



Interface for cycling expertise

Towards people oriented indicators for accessibility, road safety and environment



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Contribution to UNEP's Share the Road project |

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1 Introduction



UNEP is currently embarking on a project to encourage institutional donors to allocate a percentage of all investments in road infrastructure to facilities for improving the safety of all users, inclusive of Non-Motorized Transport, with the objective of making entire transport systems safer, more sustainable and more accessible. In order to be able to assess the impact of any investment, the effect on road safety, environment and accessibility has to be anticipated by the investor, the authority and the decision-maker.

UNEP requested I-CE to propose indicators in these three areas which should allow decision-makers to choose between alternative options to invest in infrastructure for NMT as part of an overall investment in improving roads for all users. There are no such indicators on accessibility yet and these have to be developed from scratch. Indicators for road safety have been developed by iRAP and, in consultation with iRAP, will be incorporated in this project. Indicators assessing emission reduction are available from literature; relevant literature has been reviewed and organizations contacted for this project's goal. Indicators have been reviewed mainly to analyze how these indicators can be used in one cohesive and user-friendly manner for all three policy aims. As such a methodology for suitable assessing the impact of roads (e.g. in safety figures, emissions avoided, etc) integrating safety, sustainability and accessibility will be proposed.

The completed methodology, explanatory text, and accompanying data and literature, will be integrated into a UNEP report called *Share the Road: Investment in Walking and Cycling Road Infrastructure*. The chapter on indicators will cover the following elements:

- 1 Definition of three indicators to form an integrated assessment template/methodology for the three requirements for good roads (safety, sustainability, and accessibility), focusing on NMT usage and users.
- 2 Suggest application of this set of indicators in road project assessment and by relevant institutions.
- 3 Describe what the application of this methodology/set of indicators will entail in terms of actual road building when applied on a project basis, i.e. how would the indicators assist in the assessment of alternatives and support the integration of safety together with NMT infrastructure.
- 4 Suggest ways in which the indicators can be further developed, expanded, integrated, and used by institutions to include larger road safety and environmental considerations.

2 Conceptual framework for looking at transport and its impacts.

2.1 An unbiased view on mobility

Mobility is one of the most important prerequisites to achieve an improved standard and quality of living. In low and middle income countries all over the world prosperity increases. This is accompanied by an explosive growth of cars, particularly in cities. The World Health Organization characterizes this development in 2004 as critical.¹ Not so much because increasing prosperity would be a negative development, but more that transport policies and road users are not prepared for it. As a consequence traffic behaviour is not adapted. The growth in car-use is accompanied by an increasing number of traffic accidents, causing road deaths and injuries. The WHO foresees a major public health problem in the next decades caused by road safety.

Following rapid urbanization and growing prosperity, new roads are constructed to accommodate the growing number of motorized vehicles.

New origins and new destinations have to be connected to the existing ones. This infrastructure, mainly designed for motorized car traffic, is considered to contribute to economic development and prosperity. The affluent parts of the population will benefit most from these investments, as only they can afford to have cars. The impact of new roads on the livelihoods of the urban citizen is hardly considered. New infrastructure allows those who have access to motorized vehicles to reach a wider range of destinations. Without facilities to regulate the interaction between motorized vehicles and non motorized modes of transport: walking and cycling, this new infrastructure limits the freedom of movement of the common citizen substantially. They are dependent of these non motorized modes. To include the interests of the whole population in the decisions on road investments, their impact has to be assessed not only in terms of improved performance of the vehicular system, but much wider on the impact to the well being of all people affected by the investment.

Moreover, transport is globally one of the most important sources of CO₂ and Greenhouse Gas emissions.² This is also true for developing countries where transport is also the fastest growing sector in terms of CO₂ emissions. There is therefore an urgent need to make transport more climate-friendly³. To avoid a further rapid growth of GHG emissions from the sector there is a need to

¹ Peden, Margie and others, World report on road traffic injury prevention, Geneva, World Health Organization, 2004.

² A large and broad group of organizations in the transport sector decided in 2008 to set up an Action Plan to make transport in developing countries more climate-friendly. At the start, the goal has been formulated as to: "Find and implement a sustainable pathway that limits GHG-emissions from transport and minimizes other negative externalities without compromising economic growth and social inclusion". For the UNEP project, the Action Plan is most relevant. More in particular, the policy options and the call for new methodologies to endorse a co-benefits approach, are in line with the objectives of the UNEP project. Documents have only be disseminated yet for limited circulation. Annex 1 provides a summary.

³ Transport is responsible for 13% of all world GhG, 23% of CO₂ emissions from fuel combustion of which: road transport (both passengers and freight) - 75%, aviation - 11.5%, maritime - 10.3%. Private vehicles account for 10% of global CO₂. Emissions are expected to increase 57% worldwide in the period 2005 - 2030. It is estimated that PRC and India account for 56% of this increase.

counter high motorization rates and declining quality and use of public transport systems . Policies, programs and projects to ensure the actual reduction of CO2 emissions from the transport sector in developing countries will have to be implemented by national and local governmental, private sector and other local stakeholders. Regional and international organizations and initiatives can, however, play a pivotal role in helping to shape such actions. I-CE advocates a shift from vehicle based indicators towards people oriented indicators. If the impact of investments on travel behaviour and the quality of the journey of people is measured irrespective of their mode of transport, then results of the subsequent assessment of these impacts will be less biased to only one category of (motorised) road users. Consequently the benefits and disadvantages for non motorised road users can get an equal weighing in the decision taking process. This document sets the theoretical outlines for such set of indicators and concludes with a direction for the definition of the new set of indicators.

First we focus on the impact of new infrastructure on social and economic development of urban communities and point to the need to include all people in any impact assessment. To better understand the potential benefits of infrastructure facilities for all people the theoretical framework is shaped around a fundamental understanding of travel behaviour by adopting a conceptual model of transport systems based on travel, transport and traffic market analogies. As such a people oriented approach of transport policies is created.

Accordingly, in order to understand the travel needs of people and take into account the negative effects of travel, it is not mobility (i.e. distances travelled) that counts but the extent to which the travel provides access to social and economic participation. Basically this is true for all people, regardless their socio-economic status. After an elaboration of this we pay attention to the limitations people have in travel time budgets and how this relates to the radius of action for various categories of road users. Then we provide a critical observation on the way sustainability is treated in relation to transport policy interventions, followed by an evaluation of road safety principles and indicators to assess the impact of interventions on road safety.

We propose to use changes on the travel, transport, and travel market to study change as a consequence of interventions.

In the conclusions, we come with considerations and proposals for common denominators to assess the impact of infrastructure interventions on various aspects.

2.2 New infrastructure and the impact on the livelihood of the urban poor

Howe & Bryceson (2000) point at the lack of understanding of the relationship between poverty and transport, and spatial location and mobility beyond general observations. They note a changing nature of travel behaviour by people relying on the informal sector as a source of income. Trading, hawking and employment-seeking are associated with more complex irregular movements

than simple commuting peaks along the radial roads that are served by public transport systems. They argue that mobility and income criteria are insufficient for a good understanding of the relationship between mobility and poverty.

