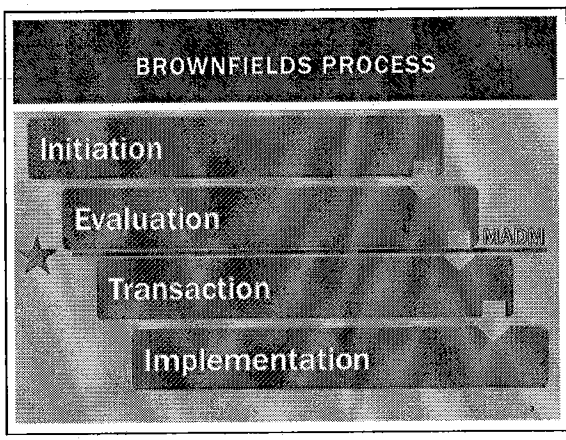
Table 7: Brownfield Sites' Travel Time Comparisons with the National Averages

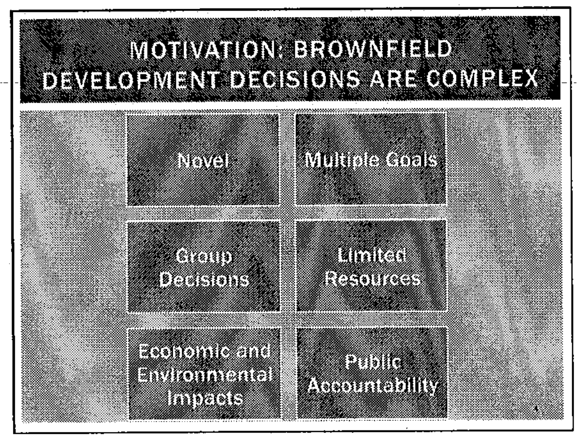
	Home-Based Work (min)	Home-Based Non-Work (min)
This Study	12	19
NHTS 2009 (National Average)	24	18
Census 2000 (National Average)	26	-

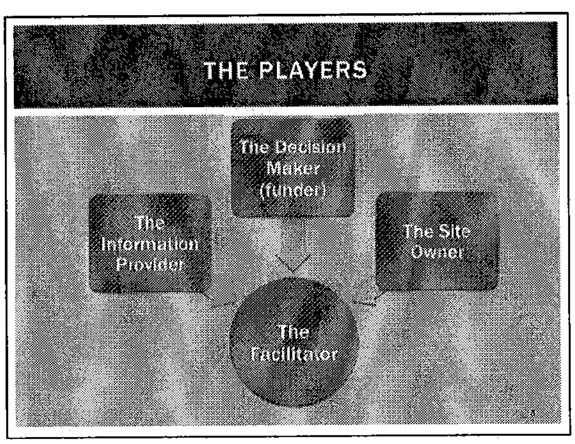
APPENDIX B

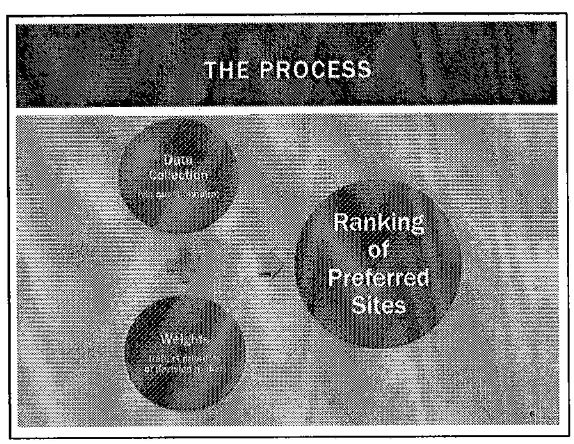

DECISION SUPPORT FOR BROWNFIELD DEVELOPMENT
By: Deborah Lange, PE, PhD
Carnegie Mellon University
Pittsburgh, Pennsylvania USA
Prepared for: Technical University of Ostrava
Date: March 1-2, 2012


MULTI ATTRIBUTE DECISION MAKING PROCESS
Multi-attribute decision making
• Diagram problem
• Consider options and available information
• Allows for relative decisions
Decision support, not decision making
• Collecting and verifying information
• Assessing the problem
• Identifying alternatives
• Making logical decisions based available information
• Evaluating decisions and their consequences
• Informing others of the decision and its rationale


