Sustainable Transport and Potential Mobility

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Any index that seeks to assess transport sustainability for different areas will soon confront the problem that these areas must also have some reasonable level of mobility. Implicitly the impacts on sustainability are the least where the economy has not yet developed. As a result there is a need to explicitly consider the level of potential mobility that the economy is capable of supporting. An index is proposed here that is based on the difference between the level of sustainability and the level of potential mobility, standardized for population size and units of measurement. The index is illustrated for a number of different policy and regulatory situations. More important than the index developed are the limitations of this or other measurement systems in this area. These range from how one can allocate aviation fuels to specific countries to how one can translate current environmental targets into index values. These will have to be considered in the development of any future indices in this area.

1. Introduction

A substantial literature has developed over the last decade on the subject of sustainable transport. Indicators abound that are said to reflect one or more dimensions of this variable, yet an index of sustainable transport that would enable policy makers to assess their area's status, note progress or evaluate policies has not been forthcoming. The purpose of the present paper is to suggest the form that such an index might take and to illustrate its use in several different situations. The index proposed is not without flaws; it could be improved in many ways, but the intent here is not so much to prescribe as it is to foment discussion on some of the desirable attributes of such an index and to note the problems that will be encountered in any attempt to measure the somewhat elusive notion of sustainable transport or mobility.

2. Sustainability in Transport

One of the basic definitions of sustainable transport stems from the Brundtland Report (World Commission on Environment and Development, 1987) and this is "satisfying current transportation and mobility needs without compromising the ability of future generations to meet these needs" (Black, 1996). It is generally recognized that our current transport systems (particularly the motor vehicle-highway systems) are not sustainable and the question arises as to exactly what it is that prevents these systems from meeting future transport and mobility needs. This has been addressed elsewhere (Black, 2000) and it is known that among the barriers to long term transport sustainability are:

1. Global environmental problems
2. Non-renewable resource use by current transport modes
3. Excessive fatalities and injuries
4. Local air pollution problems
5. Congested facilities

Some further discussion on these five broad categories is merited.

Global environmental problems. It is well recognized that current transport systems are non-sustainable in that they result in carbon dioxide production that reinforces the greenhouse effect thus resulting in a warmer planet and sea level rise. There is practically no argument on this basic process, but there are questions as to how much eventual warming and sea level rise there will be and when this will occur.

Non-renewable resource use by current transport modes. The primary concern on the non-renewable resource side is that there is a finite amount of petroleum to be had on the planet and by most indicators the reserves remaining will be insufficient to meet transport and other needs during this century. There is some controversy on this point in that some scholars believe petroleum recovery may peak within the next decade and others believe this may occur within the next two decades. One thing that geologists and energy experts seem to agree on is that petroleum will cease to be available in sufficient amounts to use as the dominant transport fuel during the period from 2030 to 2050 (see Deffeyes,2001).

Excessive fatalities and injuries. One should hardly be willing to accept a transport system as sustainable that results in one-half million fatalities a year, yet this is the estimated annual toll on the world's highways. It is estimated that another 30 million people may be injured each year.

Local air pollution problems. The world's cities are recipients of a host of emissions from the tail pipes of the current motor vehicle fleet. Carbon monoxide, oxides of sulfur and nitrogen, hydrocarbons and particulates are harmful to the health of human occupants in the short and long term and should not be acceptable today.

Congested facilities. Assuming that none of the other factors noted above were operable we would still have the problem of too many vehicles on the roads, streets and highways of the world. Perhaps this is a problem that would be tractable with a combination of policy and technology, but little progress has been made. Its solution may necessitate a change in human behavior that will only be agreed to with reluctance.

The number of individual indicators that have appeared in the literature is legion (see *inter alia* EPA, 1996; Heanue, 1997; Litman, 1999; Gudmundsson, 2000; Gilbert, *et al.*, 2002). Some of these may merit inclusion with those noted above. At the same time nearly all of the logically related indicators are reflected in the five broad categories above. Therefore, it seems as though a focus on these five may be sufficient to collectively represent all of these additional variables and indicators that might be included.

On the other hand some would like to see all of these indicators considered in an evaluation of an area's sustainability. This is as impractical as it is difficult. Many indicators would not be available for different parts of the world and if a global indicator is sought, it certainly should not result in a data collection effort by national governments that exceeds their capability.

It would be possible to take all of the indicators and attempt to derive some overall index of sustainable transport, but we would very quickly get bogged down in terms of the relative weighting we should give to the various components. How do we weight human respiratory damage in comparison to three additional minutes spent on a congested highway? The problems to be encountered following this avenue should be apparent.