Howe and Bryceson: *“Poverty is a complex phenomenon that requires both quantitative and qualitative descriptors, especially in relation to basic needs. Moreover these descriptors exhibit significant spatial variation that cannot easily be compared with mobility criteria that are not spatially defined. It is the accessibility that a transport system provides which is of fundamental importance to the extremely poor and this exhibits strong spatial variations. GIS based techniques and accessibility criteria offer a powerful but flexible way of exploring the complex spatial variations and inter-relationships between urban poverty and transport.”*⁴

So, infrastructure and transport play a critical role in social and economic development for which the impact has to be measured in terms of improved accessibility. Infrastructure projects benefit the users by enabling them to improve their participation in social and economic activities to improve their prosperity and ultimately their quality of life. Non motorised transport can play an essential role here for several reasons. First of all to improve quality of life for the urban poor it is essential to optimise the infrastructure for the type of use which is relevant for them. It is only obvious that this is primarily non motorised use of the public space. Secondly in the complex spatial variations in the urban fabric accessibility is much better served by very flexible modes of transport that can operate in fine meshed urban settings. These are obviously the non motorised modes.

However, traditionally, the benefits of improving transport infrastructure has been measured by performance criteria for vehicles, like improved connection, travel time, speeds and fuel savings.⁵ The costs of improvements in transport infrastructure are classically defined as construction costs, ongoing operations and maintenance costs. This provides only a limited picture on the real impacts. The performance criteria, in particular when it comes to the measurement of mobility, are to a great extent based on and applied to motorized traffic. This means that particularly in developing countries, the impact for the majority of people falls outside the scope of the calculations. It is not only the neglect of the potential impact of motorized mobility on the mobility of cyclists and pedestrians. Moreover it is the question whether they can use the roads also and how does this improve their mobility and accessibility? There is also another side of the coin. Where the speed of motorized traffic is facilitated, roads become a barrier for the mobility and accessibility by other the road users. This results often in an increasing number of road deaths and injuries, as well as to a deterioration of air quality. This indirect impact of the project is almost not included in the traditional cost benefit analyses (CBA). Whether the impact of the project is positive or negative depends on the nature of the project. Arora and Tiwari (2007) plead to fully include an assessment on accessibility for every

⁴ Howe, J. and Bryceson, D., Poverty and Urban Transport in East Africa, Review of Research and Dutch Donor Experience, A report prepared for the World Bank, IHE Delft, December 2000.

⁵ Arora A. and Tiwari G., A Handbook for Socio-economic Impact Assessment (SEIA) of Future Urban Transport (FUT) Projects, Transportation Research and Injury Prevention Program (TRIPP), Indian Institute of Technology, New Delhi, 2007.

road project that is planned. A socio-economic impact assessment methodology should be an integral part of any cost benefit analysis. In their study Arora and Tiwari developed indicators for accessibility, mobility and socio-economic well-being.

2.3 Three markets determining travel behaviour

In order to better understand travel behaviour and analyze policy options to optimize the benefits for people and society, it is helpful to distinguish different levels for interventions. In this paragraph we distinguish three levels: the travel market, the transport market and the traffic market.

No society can exist without transport of people, goods and information. The challenge for transport and spatial planners is to affect travel behaviour to optimize social and economic well being. At the same time, policies have to control negative aspects like accidents (road deaths and injuries), impact on liveability, air quality and emissions that induce climate change. Interventions should not only focus on short term effects on mobility but also on their effects for a long term.

Level 1: The Travel Market (which trips do people want to make?)

The travel market is where demand for (participation in) activities and the supply of those activities is resulting in travel patterns. Spatial distribution of socio-economic activities and their time frames determine to a large extent the need for travel. The travel market has much to do with the location of activities. Where do people live? Where do business establish? Where are shopping centres, schools, health care services, public administration? The need for (participation in) these activities and their spatial spread affect the pattern of travel.

The travel market is subject to many socio-economic and cultural factors (affecting the aspirations of people) which are beyond the reach of the instruments of urban and transport planning. Yet government policies can influence this market to a certain extent. Land use planning (e.g. the choice of locations for living areas and industrial areas) can both stimulate the need for motorised travel (e.g. by creating distances between living areas and working areas) or minimise the need for travel by a planning based on the principles of proximity. Travel demand management can be used to affect the demand of travel. Land use planning and travel demand management are important instruments to at least prevent unnecessary growth in the need to travel. Smart land use planning can reduce trip distances, allowing those trips to be made on bicycle or by foot. Creating shortcuts for cyclists and pedestrians can reduce the impedance and hence increase the preference for cycling and walking. On the other hand, large infrastructure projects in many cases induce an adverse effect on cycling and walking by creating barriers and detours.

Level 2: The Transport Market (which transport system will be used?)

If there is a (desired) travel pattern, this demand has to be met with a supply of transport options. The transport market is focused on the cohesion between

travel demand and the availability (and affordability) of transport modes and services. The demand for travel and the supply of transport possibilities lead towards a certain distribution of transport systems for the travels to be made. A transport system is defined as a typical combination of transport modes, infrastructure and services. The transport market links the demand for travel of persons and goods with available and affordable transport modes and the belonging infrastructure and services. Different transport modes can be chosen, according to the distance to be covered, the spatial context and the availability and accessibility of different modes and infrastructure. Not only travel time, but also travel costs weigh heavily on this market.

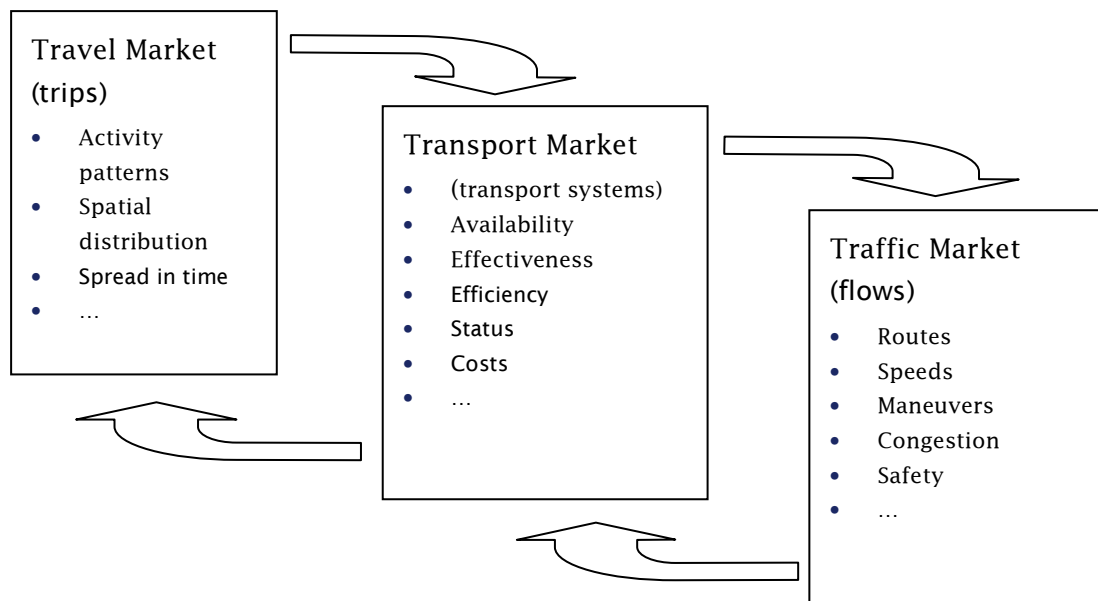
Government transport policies can influence this market in order to create a shift in the modal split. Policies should aim at promoting those (combinations of) transport modes used for travel, that offer the highest benefits for society at the lowest costs. There are two points of impact. Government can create more attractive networks of friendly and safe routes for specific modes of transport, e.g. securing better connections for pedestrians and cyclists to public transport and offering better / cheaper public transport. On the other hand government can also launch financial instruments like taxation on vehicles, differentiation in tax cuts on travel costs compensation, road pricing etc.

