Progress Report 3: April 1 – September 30, 2010
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
October 29, 2010

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.

Our work has been divided into 3 primary Activities:

- *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 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. And, Progress Report 3 addresses the time period between April 1 and September 30, 2010.

Carnegie Mellon personnel working on technical aspects of the project during the period covered by the Period 3 include Professor Chris Hendrickson, Dr. Deborah Lange, Amy Nagengast. Yeganeh Mashayekh, Michael Blackhurst (graduate students), and Kevin Williams, Natalie French, Zhe Zhuang, Siu Hei Yuen, and Ronell Auld (undergraduate students). PDC personnel working on the project include Bill Fontana and Eddy Kaplaniak.

Note that during the time period encompassed by Progress Report 3, we met with the EPA on 3 occasions to assure that the project was aware of other data that might be available through the EPA and other related research efforts:

- May 20 – Program Officer Patricia Overmeyer met with the project team at Carnegie Mellon University
- July 7 – Patricia Overmeyer and Stacy Swartwood participated in a conference call with the project team
- September 15 – Deborah Lange met with Patricia, Stacy, Charlie Bartsch, John Thomas, and David Lloyd in the OSWER office and included the Carnegie Mellon team via conference call

Overall progress with respect to each Activity is summarized as follows:
Activity 1: Training – Empowerment Through Knowledge – we continue to participate in PDC meetings and have shared information with the equivalent of more than 96 communities in Pennsylvania. PDC's brownfield webpage is now available at: http://www.padowntown.org/programs-services/brownfields .

Activity 2: Research – Quantifying the Sustainable Brownfield – We have identified a set of 12 brownfield/greenfield developments (24 sites in total) across the country for sustainability analysis. A paper based on this research is in final review for the Journal of Urban Planning and Development, American Society of Civil Engineers. For two of these developments, we have completed detailed case analyses on residential developments (one brownfield and one greenfield) to assess the environmental emissions associated with both the construction phase and the residential use phase. These resulted on 2 presentations at the April 19-21, 2010 Business of Brownfield Conference, sponsored by the Engineers' Society of Western Pennsylvania. We have also completed detailed case analyses on 2 additional residential developments, (one brownfield and one greenfield) located in Peters Township, about 20 miles south of Pittsburgh, PA. And, an article the compiles the results of all 4 detailed cases analyses is in progress.

We are learning from the data collection processes employed in the development of the case analyses and creating a methodology to collect similar site data through publically available sources of data. This past summer, 2 undergraduate students began to identify the resources required and the document challenges encountered in creating such a methodology.

Activity 3: Technical Assistance – Site Selection Through Prioritization – Activity 3 is based on the implementation of a multi-attribute decision making tool that was in development at the Western Pennsylvania Brownfields Center prior to receipt of the TRTA grant. During the time period covered by the Period 3 report, we have revisited the format of the tool and have discussed function with potential stakeholders. We have concluded that the audience is narrow and participation will be based on reward. Working with PDC, we have developed a revised implementation strategy, inclusive of rewards, and will begin the execution of the new strategy (described below) during Period 4.

C. Efforts and Accomplishments by Activity

Activity 1: Training – Empowerment Through Knowledge. Note that this effort is the primary focus of the PDC. With support from the Pennsylvania Department of Community and Economic Development, the PDC represents more than 150 communities across Pennsylvania, therefore, they represent the opportunity to educate a wide audience.

EDUCATION

Pennsylvania Downtown Center (PDC) continues to educate its members on the environmental, social and economic impacts of small site Brownfields in Pennsylvania's core communities. During this reporting period, the main educational opportunity was PDC's Statewide Conference – June 13 -16, 2010.

PDC Conference drew over 300 professionals from across the Commonwealth. On Wednesday, at the conference, a session named *Brownfield Case Studies* was conducted. Additionally, throughout the conference there were multiple informal conversations regarding small site Brownfield redevelopment. As a result of these conversations, PDC learned that there is a need to educate municipal officials and staff and to provide specific technical assistance in the site evaluation phase.   PDC has incorporated these two activities into its community-initiated feasibility process outlined later in this document.

In addition to PDC's annual conference, PDC continues to reinforce the virtues of small site brownfield remediation at all of its formal trainings and workshops. In this period they are as follows:

- Elm Street Manager training – 6/6/2010 – 15 people
- New manager training – 4/26, 6/24, 7/26, 9/13, 2010 - 14 people total
- Community Revitalization Academy, Safe Clean & Green: 4/28-29/2010 – 19 people
- Community Revitalization Academy, Organization: 7/24-25/2010 – 24 people
- Community Revitalization Academy, Design: 9/15-16/2010 – 24 people

WEBSITE

PDC's new website, which includes a Brownfield section, went live in May 2010. The transition was not an easy one for PDC and its staff. Now that the website is live, PDC's staff can make changes and updates. PDC, working with CMU, will continue to add content including videos, progress reports, and educational opportunities, to the Brownfield area of the site
The website will also track the community-initiated feasibility pilot program, which will include a data base of possible small site Brownfields.

Activity 2: Research – Quantifying the Sustainable Brownfield

We are pursuing three sub-activities within Activity 2. In Activity 2A, we are making site specific comparisons between a local brownfield and greenfield development. In Activity 2B, we are looking at census data gathered in year 2000 to evaluate the commuting behavior of people living in census tracts that contain brownfield development as compared to census tracks that contain greenfield developments. In Activity 2C, we are evaluating all vehicular transportation of residents for a number of brownfield/greenfield pairs using regional travel demand models.

All activities are in a pilot stage and will be expanded to include more communities as our work proceeds.

Activity 2A: Site Specific Comparisons

Completed during this period was the analyses of Summerset at Frick Park (brownfield) and Cranberry Heights (greenfield) residential developments. With all costs are adjusted to 2002 values, the results ate summarized in the following tables:

Item	Unit	Greenfield (Cranberry Heights)	Brownfield (Summerset Phase I)	% Difference from Greenfield
Initial Cost	$ Million 2002	3.4	23.4	688
CO2E Emissions	Metric Ton (Millions)	2,200	9,090	413
Allocated Initial Cost (0% interest)	$/person/year	74	1,176	1589
Annualized Initial Cost (5% interest)	$/person/year	203	3,204	1578
Allocated CO2E Emissions	Metric ton/person/year	0.05	0.46	930

Table 1: Initial Infrastructure Investment Costs and Greenhouse Gas Emissions (50 Year Planning Horizon).

Item	Unit	Greenfield (Cranberry Heights)	Brownfield (Summerset Phase I)	% Difference Relative to Greenfield
Private Vehicle	Miles/year/person	8230	7350	-11
Public Transit	Miles/year/person	2040	600	-71
Other	Miles/year/person	240	325	35
Private Vehicle	$/year/person	4,100	3,700	-10
Public Transit	$/year/person	580	170	-71
Private Vehicle GHG	Mt CO2E /year/person	3.9	3.5	-10
Public Transit GHG	Mt CO2E /year/person	1	0.3	-70

Table 2: Estimated Travel Differences for Brownfield (Summerset) and Greenfield (Cranberry Heights) Developments

Item	Unit	Greenfield (Cranberry Heights)	Brownfield (Summerset Phase I)	% Difference Relative to Greenfield
Average Floor Space	Sq. ft./residence	2,700	2,460	-9
Land Area	Acres/residence	1.1	0.16	-85
Natural Gas	$/residence	170	89	-52
Electricity	$/residence	133	94	-29
Water/Sewer	$/residence	79	27	-66
Total Utilities	$/residence	382	210	-45
Total Utilities	$/person	103	105	3
Floor Space	Sq. ft./person	730	1,230	68
Development Area	Acres/person	0.3	0.08	-73
Building Construction GHG	Mt Million	61,400	30,909	-50
Allocated Building Construction GHG	Mt/person/year	1.3	1.5	15
Utility GHG	Mt/person/year	5.9	9.6	63

Table 3: Residential Building Differences

Two additional case analyses are ongoing; Hidden Brook (brownfield) and The Woodlands (greenfield); both residential developments in Peters Township (located about 20 miles south of Pittsburgh, PA.) The developments are about 5 miles apart.

Hidden Brook: Built on a coal refuse pile, Hidden Brook is now a residential development of approximately 89 acres. In addition, there is about 76 acres of undeveloped land where the shooting range used to be. Development at Hidden Brook began in 2003 and is ongoing. Of the existing 202 residential buildings, XX are single-family homes and YY are patio homes. Based on the input of the developer, the floor plans for the houses are basically the same and therefore the only difference is in the number of residents. The typical driving distance to work and school are 17.0 and 3.1 miles, respectively.

The Woodlands: The residential acreage of the development is approximately 50 acres with 99 total residential housing units in the development. The styles of houses is similar to that found in the Hidden Brook development. Development at The Woodlands began in 2001. The typical driving distance to work and school are 15.2 and 5.0 miles, respectively.

Given the 4 case analyses that have been conducted (or are currently underway), the following observations can be made:

- With respect to construction, the emissions associated with housing construction are much greater than emission associated with site development.
- With respect to 'use,' emissions associated with utility consumption outweigh those associated with transportation.
- Overall (and over a given planning horizon), emissions associated with the 'use' phase greatly exceed those of the construction phase.