BROWNFIELDS PROCESS
Initiation
Evaluation
MADM
Transaction
Implementation


MOTIVATION: BROWNFIELD DEVELOPMENT DECISIONS ARE COMPLEX
Novel
Multiple Goals
Group Decisions
Limited Resources
Economic and Environmental Impacts
Public Accountability


THE PLAYERS
The Decision Maker (funder)
The Information Provider
The Site Owner
The Facilitator


THE PROCESS
Data Collection
Ranking of Preferred Sites
Weights

DATA COLLECTION - PROPERTY PROFILE

- General Information
- Property Owner
- Site Information
- Environmental Information
- Local Demographics

DATA COLLECTION SITE ATTRIBUTE QUESTIONNAIRE

Multi-page questionnaire organized by the following CATEGORIES helps to define the 'site:'

- Development Driver/ Champion
- Development Potential
- Infrastructure
- Real Estate Market Information

CATEGORY 1 DEVELOPMENT DRIVER/CHAMPION

Development Driver/ Champion

- An entity, preferably an individual, who organizes, instigates, and connects
- For example, private sector developer, local government official, community-based organization, or local redevelopment authority

CATEGORY 2 DEVELOPMENT POTENTIAL

Development Potential

- Likelihood of redevelopment
- Indicators
  - End use
  - Funding
  - Time
  - Labor market
  - Property ownership
  - Community support
  - Quality of life

CATEGORY 3 INFRASTRUCTURE

Infrastructure

- Availability of infrastructure adjacent to a site
  - Infrastructure can be a strength or weakness
- Indicators
  - Public utilities
  - Transportation systems

CATEGORY 4 REAL ESTATE MARKET INFORMATION

Real Estate Market Information

- Understanding of the surrounding community in which the brownfield site is located
- Allows for the comparison of the site with other (non-brownfield) properties in the area with respect to indicators:
  - Property values
  - Potential tax revenues

SCORING – AS A WAY TO QUANTIFY SITE CHARACTERISTICS

- Questionnaire responses assigned a numeric value
- 'Scores' entered into spreadsheet
- 'Scores' are 'weighted' given priorities of decision maker

SAMPLE 'SCORING'

- Category 1, CW_1 (Category weight)
  - Indicator (a), IW_a (Indicator Weight)
    - Question 1
    - Question 2
    - Question 3
      - IS_a = Score for indicator (a) = (10/3) x IW_a
  - Indicator (b), IW_b (Indicator Weight)
    - Question 1
    - Question 2
    - Question 3
      - IS_b = Score for indicator (b) = ([illegible]/3) x IW_b
  - CATEGORY SCORE = $CW_1(IS_a+IS_b)$
  - FINAL SCORE = SUM OF ALL CATEGORY SCORES = $CW_1+CW_2+CW_3+CW_4$

FINAL SCORE FOR A SITE

$$Score = \sum_c \left[W_c * \sum_i W_i * \overline{I_i} \right]$$

- C = Category
- I = Indicator
- I = Vector that defines the responses to questions in Indicator I
- W = Weight

THE STEPS TO DEFINE AND WEIGH PRIORITIES

Decision Makers
- Assemble as a group
- Develop common understanding of indicators
- Assign weights

Facilitator
- Collect data from Decision makers
- Conduct discussion to result in consensus

Optional
- Pair-wise comparison to validate results

TRIAL APPLICATION OF THE MADM PROCESS

- Statewide community development organization
- 17 Communities, 79 Sites
- Screened via 'Profile' – reduced to 30 Sites
- 23 Questionnaires submitted
- Weights (based on facilitated discussion with Board members)
  - Champion – 30%
  - Development Potential – 48%
  - Infrastructure – 17%
  - Real Estate Market Information – 5%

SITE 1 – HIGH RANK – 70%

- Greensboro Lock Power House
  - 75 miles south Pittsburgh
  - Basis for rank – high in all indicators



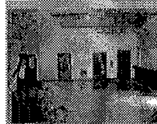
SITE 2 – MIDDLE RANK – 52%

- Local Pub – in northwest Pennsylvania
- Basis for rank
  - Low development potential – no funding, minor improvements to local quality of life
  - Little environmental contamination