With these instruments the transport market can induce the shift to public transport or to low or zero emission modes of transport.

Level 3: The Traffic Market (the routes and roads to be used)

Once a transport system has been chosen for a certain travel, this will result in the factual use of the available infrastructure and its attributes such as traffic management instruments, resulting in a traffic pattern. The quality of infrastructure including traffic management systems should assimilate the demand for transport. Once the trip maker has chosen to travel using a certain transport mode, (s)he will have to make choices with regards to factual road behaviour. Aspects like route, speed, safety and, interestingly, the possibility to combine destinations will influence the quality of the trip.

Decision makers can affect this market by infrastructural activities like the layout of streets and crossroads, traffic calming, diverting streams of motorized traffic to more suitable routes. Non infrastructural actions are also possible by training (and examining) road users, protecting and promoting non motorized activities along the street, creating parking facilities and offering amenities for people waiting for public transport.



figure⁶

It is very obvious that these markets are interrelated. Changing a series of streets into safe and friendly routes for non-motorized traffic, for instance, can influence the modal choice, and in some cases also the choice of destinations.

Diminishing the number of on-street car-parking in the city centre and raising the fees, while at the same time making room for non-motorized traffic and social activities is another example. At a certain level car users will look for other ways to reach the city-centre, resulting in a modal shift. It will also enhance street-life and the attractiveness of the city-centre, inducing a shift in businesses. Some business will move to a more car-oriented place, being replaced by others wanting to enter the city-centre because there are more passers-by. If this happens, all three markets are obviously influenced.

To assess the impact of a certain project, or a government policy, one should try and estimate the resulting changes on each of the three markets.

The reason for introducing these three markets is to show that comprehensive traffic and transport policies go far beyond the traditional road engineering approach. Each market provides possibilities for action to improve the overall performance of the traffic and transport system.

Law of constant travel time and trips⁷

Departing from the fact that a day counts only 24 hours, and given the time that has to be spent on sleeping, feeding etc, the time budget for travel is limited.

⁶ The figure showing the interrelations between the travel, transport and traffic market is based on a more complex scheme showing the spatial traffic and transport system in its societal context, originally made by TNO-Inro, an interdisciplinary research institute on traffic, transport, spatial planning and regional economy in the Netherlands. The figure is both a simplification and an elaboration in some respects of the original figure, and as such made by Tom Godefrooij, staff member I-CE.

⁷ Hupkes, G., Gasgeven of Remmen: Toekomstscenario's voor ons vervoerssysteem, Deventer 1977

Over longer periods of time the average time budget for travelling per person per day appears to remain more or less constant (with high individual variations) at around 1,5 hours a day anywhere on the globe, but with rather high differences between people (many poor people need much more time⁸). Since the time budget for travel per person is limited, the number of trips per person per day is limited too: one cannot make an infinite number of trips. So trips have to be made within the constraints of time (and money) budgets. For a large population the average number of trips per person also appears to be more or less constant. This finding that people *on average* use a more or less constant amount of time to make a more or less constant number of trips per day is called the '*law of constant travel time and trips*'⁹.

This 'law of constant travel time and trips' and the captivity of walking and cycling for poor people in developing countries limit their radius of action and thus their access to destinations farther off. To analyze the impact of infrastructure on the well being of poor people, this law has to be taken into account.

⁸ If poor people have to spend much more time to travel to livelihood opportunities, the effect will be that a number of them will spend extreme long travel time and that other will be stuck, i.e. will not make the trip at all. To which extent there are strong variations between groups should be researched more in depth.

⁹ In the rich world there seems to be a reported tendency to a (tiny) increase in the travel time budget. This could be explained by the fact that modern communication means allow people to do other productive tasks (like phone calls) during their travel time. So the (small) increase in average travel time budget could be due to the growing possibilities for multi tasking during the trip.

3 Shift towards people oriented indicators

3.1 Introduction

In the three markets described before many decisions are possible at different levels. People decide and make their choices within the dynamics of demand and supply in these markets. The result of their choices is a travel behaviour that enables to a certain level of participation in socio-economic activities, in order to meet to a larger or lesser extent their aspirations. Effects of interventions on these markets therefore should in principle be measured in those term: to which extent do these interventions (like road projects) have an impact on travel behaviour overall and on socio-economic participation.

Traditionally, however, effects of road projects are measured in (car)capacity of roads, travel time by car, congestion (for motorized vehicles) etc., thus only measuring a small portion of the choices made in the market, and paying no attention to essential feed back mechanisms on the functioning of these markets overall. Appendix 1 describes the common denominators to assess the impact on aspects like accessibility, road safety and sustainability.

So, the current widely-used approach of travel, transport and traffic is often a technical one at the level of one (or a few) specific modes. This is rather peculiar. Travelling is about moving people from one activity-place to another, from an origin to destination. The social and economic value of a trip is not only dependent on the distance travelled, and has to be assessed in terms of the quality of the activity that can be undertaken as a result of a trip. Also people without cars do have to travel to participate in social and economic activities. At the same time negative impacts of facilities for different modes of transport on the travel and accessibility possibilities of all people and negative impacts on society have to be taken into account.

3.2 Accessibility

Accessibility is essentially a quality of locations. The quality of the accessibility of a certain location is inversely proportional to the amount of time, money and effort that it takes from users to travel from their origin to the location (and back) for the purpose of their activities at that location.¹⁰

Talking about the extent to which the transport system is determining the quality of 'accessibility' in a general (aggregated) sense we can use two perspectives:

1. Destination oriented perspective
Accessibility can be defined as the amount of people that can reach a certain location within a certain time (catchments area of the destination).
2. Origin oriented perspective
Accessibility can be defined as the number of destinations (jobs, education, healthcare, public services) that are in reach within a certain time (radius of action of an individual).

