SUSTAINABILITY AS A CRITERION FOR ASSESSMENT OF TRANSPORTATION PROJECTS

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abstract: The state of science of transportation project assessment is imperfect. This is primarily due to the dominant value of non-market impacts whose treatment is inherently subjective and biased. Transportation infrastructure developments are also seen as contrary to the concept of ecologically sustainable society. Two propositions are presented to advance the techniques of project assessment. Firstly, a new dimension of ecologically sustainable development should be introduced in impact assessment. Secondly, due to imperfection in estimation of health and climatological effects of vehicular emissions, the quantity of emissions of various pollutants rather than their impacts, should be used in project assessment.

1. INTRODUCTION

Most transportation projects are characterised by vast outlays and involve several stakeholders. These projects have diverse and far reaching impacts. There has been considerable work on identification, quantification, and monetisation of transportation impacts. However, while some impacts can be monetised with relative ease while others are considerably hard to be converted to dollar terms. Many impacts are very difficult to quantify let alone monetise.

Some well-known models for quantification of selected economic and environmental impacts include project cost models, and models to estimate delays, fuel consumption, emission, noise and prediction of traffic volumes. The state of science of impact assessment, however, remains imperfect and needs innovative approaches and further refinement of existing techniques. The single most important limitation in impact evaluation is the relatively dominant value of non-market impacts whose treatment is inherently subjective and biased. There are many secondary, derived and consequential aftermath which occur many years after the primary impacts. Most notables of these are the health effects and the global warming or the greenhouse effect. The inadequate state of impact assessment is accompanied by a rising general feeling that construction of more transportation infrastructure and increased travel by motorised modes is not desirable and is contrary to the concept of ecologically sustainable development. In view of the economic and strategic importance of transportation, developments in this sector are, however, expected to continue.

It is the ethical and professional responsibility of transportation engineers, planners and managers to ensure that the selected transportation projects bring the largest benefits to the community and minimise the undesirable consequences of these developments. A methodology for assessing the impacts of transportation projects is needed which is consistent, comprehensive, unambiguous and conforms to the community attitudes and aspirations. Environmental quality and global sustainability are integral part of the attitudes of the modern society.

Two propositions are advanced. Firstly, in keeping with the community attitudes, a new dimension of ecologically sustainable development should be introduced in impact assessment. Secondly, due to imperfection in estimation of health and climatological effects of vehicular emissions, the quantity of emissions of various pollutants rather than their impacts, should be used in project assessment.

A new dimension in the criteria for evaluation of projects should specifically deal with sustainability. Therefore emphasis on non-motorised modes and public transport modes in transportation projects should be an important consideration in project assessment. This is one of the factors in a checklist presented in this paper. The checklist is designed to ascertain if the proposed project scores well on various aspects of sustainability. These include effects on induced traffic in vehicle-kilometers, mode switching (percentage and number of travellers shifting to public transport, bicycle, walking and motor vehicles), resource (road space, etc.) use per unit of travel undertaken by or on the proposed project, fuel consumption, emissions of various contaminants and effect on safety of system users. The projects should be economically viable, fuel efficient, safe, environmentally clean, require minimal resources, and satisfy community expectations. In short, the projects should contribute to sustainable transportation systems.

It is also proposed in this paper is that the estimation of health effects and contributions to global warming from highway emissions should be substituted by the quantity of emissions of various contaminants. It is universally agreed that vehicular emissions contribute to long-term climatological impacts such as acid rain, greenhouse effect and ozone depletion. It is also agreed that there are adverse health consequences of emissions from motor vehicles. However, because of the difficulties of estimation of these impacts and of associating monetary values to these impacts, project evaluation procedures should consider the amounts of pollutants generated. These emissions can be converted into dollar values through the application of environmental levies such as the carbon tax.

It is believed that introducing sustainability criterion and alleviating the need to estimate the very subjective, biased and imprecise long-term effects on health and climate will be a step forward in project assessment and ensure that new transportation projects are ecologically sustainable and conform to the current and future community attitudes and preferences.