The approach taken here is to select several indicators representative of the five broad categories mentioned above that form the basis for non-sustainability of the transport sector for states in the U.S. and subject these to a principal components analysis. The variables included were:

1. Carbon dioxide emissions
2. Carbon monoxide emissions
3. Motor vehicle crash fatalities
4. Gasoline sales
5. Motor vehicle crash injuries
6. Motor vehicle registrations
7. Nitrogen oxide emissions
8. Vehicle kilometers of travel
9. Volatile organic compounds (VOC) emissions

The single component result of the analysis for the U.S. states appears as Table 1. The most representative variable for the factor derived is vehicle kilometers of travel with a .99103 component loading.

This analysis was repeated using the same indicators for the 28 member nations of the OECD. The results were comparable, a single component was derived that accounted for 96.6% of the variance in the data (see Table 2). Although vehicle kilometers traveled was not the strongest variable on the component, it was very high at .99071. Based on these two analyses it seems reasonable to conclude that a very good indicator of decreasing sustainability is vehicle kilometers of travel (VKT) . Or conversely, the most sustainable areas are those with the least VKT.

Table 1. Principal Component Analysis for States of the U.S.

	Component Loading
Carbon dioxide emissions	.97648
Carbon monoxide emissions	.95825
Motor vehicle crash fatalities	.97349
Gasoline sales	.98579
Motor vehicle crash injuries	.91868
Motor vehicles registered	.96775
Emissions of nitrogen oxides	.96823
Vehicle kilometers of travel	.99103
Emissions of volatile organic compounds	.97134

N = 50, eigenvalue 8.4, variance accounted for 93.7%. Based on data for 1997.

Table 2. Principal Component Analysis for 28 OECD Nations

Indicator	Component Loading
Carbon dioxide emissions	.99467
Carbon monoxide emissions	.99686
Motor vehicle crash fatalities	.88604
Gasoline sales	.99434
Motor vehicle crash injuries	.99358
Motor vehicles registered	.99344
Emissions of nitrogen oxides	.99810
Vehicle kilometers of travel	.99071
Emissions of volatile organic compounds	.99474

N = 28, eigenvalue 8.7, variance accounted for 96.6%. Nations included are Canada, United States, Australia, New Zealand, Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Luxembourg, Netherlands, Norway, Poland, Portugal, Spain, Sweden, Switzerland, Turkey, United Kingdom, Slovakia and Russia.
All data are for 1997

Data quality seems to be highest for the United States, so there is a tendency to place more confidence in the results from that analysis. As a result it seems as though using vehicle kilometers of travel would make it possible to measure just about all that these nine variables in the principal component analysis represent. In other words as this variable increases, transport sustainability as indicated previously will decrease.

Although VKT will pick up changes in numerous variables, it ignores differences in fuel efficiency. For example, California is in the process of developing one of the most diverse motor vehicle fleets in the world in terms of fuel use. If the state shifted completely to zero emission vehicles, it would have no influence on VKT and we would misinterpret the state=s transport sustainability. In a similar manner, European vehicles tend to be smaller and more fuel efficient than US vehicles, and VKT would not measure this aspect of sustainability.

To compensate for this it seems apparent that a fuel use variable has to be added to the analysis. At first gasoline or petrol use was considered. This gets at what we want to measure, but some areas use diesel fuel and one can hardly call a change from gasoline to diesel a move in the direction of transport sustainability. As a result the fuel variable was expanded to include total gasoline (petrol) and diesel fuel use by the transport sector.

This additional variable also adds a behavioral dimension to the index in that if a substantial number of areas, or individuals within those areas, decide to switch to more fuel efficient vehicles, this will be reflected in the index value obtained. Of course major behavioral changes induced through taxes will also be reflected in this fuel use dimension of the index as will be demonstrated below. As suggested earlier, the indicators used to this point in the index may capture sustainable transport, but it is unlikely that most areas would view a benign situation where environmental impacts are few as desirable. After all these situations represent the least developed areas (or nations) of the world. Instead the desirable situation is one that has a reasonable level of mobility as well as a sustainable transport system. Before assembling the VKT and fuel use portions of the index, let us look at mobility a little more.

3. Potential Mobility

It is common to speak of something or someone being mobile if they are capable of moving or being moved from one location to another location. Inherent in such a definition is some indication of the availability of transport stocks (vehicles or networks). Aging rural residents that are unable to drive motor vehicles any longer due to the infirmities of old age are said to have a low level of mobility. The U.S. rail passenger system was once lauded for the high level of mobility it gave its populace, but now through Amtrak it offers only a skeleton of that earlier service. In the first case a vehicle is missing, and in the second case the infrastructure of networks and vehicles has been reduced, but both of these lead to a decrease in mobility. Any index that seeks to measure transport sustainability must recognize that it is related to mobility in the sense that the most sustainable transport conditions may reflect an immobile population, which is also undesirable. The question is: How do we go about measuring this mobility aspect? One could offer several variables that taken together would reflect mobility. These would include such measures as: number of motor vehicles, miles of rail network, number of transit vehicles, miles of highways, and similar measures. If quality data existed on each of these one could use this approach. Unfortunately, the age of vehicles is important; the condition of the highways (paved or unpaved) is critical; and, whether the rail network is used primarily for freight or passengers must also be considered. The one thing that we do know is that most of these measures of transport stocks are related to the economic level of the area or country. As a result, instead of measuring mobility we will use a measure of the economy as an indicator of potential mobility, or the ability of the country to provide mobility (transport stocks).