¹⁰ Korte Afstanden Grootste Kansen, Werkgroep Bereikbaarheid, Strategische Agenda Milieu, Economie en Ruimte, 's-Hertogenbosch, 2003

In developing countries the characteristics of travel and transport differ from those in, for example, the USA and Europe. This is an important consideration when using the theory of the travel markets. Obvious differences in travel patterns exist, for instance in the large share of walking trips as the main mode (in Africa it can be 60 percent in commuting between peripheral habitat and CBD). This is fortified because people have no choice for other transport modes; there is a dominance of captivity in walking (and cycling). The high share of walking (and to a lesser extent cycling) is not problematic as such, but because of the fact that it is a result of a lack of choices rather than the consequence of an attractive walking and cycling environment in which people choose to do so. In their vision of accessibility Arora and Tiwari (2007) developed indicators that fit specific circumstances in developing countries. They use the 'origin oriented' definition of accessibility, being determined by the proximity of destinations and (or: in combination with) the facilities offered by the transport system to reach them. It should be noted here explicitly that 'proximity' should be understood as 'the distance to be travelled' which is often much more than the Euclidian distance 'as the crow flies'. An urban arterial which constitutes a barrier for pedestrians and cyclists in the transversal direction is, in this perspective decreasing the proximity of destinations at the other side of this arterial/barrier. For public transport for instance the indicator is a combination of the walking distance to the bus stop and the time gap between two successive buses.

In search for an increase of prosperity poor people in developing countries cause a continuous influx of new customers in transport / travel market: immigrants into the urban economy and migrants within the city (evicted slum dwellers or voluntary migrants to better habitats in the urban periphery).

For the future, this creates an opportunity: in terms of modal choice, the majority of the trips are being undertaken by sustainable modes; public transport, cycling or walking. These modes should be defended, by transforming this choice from a captive one to a free choice for at least a substantial part of all trips when the alternative for private motorized vehicle use has arrived.

3.3 Environment and Climate

Will an impact assessment from a people's point of view also makes sense when incorporating the consequences for the environment and climate, for sustainability?

In mitigating climate change there are two important strategies; one is to reduce actual carbon emissions and the other is to prevent potential carbon emissions to be released. In the transport sector the common strategy is to reduce the actual pollution of the vehicles transporting passengers and goods, fine particles as well as CO₂ out of fossil fuel. Transport emission policies therefore focus on fuel-efficient vehicles and renewable energy sources.

Cycling and walking add another dimension, permitting a prevention strategy. Non motorised mobility can be seen as a carbon sink, similar to a forest. If trees

are cut or burnt it releases carbon captured in the forest. If cyclists would change to the use of public transport, motorcycles and Nano's it releases carbon emissions which can be attributed to the cycling practice as a carbon capture, similar to forests. And carbon captures need to be protected and preserved.

Preserving cycling and walking mobility is not really difficult; it basically comes to countering prohibitive parameters such as lack of access and getting killed on the road. Cycling can be humanised a lot by providing connections over physical barriers (rivers, roads) and separate cycling facilities and sidewalks along dangerous roads. With intelligent traffic management these provisions constitute a backbone network connecting origin and destination areas, in which traffic calming ensures that cyclists can share the road space. Comfortable sidewalks, paying respect to the pedestrian, are a requirement anywhere.

What keeps City Governments from making these investments in cycling and walking provisions? The answer probably is that cyclists are poor, and provisions for the poor easily succumb as political priority. But what if these poor active transport users happen to represent carbon credits? They become politically interesting once the City Government can sell the cycling credits to an airline company and so generate funding for their investments in cycling provisions.

If, as a result of good cycling provisions current motorists leave their motor vehicles and take up cycling to practice fitness while commuting, this new cycling will contribute to the carbon reduction obligations of emerging economies.

The UN Framework Convention on Climate Change (UNFCCC) issues a validation and verification manual for CDM projects, which provides the basis for transport calculation models and emission measurement of vehicles and fuels. In order to fully utilise the potential of non motorised transport, we should not try to squeeze cyclists and pedestrians into a validation system for vehicles and fuels. What we need is a paradigm shift in the sense that carbon emissions are directly linked to citizens making mobility choices; so climate strategies should not give credit for producing green engines and fuels but for enabling the citizens' choice for sustainable mobility: cycling and walking integrated with efficient (also emission-efficient) public transit. This approach is also positive for local air quality.

The conclusion is that also for environmental indicators it makes sense to shift from a vehicle oriented to a people oriented perspective. Again this shift will help to give more weight to investments in facilitating non motorised transport properly.

3.4 Road safety

The UNEP project team proposed in June as a definition for Road Safety: The decrease of road injury risk and a minimizing of the fear of road injury risk. The fear of road injury risk is an important issue for transport policies since this inhibits people's movements, i.e. their accessibility. This fear should therefore be incorporated in the (definition and) application of accessibility. Our proposal is to limit the definition to the risk per person on serious road injuries. Note that we propose a shift from risk per km travelled to risk per person (regardless

the distance travelled). Thus the indicator doesn't implicitly allow for an ongoing growth in mobility and are we linking risk to the accessibility concept. Over 90 percent of the world's fatalities on roads occur in low-income and middle-income countries, which have only 48 percent of the world's vehicles.¹¹ One of the key recommendations of the *Global Status Report* is that *governments need to take in consideration the needs of all road users when making policy decisions that impact on road safety. To date, the needs of vulnerable road users have been neglected in many countries and should be given renewed emphasis, particularly when decisions are made about road infrastructure, land use planning and transport services.*

This way of approaching road safety (be aware of / take in consideration the effects of road safety for all road users) is known in The Netherlands as *Sustainable Safety*. This Sustainable Safety vision of road safety is based on five principles. They refer to the functionality of roads, the homogeneity of mass and / or speed and direction, physical and social forgivingness, recognition and predictability of roads and behaviour, and state awareness.¹² The essence of the Sustainable Safety vision is the premise that the human being is the measure of all things with due consideration of his physical vulnerability and cognitive capabilities and limitations. For this an integrated approach to the elements human – vehicle – road, which is tuned to the human measure is necessary. To reach the level of Sustainable Safety serious crashes should be prevented, and whenever accidents do happen (as they will), the almost total elimination of risk of severe injury.

Sustainable Safety Principle	Description
Functionality of roads	Mono functionality of roads as either through roads, distributor roads, or access roads in hierarchically structured road network.
Homogeneity of mass and / or speed and direction	Equality of speed, direction and mass at moderate and high speeds.
Forgivingness of the environment and of road users	Injury limitation through a forgiving road environment and anticipation of road user behaviour
Predictability of road course and road user behaviour by a recognizable road design	Road environment and road user behaviour that support road user expectations through consistency and continuity of road design.
State awareness by the road user	Ability to assess one's capacity to handle the driving task. (In other words: do road users have the right perception of their own ability to safely drive a car, ride a bicycle or walk the street given the circumstances at the time, including their own state of mind.)

Table 1: Description of the five Sustainable Safety principles

¹¹ Global status report on road safety: time for action. Geneva, World Health Organization, 2009.

¹² SWOV, Background of the five Sustainable Safety principles, Leidschendam (The Netherlands) SWOV, Institute for Road Safety Research 2007.