In addition to the case analyses, we have been working in parallel to develop a methodology that allows the preparation of case analyses by the acquisition of publicly available information and with out the burden of residential surveys and visits to the municipal engineer. Over the summer, students sought to identify publicly available sources of the following information:

- Remediation
- Site Preparation
  - Clearing and Grubbing
  - Grading
  - Excavation and Fill
  - Roads and Utilities
- Housing Construction
- Residential behaviors
  - Utility consumption
  - Transportation

This effort proved to be quite difficult and we were unable to replicate the more labor-intensive case analyses; but an initial list of potential sources of information follows:

- General site boundaries, use and history
  - Sanborn Maps
  - Google Earth
- Remediation
  - Environmental Protection Agency's Remediation Technology Cost Compendium
  - Clean Ohio Program
  - Federal Remediation Technologies Roundtable
- Site Preparation
  - RS Means
  - American Road & Transportation Builders Association
- Housing
  - RS Means (with regional adjustments)
- Utilities
  - Home use calculators (offered by utilities)
- Transportation
  - Traffic Analyses Zones

Activity 2B – Commuting Behavior of Residents

The commuting behavior of residents in brownfield and greenfield neighborhoods within six cities[1] was accomplished using the 2000 US Decennial Census and supplemental external data.

The final analysis combines public and individual automobile transportation in order to better define the energy and greenhouse gas estimate per commuter. The research and technical documentation is complete including supplemental information on the brownfield and greenfield census tracts and Google map locations. A publication based on this work is currently under final

[1] Baltimore, Chicago, Milwaukee, Minneapolis, Pittsburgh, and St. Louis

review by the *American Society of Civil Engineers (ASCE)-Journal of Urban Planning and Development* which is included as Appendix A.

From this research, we find that the brownfield development neighborhoods are closer to center cities, have higher public transportation use for commuting, comparable average travel times to work and lower energy and greenhouse gas emissions for commuting.   Figure 1 depicts the modal shares between the brownfield and Greenfield. The largest commuting modal differences in brownfield and greenfields are seen in carpooling, bus ridership and walking.

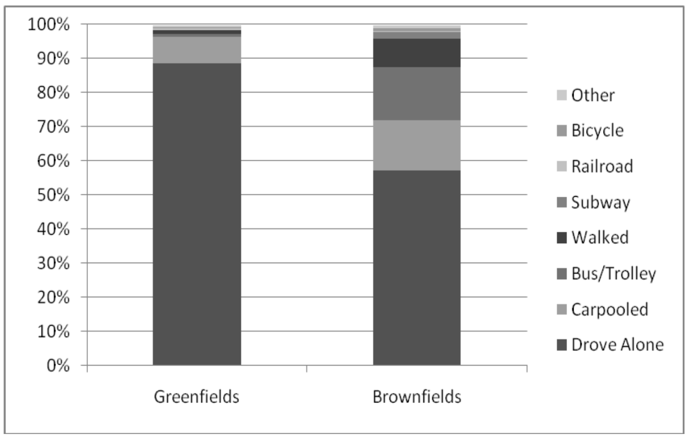


Figure 1: Greenfield and Brownfield Disaggregated Commuting Modal Shares

Incorporating census track population, travel time as well as both individual automobile and public transportation, we determined that the greenfield development commuters on average consume 75,000 MJ/commuter/yr (71 MBTU/commuter /yr) versus 47,000 MJ/commuter/yr (45 MBTU/commuter/yr) for brownfields. In terms of greenhouse gas emissions, the greenfield development emits 11,000 lbs $C0_2$/commuter/yr compared with 7,000 lbs $C0_2$/commuter/yr for brownfield developments. Thus, brownfield commuters had on average 37% lower energy and 36% lower greenhouse gas emissions for their commuting trips. Figure 2 depicts the annual energy consumption per commuter for each brownfield and Greenfield.

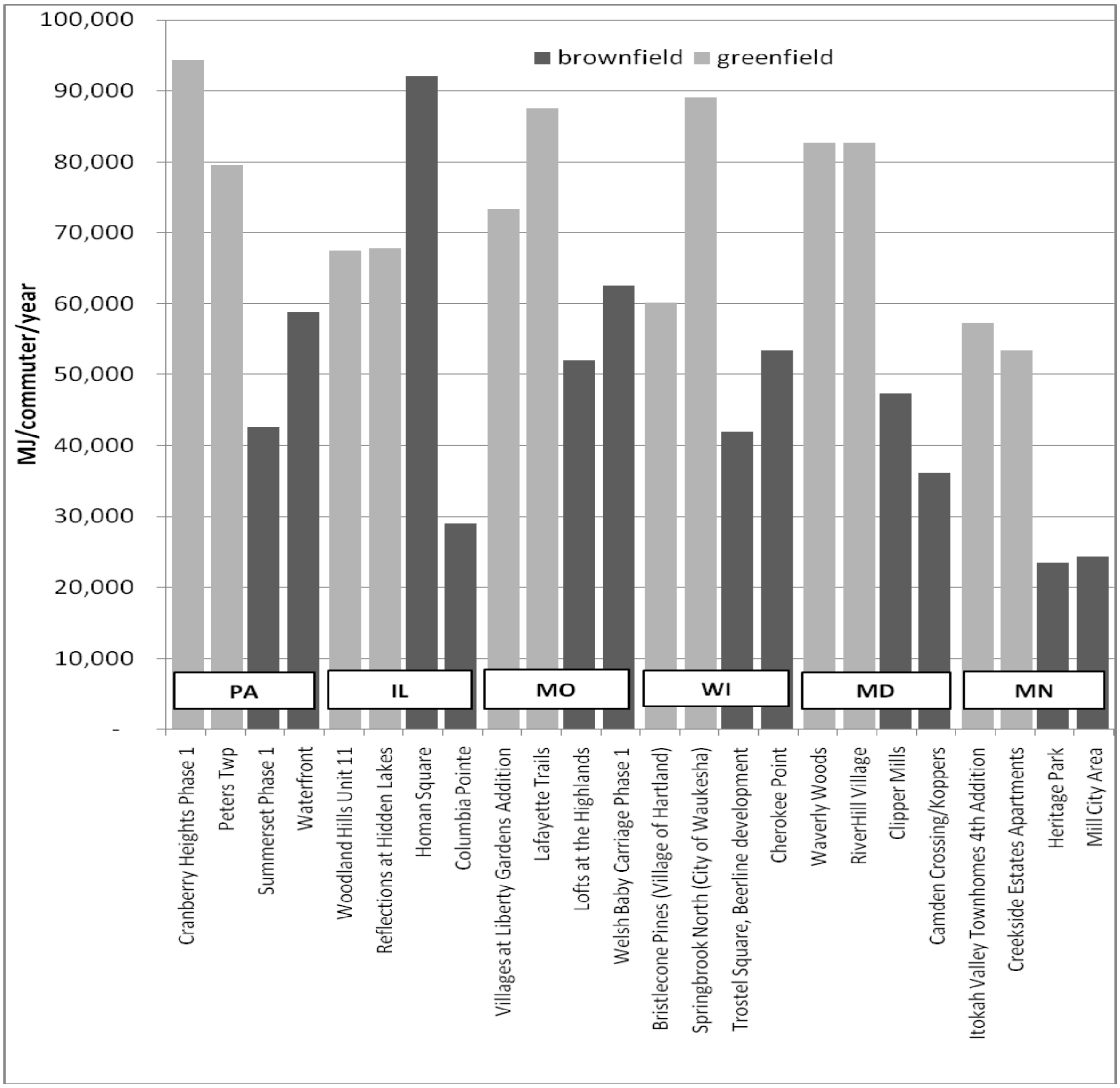


Figure 2: Total Greenfield and Brownfield Development Energy Impacts from Commuting

Activity 2C – Impact of Brownfield Development on Reducing Vehicle Miles Traveled

Yeganeh Mashayekh, a graduate student in Civil and Environmental Engineering and Engineering and Public Policy at Carnegie Mellon is planning her PhD studies around this topic. Here is the abstract that was prepared for her Engineering and Public Policy qualifying examination:

> Accounting for about 30%, the transportation sector is the second largest source of greenhouse gas (GHG) emissions in the U.S. contributing to today's most

crucial environmental issue, climate change. Surface transportation modes including passenger vehicles, buses, motorcycles and trucks use about 80% of the total transportation energy. While vehicle fuel economy and type of fuel have received a lot of attention in the recent years as the sources of transportation air emissions, vehicle miles traveled (VMT) have not been given as much consideration. With the vast forecasted growth of VMT by 2030, there is a chance the resulted air emissions from the increased VMT would outpace gains from improved fuel economy and alternative fuels. Hence, practices promoting VMT cutback are crucial in achieving GHG reduction goals set by various institutions. Developing brownfields is one such practice that could result in lowering VMT while preserving greenfields.

This research project examines the effect of residential brownfield developments on VMT and its resulting environmental impacts. To conduct the analysis, a set of two residential brownfield developments and two conventional greenfield developments were assembled for four different U.S. cities: Baltimore, Chicago, Minneapolis and Pittsburgh. Regional travel demand models (TDM) have been obtained from the metropolitan planning organizations (MPOs) responsible for each city. These models are being analyzed to produce datasets illustrating trips generated and distributed by each of the developments. VMT obtained from the TDM models for each of the development sites in conjunction with national vehicle emission factors from the U.S. EPA's Mobile 6.2 software and external unit cost damage factors from the Air Pollution Emission Experiments and Policy (APEEP) analysis model is being used to estimate and compare the transportation impact of each development on air emission costs. CO_2, SO_X, NO_X, $PM_{2.5}$, NH_3 and CO emissions are considered in this study due to the availability of pollution valuation data.

Preliminary analysis indicates that brownfield developments generate less VMT compared to greenfield developments for home-based work and home-based non work trips; although the difference is more significant for the first group. The difference is partially due to less number of trips and partially due to shorter commute distances to city centers and the design of structures and spaces at a human scale within walking and bicycling distances of the common destinations. In addition the preliminary results of this study verifies that the total cost of driving for Brownfield developments is not only less than Greenfield developments but also less than the initial remediation cost of brownfield developments.

Costs of remediation and cleaning of brownfield sites is obtained from the existing literature.