19

SITE 3 – LOW RANK – 34%

- Former Coca-Cola facility – in Pennsylvania state capital
- Basis for Rank:
  - Not a municipal priority
  - No funding, no improvements to local quality of life
  - Little environmental contamination



20

EXPECTED OUTCOMES

Ability to compare similar properties
- Size
- Level of environmental contamination
- Local demographics

Ability to look at individual indicators
- Champion
- Development Potential
- Infrastructure
- Real Estate Market Information

Compare calculated 'rankings' to 'intuitive' rankings
- Calculations cannot capture all 'intangibles'
- Results will get you in the 'ballpark'

Decision support
- Rational
- Transparent

21

LESSONS LEARNED

MADM tool is effective if more than 10 sites are to be compared

MADM process forces decision makers to clarify their objectives

Decision makers might see value in tool, but community participation requires incentives; "what is in it for me?"
- Grants
- In-kind support

If calculated results are not similar to intuitive results, then
- Questions might be ambiguous
- List of questions might need to be modified

22

THANK YOU

- Project Funding
  - US Environmental Protection Agency
- CMU Collaborators
  - Civil Engineering Professor Chris Hendrickson
  - Graduate Students in Civil and Environmental Engineering and Engineering and Public Policy
    - Amy Nagangasi
    - Yeganeh Mashayekh
- Contact Information

Deborah Lange
dlange@cmu.edu

23

Pennsylvania Downtown Center

APPENDIX C

PDC'S PROPERTY PROFILE

Complete on per property - fill in as much information as possible.

GENERAL INFORMATION Date: ______________________

Name and title of person completing the profile: ______________________

Name of organization: ______________________

Address: ______________________ Phone number: ______________________

E-mail: ______________________

PROPERTY OWNER

Name of site (if applicable): ______________________

Address: Street: ______________________

City: ______________________ Zip: ______________________

County: ______________________ E-mail: ______________________

Is the owner open to redevelopment options? ☐Yes ☐No ☐Not sure

SITE INFORMATION

Name of site (if applicable): ______________________

Address: Street: ______________________

City: ______________________ Zip ______________________

County ______________________

Municipality: ______________________

Tax parcel ID# ______________________ Tax millage rate: ______________________

Are there any tax liens currently on the property? ☐Yes ☐No ☐Not sure

Are there any ongoing operations on the property? ☐Yes ☐No ☐Not sure

Size of property (acres): ______________________ Zoning: ______________________

Is the property more the 25% vacant? ☐Yes ☐No ☐Not sure

Number of structures on the property: ☐0 ☐1-5 ☐5+

Condition of structures: ☐good (#_____) ☐fair (#_____) ☐poor (#_____) ☐Not sure

Age of structures: ☐< 10 yrs ☐10 to 20 yrs: ☐>20 yrs ☐Not sure

Does the property have historical value? ☐Yes ☐No ☐Not sure

Has a phase I ESA been preformed? ☐Yes ☐No ☐Not sure

Property address: ______________________________

Has a phase II ESA been preformed? ☐Yes ☐No ☐Not sure

Has there been any US EPA or PA DEP environmental response to the site?

☐Yes ☐No ☐Not sure

If YES please explain: ______________________________

____

____

____

Describe surrounding uses/neighborhood: ______________________________

____

____

____

Please include pictures of the site, and if available, site plan, floor plan, and other report that might be available.

Property address: ______________________________

ENVIRONMENTAL INFORMATION

This environmental information will help us to estimate both the likelihood and magnitude of environmental contamination of a site, either real or suspected. It is often very difficult and laborious to get site specific environmental data related to potential contamination, so we used the following qualitative metrics to assess the potential level of environmental impact and implications for public health.

Is there, or has there ever been, any perceived contamination on the site?

☐Yes ☐No ☐Not sure

If YES, please check all relevant Hazardous/Petroleum products (see appendix A for more information)

☐Controlled Substances
☐Asbestos
☐PCBs - Polychlorinated Biphenyls
☐VOCs -Volatile Organic Compounds
☐Lead
☐PAHs - Polycyclic Aromatic Hydrocarbons
☐Radioactive materials
☐Other Metals: ____________________
☐Other Contaminants: ______________

Identifying and documenting the historical uses of the site can play an important role in estimating the source and type of contamination with the eventual goal to determine an appropriate remediation strategy.