2. CHARACTERISTICS OF TRANSPORTATION PROJECTS

Major transportation projects include construction of new freeways and railway lines, substantial upgrading and new construction, significant technological advancements such as the introduction of intelligent highway systems, introduction of new modes of transport between or within major urban centres, opening up new areas through new transportation

links, development and improvement of new airports and seaports, and other urban/non-urban projects designed to foster residential or industrial growth. Such transportation infrastructural projects are characterised by vast outlays and involve several stakeholders. Some of the distinguishing features of these projects include

- Long lead periods
- Large investment; several financial sources
- Increasing role of private investment
- Long life
- Dynamic and increasing usage with time
- Massive maintenance outlays
- Community reactions
- Environmental considerations
- Users benefits
- Growth prospects
- Real estate valuation
- Land use effects

These projects have far reaching impacts. These impacts occur not only to the users of the transportation system but have also significant community, regional and national repercussions. Some of these impacts may occur to varying but diminishing degrees for other minor projects (although these projects may also require millions of dollars of investment) such as intersection redesign, bridge or culvert construction or upgrading, resurfacing of road sections, or other minor improvements. The objective of these projects is to remove black spots, re-route traffic and reduce congestion with predominantly local impacts.

3. IMPACTS OF TRANSPORTATION PROJECTS

Transportation impacts are many and varied. These include impacts on users as well as non-users. Non-users impacts comprise community, regional and national impacts which may be economic, strategic, environmental or psychological in nature.

Johnston and Ceerla (1994) have tried to undertake a system level evaluation of an automated urban freeway project. They used a combination of models such as travel demand modelling (vehicle-miles travelled, vehicle-hours travelled, vehicle-hours of delay and lane-miles of congested traffic flows), an emission model and a travel cost analysis model. The motivation for using a system-wide evaluation was based on the recognition that reducing highway congestion can have drawbacks such as induced travel, possibly greater travel costs and higher emissions.

3.1 Users Impacts

Costs to the system users are generally reduced due to more direct route, superior geometrical design with flatter and smoother horizontal and vertical curves, and improved traffic flow conditions. Lower fuel consumption, savings in travel time, lower wear and tear of vehicles, reduced driving stress etc. are the direct results of improvements in transportation infrastructure.

Reduced risk of accidents due to smoother curves and gradients, better signs, markings and lighting, and improved traffic conditions is another vital user benefit.

The current state of project assessment for transportation projects relies heavily on quantifying users benefits. These impacts are a major component in determining the benefit-cost ratio of the proposed project.

3.2 Community impacts

There are several substantial community impacts resulting from major transportation projects. These include

Dislocation of existing inhabitants of land required for acquisition for the project.
Attitude of people towards the project.
Land-use changes resulting in changes in valuation of land.
Opening up new development for residential, commercial, industrial, institutional or recreational uses.
Increase in accessibility
Noise and air pollution

Some of these effects are desirable and intended while others are unintended, undesirable and concomitant. Thus, community impacts are translated into costs as well as benefits in an economic evaluation sense. The valuation of these impacts is an integral part of the current state of project assessment.

3.3 National impacts

National impacts of large transportation projects are both strategic as well as economic. Transportation, of course, is vital in a country's defence strategy. Some transportation projects are undertaken solely from strategic considerations and may have limited or negligible civil use. Large road and rail projects also open up vast tracts of undeveloped land and attract many economic activities along the new or improved routes. This is not unexpected as transportation is one of the most important criteria used in selecting the most desirable plant location, as well an effective tool in enhancing the growth potential of certain depressed regions. National impacts can, therefore, be grouped into

Economic growth potential
Strategic potential

The economic development benefits of a major highway investments were investigated by Weisbrod and Beckwith (1991) for a 200-mile, 4-lane highway across North-Central Wisconsin. In addition to the user benefits of travel time savings, accident reduction and saving in operating costs, several economic development benefits were considered. These include expansion due to truck cost savings achieved with the new facility, additional industry attraction, and increased tourism. The major motivation for this study was the belief that unless the project was evaluated in terms of long-range economic development potential, the benefits would be underestimated.

