Title: LEED Certified Residential Brownfield Development as a Travel and Greenhouse Gas Emission Reduction Strategy

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ABSTRACT
This paper considers the cost-effectiveness of LEED certified brownfield developments as a vehicle miles traveled (VMT) and greenhouse gas (GHG) emission reduction strategy in comparison with other VMT and GHG reduction alternatives. While residential brownfield developments can be significantly beneficial in reducing VMT and GHG emission, adding LEED transportation credits to these developments results in marginal benefits. Compared with conventional greenfield developments, residential brownfield developments can reduce VMT and its consequential environmental costs by about 52 and 66 percent respectively. LEED certified residential brownfield developments that qualify for the applicable LEED transportation credits can have an additional 0.03% to 3.5% GHG reduction compared with conventional greenfield developments. Implementation and documentation costs of LEED criteria can have a potential negative impact on the cost savings of LEED certified brownfield developments. In addition, LEED transportation criteria are implemented by developers, while the residents benefit from the savings (i.e., time, fuel and maintenance). Society benefits from the reduced external environmental costs. To bridge the gap between costs incurred by the developers and benefits gained by the society and residents, governments can play a significant role by providing incentives. Furthermore, results show that with minimal implementation cost incurred by transportation authorities (about 75 to 95 percent less than other VMT reduction strategies), brownfield developments as well as LEED certified brownfield developments that have earned VMT reduction points can be a beneficial travel demand strategy and an environmentally viable option to assist federal, state, and local governments with their greenhouse gas emission reduction goals. Results of this study show that effective collaboration between transportation and environmental

agencies to select those brownfield sites with the highest cost saving potentials can assure a favorable outcome when it comes to decreasing VMT and GHG emissions. Furthermore, providing incentives and guidance to private developers of brownfields can expedite attainment of the VMT and GHG reduction goals set by the public sector.

INTRODUCTION

The transportation sector is the second largest source of greenhouse gas (GHG) emissions in the U.S., after electricity generation (EPA 2009a). Over the last decade, US vehicle miles traveled (VMT) have been increasing at the annual rate of about 2 percent (FHWA 2008). The US Energy Information Agency forecasts that VMT will continue to rise at an average rate of 1.6 percent over the next twenty years (DOE/EIA 2008). This forecasted impact of VMT growth could outpace gains from improved fuel economy and alternative fuels, resulting in further increases of transportation GHG emissions (AASHTO 2008).

To reduce VMT, federal, state and local governments have established various policy goals and initiatives. The American Association of State Highway and Transportation Officials (AASHTO) wishes to reduce the VMT growth rate to that of the population growth rate, one percent, by 2030. The Federal Surface Transportation Policy and Planning Act of 2009 has a mandate to reduce national per capita VMT annually and to reduce surface transportation's impact on GHG emissions by 40 percent by the year 2030 (US FSTPP 2009). To achieve these goals, transportation state and local authorities have been implementing various VMT reduction strategies with the objective of shifting travel activity to less carbon intensive modes of transportation such as walking and biking, reducing the number of trips per capita and increasing vehicle occupancy.

In addition, the Energy Independence and Security Act was introduced in 2007, mandating the DOT's Office of Climate Change and Environment, in coordination with the Environmental Protection Agency (EPA) and in consultation with the United States Global Change Research Program, to identify solutions to reduce air pollution generated from the Nation's transportation system (DOT 2010). In response to this mandate, in April of 2010 the U.S. Department of Transportation (U.S. DOT) submitted a report to the U.S. Congress discussing strategies that would reduce the impact of the transportation sector on climate change (DOT 2010). As part of this study the U.S. DOT examined five major categories of VMT reduction strategies: 1) pricing; 2) transit, non-motorized and intermodal travel; 3) land use and parking; 4) commute travel reduction, and 5) public information campaigns. The goal of the study was to objectively evaluate these strategies and quantify their potentials to reduce transportation GHG emissions. While brownfield developments were briefly mentioned in the U.S. DOT (2010) report within the land use category, they were not fully assessed within the scope of the report.

With the Leadership in Energy and Environmental Design (LEED) certification system developed by the United States Green Building Council (USGBC) gaining rapid popularity and recognition over the past decade, brownfields redeveloped in combination with achieving the LEED travel reduction credits can help achieve VMT and GHG reduction goals effectively and at a faster rate. Over the last half a decade most new developments in the US pursue LEED certification in order to reduce their carbon footprints.