Please check the types of activities that the site has been used for:

☐Industrial – What type of industry? ______________________________
☐Commercial - What type of commercial? ________________________
☐Residential
☐Green Space

Is the previous/current owner a documenter polluter?

☐Yes ☐No ☐Not sure

How long has the site been vacant? (in years)

☐0 ☐1-5 ☐6-10 ☐more than 10

How long has the site been underutilized? (in years)

☐0 ☐1-5 ☐6-10 ☐more than 10

Property address: ______________________________

The locations referred to in the following series of questions are all centers of human activity and/or important resources for the community. The distance that contamination lies away from these locations may dictate the urgency of remediation.

Please give the shortest distances (in miles) to each as accurately as possible.

Distance to:

a) Schools: __________________ miles

☐0 – 2 ☐3 – 5 ☐6 – 8 ☐9 – 11 ☐12 +

b) Public recreation areas ______________ miles

☐0 – 2 ☐3 – 5 ☐6 – 8 ☐9 – 11 ☐12 +

c) Properties with high market value: _________________miles

☐0 – 2 ☐3 – 5 ☐6 – 8 ☐9 – 11 ☐12 +

d) Residential neighborhoods: ______________________ miles

☐0 – 2 ☐3 – 5 ☐6 – 8 ☐9 – 11 ☐12 +

e) Closest water source (river, lake, stream): ________________________ miles

☐0 – 2 ☐3 – 5 ☐6 – 8 ☐9 – 11 ☐12 +

LOCAL DEMOGRAPHICS

As defined by the EPA, environmental justice "will be achieved when everyone, regardless of race, color, national origin or income, enjoys the same degree of protection from environmental and health hazards and equal access to the decision-making process to have a healthy environment in which to live, learn, and work" Redeveloping brownfields may be a step towards achieving environmental justice.

In Pennsylvania, the statewide average unemployment rate is 7.4%[1]. Describe your municipality's unemployment rate?

☐Lower ☐Approximately the Same ☐Higher

The percentage of Pennsylvanian residents, 25 years of age and older, with at least a high school diploma is 86.5%. The percentage of your municipality's population, 25 years and older, with at least a high school diploma is...

☐Lower ☐Approximately the Same ☐Higher

In Pennsylvania, the statewide percent of people identified as non-white is 14.3%. Describe your municipality's percentage of non-white people:

☐Lower ☐Approximately the Same ☐Higher

In Pennsylvania, the statewide percent of residents below the poverty line is 11.6%. Describe your municipality's percentage of residents below the poverty line:

☐Lower ☐Approximately the Same ☐Higher

In Pennsylvania, the statewide percent of rental units is 28.7%. How would you describe your municipality's percentage of rental units?

☐Lower ☐Approximately the Same ☐Higher

[1] U.S. Bureau of Labor Statistics, February 2011

Appendix A

Polychlorinated Biphenyls

Although no longer commercially produced in the United States, PCBs may be present in products and materials produced before the 1979 PCB ban. Products that may contain PCBs include:

- Transformers and capacitors
- Other electrical equipment including voltage regulators, switches, reclosers, bushings, and electromagnets
- Oil used in motors and hydraulic systems
- Old electrical devices or appliances containing PCB capacitors
- Fluorescent light ballasts
- Cable insulation
- Thermal insulation material including fiberglass, felt, foam, and cork
- Adhesives and tapes
- Oil-based paint
- Caulking
- Plastics
- Carbonless copy paper
- Floor finish

The PCBs used in these products were chemical mixtures made up of a variety of individual chlorinated biphenyl components, known as congeners. Most commercial PCB mixtures are known in the United States by their industrial trade names. The most common trade name is Aroclor. *– U.S. EPA website*

Volatile Organic Compounds

VOCs are organic compounds that can be isolated from the water phase of a sample by purging the water sample with inert gas, such as helium, and, subsequently, analyzed by gas chromatography. Many VOCs are human-made chemicals that are used and produced in the manufacture of...