In relation to the development of indicators, the essential relevance of the Dutch system is that interventions are centred around people. The traffic system should allow and enforce people to keep in control of their interaction with the road, their vehicle and other road users. We can distinguish interventions on the level of the travel, transport and traffic market. On the travel market urban planners can try to minimize the need for longer trips by compact and mixed land uses. On the transport market transport planners can try to change the competitive position of the various modes of transport to promote the use of safe and sustainable transport systems. And on the traffic market traffic engineers can facilitate safe route choice and promote a proper and safe interaction between road users.

If we look at indicators for road safety currently used, the most common are fatalities or injuries per km travelled or vehicles. These are not very consistent with the interventions for a proper road safety policy. When we would take trips or travel time as the denominator for an indicator on road safety, we already can measure the impact of interventions on road safety much better. Trips and travel time can be combined in the denominator 'population', an indicator sometimes used already. The advantage is that this indicator combines the risk experienced by the road user and the risk imposed on other road users. But as with sustainability, road safety, should be balanced with accessibility for all people. Trips are no more than a means towards that.

3.5 Table of traditional and new suggested indicators

Indicators	Common	Proposed
Accessibility	<ol style="list-style-type: none"> 1. Average speeds: LOS is defined using average speed of motorised vehicles. Private vehicles(cars, motor cycles) are not differentiated from buses. NMVs(bicycles and pedestrians) are completely ignored. 2. Average/max flow: Number of vehicles/hour, capacity of a facility is defined using vehicles/hour. Focus is on vehicles rather than moving people. 3. Average delay/vehicles, maximum delay/vehicle is used to define LOS for intersection. Focus is on vehicles and not movement of persons. 	<ol style="list-style-type: none"> 1. Average number of destinations within reach for persons living in a specific area given the actual access to transport modes, based of travel times of respectively 15 minutes, 30 minutes, 45 minutes and 60 minutes 2. Size and number of inhabitants of catchment area of relevant (clusters of) destinations based on travel times of 15, 30, 45 and 60 minutes specified for the various modes of transport.

<p>Accessibility (continued)</p>	<ol style="list-style-type: none"> 4. Average queue length and maximum queue length is used for intersection LOS. Focus is on motorised vehicles(public and private combined). 5. Average delay/person, maximum delay/person is used for pedestrian LOS at intersection. 	
<p>Road safety</p>	<ol style="list-style-type: none"> 1. User Safety: fatality/injury risk per trip can be used. However, most common indicators are: <ul style="list-style-type: none"> • fatality or injury/1 million passenger km travelled, • fatality or injury/ 100,000 population • fatality or injury /10,000 vehicles 2. Fatality/injury risk per trip can be disaggregated to <ul style="list-style-type: none"> • risk during access trip, • risk as occupant of the vehicle and • risk imposed to other vehicles/users on the road 3. Vehicle Safety indicators: fatality or injury/10,000 vehicles traditionally estimated for motorised vehicles only. Disaggregated risk can be applied to this also. 4. Road Safety indicators: Current indicators are: <ul style="list-style-type: none"> • Fatality/injury/km, • fatality or injury/passenger km • fatality or injury/vehicle km 	<ol style="list-style-type: none"> 1. Number of fatalities and serious injuries per 100,000 population 2. Number of fatalities and serious injuries for relevant NMT-groups per 100.000 motor vehicles¹³ <p>Additionally:</p> <ol style="list-style-type: none"> 3. Risk of being involved in an accident with MT.

¹³ *The cause of an accident is a very unreliable element. Moreover it depends strongly on the locally current definition. In many cycle unfriendly countries it is normal to assume that the cyclist (or pedestrian) is guilty unless otherwise proven. Therefore we choose as an indicator the number of road victims per number of motor vehicles, as it is a measure of how dangerous motorised traffic is for other road users.*

Environment	<ol style="list-style-type: none"> 1. Pollutants (CO₂,NO_x, SO_x, SPM, HC)/veh-km : Focus is on engine efficiency, cleaner alternate fuels. Life cycle emissions are not captured. Rebound effects are ignored. 2. Pollutants (CO₂,NO_x, SO_x, SPM, HC)/passenger -km: Same as above except higher occupancy vehicles are favoured. Life cycle emissions are ignored. 3. CO₂/person or country: Used at international negotiations. 	<ol style="list-style-type: none"> 1. Pollutants caused by travelling/ 100,000 population 2. Percentage of trips for which people have the option to (realistically) choose for a sustainable mode of transport
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Although we argue for another type of indicators to make decision making more people oriented and less vehicle oriented, it may well appear that we need the 'old' indicators to make the proper calculations on what we would want to know. So this is no plea to abandon certain types of data collection, which will remain useful. What we question is much more the implicit values that are attached to these data as basis for decision making.

4 Comparing various intervention options

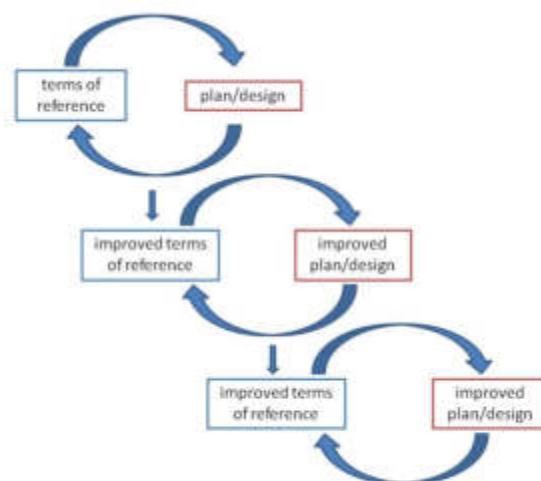
4.1 Three basic steps

Any comparison of options for interventions in the traffic and transport system starts with defining the 'Zero', 'Business as Usual' (BAU) or 'Do Nothing' 'scenario', i.e. the situation on a certain date in case neither the intended intervention, nor any alternative would be realized.

The BAU option supposes that the current conditions and trends on each of the three markets (Travel / Transport / Traffic) will not change, except as a result of policies and projects that are already decided on. However, one must take into account current trends and foreseeable external factors, like changes in population, housing, and businesses (growth of the current population, new settlers, new settlements). Especially in fast growing and constantly changing places, like the metropolitan areas in emerging economies these current trends can result in drastic changes. E.g one should not only consider formal expansion in accordance to the official land use policies, but also the development of informal settlements, and businesses.

The second step is sketching the outlines of feasible, and desirable options/scenarios. For any plan or intervention (in any of the three markets) the expected impacts have to be explored. If these impacts appear to be negative or unsure, then one should look for either improvements of the design or for fundamentally other design options. In this process planner/designers should look for an optimal solution with the best possible overall impact (of course within the limitations posed by budgets and jurisdiction). Often this results into an iterative process comparing different approaches, different variants and different details until one can agree upon a satisfactory solution. In case of a very negative 'zero' scenario the desirable impact of the intervention could be a curtailing of the expected changes.