With a mission towards smart growth, we will use the quantitative results from this project to encourage MPOs and energy policy makers to consider brownfield redevelopments to achieve greater benefits from reuse of the sites while reducing air emission costs by VMT reduction and keeping greenfields intact. Furthermore, this study should help MPOs in verification of costs, effectiveness and limitations of brownfield developments compare to other travel demand management strategies (i.e. congestion pricing, increased transit usage, and telecommuting).

Activity 3: Technical Assistance – Site Selection Through Prioritization

We have contacted communities and organizations that may be good candidates for both creating inventories and testing the multi-attribute decision making tool. We have spoken with Lawrenceville Development Corporation (Allegheny County, PA), East Liberty Development Corporation (Allegheny County, PA), City of Pittsburgh, PA, the Centre County (PA) Office of Community Planning and Development and the Pittsburgh Partnership for Neighborhood development. A summary of these efforts is provided in Appendix B; but generally, it was recognized that the communities with whom we were working were not the ideal targets for this tools because their capabilities had exceeded the value of the tool.

Working with PDC, we have refocused our efforts to target a more appropriate set of communities to develop the multi-attribute decision making tool.

PDC has created Keystone C.O.R.E Services (KCS), a sister organization of PDC, with a direct real estate intervention focus. KCS's board of directors has recognized the redevelopment potential of small brownfield sites located in core communities throughout the commonwealth and is interested in leveraging the skills and recourses of KCS with the PDC/CMU brownfield initiative. PDC proposes using KCS's skills and resources to conduct three community initiated feasibility studies in communities that participate in a process derived through the PDC/CMU brownfield initiative. The process (outlined below) creates a win-win-win.

First, it allows PDC/CMU to create a database of potential small site brownfields, a subset of which will complete the CMU Site Attribute Profile, the first step in the site prioritization process. PDC/CMU will be able to test the criteria weighting process by using KCS's board of directors as the "decision maker." Additionally, PDC/CMU will use the opportunity to continue to educate local stakeholders and decision makers on small site brownfield awareness and mitigation.

Second, the proposal allows KCS to introduce its mission and services to communities while providing a framework to evaluate and choose sites to actively engage in redevelopment activities.

Third, the MS and ES organizations win by having targeted technical assistance and capacity building focused around real estate intervention delivered to their communities.

<u>The Process</u>

1) Communities interested in assistance from Keystone C.O.R.E. Services will have to first complete a site inventory of abandoned, blighted, underutilized properties. Communities can submit as many properties as they would like that meet the criteria.
2) From the submitted sites, PDC will chose 30 sites (the intent is that the 30 sites will be in 30 DIFFERENT communities) to move to the next level of evaluation.
3) Working closely with PDC staff, the 30 chosen communities will complete a site attribute profile for each of the sites selected.
4) While the site attributed profiles are being completed KCS's board of directors will work with CMU to weigh the criteria.

5) CMU will combine the completed site attribute profiles with the criteria weighting system.

6) KCS's board of directors will choose 3 sites (from the weighted 30) to undertake a community initiated feasibility study. KCS intends on using 3rd and 4th year college interns to help facilitate the data collection on the 3 sites.

Timeline

- Oct Nov Dec 2010 - Communities complete site inventory.
- Jan 2011 - PDC chooses 30 sites from site inventory list to move to the next stage – site attribute profile.
- Feb 2, 2011 – PDC chooses 20 sites from the site inventory list to move to the next
- Mach April May 2011 - PDC works with the 30 communities to complete the site attribute profile.
- May 2, 2011 – KCS's board works with CMU to weight the criteria.
- May 2011 - CMU applies criteria to the attribute profiles.
- June 6, 2011 - Keystone C.O.R.E Services chooses three (3) communities to move to the next stage – site feasibility analysis
- June July Aug 2011 - Interns gather site specific feasibility information on each site.
- Sept 2011 - KCS conducts its first taskforce visit to complete a community driven feasibility study.
- Oct 2011- KCS conducts its second taskforce visit to complete a community driven feasibility study.
- Nov 2011 - KCS conducts its third taskforce visit to complete a community driven feasibility study.

The effort with Pennsylvania Department of Environmental Protection and Baker Corporation to develop a web-based version of the inventory as well as the MADM tool has been delayed as we continue to work to determine the appropriate audience.

D. Progress vs Proposed Milestones

The proposed milestones for Years 1 and 2 are presented in our application package are summarized as follows:

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 all 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 in select Main Street/Elm Street communities

Our progress to date (through Year 2) can be summarized as follows:

Activity 1: We are on track and working with PDC is their regional events. In addition, we presented to papers at the Business of Brownfields Conference (hosted by the Engineers' Society of Western Pennsylvania) in Pittsburgh on April 19-21, 2010. PDC webpage is active and we will begin to populate with case studies. (Note that we continue to add case studies to the webpage hosted by the Western Pennsylvania Brownfields Center: www.cmu.edu.steinbrenner/brownfields

Activity 2: We are looking at the sources of environmental emissions: remediation, site preparation, housing construction, utility consumption (of residents), and transportation behavior (of residents). We have a better understanding of transportation behavior associated with brownfield development vs. greenfield development and we are continuing to develop the best methodology for comparative case analyses to better understand the inputs to the other sources of emissions..

Activity 3: We have been challenged in finding the best way to engage PDC's Main Street and Elm Street managers so we are adopting a new strategy.

E. Actual vs, Proposed Expenditures

Actual expenditures continue to lag proposed expenditures due to both delays in getting the award finalized as well as delays in getting students on board. If possible and appropriate, we would like to consider a no-cost extension in order to effectively use these funds through the remaining 3 years of the grant period.

F. Lessons Learned and Goals by Activity

Activity 1: Training – Empowerment Through Knowledge

The Brownfield Taskforce met several times and two things become clear. First, the definition of a brownfield, although comprehensive in nature, is still widely seen to PDC members as referring to large industrial sites. Second, collecting brownfield data is difficult if it is not in the larger context of site redevelopment. Meaning, communities/managers are rarely addressing environmental issues on a site without a developer in the conversation.

As a result, PDC has begun to reframe the conversation around site redevelopment, knowing one of the first steps in site redevelopment is a Phase I ESA. Understanding the possible environmental contaminants on a site, and their impact on the community, will allow the managers to have a more constructive conversation with potential developers and/or municipal officials – being more proactive instead of reactive. PDC will be incorporated environmental issues as a category in its property inventory worksheet.

Additionally, to help make the connection between understanding the challenges associated with a redevelopment site (environmental included) and being proactive with attracting developers, PDC has moved the Brownfield Taskforce under the purview of its sister real estate organization, Keystone C.O.R.E Services (KSC).

Activity 2: Research – Quantifying the Sustainable Brownfield

Activity 2A

The performance of site specific analyses by direct contact with stakeholders (such a the local engineer, developers and residents) is thorough albeit time consuming. The strategy to collect equivalent site specific data through publically available sources may ultimately be less time consuming but sources of the required data are not obvious nor readily accessible. Going forward, we will continue to identify sources of publicly available data so that we can prepare additional site analyses. To date, we have performed 2-pairs (or 4) site analyses. Results are somewhat consistent in suggesting the environmental emissions from the 'operating' portion of the development (ie residential behavior on a brownfield or a greenfield development) greatly exceed the emissions that result from the combination of remediation and construction activities. We will continue to prepare additional analyses, via direct and indirect communications and data collection, to further understand this potential trending.

Activity 2B

Our results have some significant uncertainties. First, our sample was limited to twenty-four developments. Second, we used average metropolitan travel speeds and average impacts per public transportation passenger in our estimation. Third, there is considerable uncertainty in energy and greenhouse gas emission estimates. Fourth, the greenfield and brownfield developments include the surrounding neighborhoods as defined by the US census tracts. Finally, we did not consider other travel, buildings or other impacts of the developments. Nevertheless, there does appear to be substantial differences in the impacts of commuting for the two types of developments.

Activity 2C

Working with various metropolitan planning agencies to collect data and to obtain travel demand models have been a challenging and time consuming part of this project. While each agency has been very helpful in providing data, their timelines in providing such data were not matching ours; hence delaying the work significantly.

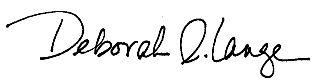
Furthermore, different jurisdictions utilize different software programs and assumptions to develop their travel demand models. Analyzing these models to produce consistent outputs for all our study sites within the selected four cities has not been an easy and straight forward task. We have learned to go through conformity reports produced by each agency to learn the assumptions behind their models in order to perform a solid comparison. We are also using some reasonable ranges for these assumptions to perform uncertainty analysis on our results.

Activity 3: Technical Assistance – Site Selection Through Prioritization

The audience for the multi-attribute decision making tool has changed over time. Some communities, such as many in the City of Pittsburgh, have the capabilities to make effective decisions regarding their brownfields based on expertise in the City and County governments. Communities with less capabilities (and less resources) can benefit from the tools require additional incentives. Working with PDC, we are implementing an alternative approach to reach these communities within the Main Street and Elm Street Programs.

We note that Progress Report 4 will include efforts performed between October 1, 2010 and March 31, 2011.

Respectfully submitted,



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

APPENDIX A – *SUBMITTED FOR PUBLICATION*

Commuting from US Brownfield and Greenfield Residential Development Neighborhoods

By Amy Nagengast[2], Chris Hendrickson[3] Hon. M. ASCE, and Deborah Lange[4] M.ASCE

Abstract

While brownfield development is of widespread interest, there is scant literature on the environmental impacts of brownfield developments relative to conventional developments. We assembled a set of two residential brownfield and two conventional greenfield developments for a sample of US cities including Baltimore, Chicago, Milwaukee, Minneapolis, Pittsburgh, and St. Louis. Using the travel time and modes of transportation information from the 2000 US Decennial Census, we analyzed the long term commuting impacts from the two types of developments. Relative to greenfield development neighborhoods, we find that the brownfield development neighborhoods are closer to center cities, have higher public transportation use for commuting, comparable average travel times to work and lower energy and greenhouse gas emissions for commuting. Future work will extend these results to consider other differential impacts of the two types of developments.