- paints
- adhesives,
- petroleum products
- pharmaceuticals
- refrigerants

They often are compounds of

- fuels
- solvents
- hydraulic fluids
- paint thinners
- dry-cleaning agents

VOC contamination of drinking water supplies is a human-health concern because many are toxic and are known or suspected human carcinogens. - *U.S. Geological Survey, 2005*

Polycyclic Aromatic Hydrocarbons

PAHs are a group of chemicals that are formed during the incomplete burning of coal, oil, gas, wood, garbage, or other organic substances, such as tobacco and charbroiled meat. There are more than 100 different PAHs. PAHs generally occur as complex mixtures (for example, as part of combustion products such as soot), not as single compounds. PAHs usually occur naturally, but they can be manufactured as individual compounds for research purposes; however, not as the mixtures found in combustion products. As pure chemicals, PAHs generally exist as colorless, white, or pale yellow-green solids. They can have a faint, pleasant odor. A few PAHs are used in medicines and to make dyes, plastics, and pesticides. Others are contained in asphalt used in road construction. They can also be found in substances such as crude oil, coal, coal tar pitch, creosote, and roofing tar. They are found throughout the environment in the air, water, and soil. They can occur in the air, either attached to dust particles or as solids in soil or sediment.

Although the health effects of individual PAHs are not exactly alike, the following 17 PAHs are considered as a group in this profile:

- acenaphthene
- acenaphthylene
- anthracene
- benz[a]anthracene
- benzo[a]pyrene
- benzo[e]pyrene
- benzo[b]fluoranthene
- benzo[g,h,i]perylene
- benzo[j]fluoranthene
- benzo[k]fluoranthene
- chrysene
- dibenz[a,h]anthracene
- fluoranthene
- fluorene
- indeno[1,2,3-c,d]pyrene
- phenanthrene
- pyrene

These 17 PAHs were chosen to be included in this profile because (1) more information is available on these than on the others; (2) they are suspected to be more harmful than some of the others, and they exhibit harmful effects that are representative of the PAHs; (3) there is a greater chance that you will be exposed to these PAHs than to the others; and (4) of all the PAHs analyzed, these were the PAHs identified at the highest concentrations at NPL hazardous waste sites. – *Center of Disease Control - Agency for Toxic Substances and Disease Registry*

APPENDIX D

Site Attribute Questionnaire

Pennsylvania Downtown Center and The Western Pennsylvania Brownfields Center at Carnegie Mellon is designing a multi-attribute decision making tool to assist in prioritizing sites in Core Communities for redevelopment. The tool will allow Keystone C.O.R.E Services (KCS) to optimize their site selection process by weighting criteria of local and immediate interest as they determine where to allocate **environmental assessment and predevelopment** funds.

KCS first develops a weighting system to emphasize what is important to them. Then the tool uses a comprehensive list of factors to measure a site's redevelopment potential and assigns each site a score. These scores are adjusted according to the weighting scheme dictated by KCS. The weighted scores are then ranked to determine which sites would yield the greatest benefit.

For your convenience, the survey has been split into two parts; the first part was the **Property Profile** you completed which is necessary for a score to be calculated. The second part, the **Site Attribute Questionnaire**, is attached. The questionnaire asks for information that is publicly available. KCS will work with the community to fill out the questionnaire as completely as possible. The community's participation and input will help us to improve the questionnaire and prepare it for broad distribution.

Thank You,

Keystone C.O.R.E. Services

Before you begin

Omitted Answers

This questionnaire was designed to be as user friendly as possible; to that end there is the option to submit a "I don't know" response. Please submit this answer if you are unsure instead of leaving the question blank. **NOTE: Blank responses will be assigned a score of negative 0.5 (-0.5) on the spreadsheet**

It is important to remember that there is no right or wrong answer to each question, the questionnaire is meant to evaluate the situation, not test your knowledge of the site. Please only select one answer per question.

For some quantitative questions, the answers are split into sections, for example "5-10 years". If you know the exact answer, please write that down (in addition to checking the appropriate box!)

Understanding the "actors"

There are several key people in this prioritization process.

The decision maker – They use the tool to prioritize the sites and decide how the assessment/predevelopment funds will be allocated. The decision maker is the entity that has access to funding. In this case the decision maker is Keystone C.O.R.E. Services

The information provider – He or she completes the questionnaire for specific sites. This person is unbiased towards the site and understands the role the site plays in the community.