This paper builds upon a previous study conducted by Mashayekh et. al (2011) analyzing travel patterns of sixteen residential brownfield and conventional developments in the U.S. In this paper, we examine the cost-effectiveness of LEED certified residential brownfield developments, as a VMT and GHG reduction strategy compared with conventional greenfield developments. We then compare the cost-effectiveness of residential brownfield developments and LEED certified residential brownfield developments with other VMT reduction strategies including transit, teleworking, biking, and pricing. Finally we assess whether brownfield developments combined with VMT reducing LEED credits lower the impact of the transportation sector on the environment. This paper analyzes changes in travel patterns, VMT and GHG emission that may occur or reduced, when people decide to live in LEED certified residential brownfield developments. The paper does not discuss other factors that influence people's reasons to live in these developments, such as tax rate, crime rate, and quality of school.

BENEFITS AND COSTS OF BROWNFIELD DEVELOPMENTS AS A VMT REDUCTION MEASURE

Estimates show there are between 450,000 to 1,000,000 brownfield sites across the U.S. (U.S. GAO 2004). As defined by congress and then the U.S. Environmental Protection Agency (EPA), "brownfields are properties for which expansion, reuse or redevelopment may be complicated by the presence or suspected presence of contaminants, hazardous materials or pollutants." (EPA 2009b). To develop a brownfield site, an assessment is required first, usually followed by remediation. While remediation cost varies significantly depending on the type of contaminants, level of exposure and extent of clean up (EPA 2001b, Rast 1997), Chicago (2003) reports a range of $24,000 to $550,000 per acre ($59,000 to $1,400,000 per hectare) with a median remediation cost of $190,000 per acre ($470,000 per hectare).

Brownfield developments are usually 'infill' sites within metropolitan areas. VMT reduction benefits of brownfield developments include time, fuel and automobile maintenance savings that are the direct result of less travel activity. Furthermore, reduction in VMT results in external environmental cost savings. Mashayekh (2011) categorizes brownfield VMT reduction cost savings into groups of direct (time and fuel) and indirect (external environmental costs) cost savings. Table 1 summarizes the annual travel reduction and its consequential cost saving percentages from conventional versus brownfield developments based on Mashayekh (2011). Reductions shown in Table 1 are results of an analysis of sixteen residential brownfield and greenfield sites in Chicago, Baltimore, Pittsburgh and Minneapolis (Mashayekh 2011). Travel demand models for the actual brownfield and greenfield sites in these four cities were used to analyze travel patterns of the sites. VMT reductions are attributed to fewer trips per brownfield household (due to a better accessibility to transit and other facilities and also fewer people per household) and shorter trip distances (due to close proximity to city centers and places of work).

TABLE 1: Annual Travel Pattern Differences from Conventional versus Brownfield Developments per Household for Sixteen Sites; Mashayekh (2011)

	% Reduction from Conventional to
Vehicle Miles Traveled (VMT)	52
Number of Trips	28
Direct Cost of Time	60
Direct Cost of Fuel	60
Indirect Environmental Cost of Driving	66

Using pollution valuation data and cost of time and fuel, Mashayekh (2011) estimates direct cost savings of VMT reductions to be $2,600 per household per year and indirect environmental cost savings of VMT reductions to be about $450 per household per year. These figures are equivalent to a total average annual cost savings of about $3,100 per household or $1,300 per person. Major assumptions included: automobile maintenance cost of $0.05 per mile, average density of 15 units per acre and an average household density of 2.4 people per dwelling unit. To compare the annual cost savings with the one time remediation cost of brownfield sites, the median cost of $190,000 per acre was annualized with a 7 percent discount rate for 30 years. Table 2 shows that, on average, brownfield developments result in total annual savings of $2,200 per household.

TABLE 2: Brownfield Developments Annual Cost Savings per Household and per Capita

Annual Cost Savings	$/Household	$/Person
Cost of Fuel	425	180
Value of Time Savings	1925	800
Maintenance Saved	280	120
Total Direct Savings	2630	1100
External Environmental Costs Saved	450	190
Total Savings	3080	1300
Cost of Remediation	(900)	(400)
Net Savings	2180	900

Other studies (EPA 1999, EPA 2001a, EPA 2002, EPA 2010a, NRDC 2003, Schroeer 1999, IEC 2003, USCM 2001) report brownfield developments' VMT reduction from 30 to 80 percent. Nagengast (2010) reports a 36 percent decrease in brownfield developments' greenhouse gas emissions due to less commuting travel. Section 4 of this paper discusses how the benefits and costs of brownfield developments compared with other VMT reduction strategies.