A design or planning process can be described as an iterative process in which terms of reference are the basis for a design or plan; the design is then used to reflect on the quality of the terms of reference: 'Is this really what we want?' Subsequently an improved terms of reference will result in an improved design. This process can be repeated until a satisfactory solution has been reached. The reflection phases in this process should make use of the indicators to explore expected impacts.



The third step is in fact the reality check. Choose a date in the future on which the customers will probably have found an optimal answer to the changes on the three markets (Travel / Transport / Traffic) resulting from any eventual option. The basic question here is: has the intervention indeed the impacts as predicted/intended. Are there any additional unexpected impact, either positive or negative? These evaluations are extremely important to improve future interventions and also for further improvement of the indicators. Do they really cover all relevant impacts of the interventions?

Most infrastructural projects are meant to accommodate streams of motorized traffic and/or public transport along transport axes. They may consequently help to free adjoining neighbourhoods from excessive traffic. At the same time however, they may create barriers and detours for people that want to cross. Consider therefore not only the effect on trips along the axis of the project and its extensions, but also the effect on trips crossing these lines.

No general rule can be given to establish the limits of 'catchment areas'. Try to take in account any number of trips that might be accommodated, or affected. A small percentage of trips originating from a large area may still result in a considerable number of trips.

4.2 Hypothetical case description

Now the question is: what difference does the application of the proposed indicators make when it comes to real projects. Let us imagine a large and fast growing city in a developing country. Its population has been growing rapidly from 400.000 to over 1 million inhabitants. One third of the inhabitants is living in so called unplanned, informal areas most peripheral. Many inhabitant there are evicted from centrally located slums. In the past decades a few arterial roads have been upgraded to accommodate a growing number of vehicles (lorries busses private cars). Although private cars are only used for a limited proportion of all trips, they fully dominate to a large extent the traffic scene on these few arterials available and the perception of traffic problems. These arterials typically get congested in the directions from and to the Central Business District (CBD) during peak hours. During the same peak hours a vast majority of the population is either walking or using public & collective transport in all sorts, and to a lesser extent cycling. Pedestrians are confined to use the unpaved shoulders of the arterials, and no separate facilities are available for cyclists. Subsequently they are often in conflict with pedestrians and street hawkers.

In order to improve this chaotic traffic situation the municipal council has decided to rationalise the public transport system and build a *bus rapid transit* (BRT) corridor. Now one of the points debated is the extent to which non motorised transport needs to be incorporated in the planning.

Now an assessment has to be made of the expected impacts of the project in order to decide on the best variant of the project.

The engineering tradition usually is focussing on the performance of the corridor itself: what will be the carrying capacity of the BRT (in terms of vehicles

or passengers), how can flows of (other) traffic be accommodated, what will be the average speed on the arterial. In such projects engineers – very understandably – will focus on the quality of their output: in this case a well performing bus system in terms of capacity and flow. It is the authorities' responsibility to also look at the desired outcome: a better functioning city. More specifically: a better functioning traffic and transport system. This can be done by studying the effect of the project on the three traffic and transport markets. So we need an assessment of the BRT project on the three markets.

4.2.1 Travel market

The question on the travel market is: how does the project influence the radius of action of the various groups in society. How many relevant destinations come within reach of (all) people which weren't within reach before. In other words how has spatial accessibility improved and for whom. The changes in radius of action should ideally be measured from the origin locations of all trip makers, taking into account the individuals' access to the various transport modes as well.

The total effect of the project could then be defined as the sum of all positive and negative changes in the radius of action of the inhabitants in the area considered. Of course that is virtually impossible because of the detailed data need of such calculation and because of the need for demarcation of relevant study area. To simplify the exercise we confine ourselves to the changes in the size of the catchment area of important (clusters of) destinations differentiated according to the various modes of transport. These catchment areas can be drawn on a map as 'isochrones' for travel times of respectively 15, 30, 45 and 60 minutes.

If the BRT-corridor happens to constitute a barrier for pedestrians between living areas with local markets on both sides of the corridor, then this will become clear in the catchment areas of those markets as established for walking, provided the isochrones calculation is sensitive to networks and barriers (latest GIS software can do this). If the catchment area is enlarged for bus users, but decreased for pedestrians, then this can have several effects on the travel patterns of people. To make it not too complex right away, we start to simply count the number of inhabitants for whom we can identify improvements or deteriorations.

Suppose that the result of this exercise would be that 10.000 people are potentially affected by an increase of the catchment area for bus transport, and 10.000 people are affected by a decrease of the catchment area on foot, what should then be the conclusion? This is actually very difficult to answer. The increase is good, the decrease is bad. The public transport trips might be costly trips but cater for a longer distance, while the walking trips may be short distance and free of cost. The real question should be: how can we improve the project in such a way that the decrease of the catchment area on foot doesn't happen, while the increase in catchment for public transport is still there? Then additional measures have to be taken to soften or undo the barrier character of the BRT corridor.

To summarize in formula:

Changes in the quality of accessibility of a destination (area) can be calculated by:

$$A = (Ch_{\text{walk}} * Sh_{\text{walk}}) + (Ch_{\text{cycl}} * Sh_{\text{cycl}}) + (Ch_{\text{pt}} * Sh_{\text{pt}}) + (Ch_{\text{mt}} * Sh_{\text{mt}})$$

In which

A = Impact on quality of accessibility of a certain destination area

Ch = positive or negative change as consequence of the intervention in size of the catchment area measured in the number of people living in the catchment area

Sh = the share or percentage of people in the catchment area that has access to a certain mode of transport

walk = walking

cycl = cycling

pt = public transport

mt = (private) motorised transport

It should be noted that here we are only using the most obvious categories of transport modes. In reality e.g. any public transport trip will include an access and egress trip (or feeder trips). Taking these into account one should also include the time needed for a transfer between feeder mode and public transport mode. Anyhow public transport is a parcel of very diverse transport techniques, which all need to be incorporated separately in this formula.

This formula is taking into account the cost aspect of accessibility in so far as that costs is a main factor to determine whether socio-economic groups do have access to certain modes. But other factors determining quality of the accessibility for users of certain modes of transport such as perceived road dangers and unpleasant road conditions are not included in this 'measure for accessibility'.

As the catchment area is defined as the area from which the destination can be reached within a given travel time, the basis for this calculation is the expected changes in travel time (i.e. changes in the product of travel distance and travel speeds) as a consequence of the intervention. This includes (anticipated) increases and decreases of delays, detours, congestion, speed regime et cetera.

In the case of the BRT corridor the obvious aim of the project is to bring the peripheral slum areas within the catchment area of important destinations in the city centre. Additionally this approach will force the project executers to not only think about the performance of the bus system, but also on severance effects. It is a well known effect that heavy traffic flows and large crossing distances have a detrimental effect on relationships across the corridor, but as the concerning people affected are not the target users of the BRT, these impacts are easily underestimated if not forgotten at all. Once the assessment is made that because of the BRT project a certain number of people is suffering from deteriorating accessibility, then the implication is that the corridor should be designed with enough safe and easy to use crossing facilities at the most appropriate locations. The method sketched will help to identify where the crossing facility has the highest positive impact in improving accessibility for non motorised transport users by bringing the highest number of inhabitants within the catchment area of the most important destinations.