The site owner –It is not necessary for the site owner to be involved in the data collection or prioritization process unless their data is needed to provide an accurate survey of the site. Should their site be ranked among the top and chosen for fund allocation, then the owner should be notified and further steps can be taken.

Indicator Questions

A. Development Driver/Champion Indicator

The champion is an entity, preferably an individual, who takes on the role of the organizer, the instigator, the cheerleader and the connecter. He or she "drives" the redevelopment effort. They might be part of a private sector developer, a community-based organization, or a local redevelopment authority.

1. To what level has a developer (or other private sector investor) expressed an interest in the site?

☐Interested, and has funds for redevelopment	5
☐Interested, but does not have adequate funding	3.67
☐Somewhat, but only has a preliminary interest	2.33
☐No developer (or other private sector investor) has expressed an interest	1
☐I don't know	0

2. To what level has the municipality or other non-profit NGO expressed an interest in the site?

☐Interested, and has funds for redevelopment	5
☐Interested, but does not have adequate funding	3.67
☐Somewhat, but only has a preliminary interest	2.33
☐No municipality or other non-profit NGO has expressed an interest	1
☐I don't know	0

B. Development Potential Indicator

This indicator assesses the likelihood that a site will be redeveloped. There are seven sub-indicators within development potential: end use, funding, time, labor market, property ownership, community support and quality of life. Using your answers, we will be able to assess what sites stand a better chance of redevelopment.

End Use

The end use plan is a realistic plan that integrates important details like current land use, demographics, community master plans, historical development patterns, etc... The existence of an end use plan indicates that site champions have put some level of thought into the site.

3. How consistent is the proposed end use with the surrounding land use?

☐Very consistent 5
☐Consistent 4
☐Somewhat consistent 3
☐Inconsistent 2
☐No end use has been determined 1
☐I don't know 0

4. Given today's economic and development climate in the area, how beneficial will the proposed end use be to the community?
   ☐Very beneficial 5
   ☐Beneficial 4
   ☐Neither beneficial nor detrimental 3
   ☐Detrimental 2
   ☐No end use has been determined 1
   ☐I don't know 0

5. How many long term jobs would be supported on this site?
   ☐0 (1) ☐1-25(2) ☐26-50(3) ☐51-75(4) ☐75+(5)

Funding

Finding sufficient funding for a project can be challenging due to a variety of reasons, including the lenders' fear of environmental liabilities. However, there are a variety of available funding sources – both public and private – that are specifically targeted at brownfields.

6. Are there at least partial funds for the environmental investigation?
   ☐Private(3) ☐Public(2) ☐Both(4) ☐None(1) ☐Completed(5) ☐ I don't know(0)

7. Are there at least partial funds for the environmental remediation?
   ☐Private(3) ☐Public(2) ☐Both(4) ☐None(1) ☐Completed(5) ☐ I don't know(0)

8. Are there at least partial funds for pre-development costs; such as engineering and permitting?
   ☐Private(3) ☐Public(2) ☐Both(4) ☐None(1) ☐Completed(5) ☐ I don't know(0)

9. Are there at least partial funds for construction costs?
   ☐Private(3) ☐Public(2) ☐Both(4) ☐None(1) ☐Completed(5) ☐ I don't know(0)

Time

Please answer the following questions as if the necessary funds were available.

10. If the environmental investigation would begin today, how long would it take to complete? (in months)
    ☐Completed(5) ☐1-6(4) ☐7-12(3) ☐13-18(2) ☐19 +(1) ☐I don't know(0)

11. Estimated time to complete the remediation (in months)
    ☐Completed(5) ☐1-6(4) ☐7-12(3) ☐13-18(2) ☐19 +(1) ☐I don't know(0)

12. Estimated time to complete the infrastructure (in months)
    ☐Completed(5) ☐1-6(4) ☐7-12(3) ☐13-18(2) ☐19 +(1) ☐I don't know(0)

Property Ownership

The number of owners a piece of property potentially influences the ease of property acquisition. Getting permission from the owner(s) to assemble all sites and/or occupy them can be challenging.