LEED CERTIFIED BUILDINGS AS A VMT REDUCTION MEASURE

The types of buildings included in a brownfield development are the result of design decisions made by constructors and owners. These design decisions include energy efficiency, layout and material options. They can also include features that can further reduce VMT. Since brownfield development VMT reductions shown in Table 1 focus on residential developments, in this section we consider travel reduction credits in the LEED new residential development (LEED® for Homes) and LEED™ for Neighborhood Development (ND) standards. The goal is to gauge the additive impact of VMT reduction LEED credits, when they are incorporated into the design of brownfield developments.

USGBC LEED certification is the most popular green building standard in the U.S. The certification is obtained by amassing a prescribed number of credits for each new development, with different levels of certification corresponding to different levels of credits obtained. For instance for "LEED® for Home" rankings, "certified" developments earn between 40-49 points; between 50-59 the ranking would be "silver", between 60-79 it would be "gold", and above 80 it would be "platinum". The brownfield site VMT reductions estimated in Table 1 would have occurred without LEED certification.

In the LEED® for Homes Rating System report (USGBC 2008), there are two sections providing points that could potentially reduce VMT: 1) Sustainable Site (SS) and 2) Location and Linkages (LL).

Under the SS section, the "compact development" category (SS 6) provides 2, 3 or 4 points corresponding to moderate, high and very high density development, while potentially reducing VMT. The objective of the SS 6 is to preserve land while increasing transportation efficiency and walkability. Multi-housing units with average density of 7 to 20 or more residential units can earn LEED points under this category (USGBC 2008).

Under the LL section of LEED® for Homes, the six measures shown in Table 3 can provide a maximum of 10 LEED points. Thus, if LL1 is satisfied, LL2-6 cannot be used and vice versa.

Developments that are certified as LEED™ for Neighborhood Development (ND) can earn up to 10 points under LL 1 (USGBC 2009a). A neighborhood development should earn a minimum of 40 points out of 110 points possible to be certified as LEED ND. Of the 110 points possible under LEED ND a maximum of 41 VMT reduction points can be acquired.

Table 3: Location & Linkages Category under LEED for Homes Rating System (USGBC 2008)

LL1: LEED for Neighborhood Development	Maximum Points: 10
LL2: Site Selection	Maximum Points: 2
LL3: Preferred Locations	Maximum Points: 3
LL4: Infrastructure	Maximum Points: 1
LL5: Community Resources/Transit	Maximum Points: 3
LL6: Access to Open Space	Maximum Points: 1

In the case that a residential brownfield redevelopment is not LEED ND certified, a maximum of 10 points from LL2 to LL6 categories (Figure 1) can be accrued. In that case LL5 is the only measure that potentially can result in VMT reduction:

"LL5: Community Resources/Transit with an objective of promoting less VMT for a maximum of 3 points

- Select a site that is located within ¼ a mile of 4 to 11 basic community resources such as banks, daycare centers, school, restaurants, etc.
- Or select a site that is located within ½ a mile of 7 to 14 basic community resources.
- Or select a site that is located within ½ a mile of transit services that offer 30 to 125 transit rides per weekday (bus, rail and ferry combined)" (USGBC 2008).

In summary a LEED certified multiunit residential brownfield development can have up to seven VMT reduction points under LEED® for Homes SS6 and LL5 categories or up to ten points under LEED® for Homes LL1 category (equivalent to LEED™ ND certification). Therefore LL1 can leverage all of the VMT reduction points assumed under LEED™ ND.

To assess the impacts and cost-effectiveness of VMT reduction measures under any of the two LEED systems (i.e. LEED™ ND, LEED® for Homes), we categorize them into the following three types of measures:

1- Measures reducing VMT due to high density or compact nature of the development. (e.g., SS6)
2- Measures reducing VMT due to accessibility to transit and community resources. (e.g., LL5)
3- All other measures (e.g., measures under LEED ND such as walkable streets)

Since brownfield sites are typically within the urban core of the cities, where land is scarce and public transportation and community centers are most accessible, it is unlikely that type 1 and type 2 measures have additive impacts to VMT reductions already calculated as part of brownfield developments in the previous section. Brownfields are typically built at a higher density and their location within the city centers assures reasonable accessibility and close proximity to transit, community, civic and recreational facilities.