Subject Headings
Energy Consumption, Public Transportation, Travel Time, Travel Modes, Brownfields, Greenhouse Gas Emissions; Life Cycle Assessment

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[2] Research Assistant, Brownfields Center, Carnegie Mellon University
[3] Professor, Dept. of Civil and Environmental Engineering, Carnegie Mellon University
[4] Executive Director, Steinbrenner Institute for Environmental Education and Research (SEER), Carnegie Mellon University

INTRODUCTION

With population growth and urban sprawl on the rise, cities are paying special attention to effective use of limited available land. The Environmental Protection Agency's Smart Growth program aims to "help communities grow in ways that expand economic opportunity, protect public health and the environment, and create and enhance the places that people love" (EPA 2010). Furthermore, the Department of Transportation's Livability Initiative promotes the integration of quality transportation to areas that enrich citizens and communities (DOT 2010). This multi-disciplinary focus of these Federal agencies reflects the importance of sustainable development through the interrelationships between land use and transportation.

One example of land and mobility intersections can be examined through brownfield development sites. Brownfields are properties with the presence (or suspected presence) of hazardous substances or contaminants (EPA 2009). Brownfield remediation and development are intended to improve environmental quality and reduce pressure for development of green spaces. A variety of grants and support programs are available to spur brownfield development in the US at the federal, state and local levels (Wernstedt 2006, Lange 2004). Brownfield development requires assessment of environmental risks and, in most cases, remediation activities before development is possible. However, brownfield development might take advantage of existing infrastructure such as water and sewer distribution and collection networks, roads and power supply. Furthermore, brownfield development results in significant benefits to the surrounding citizens through reduced health risks, neighborhood improvement and transportation externalities (De Sousa 2002).

Transportation is an integral component of sustainable development. The topic is now expanding beyond mobility into discussions surrounding human health and ecosystem protection (Deakin 2001-2003). To help understand the role of transportation in sustainable growth, we compare the travel time, energy and greenhouse gas emission impacts of commuting from a sample of brownfield and greenfield development neighborhoods. Our intent is to investigate the various long term effects of brownfield developments relative to conventional greenfield developments. Commuting is an important component of such long term effects. Our analysis is based on US Census tracts that include the brownfield and greenfield residential developments as well as surrounding housing.

SAMPLE OF BROWNFIELD AND GREENFIELD DEVELOPMENT NEIGHBORHOODS

Brownfield developments range widely in size and intended use. For example, numerous brownfield developments involve remediation and reuse of individual gasoline service stations while larger brownfield developments may be former industrial plants that are converted to office parks or golf courses.

For this study, we sought a sample of representative US brownfield and greenfield residential developments. We restricted our sample to metropolitan areas for which knowledgeable local representatives could identify two relatively large brownfield developments and two comparable greenfield development areas. The chosen developments were to have occurred in the past twenty years and include one hundred or more housing units. Our final sample set is based on suggestions from local urban planners and community economic and development organizations that were contacted via email and telephone. The final sample set includes developments in Baltimore, Chicago, Milwaukee, Minneapolis, Pittsburgh, and St. Louis.

The distance to center city for each development is listed in Table 1 for greenfields and Table 2 for brownfields. Distance to center city was obtained from Google Maps directions and represent roadway distances with the shortest travel time (Google 2009). Within the supplemental information, maps display the shortest travel time route, the development location, and the corresponding census tracts used for analysis.

Greenfield developments are on average 24 miles (38 km) from center city and six times further from the center city than the average for brownfields. This result is not surprising. Greenfield developments are built where land is available and relatively inexpensive, which typically means the outskirts of metropolitan areas. Brownfield developments occur where earlier development has already taken place and the property was subsequently vacated, so we expect they would be closer to the center city and supporting infrastructure.

With closer proximity to the urban core, we expect that brownfield residents may have fewer vehicle miles of travel (VMT) overall. Paull's analysis on the Maryland Historic Tax Credit Program notes that compact development has been correlated to a reduction of 20-40% in VMT compared to sprawl (Paull 2009). The Transportation Research Board report on driving and the built environment also identified reductions in VMT for compact city development (TRB 2009). Shammin (2010) found that compact living had roughly 18% lower energy intensiveness than sprawling developments.

Table 1: Distance to Center City for a Sample of Greenfield Development Census Tracts

State	County	Name	Distance to City Center (miles)	Distance to City Center (kilometers)
PA	Butler	Cranberry Heights	28	44
PA	Washington	Peters Township	14	22
IL	Dupage	Woodland Hills Unit 11	35	56
IL	Dupage	Reflections at Hidden Lakes	25	39
MO	St. Louis	Villages at Liberty Gardens Addition	21	34
MO	St. Louis	Lafayette Trails	34	54
WI	Waukesha	Bristlecone Pines (Village of Hartland)	25	40
WI	Waukesha	Springbrook North (City of Waukesha)	38	61
MD	Howard	Waverly Woods	18	29
MD	Howard	RiverHill Village	24	38
MN	Dakota	Itokah Valley Townhomes 4th Addition	18	29
MN	Hennepin	Creekside Estates Apartments	9	14
Average Distance			**24**	**38**

Table 2: Distance to Center City for a Sample of Brownfield Development Census Tracts

State	County	Name	Distance to City Center (miles)	Distance to City Center (kilometers)
PA	Allegheny	Summerset at Frick Park	6	9
PA	Allegheny	Waterfront	6	10
IL	Cook	Homan Square	5	8
IL	Cook	Columbia Pointe	9	14
MO	St. Louis City	Lofts at the Highlands	5	8
MO	St. Louis City	Welsh Baby Carriage Phase 1	2	2
WI	Milwaukee	Trostel Square, Beerline Development	1	2
WI	Milwaukee	Cherokee Point	7	12
MD	Baltimore City	Clipper Mills	3	5
MD	Baltimore City	Camden Crossing/Koppers	2	2
MN	Hennepin	Heritage Park	2	4
MN	Hennepin	Mill City Area	1	1
Average Distance			**4**	**6**

MODAL SHARES AND COMMUTING TIME

At a aggregate level, commuting modal shares in the US Census (2009) data are divided into Individual Automobile, Public Transportation, Motorcycle, Bicycle, Walked and Other Modes (Figure 1). Of the various modes in the Census data, only the Individual Automobile, Public Transportation, and Walking had substantial ridership in both brownfield and greenfield developments.

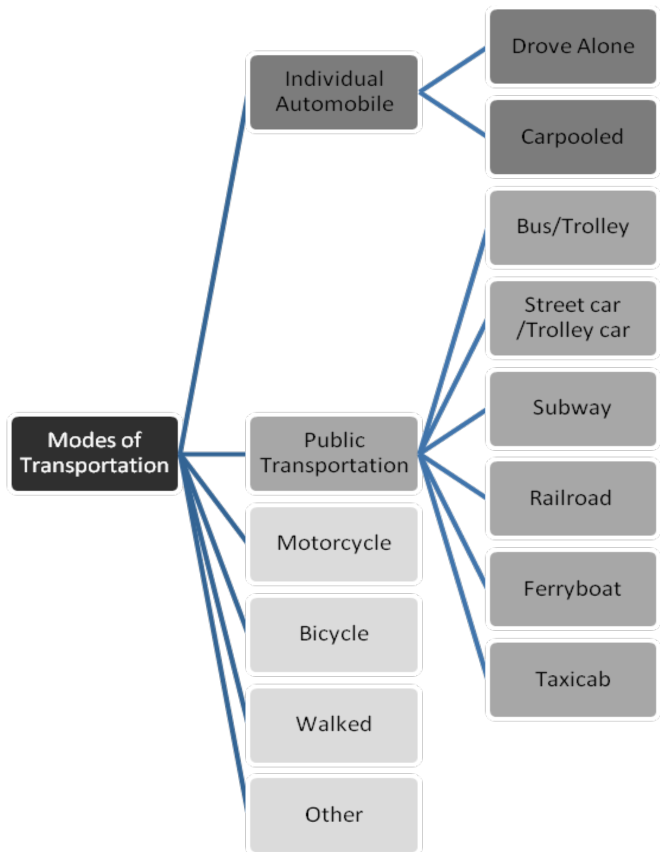


Figure 1: US Census Modes of Transportation Categories and Subcategories

For individual vehicle transportation, residents of greenfield development use their personal vehicles 97% of the time for travel to work, with 8% carpooling and 89% drive alone. In brownfield neighborhoods, the commute to work by personal automobile is substantially less at 72%. Of those individuals who drive individual vehicles, almost twice as many carpool (15%) as compared to greenfields residents (8%). Commuting modal share tables are summarized in Table 3 for greenfields and Table 4 for brownfields with the full analysis in Figure 2 and in the supplemental information.

The second main type of commuting mode is public transportation that is responsible for 2% of the trips to work by residents in greenfield neighborhoods and 18% for brownfield neighborhoods. Finally, the share of commuting by walking is 1% for greenfields and 8% for brownfields. These transportation differences are likely due to the greater attractiveness and availability of public transportation closer to center cities as well as shorter average commuting distances from brownfield developments. There might also be greater interest in car-pooling, public transportation and walking among residents choosing to live in a brownfield neighborhood. Figure 2 shows the overall shares of commuting modes.

Table 3: Commuting Modal Shares for Greenfield Development Neighborhood Census Tracts

[a] Total Public Transportation is comprised of Bus/Trolley, Walked, Subway, Railroad, Bicycle and Other categories.

Note: This table excludes the Other mode category so the rows will not equal 100%.