The aimed for result of the BRT project on this market is that more people get more opportunities to safely reach important destinations. It is important to prevent that the gains for one group of persons is undone by the losses of another group.

4.2.2 Transport market

On the transport market the project may have an effect on the mode choice of people. On the one hand this can be a direct consequence of the effects we have seen on the travel market. If walking times to certain destinations increase, one may choose to use a faster mode, e.g change over to a bicycle or the bus service, or even the car.

But in the competitive position of the various modes¹⁴ it is not only the travel times that count. It is also the (perceived) comfort of the trip made by a specific mode, the (perceived) safety and the (perceived) status. These are all influenced by the quality of the design for the respective modes of transport (vehicles, schedules/frequencies as well as infrastructure). E.g. if pedestrians have to use dusty shoulders, then this will not contribute to pleasant walking and it will not enhance their status either. So regardless the impact on travel time the walking conditions would be a disincentive to walk. These are exactly the qualitative aspects of accessibility which we could not assess in the calculation we suggested to use for impacts of an intervention on the travel market. One might argue that these aspects are subjective, and to a certain extent they are. But there is enough objective evidence on how on average people experience these aspects and how this has an impact on their modal choice.

¹⁴ Mode choice is the outcome of an individual cost/benefit weighing. In this weighing the various modes are 'in competition to be chosen'. The better the (perceived) cost/benefit ratio of a certain mode for a certain trip, the better the competitive position towards other modes. Costs and benefits may not be the same for everyone, and have both more rational objective and more subjective somewhat 'irrational' aspects. Policies may have an impact on all these various aspects and the perception thereof, thus indeed influencing the (perceived) cost/benefit ratio and hence the competitive position of the various modes.

The change in the competitive position of a certain mode can be expressed in:

$$\text{Comp}_{\text{mode}} = \frac{\text{Change attractiveness}_{\text{mode}}}{\text{Change attractiveness}_{\text{average}}}$$

In which:

$\text{Comp}_{\text{mode}}$ = The change in competitive position of a certain mode

$\text{Change attractiveness}_{\text{mode}}$ = positive or negative changes in the attractiveness of the concerning mode

$\text{Change attractiveness}_{\text{average}}$ = positive or negative change for all modes on average

$\text{Attractiveness}_{\text{mode}}$ = average resultant of the individual weighing of aspects such as travel times, costs, status, comfort, perceived safety, road environment, additional services, et cetera to choose or not choose a certain mode of travel. In assessing the attractiveness of the various modes it might be useful to differentiate between types and lengths of trips to be made, as each mode has its own strengths and weaknesses.

As the formula shows, the competitive position of a mode is relative. If the situation for non motorised transport is improved, but the situation for motorised transport is even more improved, one should not be surprised if the shift to motorised transport appears to continue. So if there is a wish to influence the competitive position of certain modes, one has to look at impacts in both the numerator and the denominator.

Here we have put the average attractiveness in the denominator, but of course one can similarly look at specific competitive relationships between specific modes. Politicians can set goals to encourage certain and/or discourage the use of other modes.

In any case we have to assess how many persons are affected by the intervention by either improvements or deteriorations of the quality of their trip with regards to safety, comfort and status. We need to do this in order to be able to make an estimation of the modal shift as a consequence of the intervention.

We can use the number of people affected on the travel market as a starting point for this assessment. This is the total of all people living in the established catchment areas. If we can make an estimation of their access to the different transport options, then we can establish for how many persons travel reality potentially can improve or deteriorate. If e.g. in the catchment area for car use only 5% of the inhabitants has access to a car, then that is the number which is affected by an improvement or deterioration of the travel conditions by car. (We can also simplify this calculation by taking all catchment areas together, instead of making the calculation for each defined catchment area separately.) If we do this exercise for all modes of transport, we can make an assessment on how this project has an impact on the competitive position of each mode, and consequently make an estimation of an expected modal shifts. If we see here

undesirable impacts, we can again reconsider the design of the project in order to undo the unwanted effect.

In the case of the BRT corridor it is an obvious goal to make public transport more competitive.

Now two questions arise: do we want to improve the competitiveness also in relation to non motorised transport on those trips for which according to distance NMT is a good option? And secondly: what is the contribution of the quality of feeder trips to the competitiveness of the bus service? By forcing them to make an assessment of the impact of the BRT project on the competitive position of all modes they will deal more consciously with the interests of the various categories of road users.

4.2.3 Traffic market

The traffic market: the changes on the travel market and the transport market will in the end become visible in road behaviour on the traffic market: routes, flows, speeds, manoeuvres, interactions between road users. By traffic management measures we can steer the actual road behaviour to a large extent. And apart from the main purpose of (the majority of) the trips (to arrive at certain destinations for certain activities) these trips have other impacts: on safety, air quality, noise, CO₂-emissions et cetera.

Of course these impacts can be measured after the project is implemented as factual impacts, but of course we want to make a realistic estimation on beforehand for the various options we have for the project. And as explained before, we are not only interested in the performance of a limited group of road users at the corridor; we wish to have insight in the overall impact per person for the considered area. There are all kinds of feed back mechanisms and rebound effects between the choices made on the 3 markets. This will make a proper estimation of impacts quite complex. So some imperfections are inevitable.

We have also to deal with the issue how we translate project scale effects to their impact on overall performance figures of the transport system. With regards to safety and environment at project level we can mainly make qualitative estimations of effects on the chosen indicators unless we can use sophisticated transport models. These sophisticated models aren't generally available yet, and certainly not in developing countries. The impacts on safety and sustainability are the result of changes on all three markets:

- The number of trips made and the distances covered. As we assume that the number of trips is on average constant per person, the most important impact is the effect of the project on the total distance travelled.
- The modal split. As each mode has its own characteristics with regards to safety risks for its user, safety risks imposed on other road users, emission characteristics, use of road space. On the basis of index numbers one can calculate those impacts if one knows the total distance covered per mode. Here we do need the (expected) modal split per distance to calculate the overall impact on emissions and to a lesser extent safety. This is paradoxical

as we earlier argued for not using distance as a denominator for measuring the accessibility performance of the transport system. In this case however we need distance as an intermediate denominator to calculate the overall performance of the system with regards to air quality, CO₂-emissions, and tentatively on safety.

- The actual impact of performed road behaviour. Obviously one of the objectives of the project should be that road users behave more safely. This is the most difficult part of the assessment. In the case of this specific project we have to compare the different performance of different design options of the project on these impacts. Then it comes to questions like what is the expected impact of the anticipated speed on the safety and the emissions? What would be the effect of a lower design speed? (And what type of design do we need to keep speeds low?) What is the impact of the number of pedestrian crossings on the performance of all these impacts. What is the impact of cycling facilities? And if planned, what quality standards should be applied to get the required results? And so on and so forth. Basically we have to rely here on expert judgement on the effect of certain design decisions. A complicating factor here is the already mentioned feed back and rebound effects on choices on the transport respectively travel market. (If e.g walking trips become safer, people might be inclined to walk more often.) It is clear that here profound expertise on (the complexities of the) micro level is required to come to a solid and trustworthy assessment.