Type 3 measures, however, can have some additive impacts to the already calculated residential brownfield VMT reductions shown in Table 1. A LEED certified development can satisfy the following four LEED ND points (type 3 measures):

1- Bicycle Network and Storage
2- Walkable Streets
3- Reduced Parking Footprint
4- Transportation Demand Management

For the first two measures the Center for Clean Air Policy (CCAP) suggests 1-5% VMT reduction for bicycle improvements and 1-10% VMT reduction for pedestrian improvements (CCAP 2011). Some of these improvements are already accomplished through the compact and mixed-use nature of brownfield developments, since residents of brownfields have better accessibility to various facilities and live in close proximity of them. However, design factors such as providing connectivity through building sidewalks and bike paths, illumination of streets, sidewalks and bike paths as well as providing scenery and shade can be incorporated within the developments to further encourage biking and walking. Although separating the impacts of the design factors from the effects of mixed use and high density developments is not an easy task, there is some literature attempting to do so. A study of fifty developments done by Cervero (2001) found that each doubling of a connectivity design factor reduced VMT by 3 percent.

LUTAQ (2005) analyzed VMT in the Puget Sound area and found that residents living in communities with the most interconnected street networks drive 26 percent less than unconnected street network. Boarnet (2001) found that pedestrian environmental factors have a significant impact on increasing non-work travel at the neighborhood level. Case studies in Davis, California and Boulder, Colorado further show that providing bike networks and walkable streets can decrease driving from 1 to 10 percent (CCAP 2011). Summarizing what was found in the literature, given that reduction of VMT due to the compact and high density nature of brownfields is already incorporated into the brownfield VMT reduction calculations in Table 1, we estimate 1 to 5 percent of additive VMT reduction impact due to pedestrian and bicycle design factors is achievable.

CCAP suggests the VMT reduction from qualifying for the reduced parking footprint credit might range from 5 to 25 percent. These parking management programs could include car sharing programs, unbundling of parking and rent prices, providing transit passes, incorporating maximum parking limits, providing cash out incentives to employers, and others. Most of these programs (e.g., cash out incentives) are more feasible for retail and commercial developments. For residential developments, providing car sharing programs and unbundling of pricing seem to be most feasible. Based on the literature, VMT reduction from car sharing varies significantly and no study on impacts of unbundling could be found. Steininger (1996) suggests that car sharing reduces urban VMT by 2.7%. Shaheen (1998) reported VMT reduction of 37% and 58% in Netherlands and Germany respectively due to car sharing. Copper (2000) shows 7.6% VMT reduction with the use of car sharing programs. Litman (2000) and Lane (2005) forecasted that the impact of car sharing would be a reduction of privately owned vehicles by 6 to 12 percent. Cervero (2004) assumes that car share users would reduce their VMT by 25%. Based on the literature review, for the residential brownfield development we use a market share of 20% (Shaheen 2007) - meaning that 20% of residents enroll in a car share program - and a VMT reduction range of 7 to 12 percent for those enrolled.

For Transportation Demand Management LEED points, the following five options are possible (one point for every two options for a maximum of two points (USGBC 2009a)):

TABLE 4: LEED Transportation Demand Management Options

Options	*Description*	*Feasibility*
TDM Program	Create a program that reduces weekday peak period VMT by at least 20%	Very Low
Transit Passes	Provide transit passes for at least a year, subsidized to be half of regular price or cheaper	Low
Developer Sponsored Transit	Provide year-round, developer sponsored private transit service from at least one central point in the project to other major transit	Low
Vehicle Sharing	Locate the project such that 50% of the dwelling units entrances are within one quarter of a mile walk distance of at least one car	Moderate to High
Unbundling of Parking	To sell or rent parking spaces separately from the dwelling units.	Moderate to High

The third column in Table 4 rates the feasibility of each option: in a residential brownfield development that is already reducing VMT due of its compact and high density characteristics, the feasibility of creating other TDM programs that could reduce VMT by an additional 20 percent is very low. LEED^{TM} ND comes to a similar conclusion (USGBC 2009a): "Any trip reduction effects of Options 2, 3, 4, or 5 may not be included in calculating the 20% threshold." Providing transit passes and developer sponsored transit services are not common in residential developments, but are more common in mixed use developments with commercial and retail components. The additive impact of vehicle sharing and unbundling parking, while more feasible to implement, is already accounted for in the Reduced Parking Footprint criteria. As a result, no additive VMT reduction impact is considered for the vehicle sharing option.