The standard measure of a nation=s economy is gross domestic product (GDP), the total value of a country's goods and services. There is a similar measure for states in the United States; it is gross state product (GSP) and it is defined in the same manner as GDP. These are measures of productivity and wealth and they have always been highly interrelated with mobility at all scales. In studies of transport and national development, Owen (1964) noted the importance of gross national product (an indicator abandoned in 1991 in favor of GDP) for determining the level of transport stocks. Similarly, urban transport studies have consistently found automobile ownership (a mobility stock variable) as being highly related to household income (a measure of productivity). By using GDP a better measure is obtained, not of mobility, but of potential mobility. It is a measure of the potential of a state or country to provide transport stocks.

4. Creating the index

The next step is to combine these measures of travel and transport (VKT), fuel use and potential mobility into a single index value that will measure sustainable transport and potential mobility. To do so, we first divide all of these values by the area=s population. This is necessary since we don=t want to measure purely size effects. We next change the sign on the VKT and fuel variables, so that larger values (i.e., lower fuel use and travel) represent more sustainable situations. We then place all three measures in the same units. This is a common statistical procedure and it is accomplished as follows for the case of vehicle kilometers traveled.

$$X_i = (1000\ VKT_i)/P_i \qquad (1)$$

$$M_x = \sum X_i\ /N \qquad (2)$$

$$S_x = [\sum (Xi - M)^2\ / N]^{.5} \qquad (3)$$

$$TVKT_i = -10\ (Xi - M_x)/S_x + 50 \qquad (4)$$

where X_i = the vehicle kilometers traveled per capita for the i^{th} place, VKT_i = the vehicle kilometers of travel for the i^{th} place in 1,000s, P_i = the population of the i^{th} place, M_x= the average VKT for the N countries examined, S_x = the standard deviation of the X_i place values, $TVKT_i$ = the standardized VKT_i value for the i^{th} place.
These new values have a mean of 50 and a standard deviation of 10. The negative 10 in the final equation makes smaller values of VKT larger. The same procedure is used on the FUEL variable for the same reason. When standardizing the GDP values the value of 10 in the above equation would be positive. The expansion by 1000 above for VKT is carried out for GDP as well since both of these figures (in the table of the appendix) are in 1,000s. Actually neither of these operations is necessary due to the standardization of the final numbers.
Completing the procedure we get the index of sustainable transport and potential mobility, STPM, for some place i as follows:

$$STPM_i = TGDP_i - ((TVKT_i + TFUEL_i)/2) \qquad (5)$$

Bear in mind that all of these variables have been converted to per capita figures and standardized. Each has a mean of 50 and a standard deviation of 10, except for STPM.
If an area has an average value of 50 for each of the variables, the value obtained for the index will be 0. This is a desirable value that indicates the level of potential mobility is relatively the same as travel (TVKT) and fuel use (TFUEL). For most states of the U.S. the potential mobility level is high, while their sustainability component is low and this results in a positive value for the STPM index. These areas have the economic potential to provide

good mass transit services, fuel efficient vehicles, and so forth, but they opt to rely on personal transport modes that use high levels of fuel. Developing countries will frequently be unable to provide high levels of mobility to their population (low potential mobility). At the same time they do have higher, sustainable levels of transport through using mass transit, walking, biking, and so forth. Their STPM values will tend to be negative.

4.1 Illustrations of the Index

A few examples may clarify some of these ideas. Substituting values for the U.S. state of Texas in the above equation we get:
STPM = 59.77 - ((40.07 + 42.48)/2)
STPM = 18.49

This reflects a relatively wealthy state with excessive use of personal transport vehicles (as indicated by a standardized low TVKT value) and excessive per capita fuel use (a low standardized TFUEL value).

Substituting values for Belgium in the above equation we get:

STPM = 52.90 - ((52.21 + 47.99)/2)

STPM = 2.80
This is a desirable value in that it is near 0 implying that the country has a desirable level of sustainable transport and potential mobility.

For Kenya the figures are:
STPM = 33.74 - ((63.52 + 64.70)/2)
STPM = -30.37
While Kenya has attractive sustainability values, it is apparent that this is due to a low level of mobility, which is also undesirable.