Projects based on strategic considerations alone may not normally be assessed with the same methodology as used for civil projects. However, the strategic impact of transportation projects is one of the vital outcome of several transportation projects.

3.4 Environmental impacts

Of growing concern to the modern community are the impacts of new projects on the environment. These could include

Induced traffic growth
Fuel consumption
Noise pollution
Air pollution
Resource depletion
Impacts on flora, fauna, and sites of historical, religious and other significance, environmentally sensitive areas.

Induced traffic growth is contrary to the concept of sustainability. Although some traffic growth is intricately linked with economic growth, it is premised that the induced traffic growth should be minimum commensurate with the expected economic growth and that the traffic increase be directed to sustainable modes, as far as practical.

The alignment of a new project may be dictated by natural environmental conditions. In fact, the fate of a new proposed project may well be determined by community concerns regarding impacts on natural environment as well on the resulting noise and inconvenience to residents affected by the proposed projects. The current proposal to build a new freeway between Brisbane and Gold Coast in Queensland, Australia is meeting very strong community resistance. The proposed alignment passes through some of the unique flora and fauna. The cost of the proposed project has already risen significantly to avoid an environmentally sensitive area by means of underground tunnels so as not to endanger the existing natural environment. However, the community feelings are still running high.

4. TECHNIQUES OF IMPACT EVALUATION

The evaluation framework comprises of operating and capital costs incurred by the operating agency, and impacts on system users and non-users. Impacts on system users include travel costs by user groups, safety, disruption, comfort, access to opportunities, noise and air pollution, convenience, aesthetics, etc. The non-system users can also be heavily impacted in terms of dislocation, disruption, land values, proximity effects, noise and air pollution, aesthetics, amenity, water quality, solid waste and ecology impacts.

4.1 Classification of impacts

The impacts of transportation projects may be classified into three groups:

(i) those which can be quantified and monetised
(ii) those which can be quantified but are difficult to monetise
(iii) those which are difficult to quantify let alone monetise

Examples of first type include users benefits in terms of fuel consumption, wear and tear of vehicles and operating costs, project costs, relocation costs etc. Group two includes a variety of impacts which range widely in difficulty in assigning monetary value. Some examples are travel time savings, reduction in accidents (property damage, injuries and fatalities), emission of pollutants, noise pollution, induced traffic growth, changes in modal shares, etc. The last group includes such subjective and intangible factors as the driver stress, trauma and sufferings of accident victims and their families, health effects of air pollution, long-term environmental effects such as acid rain and greenhouse effect, effect on flora and fauna especially endangered species, aesthetics, etc.

The development of techniques and models to quantify and monetise the impacts listed in groups two and three above has been steadily progressing. Traffic accidents resulting in property damage, injuries and deaths have been researched extensively. Data exist on the magnitude of these effects and the Australian Road Research Board and the Bureau of Transport and Communication Economics (1989) have undertaken studies to estimate the cost of highway accidents in Australia. Considerable work has also been done in Australia and overseas on value of time which is used in transportation project evaluation. However, most effects in the third group can only be monetised in contingent market framework. This is further discussed in Section 4.3.

Since 1968, the cost of road accidents was based on loss of output, medical costs and an estimate of human costs (pain, grief and suffering). It was replaced by the Willingness-To-Pay (WTP) approach. WTP is the amount that individuals are willing to pay for a reduction in the risk of a fatal accidents. In the new approach used in U.K., the direct economic costs (net output and medical costs) are added to WTP valuation to produce a total value of preventing a fatality. The revised WTP is more consistent with the principles of benefit-cost analysis used by the Department of Transport (O'Reilly et al, 1994).