In summary, the additive VMT reduction impacts of capturing transportation-related LEED points ranges between 1 to 12 percent for reducing VMT through bike paths, walkable streets, unbundled parking and car sharing programs. To achieve these VMT reductions and gain LEED credit for these reductions, owners and developers need to incorporate these measures in the design and planning of their brownfield development projects.

Two important factors should be considered while conducting benefit and cost analysis pursuing transportation-related LEED criteria as a means to reduce VMT:

1) The likelihood of achieving VMT reduction through LEED points decreases as percent VMT reduction goes up. In other words there is a higher chance of achieving 1 percent VMT reduction through LEED points than achieving 12 percent VMT reduction through LEED points.

2) In some cases although LEED measures are implemented and a building is LEED certified, energy savings and GHG emission reductions may actually not be achieved (Scofield 2009). The same may occur for VMT reductions.

COST OF LEED CERTIFIED DEVELOPMENTS

On the cost side, a LEED certified development incurs a higher cost of construction compared with a conventional development plus an additional soft cost of documentation, review fees and commissioning. A USGBC (2009b) report examined 110 projects in New York City of which 63 were LEED certified. Results show that on average LEED certified high-rise residential buildings on average cost $175,000 per acre more than non-

LEED buildings (USGBC 2009b). According to Kats (2009), green buildings cost about 2 percent more to construct than conventional buildings. Kats reports that the construction cost of green buildings is \$3-\$5/ft^2 higher than conventional buildings (approximately \$130,000 to \$220,000 per acre). An older study, NEMC (2003), reports LEED certification adds 4 to 7 percent to a project's construction cost. In addition NEMC (2003) reports the cost of documentation as low as \$10,000 and as high as \$60,000 per project. For the cost side of this analysis we use an average of \$175,000 per acre assuming our residential brownfield redevelopment is LEED certified (USGBC 2009b). Higher ratings of LEED certification (i.e. silver, gold) can reasonably be assumed to further increase the cost of construction. However this paper analyzes costs and benefits of minimum required points for certification only. To qualify for compact developments under LEED, density should be between 7 to 21 dwelling units per acre. As described earlier, we assume an average density of 15 dwelling units per acre, and 5 percent discount rate for 30 years.

METHOD FOR ESTIMATING DIRECT AND EXTERNAL COSTS ASSOCIATED WITH LEED CERTIFIED BROWNFIELD DEVELOPMENTS

Home-based work and home-based non work VMTs for each of the sixteen brownfield and greenfield sites were analyzed and estimated from the metropolitan areas travel demand models. The following LEED VMT reduction percentages (Table 5) were then applied to the VMTs for each brownfield site.

Table 5: Potential VMT Reduction Measures from LEED Neighborhood Development Measures

LEED VMT Reduction Measure	Percent VMT Reduction
Walkable Streets	1-5%

Bicycle Network and Storage	1-5%
Reduced Parking Footprint	5-25%
TDM	20%*

*20% is required to qualify for LEED credit.

The new reduced VMTs were then divided into freeway and arterial mileages with assumed speed of 60 miles per hour and 35 miles per hour respectively. EPA Mobile 6.2 emission factors were used to estimate the fuel energy and cost of fuel. Mobile 6.2 (EPA 2003) incorporates fuel combustion, break wear, tire wear, and evaporative losses for each vehicle time and speed limit to determine emissions in gram per mile. Fuel energy was estimated with the freeway and arterial speeds mentioned above, a Reid Vapor Pressures of 8.7 psi with July freeway conditions, and gasoline price of $2.8 per gallon, which is consistent with the DOT report used for the comparison portion of this analysis (DOT 2010)

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

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

where:

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

FE = Fuel energy (MJ/mile);

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

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

C = 121.3 MJ/gallon of gasoline

$DVMT_{(a)}$ = Daily vehicle Miles traveled for site after LEED VMT reduction credits (miles/day);

i and j represent freeway and arterial respectively.

To estimate the cost savings associated with time, the average value of time was assumed to be having a range between minimum wage of $7.25 per hour in 2009 and maximum wage of $30 per hour. The range of values was analyzed in the Monte Carlo situation done for sensitivity analysis.