State	Name	Drove Alone	Carpooled	Total Public Trans[a]	Walked
PA	Cranberry Heights	92%	7%	1%	0%
PA	Peters Township	91%	3%	5%	0%
IL	Woodland Hills Unit 11	81%	13%	5%	0%
IL	Reflections at Hidden Lakes	91%	6%	3%	0%
MO	Villages at Liberty Gardens Addition	90%	8%	2%	1%
MO	Lafayette Trails	94%	6%	0%	0%
WI	Bristlecone Pines (Village of Hartland)	89%	6%	0%	4%
WI	Springbrook North (City of Waukesha)	88%	10%	1%	1%
MD	Waverly Woods	90%	7%	1%	1%
MD	RiverHill Village	91%	7%	1%	0%
MN	Itokah Valley Townhomes 4th Addition	86%	9%	3%	1%
MN	Creekside Estates Apartments	87%	9%	3%	1%
Average Modal Split		**89%**	**8%**	**2%**	**1%**

Table 4: Commuting Modal Shares for Brownfield Development Neighborhoods Census Tracts

[a]Total Public Transportation is comprised of Bus/Trolley, Walked, Subway, Railroad, Bicycle and Other categories.

Note: This table excludes the Other mode category so the rows will not equal 100%.

State	Name	Drove Alone	Carpooled	Total Public Trans.[a]	Walked
PA	Summerset at Frick Park	61%	16%	20%	3%
PA	Waterfront	62%	13%	15%	8%
IL	Homan Square	47%	39%	13%	2%
IL	Columbia Pointe	40%	10%	31%	15%
MO	Lofts at the Highlands	76%	13%	5%	5%
MO	Welsh Baby Carriage Phase 1	80%	10%	6%	3%
WI	Trostel Square, Beerline Development	87%	3%	6%	4%
WI	Cherokee Point	81%	10%	2%	5%
MD	Clipper Mills	54%	21%	14%	10%
MD	Camden Crossing/Koppers	43%	20%	21%	13%
MN	Heritage Park	27%	24%	42%	5%
MN	Mill City Area	28%	0%	41%	26%
Average Modal Split **		**57%**	**15%**	**18%**	**8%**

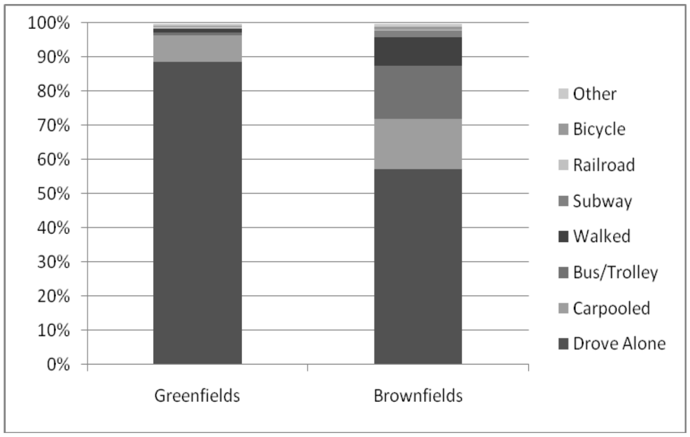


Figure 2: Greenfield and Brownfield Disaggregated Commuting Modal Shares

While the modal split of the two types of development neighborhoods are quite different (Figure 2), the average travel time to work is quite similar with 28 minutes for greenfields and 27 minutes for brownfields (Table 5 and 6).

It is helpful to look at the disaggregation of the travel time by mode for use in calculating energy consumption and greenhouse gas emission of the various developments. These average travel times from the US Census data can be disaggregated by mode into two broad categories, "Public Transportation" and "Other" as seen in Tables 5 and 6. The "Other" category includes Individual Automobile, Motorcycle, Bicycle, Walk and Other (Figure 1). Since individual automobile is used by most residents (97% greenfields and 72% brownfields), we assumed that the average travel time is representative of private vehicle travel times.

Table 5: Average Total Travel Time to Work One Way (min) and Disaggregated by Mode for Greenfield Neighborhoods Census Tracts

State	Greenfield Name	Avg. Across all Modes	Avg. Public	Avg. "Other"
PA	Cranberry Heights	30	63	29
PA	Peters Township	28	55	27
IL	Woodland Hills Unit 11	32	75	30
IL	Reflections at Hidden Lakes	29	58	29
MO	Villages at Liberty Gardens Addition	25	44	24
MO	Lafayette Trails	28	0	28
WI	Bristlecone Pines (Village of Hartland)	21	20	21
WI	Springbrook North (City of Waukesha)	30	45	30
MD	Waverly Woods	32	64	32
MD	RiverHill Village	32	73	31
MN	Itokah Valley Townhomes 4th Addition	22	33	22
MN	Creekside Estates Apartments	21	36	20
	Average Travel Time (min)	**28**	**47**	**27**

Table 6: Average Total Travel Time to Work One Way (min) and Disaggregated by Mode for Brownfield Neighborhoods Census Tracts

[a] The US Census tract containing the Homan Square brownfield neighborhood has reported travel times across all modes that are unusually high compared to the remaining brownfields and greenfields in Tables 5 and 6. Homan Square development also has a high carpooling rate. For this analysis, we have assumed two persons per vehicle for carpooling..

State	Brownfield Name	Avg. Across all Modes	Avg. Public	Avg. "Other"
PA	Summerset Phase 1	19	29	17
PA	Waterfront	26	38	24
IL	Homan Square[a]	50	23	54
IL	Columbia Pointe	30	44	23
MO	Lofts at the Highlands	19	19	19
MO	Welsh Baby Carriage Phase 1	24	48	23
WI	Trostel Square, Beerline Development	15	24	15

WI	Cherokee Point	20	41	20
MD	Clipper Mills	27	38	26
MD	Camden Crossing/Koppers	26	34	24
MN	Heritage Park	30	50	16
MN	Mill City Area	31	41	24
	Average Travel Time (min)	**27**	**36**	**24**

ENERGY IMPACTS OF COMMUTING

Scope and Assumptions

In this energy impact analysis, our scope includes the upstream supply chain production of the transportation fuel and the combustion of the fuel during the vehicle use phase. We estimated supply chain fuel production and combustion data for individual automobile and public transportation separately. To calculate these impacts, commuting speed, automobile fuel efficiency, price of fuel and electricity, public transportation information, and upstream supply chain and combustion impacts were required.

Individual Automobile Transportation

Automobile Fuel Energy

In order to quantify the upstream energy required to produce automobile fuel, the Economic Input-Output Life Cycle Assessment (EIOLCA) US 2002 Producer Price model was chosen (Hendrickson 2006; CMU 2010). Within the model, we chose the "Petroleum Refineries" sector group for analysis. This specific sector accounts for "establishments primarily engaged in refining crude petroleum into refined petroleum" and associated upstream impacts (CMU 2010). The EIOLCA model estimated that 31.7 TJoules/$1Million resulted from the supply chain of fuel production (CMU 2010). Assuming the average price of gasoline in 2001 was $1.53/gallon (EIA 2008a), the upstream energy impact translates to approximately 49 MJ/gallon.

The energy input for direct gasoline fuel combustion was assumed to be 132 MJ/gallon (EIA 2009). Thus, the total energy for fuel was the sum of upstream (supply chain) and direct use, 49+132 = 181 MJ/gallon.

Individual Automobile Combustion Energy Impacts

To estimate the combustion energy of fuel used per commuter in each development, we included the number of people who use individual automobiles, commuting travel time, average commuting speed, automobile fuel efficiency and the energy in motor gasoline. The number of residents who used individual automobiles and the commuting travel time was from the US Census tract information (US Census 2009). We assumed those residents who carpooled had only two commuters per vehicle. We modeled the average commuting speed based on the 2009 Annual Urban Mobility Report published by the Texas Transportation Institute for an industry wide car and light truck stock having a fuel efficiency of 20.3 miles per gallon (Schrank 2009; EPA 2005). The average commuting speeds are reported by city and by roadway type for 2007. For this analysis, we assume that the cities commuting time is the average speed based on freeway and arterial street information (Table 7).

Table 7: Average Commuting Speeds for Cities in 2007 (Schrank 2009)

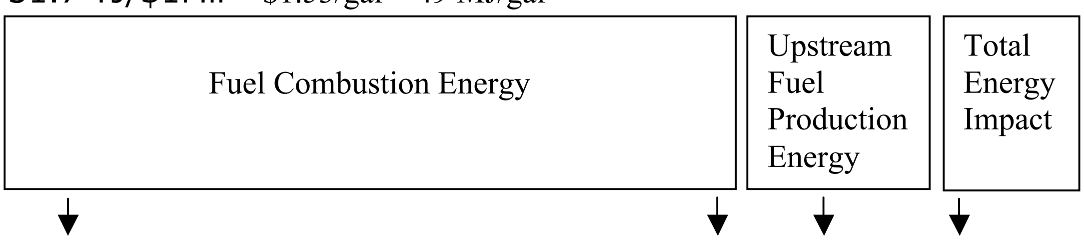
		2007 Traffic Speed Estimates (mph)		
State	**City**	**Freeway**	**Arterial Street**	**Average**
PA	Pittsburgh	56	32	44
IL	Chicago	41	25	33
MO	St. Louis	53	30	42
WI	Milwaukee	50	32	41
MD	Baltimore	44	28	36
MN	Minneapolis	46	29	38

Energy used for a vehicle trip is calculated from the average travel time to work (Tables 5 and 6), average travel speed in each city (Table 7), the average vehicle fuel efficiency (20.3 mi/gal), and the automobile fuel energy (181 MJ/gallon):

$$EVT_i = t_i \times v_i \times 181/20.3 \qquad \text{Eq. (1)}$$

Where EVT_i is energy per vehicle trip for development i, t is average travel time and v is average speed. An example calculation for the individual automobile energy intensity per vehicle trip for Cranberry Heights located near Pittsburgh, PA is provided in Figure 3. For this paper, a vehicle trip represents a resident's commuting distance to work one way.