13. How many 'owners of record' are there for the property of interest?
    ☐1(5) ☐2(3) ☐3+(1) ☐I don't know(0)
14. Has a plan that includes site acquisition, site assembly, etc. been completed?
    ☐Yes(5) ☐No(1) ☐I don't know(0)

Community Support

Brownfields have been shown to be an integral component of the fabric of the communities in which they sit. Historically, community involvement has an obstructionist reputation – especially in federally influenced redevelopment activities. But due to the complexity of the site histories, legal and financial issues and environmental contamination, community engagement is very important to brownfield redevelopment.

15. How supportive is the surrounding community of the redevelopment plan for this specific site?
    ☐Supportive (5)
    ☐Indifferent (3.67)
    ☐Opposed (2.33)
    ☐No current redevelopment plan exists (1)
    ☐I don't know (0)

16. How interested is the community in promoting brownfield development?
    ☐Interested (5)
    ☐Indifferent (3)

☐Disinterested (1)
☐I don't know (0)

Quality of Life

Many times, and especially in older communities, the land occupied by brownfields can be a key asset to the community.

17. If the end use is determined, will the redevelopment provide more recreational opportunities for the community?
    - ☐Many more recreational opportunities (5)
    - ☐Some recreational opportunities (3.67)
    - ☐No recreational opportunities (2.33)
    - ☐No end use has been determined (1)
    - ☐I don't know (0)

18. If the end use is determined, will the redevelopment provide more green space for the community?
    - ☐Much more green space (5)
    - ☐Some green space (3.67)
    - ☐No green space (2.33)
    - ☐No end use has been determined (1)
    - ☐I don't know (0)

C. *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. For these criteria, we ask for feedback on the public utilities and transportation systems.

Public Utilities

Does the site have curb connection/access to the following?

19. Municipal water:
    ☐Yes(5) ☐No(1)

20. Power grid:
    ☐Yes(5) ☐No(1)

21. Sewage system:
☐Yes(5) ☐No(1)

22. Septic:
☐Yes(5) ☐No(1)

23. Cable/DSL:
☐Yes(5) ☐No(1)

24. Phone:
☐Yes(5) ☐No(1)

25. Cellular service:
☐Yes(5) ☐No(1)

26. Fiber Optic:
☐Yes(5) ☐No(1)

Transportation

The infrastructure indicator estimates the availability of infrastructure adjacent to a site. 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. Please give the distances (in road miles) to each as accurately as possible. Distance to:

27. Interstate
☐0 – 2 (5) ☐3 – 5 (4) ☐6 – 8 (3) ☐9 – 11 (2) ☐12 + (1)

28. Highway
☐0 – 2 (5) ☐3 – 5 (4) ☐6 – 8 (3) ☐9 – 11 (2) ☐12 + (1)

29. Railway
☐0 – 2 (5) ☐3 – 5 (4) ☐6 – 8 (3) ☐9 – 11 (2) ☐12 + (1)

30. River
☐0 – 2 (5) ☐3 – 5 (4) ☐6 – 8 (3) ☐9 – 11 (2) ☐12 + (1)

31. Airport
☐0 – 2 (5) ☐3 – 5 (4) ☐6 – 8 (3) ☐9 – 11 (2) ☐12 + (1)

32. In what condition are the access roads?

☐Excellent (5) ☐Good (3.66) ☐Fair (2.33) ☐Poor (1)

D. *Market Information*

In order to better understand the surrounding community in which the brownfield site is located, please provide answers to the comparisons of this site with other (non-brownfield) properties in the area with respect to property values and potential tax revenues.

33. What is the difference in the perceived and/or approximate surrounding property values from that of this site?

☐Surrounding property values are significantly higher than site's (5)
☐Surrounding property values are moderately higher than site's (4)
☐Surrounding property values are slightly higher than site's (3)
☐Surrounding property values are comparable to site's (2)
☐Surrounding property values are lower than sites (1)

34. What is the difference in perceived and/or approximate potential property tax revenue from surrounding sites from that of this site?

☐Surrounding properties have significantly higher tax revenue than site's (5)
☐Surrounding properties have moderately higher tax revenue than site's (4)
☐Surrounding properties have slightly higher tax revenue than site's (3)
☐Surrounding properties tax revenue is comparable to site's (2)
☐Surrounding properties have lower tax revenue than site's (1)

35. Are there any deed restrictions on the property?

☐Yes (1) ☐No (5) ☐Not sure (0)

Thank you for completing the WPBC Brownfield Prioritization Method Questionnaire

What happens next?