STPM values have been calculated for the states of the United States, most of the OECD nations, and some developing nations; 104 areas in all. Index values for these areas appear in an appendix of this paper. In general, the areas fall into the three groups that one would expect.
Countries of the developing world have low negative values (less than -10) reflecting low levels of potential mobility in the presence of what would ordinarily be viewed as sustainable travel and transport. This is an undesirable situation and these nations should attempt to retain their higher values on the TVKT and TFUEL measures as TGDP increases in the future.
Developed countries of the OECD and Europe have scores that fall for the most part between +10 and -10. This is a desirable range indicating average levels of per capita TGDP along with average levels of fuel use per capita and TVKT per capita.
The states of the United States tend to have high positive values (greater than +10), which indicate sufficient wealth to provide high mobility stocks, but an excessive use of personal vehicles and high per capita fuel use as reflected in the Texas example above. Exceptions to this general statement are Colorado (-3.40), Idaho (4.89), Nebraska (4.04), Rhode Island

(9.05), Tennessee (2.31) and West Virginia (9.52). The values for the other states can be found in the aforementioned appendix.

5. Use of the Index to Evaluate Technologies and Policies in Developed Areas

Aside from the index giving an area some indication of its standing relative to other areas in the world, the index can also be used to evaluate changes in technology and the impact of policies and regulations. To illustrate this usage, let us return to the Texas case where the index value obtained was 18.49. If Texas were to mandate that 10% of its vehicle fleet was to be electric vehicles, this would reduce its fuel use (TFUEL) by a comparable amount. This would not necessarily reduce TVKT as the former trips would now be made by electric vehicles. Recalculating the index for Texas yields a value of 17.35. Not a major change from its original value, but nevertheless a move toward zero which is the desirable value.

If one assumes that the state of Texas puts a fuel tax in place that is intended to reduce fuel use by 10%, what would be the impact of this policy action on the index? In this case we would have that 10% decrease in the TFUEL and an associated 10% drop in TVKT. Recalculating the index results in a value of 16.15. Once again, a move in the right direction, but it is not of much significance. The index appears to be sluggish, but it should be. The population in most of the states of the U.S. have become far too dependent on the automobile. It is not a situation that will change quickly in reality or by minor changes in the components of the index. If one were to assume that a state such as Texas made a complete transfer to electric vehicles eliminating all gasoline and diesel use for transportation, what would this do for the index? To begin with one should proceed rather cautiously. The fuel use variable would be far outside the range of the variables initially used to standardize the index components, but let us assume for the moment that we wanted to evaluate this anyway. The TGDP and TVKT variables would not change, but the TFUEL variable would change from its current value of 42.48 to 65.15. Calculating the index would yield a value of 7.16, which is considerably better than the present situation. One might argue that the value should be closer to zero with these changes, but let=s look at this a little closer.

Reductions in the fuel variable result in reductions in emissions of global and local air pollutants. TVKT has not changed so highway crash injuries and fatalities do not increase or decrease, except to the extent that fires decrease due to a switch from gasoline to electrical energy sources. Similarly, TVKT remains at the same level resulting in no impact on congestion. In effect, the index does not change a lot because most of the transport sustainability and mobility variables have not been affected by the changes in the fuel variable.

There is some concern that the use of alternate modes (public transit and passenger rail transport) in varying amounts by different areas is not included in the index and that this might be quite important. Once again, it would appear that these modes and their use is considered by the index, albeit indirectly again. As use of different mass transit modes increases, overall vehicle kilometers of travel decreases, as does fuel use. It would be possible to measure the use of these modes directly, but then we would end up double-counting their influence since their use decreases VKT and fuel use, assuming its new users are former automobile users.

6. Use of the Index in the Developing World

The only way in which the index values for countries of the developing world will change is through increasing per capita GDP. One possible way of doing this is to establish a carbon emissions trading system. This would essentially provide even the poorest nations with a Anew resource@ capable of adding to GDP. It is true that a less sustainable transport system would also make the index values rise toward zero, but this is unlikely to happen with the low levels of GDP observed. As noted above, the trick is to increase GDP along with transport infrastructure without allowing rapid motorization to occur. These nations should perhaps aim at targets based on the situations that currently exist in western European nations as opposed to the states of the United States.

7. Equity as It Relates to the Index

It should be apparent that equity has not been examined as it relates to the index. Let us do that now by considering the outcomes of using this index. One could make the argument that global equity, or the lack of it is reflected in the dispersion of the index values obtained. Desirably the index values for 104 areas would approach a normal distribution with a mean of zero and a variance indicative of the spread of the values obtained (see Figure 1). One could argue that it is this variance (or dispersion) that reflects the equity, or lack of it, for the set of areas examined, i.e., the more spread to this distribution the less equity, and the less spread the more similar the areas examined are in terms of their index values, and therefore the more equity for the areas included. If the areas are extremely different in terms of STPM then the variance will be large. If the areas all had nearly the same value then the variance would be very small and one could say that these areas reflect a higher level of equity. We could go further and note that it is a reasonable global policy objective to have a low variance in the values of the STPM since this would reflect not only desirable levels of sustainable transport and potential mobility, but also an equitable situation with regard to the states and countries included.