31.7 TJ/$1Mil × $1.53/gal = 49 MJ/gal



29 min/veh-trip × 1hr/60 min × 44 mph ×1 gal/20.3 mile × (132 MJ/gal + 49 MJ/gal) = 190 MJ/veh-trip

Figure 3: Individual Automobile Vehicle Trip Total Energy Impact Example Calculation for Cranberry Heights (near Pittsburgh, PA)

On average, vehicle trips from greenfield developments consume 150 MJ of energy per vehicle trip (0.14 Million BTU/yr) compared to 130 MJ of energy per vehicle trip (0.13 Million BTU/yr) from brownfield developments (Table 8 and 9). This difference is directly linked to the variation in individual automobile commuting time and speed as shown in Tables 5, 6 and 7. These numbers assume commuters use individual automobiles to and from work 260 days per year. In addition, the energy intensity results for all developments can be seen in Tables 8 and 9.

Table 8: Greenfield Development Individual Automobile Commuting Energy Impact Intensity

Greenfield Development Name	MJ (MBTU) /vehicle trip	MJ (MBTU) /vehicle/yr
Cranberry Heights	190 (0.18)	99,000 (94)
Peters Township	170 (0.16)	90,000 (85)
Woodland Hills Unit 11	150 (0.14)	77,000 (73)
Reflections at Hidden Lakes	140 (0.13)	72,000 (68)
Villages at Liberty Gardens Addition	150 (0.14)	78,000 (74)
Lafayette Trails	170 (0.16)	90,000 (85)
Bristlecone Pines (Village of Hartland)	130 (0.12)	65,000 (62)
Springbrook North (City of Waukesha)	180 (0.17)	96,000 (91)
Waverly Woods	170 (0.16)	88,000 (83)
RiverHill Village	170 (0.16)	87,000 (82)
Itokah Valley Townhomes 4th Addition	120 (0.12)	63,000 (60)
Creekside Estates Apartments	110 (0.11)	58,000 (55)
Average	**150 (0.14)**	**80,000 (76)**

Table 9: Brownfield Development Individual Automobile Commuting Energy Impact Intensity

Brownfield Development Name	MJ (MBTU) /vehicle trip	MJ (MBTU) /vehicle/yr
Summerset Phase 1	110 (0.10)	57,000 (54)
Waterfront	160 (0.15)	82,000 (78)
Homan Square	260 (0.25)	140,000 (131)
Columbia Pointe	110 (0.11)	58,000 (55)
Lofts at the Highlands	120 (0.11)	62,000 (59)
Welsh Baby Carriage Phase 1	140 (0.13)	73,000 (69)
Trostel Square, Beerline Development	90 (0.09)	47,000 (45)
Cherokee Point	120 (0.11)	62,000 (59)
Clipper Mills	140 (0.13)	71,000 (67)
Camden Crossing/Koppers	130(0.12)	65,000 (62)
Heritage Park	90 (0.09)	47,000 (45)
Mill City Area	130 (0.13)	70,000 (66)
Average	**130 (0.13)**	**69,000 (66)**

Public Transportation
The other primary mode of commuting besides individual automobile is by public transportation. We estimated energy impacts per public transportation passenger. The National Transit Database (NTD) for 2001 provided annual energy consumption reported in gallons and kWh and annual ridership information on the six city's transit authorities containing the paired brownfield and greenfield developments. The distribution of fuel consumption by city can be seen in Table 10.

Table 10: Public Transit Authorities Annual Energy Type Consumption Distribution (NTD 2001)

	Diesel	Gasoline	CNG	Electricity
Chicago	52%	0%	0%	48%
Baltimore	70%	0%	0%	30%
Minneapolis	100%	0%	0%	0%
St. Louis	84%	0%	<1%	16%
Pittsburgh	90%	0%	0%	10%
Milwaukee	100%	0.3%	0%	0%

Public Transportation Fuel Energy

The fuel consumption information from the NTD was first combined with diesel gasoline, motor gasoline and natural gas emission coefficients from the EIA data to obtain the combustion impacts (EIA 2009). Second, the upstream impacts from fuel and electricity production were calculated using the EIOLCA model identified above. For fuel production impacts, the same initial EIOLCA factor of 31.7 TJoules/$1Million as described in Section 4.1-Individual Automobile Transportation was used and scaled by the corresponding 2001 consumer prices for diesel, gasoline and natural gas (EIA 2008 a,b,c).

The energy impact for direct diesel fuel combustion was assumed to be 146 MJ/gallon (EIA 2009). Thus, the total energy for diesel fuel was the sum of upstream (supply chain) and direct use 49+146=195 MJ/gallon.

The upstream energy impacts from electricity production used the EIOLCA "Power Generation" sector group for analysis. The model output for the Power Generation sector displayed that 114 TJoules/$1Million resulting from the supply chain of electricity production (CMU 2010). The model output was scaled by the average retail residential price of electricity in 2001 of $0.09/kwh (EIA 2008d).

Public Transportation Combustion Energy Impacts

After the upstream supply chain energy impact of fuel and electricity are calculated, the total energy consumed by fuel combustion must be added. For electricity, input energy to produce the electricity is in the supply chain, so direct use consumption is not included as it would be double counting. The use phase of fuel for public transportation agencies is reported by the NTD in gallons per year or kwh/yr for each energy source. The fuel and electricity consumption distribution percentages from the Public Transit Authorities can be seen in Table 10. The NTD annual energy sources are converted into MJ/yr using the EIA emission coefficients (EIA 2009).

Lastly, the total annual passenger trips given by the NTD seen in Figure 4 is used to compare the public transportation energy intensities per passenger across cities.

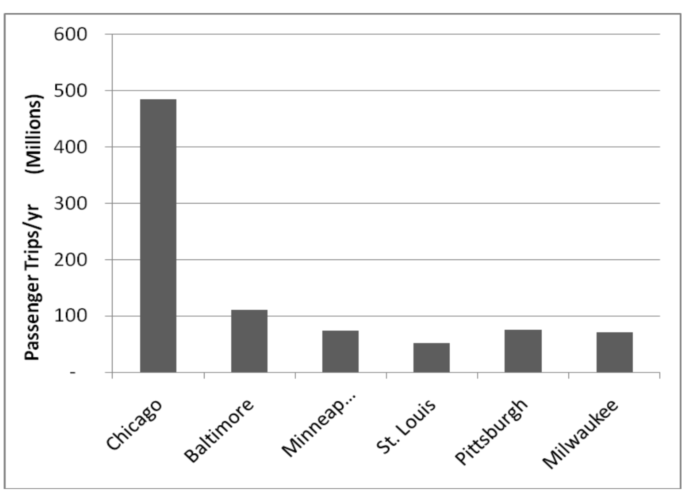


Figure 4: Public Transportation Authority Annual Ridership (NTD 2001)

Energy used for a passenger trip is calculated from the public transportation agency fuel mix (Table 10), the fuel source energy intensity (EIA 2009) and public transportation annual ridership.

$$EPT= (\Sigma f_i \times e_i)/p \qquad \text{Eq. (2)}$$

Where EPT_i is energy per passenger trip for city i, *f* is the fuel type consumption, *e* is energy intensity of fuel and p is annual ridership. Assuming a passenger uses the public transportation twice a day for 260 days per year gives an annual energy impact for each passenger. Milwaukee has the lowest annual energy impact for each passenger at 6,700 MJ/passenger/yr (6.3 MBTU/passenger/yr while Pittsburgh has the highest at 16,000 MJ/passenger/yr (15 MBTU/passenger/yr. The results for all cities and can be seen in Figure 5. This wide range results from differences in annual public transportation passenger ridership (Figure 4) and public transportation vehicle energy source distributions (Table 10).

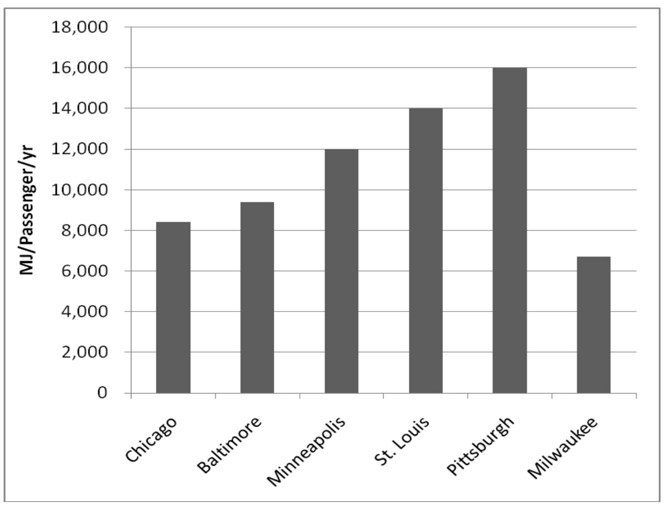


Figure 5: Public Transit Authorities Annual Energy Impact per Passenger

Energy Impacts for all Transportation Modes

Combining both individual automobile transportation and public transportation energy impacts consumed by travel to work gives a more complete picture of the differences between greenfield and brownfield developments. The energy use per commuter is calculated as a weighted average of the energy impacts for each mode, with the weights equal to the modal shares:

$$EUC_i = \Sigma_m \; \{ms_{mi} \times em_{mi}\} \qquad \text{Eq. (3)}$$

Where EUC_i is the average energy use per commuter for development i, ms_{mi} is the modal share fraction for mode m in development i, and em_{mi} is the energy use per commuter for mode m and development i. We assumed those residents who carpooled had only two commuters per vehicle trip.