To estimate the external environmental cost, the Air Pollution Emission Experiments and Policy (APEEP) analysis model was used (Muller 2007). The model links county level emissions of air pollutants to monetary damages (NRC 2010). Costs generated by the APEEP model include costs of mortality, morbidity and environmental damages associated with emissions of air pollutants that were estimated from the Mobile 6.2 model based on speed. 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. The external environmental cost of each pollutant was calculated for each development using the following equation:

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

where:

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

$DVMT_{(a)}$ = Daily vehicle Miles traveled for development after LEED VMT reduction criteria (mile/day);

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

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

TRAVEL BENEFIT VERSUS COST ANALYSIS OF LEED TRANSPORTATION CREDITS IMPLEMENTED ON RESIDENTIAL BROWNFIELD DEVELOPMENTS

Results of calculations described in the previous section to determine the net savings of residential brownfield developments that earned LEED VMT reduction credits is illustrated in Table 6.

Table 6: Per Household and per Capita Annual Cost Saving of Brownfield Redevelopments when Combined with VMT Reducing LEED Points

Annual Cost Savings	$/Household	$/Person
Cost of Fuel	570	240
Value of Time Savings	2,370	990
Maintenance Saved	290	120
Total Direct Savings	3,230	1,350
External Environmental Costs Saved	530	220
Total Savings	3,760	1,570
Cost of Remediation	(1,500)	(600)
Net Savings	2,260	970

Table 5 shows that when a brownfield site is developed as a residential multiunit development, incorporating and implementing LEED VMT reduction measures - including bicycle network and storage, walkable streets, unbundling and car sharing programs – can potentially save each household up to an extra $600 and each person up to an extra $250 a year on the direct costs (time, fuel and maintenance). However since cost of LEED certification adds about 70% to the original cost of brownfield remediation, the net savings are comparable between the two alternatives (i.e., LEED vs. no LEED).

As mentioned previously, this paper only includes residential developments. Therefore only LEED points that pertain to residential developments were included in the analysis. Brownfield developments often have commercial and retail components to them. If analyzing a commercial brownfield development, LEED for New Construction (LEED NC) points are more favorable to be used for the analysis. LEED NC includes the following three potential VMT reduction measures (USGBC 2011):

1- Alternative Transportation: Public Transportation Access
2- Alternative Transportation: Bicycle Storage and Changing Rooms
3- Alternative Transportation: Parking Capacity

Of these three measures, public transportation access (as mentioned previously) will not have much of an additive impact since brownfields are already located in urban cores with good access to transit. The next two measures, bicycle storage and changing rooms as well as parking capacity, are common to all LEED standards and have already been accounted for in the analysis of brownfield residential developments. Therefore, if commercial components are added to brownfield residential developments, we do not anticipate a significant incremental cost savings from any additional LEED VMT reduction measure.

SENSITIVITY ANALYSIS

Due to the nature of the assumptions made for various VMT reduction measures, a Monte Carlo simulation was performed, allocating various distributions to the assumptions made for this analysis. Figure 1 illustrates the result of the Monte Carlo simulation while Table 6 shows the ranges of cost savings resulted from the implementation of VMT reduction strategies.