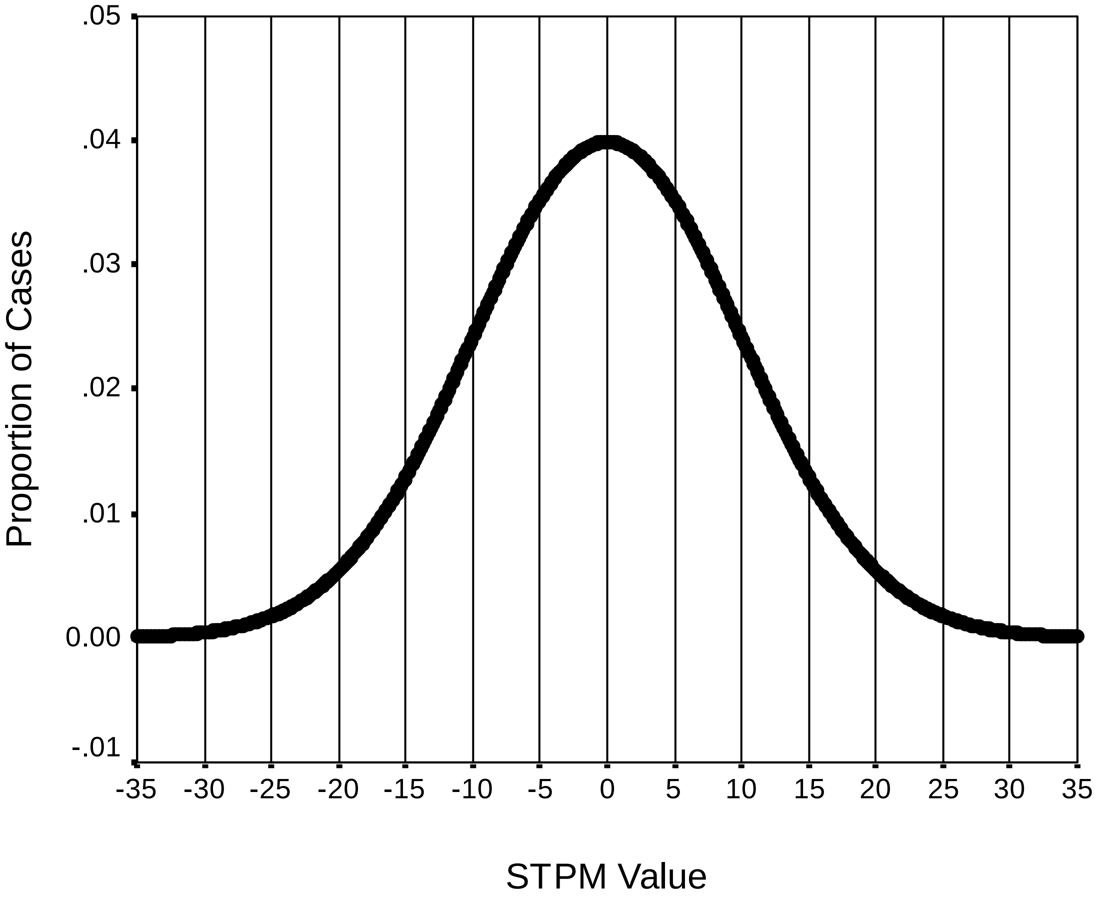

Figure 1. The general distribution of STPM values with larger positive values reflecting developed areas that are very reliant on motor vehicles for transportation and the smallest negative values reflecting developing nations of the world lacking mobility.

8. Limitations of the Approach

A few points should be clarified about the index proposed. First, it is not a normative index. Instead it is a descriptive index indicating where an area stands in relation to other areas. In this regard it is similar to the consumer price index (CPI) in the United States. Second, as is true of the CPI, the index can be re-calibrated every few years as things improve or alternatively become worse so that the index is more informative.

It should be apparent that the index is based on 104 areas and the extent to which it has meaning beyond this sample is a function of how representative this sample is of all other places in the world that could be evaluated. One could use this index to evaluate provinces in France or Canada, counties in the U.S. and U.K., and possibly some metropolitan areas. The key to these applications rests on the extent to which the input variables used here could be meaningfully defined for these other, often smaller areas.

A major limitation of the index is that it fails to allocate aviation fuel stocks to individual countries. This is a major use of petroleum stocks that is increasing, and it should be assigned to some area, but how can this be done? One could identify the ownership of air carriers and allocate the fuel used to these (public ownership) nations or the (private ownership) nations where the carriers are based or held, but this seems inappropriate particularly for global carriers. Or, one could identify the amount of fuel being used at various airports within countries, but these fuel allocations would reflect traffic departing from these airports. This may have very little to do with that nation's travel since the flights from major world airports represent passengers from dozens of the world's nations. Finally, one could allocate the aviation fuel used to the home country of each passenger, but this might very well create a data collection nightmare. So exactly how to allocate aviation fuel use remains unresolved, but worthy of further analysis.