You're done!

Thank you so much for the time and effort that you've put into this part.

The information's journey

The information gathered will be scored and weighted according to the preferences KCS has defined. The final score will ultimately be ranked against the scores of yours and other sites. You will receive a report of the final scores.

Thank you for your patience and continued support. In the near future, the questionnaire and tool will be put online for your convenience. Feel free to contact us if you have any questions or concerns.

The Pennsylvania Downtown Center and Keystone CORE Services
(717) 233 - 4675
www.padwontown.org
Bill Fontana – Executive Director billfontana@padowntown.org

The Western Pennsylvania Brownfields Center
(412) 268 - 7121
Carnegie Mellon University
http://www.cmu.edu/steinbrenner/brownfields
Deborah Lange – Executive Director dlange@andrew.cmu.edu

Appendix A

Polychlorinated Biphenyls

Although no longer commercially produced in the United States, PCBs may be present in products and materials produced before the 1979 PCB ban. Products that may contain PCBs include:

- Transformers and capacitors
- Other electrical equipment including voltage regulators, switches, reclosers, bushings, and electromagnets
- Oil used in motors and hydraulic systems
- Old electrical devices or appliances containing PCB capacitors
- Fluorescent light ballasts
- Cable insulation
- Thermal insulation material including fiberglass, felt, foam, and cork
- Adhesives and tapes
- Oil-based paint
- Caulking
- Plastics
- Carbonless copy paper
- Floor finish

The PCBs used in these products were chemical mixtures made up of a variety of individual chlorinated biphenyl components, known as congeners. Most commercial PCB mixtures are known in the United States by their industrial trade names. The most common trade name is Aroclor. – *U.S. EPA website*

Volatile Organic Compounds

VOCs are organic compounds that can be isolated from the water phase of a sample by purging the water sample with inert gas, such as helium, and, subsequently, analyzed by gas chromatography. Many VOCs are human-made chemicals that are used and produced in the manufacture of...

- paints
- adhesives,
- petroleum products
- pharmaceuticals
- refrigerants

They often are compounds of

- fuels
- solvents
- hydraulic fluids
- paint thinners
- dry-cleaning agents

VOC contamination of drinking water supplies is a human-health concern because many are toxic and are known or suspected human carcinogens. - *U.S. Geological Survey, 2005*

Polycyclic Aromatic Hydrocarbons

PAHs are a group of chemicals that are formed during the incomplete burning of coal, oil, gas, wood, garbage, or other organic substances, such as tobacco and charbroiled meat. There are more than 100 different PAHs. PAHs generally occur as complex mixtures (for example, as part of combustion products such as soot), not as single compounds. PAHs usually occur naturally, but they can be manufactured as individual compounds for research purposes; however, not as the mixtures found in combustion products. As pure chemicals, PAHs generally exist as colorless, white, or pale yellow-green solids. They can have a faint, pleasant odor. A few PAHs are used in medicines and to make dyes, plastics, and pesticides. Others are contained in asphalt used in road construction. They can also be found in substances such as crude oil, coal, coal tar pitch, creosote, and roofing tar. They are found throughout the environment in the air, water, and soil. They can occur in the air, either attached to dust particles or as solids in soil or sediment.

Although the health effects of individual PAHs are not exactly alike, the following 17 PAHs are considered as a group in this profile:

- acenaphthene
- acenaphthylene
- anthracene
- benz[a]anthracene
- benzo[a]pyrene
- benzo[e]pyrene
- benzo[b]fluoranthene
- benzo[g,h,i]perylene
- benzo[j]fluoranthene
- benzo[k]fluoranthene
- chrysene
- dibenz[a,h]anthracene
- fluoranthene
- fluorene
- indeno[1,2,3-c,d]pyrene
- phenanthrene
- pyrene

These 17 PAHs were chosen to be included in this profile because (1) more information is available on these than on the others; (2) they are suspected to be more harmful than some of the others, and they exhibit harmful effects that are representative of the PAHs; (3) there is a greater chance that you will be exposed to these PAHs than to the others; and (4) of all the PAHs analyzed, these were the PAHs identified at the highest concentrations at NPL hazardous waste sites. – *Center of Disease Control - Agency for Toxic Substances and Disease Registry*