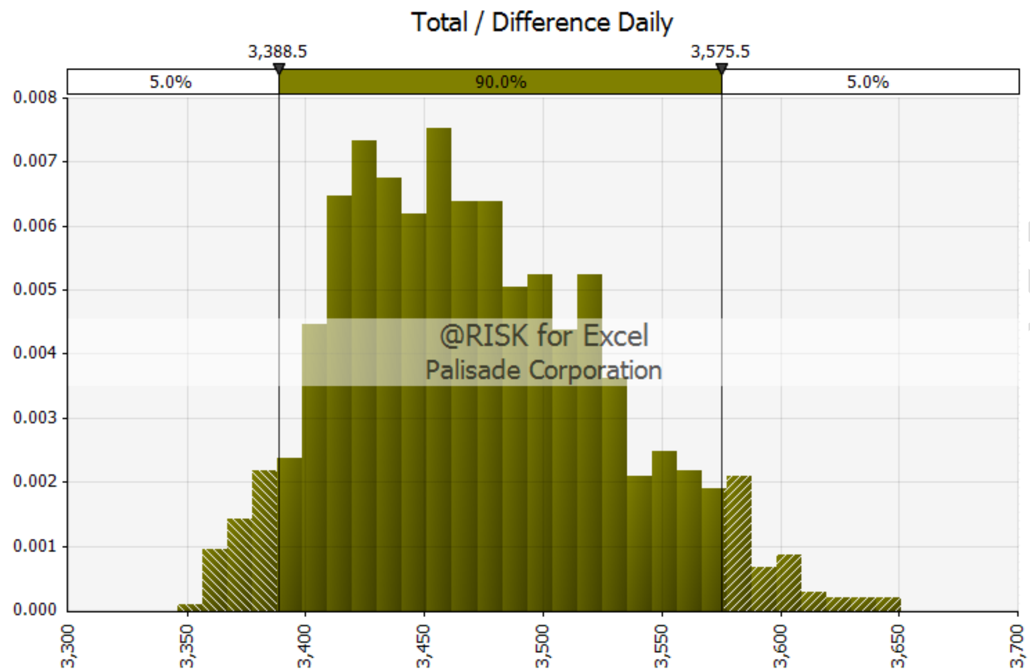

Figure 1: Monte Carlo Simulation Results for Total Travel Savings

TABLE 7: Per Household and per Capita Annual Cost Saving Minimum and Maximum Ranges of Brownfield Redevelopments when Combined with VMT Reducing LEED Points

Annual Cost Savings	$/Household	$/Person
Cost of Fuel	470-700	190-290
Value of Time Savings	2200-2400	910-1000
Maintenance Saved	280-300	120-125
Total Direct Savings	2950-3400	1200-1400
External Environmental Costs Saved	520-540	220-225
Total Savings	3470-3940	1440-1640
Cost of Remediation	(1500)	(600)

Net Savings	1970-2440	840-1040

As seen on Table 7, implementing LEED VMT reductions might have a negative impact on the net cost savings of brownfield developments compared with no LEED (Table 2). The combination of remediation cost and LEED implementation and documentation cost may decrease the cost effectiveness of the LEED VMT reduction strategies implemented in residential brownfield developments.

LEED CERTIFIED BROWNFIELD DEVELOPMENTS VS. OTHER VMT REDUCTION MEASURES

In recent years a number of studies have been conducted to quantify benefits and costs of various VMT reduction strategies (CCAP 2011, CSI 2009, Ewing 2008, NRC 2009). The U.S. DOT (DOT 2010) report to the U.S. Congress combines results of many of these studies to show how various VMT reduction strategies can be environmentally effective. To compare brownfield redevelopments and LEED certified brownfield redevelopments with other travel reduction strategies, the same definitions and assumptions as DOT (2010) were used to generate the cost-effectiveness estimates for this part of the study: for direct implementation cost, remediation cost and the cost of LEED certification are considered. For the net benefit, direct implementation costs as well as cost savings from fuel use, externalities and vehicle operation were included. For consistency between this study and the DOT report, all direct costs are reported in present year real dollars without inflation or discounting. For calculating net benefits, however, future year operating cost savings were discounted using the rate of 7 percent. The 7 percent discount rate is consistent with DOT (2010). Results are shown in Table 8.

TABLE 8: Comparison of Various VMT Reduction Strategies*

Strategy	*Key Assumptions*	*Cost Effectiveness*	
		Implementation Cost ($/tonne CO_2e)	**Net Benefit ($/tonne CO_2e)****
LEED Certified Brownfield Redevelopments	Brownfield redevelopments with LEED Transportation Credits including LEED VMT reduction points.	30-60	200-450
VMT Fee	VMT fee of 2 to 5 cents per mile	20-280	650-950
Pay As You	Require states to permit PAYD insurance	30-90	920-960
Congestion Pricing	Maintain level of service D on all roads (average fee of 65 cents/mile applied to	300-500	440-570
Cordon Pricing	Cordon charge on all U.S. metro area	500-700	530-640
Transit	2.4-4.6% annual increase in service;	1200-3000	(1000)-900
Non-Motorized	Comprehensive urban pedestrian and	80-210	600-700
Land Use	60-90% of new urban growth in compact, walkable neighborhoods (4,000+	10	700-800
Tele-Working	Doubling of current levels	1200-2300	180

*Source: A sample of VMT reduction strategies from the Report to Congress by U.S. Department of Transportation (with an exception of numbers for brownfield redevelopments and LEED certified brownfield redevelopments (first two rows)).