Also not explicitly caught by the index are freight shipments by motor carrier and railroads. It is true that motor carrier moves are captured in the VKT, but reductions in these moves or diversions of this traffic to rail would not be caught very effectively.

Perhaps the major limitation of this index and something that future indices will have to incorporate is some translation of current environmental targets into components of the index. For example, if it is a reasonable goal to reduce carbon dioxide emissions by 7%, what does this mean in terms of the index? Put another way, how many vehicles must be removed from the road to result in a decrease in VKT that meets current target values as specified by documents such as the Kyoto Protocol? These relationships also will have to be established, if any index is to be meaningful to governmental policy makers.

The index proposed here might very well be unacceptable to the states of the U.S. or the developed nations of Europe. The states do not particularly like to look bad on any indicator, and many would likely protest their representation as a gas guzzling state. This is unfortunate, because any index that would fail to reveal this is probably an inaccurate index on its face. At the same time the nations of Western Europe that actually appear in a very desirable light here, might very well find this unacceptable since it could potentially undermine their advocacy of still more rigorous policies that would improve the current situation. These reactions are hardly a basis for condemning the approach, but they are likely responses that would have to be considered here as well as in any other index developed.

9. Possible Changes in an Area's Index Value

At the outset of this paper the main factors preventing today's transport systems from being sustainable were identified. It was then demonstrated that indicators of several of these phenomena tended to be highly related to vehicle kilometers of travel. An index was developed based on this key variable, along with gross domestic product, and fuel consumption (all represented on a per capita basis and standardized). Assuming the STPM index or for that matter any similar index were acceptable to policy makers, what could an area do to improve its value for the index?

What most of the states of the U.S. would need to do is reduce their vehicle kilometers of travel. If this could be done there would be a decrease in both global and local air pollution problems, there would be a decrease in injuries and fatalities, and congestion would drop as fewer vehicles crowded onto the highways and motorways. A decrease in fuel use (due to lower VKT) should also improve the standing of some of these states on the STPM index.

Of course one might want to deal more directly with the variables of interest. Motor vehicles could be loaded with ITS technologies and controls on vehicle speeds could be introduced, and in this way there would be improvement in the injury and fatality picture, but this would do nothing for the other areas of concern. We could use technology to clean the emissions, but this would also leave the other problems unaffected. These are only partial solutions to the non-sustainable transport problems. On the other hand areas could take direct action to reduce the use and need for motor vehicles. This would not solve the problem completely, but it would chip away at all the various dimensions of it.

These partial approaches would improve the situation, but for the most part they would not impact the index. The index uses VKT and fuel as surrogates for a series of other variables and it is able to do this because these variables are coupled with VKT and fuel. For example, if we improve incident fatality rates or emissions with technology, the index will be unaffected. This is one limitation of the index that could limit its long term use and it is also something that should be considered in the development of alternative indices. In the future it would be desirable to see the five criteria leading to non-sustainability in the transport sector de-coupled from vehicle kilometers of travel. For example, it may be possible to virtually eliminate highway fatalities in the future so that this variable ceases to be of concern as a component of the non-sustainability of transport. This would improve the situation, but it would not make the transport systems sustainable. To make these transport systems sustainable there is a need to shift to a hydrogen fuel derived from water using solar power. This would eliminate harmful local and global emissions and remove any concerns about a finite fuel with limited reserves. Finally, there is a need to use ITS to platoon vehicles on highways and to regulate their movement. Policies that would mandate higher vehicle occupancy or the use of smaller vehicles are necessary to solve the congestion problems that exist in parts of the system. Of course these are solutions for the long term. In the interim the sustainable mobility of the current system can be improved if vehicle kilometers of travel are limited.

For the developing world there is also a need to increase their sustainable mobility, with an emphasis on the mobility portion of that phrase. This will not be easy since these areas lack the resources to improve their mobility in many cases. It is apparent that a CO_2 emissions trading system could provide some of these areas with a much needed new resource which they could Aexport@ to developed areas of the world, resulting in a general improvement in both areas.

10. Summary

This paper has taken on the task of illustrating the form that an index that measures both sustainable transport and potential mobility might take. It was noted that vehicle kilometers of travel is a variable that is highly related to all other variables of interest in terms of sustainability. However, it does not recognize fuel economy and for this one must also look at fuel consumption. Although these two variables reflect the presence or absence of transport sustainability, it is also recognized that potential mobility must be considered in any measurement system developed. Using gross domestic product (gross state product for U.S.

states), an index was derived to measure sustainable transport and potential mobility. The index may be used to assess where different areas stand relative to each other. It can also be used to evaluate changes in technology and the impacts of implementing different policies and regulations.