Haight (1994) describes the many problems in estimating costs of safety which include pain, grief and suffering (PGS) and the value of life to the society. Small and Kazimi (1995) conclude that the measurable costs of air pollution are high enough to justify substantial expenditures to control vehicle emission rates. They however, acknowledge that the costs of environmental damage are not precisely measurable. Even the principles of measurement are not universally acceptable. Based on the estimate of costs per ton of emission for VOC, NO_x, SO_x and particulate matter, Small and Kazimi have determined the health costs of air pollution from automobiles in the Los Angeles area in California. A value of U.S.$ 0.03/mile has been obtained. This cost is dominated by mortality from particulate matter including the secondary effects of air pollution.

Collins and Evans (1994) have applied the powerful pattern recognition properties of artificial neural networks (ANN) to Manchester international airport and compared their results with those obtained with hedonic studies

4.2 Models and Techniques

Several models have been developed to estimate the effects of transportation projects. Some have long been used in transportation planning studies. Some examples of these models include the following:

Delay estimation models
Fuel consumption models
Emission generation and dispersion models
Noise estimation
Estimation of traffic volumes
Dose response functions (epidemiological)

Tools which are commonly used for estimating these impacts are some of the well-known traffic simulation and transportation models. These include QRS II, HCM/Cinema, SIDRA, TRAF-NETSIM, SIGNAL, TRANSYT etc. These models are commonly used for a variety of urban transportation studies with diverse objectives and are valuable tools for someone involved in project assessment. These models are used to estimate the amount of travel undertaken, travel times (vehicle-hours), delays (vehicle hours) as well as lane-kilometers of congestion. Based on the predicted quality and quantity of travel, fuel consumption, air pollution, noise pollution and other impacts are estimated.

4.3 Monetisation

Some of the impacts of transportation projects are relatively easily monetised. These include many of the users costs including fuel consumption and motoring costs, effects on land values, and other economic impacts. Significant work on valuation of time, life, injuries, etc. has also been carried out but their findings are inconclusive and not universally accepted. These pose some difficulties with monetising some impacts. However, major difficulty with project assessment is in the valuation of the many effects of the transportation projects which are hard even to quantify. These include

Loss of aesthetics
Value of inconveniences (noise)
Value of suffering - stress, trauma of accident victims
Value of dislocation and inconvenience to affected residents
Value of adverse health effects
Value of environmental damage

Some advancements in the valuation of intangible and non-quantifiable effects have been made by treating these effects in contingent markets. Techniques such as willingness-to-pay, statistical risk, indirect valuation, etc. are being developed and applied but are still inherently subjective and biased. Awards/rulings made by courts also provide some answers to the valuation of sufferings and injuries. Inspite of some advancement in the valuation of intangible impacts, the monetary values obtained by different researchers and using different techniques vary by an order of magnitude and would remain subjective and biased. However, the discussion and development of these techniques are outside the scope of this paper.

4.4 Economic Evaluation

This is first level of impact evaluation, and is commonly used. The costs of transportation projects includes the cost of

Acquisition
Planning
Construction
Displacement/relocation
Maintenance

of transportation projects. These costs are commonly incurred by the state or a government agency, although more and more projects are now planned for private funding. The project costs have always been considered and are relatively easy to estimate. The techniques for estimating these costs are well established.

The benefits of a transportation project have included

Travel time savings
Reduction in operating costs
Reduction in accidents
Increase in traffic growth

These benefits have been always estimated in conventional economic evaluation. Further efforts in estimating other potential benefits like land values and economic growth have also been undertaken. The process of project evaluation is consistently being improvised but much needs to be done before acceptable procedures are developed. This is not expected to occur in the short to medium term. The underlying problems with project evaluation arise from the growing concern of the community at the many concomitant effects of transportation projects. It has become mandatory to consider other intangibles in project evaluation, although techniques for their estimation are not well-developed.

5. FRAMEWORK FOR PROJECT ASSESSMENT FOR SUSTAINABILITY

5.1 General Criteria

Transportation projects should be economically viable, fuel efficient, safe, environmentally clean, require minimal resources, and be acceptable to the community in accordance with their attitudes, aspirations and preferences. The environmental impact on flora and fauna, aesthetics, preservation of history, general ecology as well as the air, water and noise pollution should be minimum.