**A positive number shows net savings, a negative number (xx) represents increased cost. All benefits were reduced by 14% to account for the induced demand resulting from the implementation of each VMT reduction strategy. The report does not specify the type of externalities included in these estimates and the method used to estimate the externalities.

The result of this comparison shows while land use in general and brownfields in particular have the lowest implementation cost, the net benefit of brownfield developments is comparable with all other measures. Furthermore, constructing a LEED certified brownfield project that has earned the VMT reduction points under bike network, walkable streets, unbundling and car sharing within the LEED system although increases the implementation cost by 75 to 90 percent compared with a non-LEED certified brownfield development, the cost of implementation is still lower than most other VMT measures (in some cases like transit or tele-working less than 1 percent of the cost). This result further shows the net benefit of LEED certified brownfield redevelopments are in most cases comparable with other VMT measures.

DISCUSSION

To summarize the findings of this study, VMT reduction measures specified in LEED that are applicable to residential brownfield developments and can have potential additive impact are limited to pedestrian and bicycle improvements, parking programs and vehicle sharing programs. While implementing these strategies can reduce VMT, save cost and reduce GHG emissions, the net cost savings are anywhere between negative to insignificant. This is due to the fact that cost of implementing LEED criteria in general exceeds the cost savings generated from the implemented criteria. It is important to note that there may be other benefits from LEED construction including but not limited to energy efficiency or health impacts. Not all LEED certified developments get most of their benefits and points through VMT reduction points. By the same token the cost of LEED does not apply only to the transportation related credits. The next step to further expand on this analysis should either include all benefits of LEED certification including energy efficiency and health benefits or should reduce the cost appropriately to only include the cost of LEED for implementing transportation credits.

Direct savings from LEED VMT reduction criteria (e.g., fuel, time and maintenance) can be used to incentivize people to move into LEED certified residential brownfield developments. Society at large benefits from the external environmental benefits. Developers incur the cost of implementing LEED VMT reduction strategies. To bridge the gap between the costs incurred by the developers and savings incurred by the potential residents and social benefits, governments can act to provide subsidies and incentives. From the governmental standpoint, such as state and local transportation authorities, and environmental agencies such as EPA, brownfield developments and in particular LEED certified brownfield developments can serve as a cost-effective VMT reduction and GHG emission reduction strategy compared to most other strategies. Table 9 shows some of the potential costs and benefits that we anticipate brownfield development stakeholders might incur.

TABLE 9: Stakeholders' Benefits and Costs of Brownfield Developments

Who?	*Potential Benefits*	*Potential Costs*
Local Residents	Reduced Health Risks – Increased Home Values– Reduced Crime Rate	Increased Tax – Noise Congestion
Brownfield Residents	Saved Time – Saved Fuel Improved Health	Safety Concerns Lower Quality of School
Developers	Existing Infrastructure - Zoning Differentiation - Funds and Subsidies	Remediation Cost – LEED VMT reduction
Society at Large	Improved Health Reduced Emission	Tax
The City	Property Tax – Employment Opportunities – Other Income	Negligible
Government	Achieving Emission Reduction Goals Various Fees	Funding - Subsidies
Transportation/ Environmental	Achieving VMT Reduction Goals – Increasing Cost Effectiveness of	Negligible

Most stakeholders incur some sort of cost when it comes to brownfield redevelopments that include LEED VMT reduction strategies. However governments have a minimal cost since most of the cost of development is paid by developers. This fact should give the environmental and transportation authorities an opportunity to provide funding and incentives not only for the initial remediation of the sites but also for implementing LEED VMT reduction strategies. Results of this benefit cost analysis should encourage metropolitan planning organizations and state and local transportation governments as well as transportation policy makers to consider LEED certified brownfield redevelopments as a VMT reduction strategy by encouraging and providing additional funding and incentives to other brownfield stakeholders. Furthermore, transportation authorities should join efforts with the U.S. EPA to identify and provide incentives to brownfield sites that would result in an increased modal shift, such as those that are in close proximity of transit infrastructures and services. In cooperation with the cities and planning departments, transportation authorities can also provide incentives and grants that would encourage developers and planners to implement smart growth principles such as diversity and interconnectivity.

The strategies discussed here could also be augmented with additional measures to further reduce vehicle miles traveled and greenhouse gas emissions. For example, mixed use developments could further reduce overall travel demand. Energy efficient buildings could reduce GHG emissions of heating, ventilation and cooling (Scofield 2009).

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