Although the index seems to be a reasonable indicator of sustainable transport and potential mobility, it is not without its limitations. The latter include variables that we don't know how to allocate to specific areas, the problem of equating terms in the index with targets currently being set in the policy area, and its reliance on the current coupling of various externalities with vehicle kilometers of travel. Neither this paper nor the index proposed has resolved these problems. Nevertheless, it is hoped that the index and its limitations will foment discussion and lead to additional research on the development of indices of sustainable transport and potential mobility.

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Appendix 1

	FUEL	P	GDP	VKTt	TVKT	TFUEL	TGDP	STPM
Alabama	8105	4319	103100	86010	35.00	38.95	53.49	16.52
Alaska	822	608	24400	7060	47.15	46.27	67.91	21.20
Arizona	7406	4555	121200	69980	41.66	42.45	55.92	13.87
Arkansas	5214	2582	58400	45280	38.48	36.96	52.38	14.67
California	43001	33252	1030000	459550	43.92	47.09	59.79	14.29
Colorado	5597	6753	126000	60730	50.98	53.58	48.87	-3.40
Connecticut	4306	3275	134600	45940	43.61	46.79	68.76	23.56
Delaware	1143	733	31600	12880	38.43	43.38	70.55	29.64
Florida	21402	14654	380600	215620	42.61	44.76	55.36	11.67
Georgia	14822	7208	229400	150150	33.66	36.44	60.54	25.49
Hawaii	1128	1107	38000	12790	47.23	50.92	62.76	13.68
Idaho	2212	1516	29100	20720	44.14	44.78	49.35	4.89
Illinois	16362	11951	393600	159800	44.57	46.03	61.53	16.22
Indiana	10562	5545	161700	110410	35.00	38.56	58.18	21.40
Iowa	5016	2852	80400	45030	41.04	40.59	57.32	16.51
Kansas	4454	2595	71800	42680	40.07	41.19	56.86	16.23
Kentucky	7491	3908	100000	72020	37.17	38.39	55.02	17.24
Louisiana	6702	4343	124300	62490	43.08	43.60	57.70	14.36
Maine	2196	1241	30200	21310	39.01	40.44	53.91	14.18
Maryland	7260	5059	153800	74990	42.45	45.11	59.28	15.50
Massachusetts	7918	6118	221000	81200	44.72	47.08	64.35	18.45
Michigan	14907	9740	272600	147630	41.96	43.78	57.14	14.27
Minnesota	6884	4686	149400	77800	39.85	44.64	60.59	18.35
Mississippi	5183	2732	58300	50710	36.98	38.66	51.25	13.43
Missouri	10308	5402	152100	101330	36.69	38.51	57.29	19.69
Montana	1726	878	19200	15110	38.96	37.70	51.72	13.39
Nebraska	3007	2323	48900	27480	46.83	47.08	50.99	4.04
Nevada	2877	1780	57400	26240	42.57	42.58	60.92	18.34
New Hampshire	1985	1191	38100	18020	42.00	41.88	60.69	18.75
New Jersey	11975	8052	294100	101860	45.63	44.38	64.71	19.70
New Mexico	3292	1738	45200	35300	34.42	38.70	55.39	18.82
New York	17316	18137	651700	194330	48.46	51.82	64.18	14.04
North Carolina	12556	7425	218900	131770	38.17	41.54	58.47	18.61
North Dakota	1308	641	15800	11460	37.98	36.66	54.18	16.86
Ohio	16577	11183	320500	166810	42.31	44.45	57.74	14.36
Oklahoma	6305	3300	76600	66610	34.61	38.47	52.91	16.37
Oregon	4891	3218	98400	51920	40.53	43.93	59.44	17.21
Pennsylvania	16354	12052	340000	157710	44.99	46.20	57.34	11.74