On average for commuting patterns, the greenfield developments consume 75,000 MJ/commuter/yr (71 MBTU/commuter /yr versus 47,000 MJ/commuter/yr (45 MBTU/commuter/yr) for brownfields. Therefore, the brownfield developments consume approximately 37% less commuting energy per resident annually than the studied greenfields (Figure 6). The lower energy requirements are due to differences in modal share (more walking, carpooling and public transport for brownfield commuters) and somewhat shorter travel times for use of private vehicles. Note that the Homan Square brownfield development is an outlier with high travel times and corresponding relatively high energy requirements.

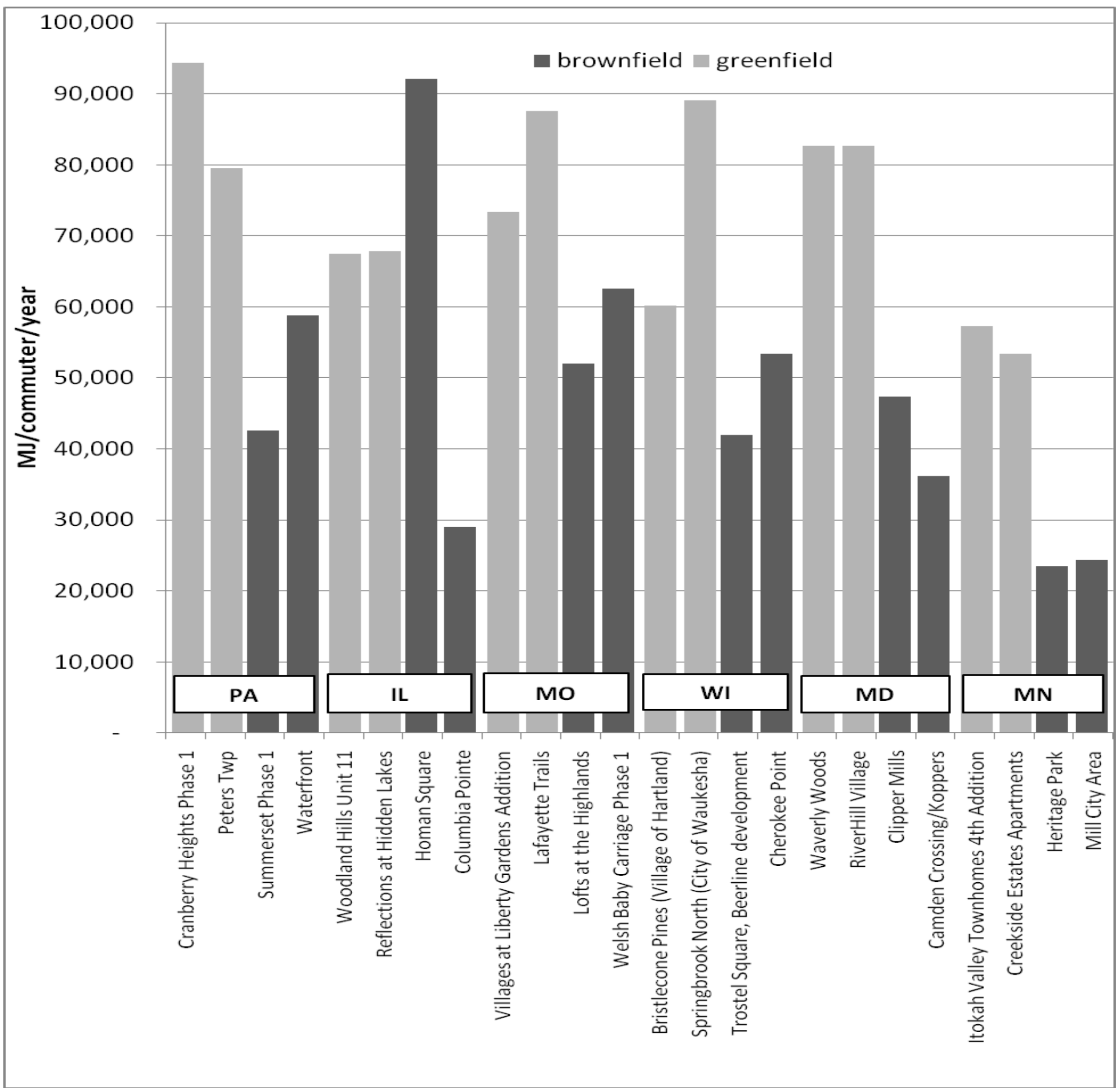


Figure 6: Total Greenfield and Brownfield Development Energy Impacts from Commuting

GREENHOUSE GAS EMISSION IMPACTS OF COMMUTING

The same method as presented above for energy impacts of commuting was recalculated for greenhouse gas (GHG) emissions. The only variations were for upstream GHG emissions for fuel and electricity production and the corresponding emission factors. These upstream impacts were calculated through the same EIOLCA model and sectors described above in Section 4. The analysis resulted in 2,380 metric tons of $C0_{2e}$/\$1 Million (5.2 Million lbs C02e/\$1Million) for upstream fuel production and 9,160 tons of $C0_{2e}$/\$1 Million (20 Million lbs C02e/\$1Million) for upstream electricity production. The combustion GHG emission factors used for fuel were from the Energy Information Administration-Voluntary Reporting of GHG Program (EIA 2009). An example calculation of the upstream impacts of diesel and electricity for public transportation of Pittsburgh, PA can be seen in Figure 7.

Total Upstream Diesel Fuel Production Energy

Reported by the National Transit Database	EIOLCA 2002 model output	EIA Cost of diesel in 2001

11,139,900 gal-diesel/yr × (5.2 Mil lbs C02e/ \$1Mil) × \$1.40/gal= 82 Mil lbs $C0_2$/yr

Total Upstream Electricity Production Energy:

Reported by the National Transit Database	EIOLCA 2002 model output	EIA Cost of Electricity in 2001

21,501,700 kwh/yr × (20 Mil lbs $C0_2$e/ \$1 Million) × \$0.09/kwh= 39 Mil lbs $C0_2$e/yr

Figure 7: Public Transportation Total $C0_{2e}$ Upstream Supply Chain Example Calculation for Pittsburgh Transit Authority, PA

Individual automobile use by greenfield residents results in is 11,000 lbs $C0_2$ per auto commuter per year which on average is approximately 37% higher than brownfields developments. The average greenhouse gas emission from public transportation averaging across all six studied cities is 2,000 lbs $C0_2$ per bus passenger per year. Incorporating both individual automobile and public transportation travel into greenhouse gas impacts of commuting by residents, the greenfield developments average 11,000 lbs $C0_2$/commuter/yr while the brownfield developments average 7,000 lbs $C0_2$/commuter/yr which can be seen in Figure 8..

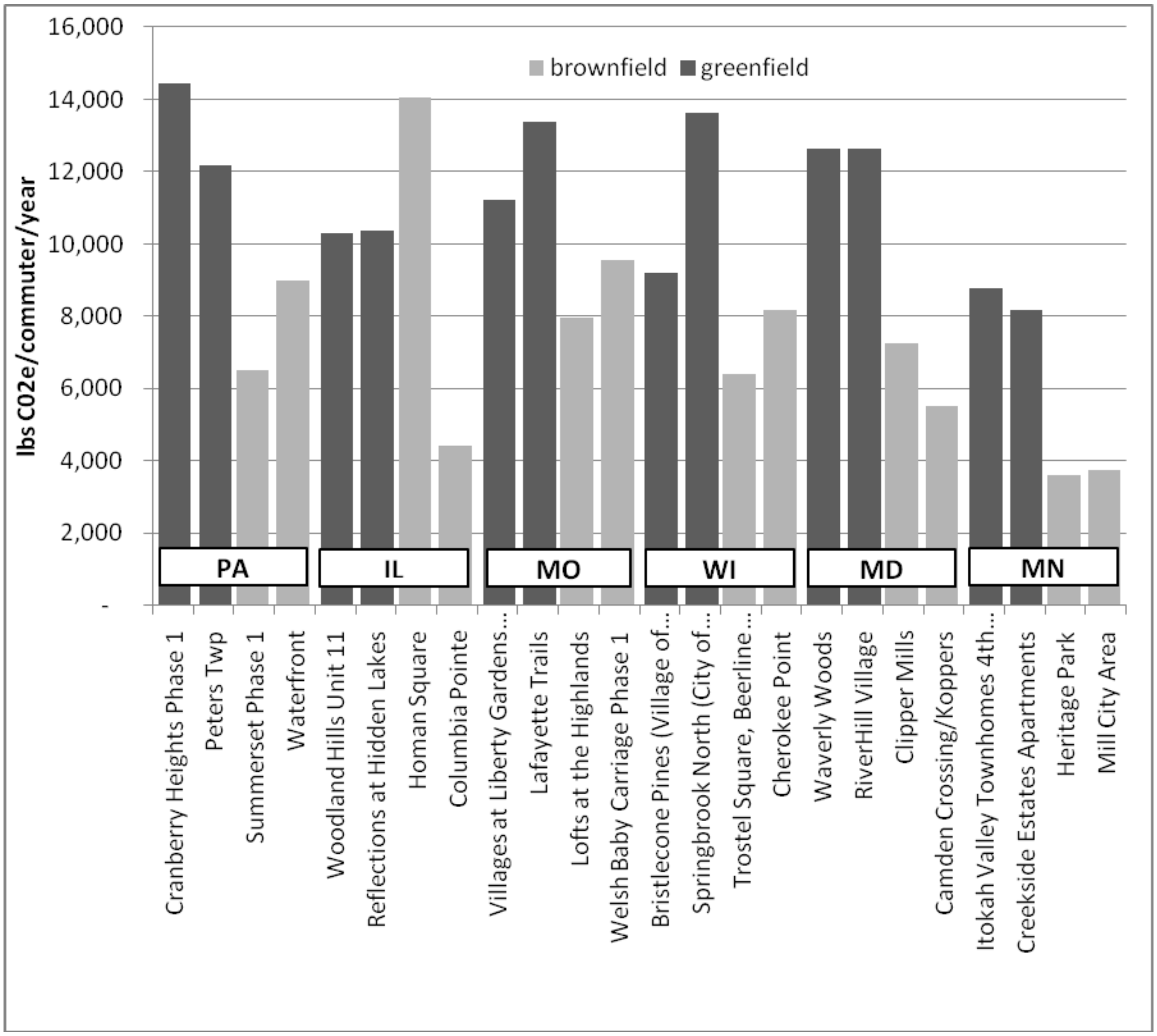


Figure 8: Total Greenfield and Brownfield Development Greenhouse Gas Emissions from Commuting