The projects should encourage the use of public transport at the expense of solo drivers, and non-motorised and non-polluting transportation modes such as walking and cycling. The projects which provide infrastructure for cyclists and pedestrians and make these modes safe, comfortable, attractive and direct would score high on sustainability.

Furthermore, the projects should limit the increase in travel demand without jeopardising economic growth, and should result in minimum environmental damage. Induced traffic growth and sustainability cannot coexist.

In summary, transportation projects should be assessed for their environmental impacts and sustainability.

5.2 Highway Transportation and Environmental Management

The considerable effects of highway transportation on health, materials, vegetation, aesthetics etc. resulting from emissions can be studied by following a framework developed by Wadhwa (1993). It includes the determination of pollutant emission inventory based on vehicle-kilometers travelled, the fleet characteristics, travel flow characteristics etc. This is followed by the application of models dealing with dispersion, transportation, removal and chemical process, based on climatological factors, to determine the effect on ambient conditions. The physical consequences are then determined by using epidemiological studies and dose-response functions. These consequences require to be converted to monetary values by using contingent market approaches. Although logically consistent and plausible, the intrinsic difficulties with impact assessment and valuation are not resolved.

5.3 Assessing Environmental Performance

The first step is to assess the impact of a proposed project on emissions. One of the ways in which this can be achieved is to determine the number of vehicles using the new facility. Traffic flow conditions, average journey speed and speed profiles (acceleration, deceleration, stops, delays, cold starts, etc.) need to be predicted by using an appropriate traffic flow simulation model. This can be used to determine the average emissions by using a fuel consumption/emissions model. Multiplying the number of vehicles using the facility (AADT) by the length of the new facility and the average emissions per vehicle-kilometer travelled would give the amount of pollutants generated on an average day. This can be converted into annual tonnage of various emissions produced. Woodmansey and Patterson (1994) have developed an annual emission inventory of emissions from aircrafts at Toronto international airport. They used aircraft characteristics and fleet composition and employed regression technique to estimate total emissions. The inventory was developed for 1990 and contained tonnages of CO, NO_x, NMHC, SO_x, and CO_2.

Of course, any new facility will have system-wide effect on traffic volumes especially on other parallel routes. This needs to be taken into account in estimating system-wide effects on pollution generation. On a long-term basis, however, it is to be expected that alternative parallel routes will gradually become congested again. Any improvement on alternative routes will only be temporary. As such, system-wide improvements can be neglected as a first approximation.

Table 1 provides a framework for recording the quantity of emissions from a project as well as the importance assigned to each pollutant.

Table 1: Effect on air quality (quantity of emissions)

Emission	Tonnes per year	Weightage (based on env. tax/ penalty)	Weighted Score
CO			
NO_x			
NMHC			
SO_x			
Particulates			
Lead			

The sum of weighted scores for all pollutants produced by the traffic activity resulting from the proposed project should form a statistic which should be treated similar to a cost value. An alternative which scores lowest on this statistic is to be preferred. It should be possible to put a maximum limit on this score for a project to be accepted. This limit could be an absolute value or based on a per kilometer or per vehicle-kilometer basis. This is an area for further deliberation and discussion. The important point to be made is that the total pollutants emitted as a result of any new project must be considered in decision-making on project selection. Obviously no attempt is made in this paper to determine the impacts of these emissions on the environment, public health, agriculture, property etc. As stated earlier, the long-term impacts of motor vehicle emissions are especially hard to estimate. Furthermore, the impacts are not easily translated into monetary units.

5.4 Effect on Induced Traffic and Modal Changes

The traffic implications of a proposed transportation project are the second most important consideration in sustainability criteria. These are expressed in terms of the increase in total travel and changes in modal shares. It is obvious that criteria based on travel aspect of sustainability of transportation projects should favour alternatives which achieve the following to greater extent:

Increase in non-motorised modes
Increase in public transport patronage
Decrease in car use
Increase in car occupancy rates

The change in modal shares should be based on the region expected to be affected by the proposed project. The definition of this region is quite crucial. It should not be too large to dilute the effects of the project on modal change nor should be too small to ignore the true changes. The definition of the region of influence should be based on a careful study of travel patterns and by 'before' and 'after' studies. Table 2 provides a format by which the modal impacts of a proposed project can be assessed and compared.