Rhode Island	1172	997	27900	11380	47.44	48.74	57.14	9.05
South Carolina	6966	3760	93300	66500	38.26	39.28	54.33	15.56
South Dakota	1445	747	20200	12770	39.13	38.14	56.30	17.67
Tennessee	9627	7763	147000	97390	45.78	47.83	49.12	2.31
Texas	31566	19439	601600	319710	40.07	42.48	59.77	18.49
Utah	3306	2049	55400	32890	40.65	42.62	56.30	14.66
Vermont	1079	589	15200	10400	38.30	39.57	55.21	16.27
Virginia	11487	6734	211600	113140	39.55	41.33	60.19	19.74
Washington	8174	5605	172300	82130	42.70	44.79	59.58	15.84
West Virginia	2948	1817	38200	29480	40.40	42.50	50.97	9.52
Wisconsin	7834	5107	147300	87540	39.06	43.73	57.90	16.51
Wyoming	1534	483	17600	12190	27.21	20.81	64.63	40.62
Canada	43218	30287	658000	274000	50.90	45.23	51.59	3.53
USA	480984	267735	8080000	4.E+06	41.79	40.07	59.08	18.16
Australia	21798	18485	394000	180000	49.89	48.68	51.23	1.94
New Zealand	3528	3679	63400	28000	53.00	51.76	47.61	-4.77
Austria	6426	8115	174100	58000	53.68	54.09	51.35	-2.53
Belgium	12516	10185	236300	83000	52.21	47.99	52.90	2.80
Czech Republic	3738	10304	111900	30000	59.87	60.08	41.96	-18.02
Denmark	5922	5273	122500	42000	52.48	49.47	52.93	1.95
Finland	5418	5139	102100	46000	51.04	50.43	49.95	-.79
France	49308	58585	1320000	472000	52.35	53.40	52.31	-.57
Germany	85764	82053	1740000	619000	53.10	50.56	51.13	-.69
Greece	8610	10512	137400	55000	56.48	53.71	43.92	-11.17
Hungary	2772	10174	73200	27000	60.25	61.34	38.71	-22.08
Iceland	462	270	5710	2000	53.30	41.26	51.08	3.80
Ireland	3192	3661	59900	29000	52.54	52.98	46.84	-5.92
Italy	40320	57520	1240000	474000	52.08	55.36	51.44	-2.28
Luxembourg	1428	421	13480	4000	50.23	17.79	60.72	26.70
Netherlands	11382	15608	343900	109000	53.92	54.97	51.87	-2.58
Norway	5166	4405	120500	31000	53.84	48.77	56.58	5.28
Poland	10920	38650	280700	125000	59.40	61.20	38.77	-21.53
Portugal	5124	9935	149500	51000	56.62	57.95	45.67	-11.61
Spain	26754	39694	642400	154000	58.46	55.74	46.68	-10.42
Sweden	8484	8848	176200	71000	52.39	51.76	49.99	-2.09
Switzerland	9660	7159	172400	50000	53.92	46.31	53.68	3.57
Turkey	11466	63686	388300	46000	63.08	62.63	37.74	-25.11
United Kingdom	42672	58841	1242000	445000	53.07	55.02	51.04	-3.00
Slovakia	1176	5321	46300	11000	61.11	62.06	40.05	-21.54
Russia	43512	148878	692000	45000	63.69	61.07	36.46	-25.92
Albania	252	3300	4500	3680	62.50	64.08	33.55	-29.75

Argentina	12768	35700	348200	56590	61.81	60.15	40.98	-20.00
Azerbaijan	1848	7600	11900	2210	63.71	61.75	33.72	-29.01
Bolivia	924	7800	23100	1730	63.81	63.49	34.96	-28.69
China	85506	1227200	4250000	165000	63.94	64.17	35.41	-28.65
Hong Kong	2058	6500	181530	10340	61.81	60.73	57.09	-4.18
Costa Rica	924	3500	19600	4240	62.36	61.46	37.30	-24.61
Ecuador	3318	11900	53400	29170	60.55	61.25	36.31	-24.59
Egypt	7854	60300	267100	6220	63.98	63.33	36.26	-27.39
El Salvador	672	5900	3500	4730	62.96	63.56	32.86	-30.40
Georgia	630	5400	8100	5500	62.64	63.52	33.67	-29.41
Jordan	1470	4400	20700	6030	62.13	60.48	36.51	-24.80
Kazakhstan	4578	15800	50000	82110	56.53	61.10	35.14	-23.67
Kenya	924	28600	45300	11890	63.52	64.70	33.74	-30.37
Korea	28266	46884	631200	255830	56.15	56.73	44.27	-12.17
Lithuania	1218	3700	15400	200	64.05	60.55	36.03	-26.28
Moldova	546	4300	10800	910	63.82	63.37	34.56	-29.04
Mongolia	420	2500	5600	1740	63.11	62.80	34.32	-28.64
Pakistan	6804	128500	344000	14360	63.97	64.41	34.71	-29.48
Philippines	7056	73500	244000	190	64.13	63.81	35.28	-28.69
Romania	4410	22600	114200	33900	61.94	62.42	36.82	-25.37
Saudi Arabia	23646	20100	206500	120700	55.35	48.72	41.44	-10.59
Sri Lanka	1344	18600	72100	1150	64.04	64.14	35.77	-28.32
Thailand	18018	60600	525000	99900	61.72	61.00	40.02	-21.34
Ukraine	7266	50700	124900	60170	62.40	63.15	34.52	-28.25
Yemen Republic	1680	16100	31800	11480	63.09	63.69	34.09	-29.30

Notes:
FUEL: daily gasoline and diesel fuel used in the transport sector (1,000s of gallons), 1997
Population: total population of area (1,000s), 1997 estimates
GDP: gross domestic product (or gross state product for US states) (millions of dollars), 1997
VKT: vehicle kilometers of travel (millions), 1997

Sources:
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United Nations Statistical Division
World Resources Institute, *World Resources 1998-99*, Washington, DC: WRI, 2000