CONCLUSION

This research analyzed energy consumption and greenhouse gas emission impact differences from commuting for greenfield and brownfield developments within six cities: Baltimore, Chicago, Milwaukee, Minneapolis, Pittsburgh, and St. Louis. Greenfields are six times further from the center city on average than for brownfields (4 miles). On average, including both individual automobile and public transportation, the greenfield development commuters consume 75,000 MJ/commuter/yr (71 MBTU/commuter /yr) versus 47,000 MJ/commuter/yr (45 MBTU/commuter/yr) for brownfields. In terms of greenhouse gas emissions, the greenfield development emits 11,000 lbs $C0_2$/commuter/yr compared with 7,000 lbs $C0_2$/commuter/yr for brownfield developments. Thus, brownfield commuters had on average 37% lower energy and 36% lower greenhouse gas emissions for their commuting trips. These differences are due to differences in modal shares (with more walking, carpooling and public transportation for brownfield residents) and slightly shorter private automobile commuting trips.

Our results have some significant uncertainties. First, our sample was limited to twenty-four developments. Second, we used average metropolitan travel speeds and average impacts per public transportation passenger in our estimation. Third, there is considerable uncertainty in energy and greenhouse gas emission estimates. Fourth, the greenfield and brownfield developments include the surrounding neighborhoods as defined by the US census tracts. Finally, we did not consider other travel, buildings or other impacts of the developments. Nevertheless, there does appear to be substantial differences in the impacts of commuting for the two types of developments.

Acknowledgements

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APPENDIX B

THIS IS AN UNEDITED STUDENT REPORT THAT IS PROVIDED FOR BACKGROUND INFORMATION: DO NOT CITE NOR QUOTE

STATUS OF THE MULTI-ATTRIBUTE DECISION MAKING TOOL FOR BROWNFIELD DECISION MAKING

A REPORT PREPARED BY ZHE ZHUANG, SUMMER 2010

DIRECTED BY DR. DEBORAH LANGE

A number of years ago the EPA awarded the Western Pennsylvania Brownfields Center at Carnegie Mellon University (WPBC) a grant with the goal of helping communities "make land use decisions that are in the best interest of the local economy, while considering global environmental impacts and national policies[i]." The project, to empower small communities to make informed brownfields decisions was a natural outgrowth of the WPBC core mission to apply academic research and decision-support tools to real world problems facing public and private investors. This report will focus on the decision support component of the project, in particular the Multi-Attribute Decision Making Tool (MADM) which had been under development even before the EPA grant was received by the WPBC.

MADM was designed from the outset to address the need for a scientific and transparent metric to gauge the redevelopment potential of brownfields. One of the objectives of the EPA grant was to develop a tool to allow "governments and stakeholders to prioritize their site selection process by weighing criteria of local interest[ii]" MADM was designed to help smaller communities allocate limited time and resources to projects aimed at transforming vacant and abandoned properties, including but not limited to brownfields. The problem MADM is trying to solve is that in the absence of a metric to objectively evaluate these properties for investment, there occurs difficulty in making informed, optimal decisions about the shared and limited resources of the community. It is very difficult for one person, or even a well educated, well informed committee to consider all aspects of the numerous candidate properties and then select a few sites which if invested in would provide the optimal outcome. In addition, the decision makers involved may have a good idea of which sites to invest in, and these sites may indeed be the sites with the most potential, but MADM would provide added transparency and legitimacy to the site selection process.

At its core, MADM is an algorithmic tool that takes inputs gathered from research and surveys conducted by the community, then uses those inputs to compute a score for each potential investment site. These scores are then ranked to determine the relative suitability of each site for investment. It is important to keep in mind that MADM is not a tool to make decisions for the user, rather it should be used as part of a more comprehensive planning process. The strengths of the Multi-Attribute Decision Making model are that it compartmentalizes the problem and provides a common framework for working with each property.

During the early stages of development, it was decided that MADM would primarily consist of a survey, to be filled out by informed decision makers in the relevant communities, a weighting rubric that would help tailor MADM to the needs of a particular neighborhood and a calculator to process the quantitative data gathered from the survey and the weighting rubric.

The survey is split into several indicators, Property Attributes, the Development Driver/Champion Indicator, Development Potential Indicator, Environmental Indicator and an optional section about demographics and Environmental Justice.

> The Property Attributes section simply asks basic information like the address of the property, its acreage, the name of the property owner and asks for contact information.
>
> The Development Driver and Development Potential indicators ask about potential investors for the site and the expected difficulties in assembling properties if the site sits on land owned by several parties. In addition, these two indicators try to gauge the level of support within the community for investing in a particular site.
>
> The Environmental Indicator is designed to gauge the level of contamination if the site in question is a brownfield.
>
> The optional section contains questions that could be readily found in public sources, such as demographics information available from the US Census Bureau and GIS information. It deals with factors such as potential job creation and environmental justice.

With the exception of the Property Attributes indicator, the questions were all multiple choice and designed for ease of use. The answers would be converted numeric values and plugged into the calculator, which would then give each site a raw score and a series of raw sub-scores for each indicator. The weighting rubric would then be used to modify these sub-scores to give a final score to each site so that they can be ranked by redevelopment potential.

After developing this tool, the plan was to field test it with help from the PDCs in Pittsburgh, if the tool met with success we hoped that it would be adopted on a trial basis by communities all over Pennsylvania, this would have given us much needed data to improve MADM's specificity and relevance. Because of the academic nature of our project up to this time, we were still unclear about the real needs of the communities we were reaching out to. Our team also reached out to NFP organizations around Pittsburgh to help us test MADM. These field trials were an opportunity to find out what sort of assistance communities in Pittsburgh wanted when making decisions about vacant and abandoned properties like brownfields. A notable success MADM had during this period was a trial run conducted in the Washington Park neighborhood. Washington Park had a grant from the USEPA to conduct Phase I site assessments and needed help prioritizing dozens of sites, many of them brownfields. MADM was a valuable tool for them and helped to speed up the process of allocating time and resources. Although our project team tried to convince the PDCs to help us with our research, they were less than enthusiastic, especially with the state of the economy.

The people we talked to had mostly the same concerns and objections. The biggest concern was relevancy, the URA and President Kight both pointed out that the survey missed or did not place enough emphasis several critical factors that are important when making decisions about investment. These factors were size, end use and specificity. One of the problems with MADM is that a large site such as the Waterfront shopping center in Pittsburgh would be evaluated similarly to an abandoned corner gas station. In addition, the people we reached out to in order to ask for help with our research were concerned about what they perceived as a development bias, focused on reusing land for commercial or residential development, with not enough consideration given to other end uses for the sites. In many communities the primary goal for many prospective sites is to create a greenspace or some other project designed to enhance livability. Finally there were concerns that it was probable that a stakeholder would use a different weighting rubric for each site, greatly increasing the amount of work for each site making MADM a much less attractive option.

Another complaint we heard was that MADM did not take into account the city-wide or the community-wide development plans that might be in place. Unofficially, we also felt that there is a perception amongst the people we talked to that MADM lacks the local touch that is so important when dealing with these issues. Whether this is a problem of perception or some wrong with our method is unclear, but plainly this is a problem that needs to be addressed if we are to build support to move MADM forward.

These remarks from the people whose support we needed made our team reevaluate MADM. It is clear that in the intervening years since this component of the project has started, the needs of the communities we set out to assist have changed with the times. In order to stay relevant, our team has decided to take some time to reevaluate and redesign MADM.

Going forward, our team is committed to updating MADM in order to better fulfill the decision-making aspect of the project. The first step is to find out what kind of assistance the relevant communities are looking for. From our talks with local community leaders including the URA and representatives from the PDC Mainstreet and Elmstreet developers, there are two areas where our assistance would be useful.

The first is site specific assessment when dealing with brownfields. The cost and time associated with site assessment is a major stumbling block when considering a brownfield for investment. If the WPBC can streamline the process of site assessment, perhaps continuing some of the work done by the PEANUT project at CMU during the early nineties, we believe that this would provide a strong incentive for more organizations to support our research. Another point that was brought up repeatedly by the various parties we spoke to was the need for assistance when applying for federal, state or EPA funds. It would be beneficial for all sides if the WPBC as a neutral academic entity could coordinate better communication and understanding between government agencies in charge of promoting investment in these properties and the developers and local decision makers who are applying for financial assistance with their projects. Currently our team is preparing to send out a short survey with the mission of asking Pittsburgh communities and development organizations what it is they want out of a tool like MADM. The survey asks about long term goals for the community when considering investment in vacant/abandoned properties, especially the planned end uses for these properties. It also tries to gauge what challenges are considered the most serious when considering whether to invest in a site, be it site assembly or environmental contamination. The responses to the survey will be critical in our reevaluation of MADM, and will guide us in preparing the next iteration of this tool.

It has become clear from our work during this summer that the greatest challenge facing the MADM tool is a lack of interest from the very people whose support we are counting on to refine the tool, and who will directly benefit from its success. Our main challenge will be to align their interests with ours, and gain their support for our data collection efforts.

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[i] Brownfields Training, Research and Technical Assistance Grant Fact Sheet, USEPA
[ii] ^Ibid.