Table 2: Effect on Modal Shares

Mode	Share before project	Share after project	Change *Increase* + or *Decrease* -	Weightage	Weighted Score
Non-motorised modes				2	
Public transport modes				1	
Car mode				-2	
Average Car Occupancy				1	

The weightages shown in Table 2 are suggestive only and are based on the author's perception of the contribution made by each mode to sustainability. This analysis needs to

be carried out for each alternative being considered. As explained above, projects with highest total weighted score should be preferred in project selection.
It is also important that the amount of increase in total travel undertaken is estimated and considered in project evaluation. The effect on travel needs to be assessed over the region of influence.

5.5 Effect on Resources

These would include effect on fuel consumption - both on vehicle-kilometer basis and total consumption basis - as well as on land acquisition. The consumption of forests, and special habitats for flora and fauna must be assessed. Projects with minimal acquisition of valuable and ecologically important land should be preferred. The objective is to ensure sustainable land use and transportation. Table 3 can be used to record the resource implications of each alternative considered.

Table 3: Resource Consumption

Resource	Quantity
Fuel Consumption (ML/year)	
Total Land Acquisition, ha	
Special Habitat Area, ha	

It is obvious that projects with minimum resource consumption should be preferred. Although land consumption would be easy to estimate for any project, the effect on fuel consumption can only be determined by defining and delimiting the geographic zone affected by the project. It is suggested that the region defined in section 5.4 should also be used in this case.

6. DISCUSSION

This paper has presented a summary of the impacts of major transportation projects and the tools and techniques used in evaluating these impacts. The most significant limitations in undertaking project evaluation are the relatively dominant value of non-market impacts and the inherent difficulties in estimating such impacts and their monetary values. These are coupled with the growing interest in environmental issues and the community's desire for ecologically sustainable development. The perception is that construction of more transportation infrastructure and increased travel by motorised modes is not desirable and contrary to their expectations. These developments have enlarged the need for much greater emphasis to be placed on environmental impacts of motorised transportation. However, our understanding of the short-term as well as long-term environmental impacts and their effect on human health is limited. Our approaches to determining the cost of these impacts are intrinsically subjective and biased which lead to controversial project assessment procedures and outcomes.

Realising the above difficulties and shortcomings in project assessment, an innovative approach has been proposed. Firstly, it is postulated that the impacts of any proposed project on sustainability must become an integral part of project evaluation procedure. This

will send a positive signal to the community that transportation professional are cognizant of the society's attitudes and aspirations with regard to environmental consequences. This assessment is sometimes undertaken as a separate exercise through the preparation of an environmental impact statement for a project. It is desirable to integrate the environmental impact study with economic evaluation rather than using benefit-cost analysis as a sole criterion for decision-making. Secondly, the quantity of emissions of various pollutants, rather than their impacts, should be used in project assessment. This is justified on several grounds. The estimation of the quantities of pollutants resulting from a proposed project is much easier than estimating their impacts. The emissions inventories have already been developed on several occasions. However, the impacts of transportation emissions are both short-term as well as long-term. The latter are known to be dominant but are extremely hard to estimate. The second premise is also justified on the assumption that higher levels of emissions will lead to more severe impacts and lower values of emissions are always preferable to higher values. As different pollutants are known to have distinct and dissimilar impacts, the provision for assigning different weightages to various pollutants has been made in the suggested methodology.

Other factors contributing to sustainability criterion, which are also recommended for inclusion in the proposed approach, are the amount of induced travel, modal shifts especially the contribution to non-motorised modes, land area, special habitat area and fuel consumption. It is forcefully stressed that inclusion of sustainability as a salient criterion for assessment of transportation projects is in conformity with society's expectations and desires and a significant step forward in the current practice of project evaluation.

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