In the case of the BRT corridor on of the (aimed for) effects will be that people from peripheral slum areas will make longer trips than before, and that they will use the BRT in addition to their walking (and cycling). At this level also the behaviour of all other road users has to be taken into account. At the level of the traffic market we can observe:

- Changes in route choice
 - Preferably road users should choose the safest routes for their chosen mode of transport
- Changes in traffic volumes (flows)
 - Higher volumes of motorised traffic will result in reduced crossibility of the road
- Change in traffic composition (homogeneous flows versus mixed flows)
 - A mixed traffic composition requires low speeds to be safe
 - When speeds are high and volumes are large then flows should be made homogeneous by segregation of modes
- Changes in speed behaviour
 - Higher speeds result in more and more severe accidents, and also increased emissions
 - Lower speeds will result in a decrease of the accident level and a decrease of emissions
- Changes in interactions between road users
 - It is clear that at lower speeds road users can better interact, have eye contact et cetera.

The design of the project has a direct influence on these changes. So in the terms of reference for the project all these aspects have to be dealt with

The proposed approach is forcing the decision makers to think wider than only the performance of the BRT service. In fact they are stimulated to consider the BRT as one (be it an important) element of the urban transport system, and to think about the interrelationship of this element with other elements of the system. And most importantly: it forces them to really think about which groups in society are likely to benefit from the project and which groups potentially could suffer. As in this approach also the number of users and potential users of all modes are part of the equation, it is likely that the result is a more equitable and people centred approach.

5 Conclusions and recommendations

5.1 Conclusions

Everyone concerned to the livelihoods of the urban poor should be aware of the negative effects of the explosive growth of infrastructure for motorized traffic as shown in the western world. For this we can learn from these long term (negative) developments. The awareness of these effects should be used as a challenge for low and middle income countries to provide a mobility system which will be good for the society as a whole.

Governments should take into consideration the needs of and the effects on all people when making policy decisions on (new) infrastructure . The proposed indicators should help to weigh accessibility, road safety and sustainability. The impact of road infrastructure should be considered for road users and other people affected.

- The impact of transport projects and policies on accessibility can be measured in terms of “ the geographical dimension of access to all destinations that are relevant for the quality of life.” (i.e. that are relevant to provide in basic needs such as job locations and services such as hospitals, schools and offices’)
- The impact of transport projects and policies on road safety can be measured in terms of “Fatalities and / or Serious road injuries”
- The impact of transport projects and policies on the environment can be measured in terms of “ The harm to the natural world and natural resources”. It is quite difficult to be really comprehensive in this respect, and usually decision makers confine themselves to the impact of the transport system on air quality and climate change.

We have focused on the denominator for indicators to assess the impact of transport on accessibility, road safety and sustainability. We have found that the current denominators concentrate on kilometres travelled. The aims for accessibility, road safety and sustainability call for other denominators. We propose to bring the impact of an intervention on various aspects under one common denominator, namely the effect per 100.000 people.

However, one needs intermediary indicators to calculate the marginal differences, resulting from various options, on each of the aspects. It is clear that for that the traditional indicators remain useful.

The real point is that we need to understand the implicit values if we use them directly for political decision making purposes. So the ultimate challenge is to use available data to make a more comprehensive or holistic people centred assessment of planned road investments. In the annex, we present the need for data and differentiations between e.g. users and modes, to assess the impact of indicators on various aspects.

5.2 Recommendations

This report is a first exploration of the possibilities to formulate indicators for performance of the transport system which are rather people oriented than vehicle oriented. We have sketched a conceptual framework on how to value the

various impacts of the transport system (on a holistic basis) with regards to accessibility, safety and environment. Subsequently we have given proposals for new indicators. In this search we found that this is a very complex endeavour. At macro level (i.e. the overall performance of the transport system) these indicators can be formulated at a conceptual level. However, when it comes to concrete projects and interventions it is quite complex to show how this particular project or intervention directly relates to the performance on the indicators at macro level. At this stage we can only sensitise decision makers and project managers on the aspects which are relevant to take into consideration. But to a large extent our guiding is rather qualitative than calculable from concrete data. The hypothetical case we have given on the application of this people centred approach is tentative, and far from easy. In this sense our proposals could be criticised as being too academic.

We therefore recommend to further develop these indicators to make them better applicable for decision making on investments in road projects. We have become aware that some of the existing and criticised indicators may be needed to make proper calculations for the type of indicator we are looking for. What is needed is a straight forward method to calculate scores on people centred indicators based on feasible data collection.

6 Appendix: Common denominators to assess the impact on various aspects

Policy indicators

On the long run and for a large group, not only the number of trips, but also the travel time is constant. If we take these general rules for granted, we may bring the impact of an intervention on various aspects (like the number of casualties, or the production of CO₂) under one common denominator, namely the effect per 100.000 people.

Intermediary indicators

However, one needs intermediary indicators to calculate the marginal differences, resulting from various options, on each of the aspects. To estimate, for instance, the differences in CO₂ production by private cars, one may compare the differences in car-hours multiplied by the average of CO₂ production per car-hour on similar roads.

The most suitable common denominator for these intermediary indicators is hours, because changes in travel time and travel earning-time are the major forces pushing the consumers to try and find a new optimum in their own individual activity/travel patterns.

Factors to assess

Change in Accessibility

When measuring the (potential) impact of an intervention on all the different components of each of the three layers of the traffic and transport system it is not necessary to combine all effects in one overall effect. Estimating the marginal impact on each of the three markets (Travel / Transport / Traffic), and the consequent effects on the various components will usually do.

Start by considering the 'gains' and 'losses', in the sense of time + money + hazards + drawbacks, within the current activity/travel patterns of all relevant consumer groups.

Change in Activity Pattern

Some trip makers (the 'gainers') will be able to expand their activity pattern due to an intervention, meeting so called latent activity needs. On the other hand, others may, when confronted with 'losses' due to an intervention, reduce or change some of their activities. The differences, resulting from the various options, depend on:

- Increase/decrease in activity patterns. this can be measured by counting the number of prime activities (job locations, service areas that can be reached within a certain travel time) for the various socio-economic groups in society, while differentiating
 - Availability of modes (in term of modal split per 'class')
 - Age groups
 - Gender

Total road use hours by all trip makers distinguishing their primary available modes can be calculated.

Deriving these catchment areas (by socio-economic group) can be done by using a land use and/or topographical map, while pointing at prime locations in reach for different groups of society from the different areas. This is typically done with experts on the area. The simple Elastic Thread method (reported in Bach, 2008) can be used.

Modal Split

The modal shift may or may not be a policy goal in itself, but in any case the data are indispensable in the process of calculating the impact, resulting from the various options, on each of the aspects.

Differentiation between age groups is necessary to assess the impact on certain aspects, because junior and senior road users are limited in their obligations, abilities and vulnerabilities, and consequently in their choices.

The differences in modal split, resulting from the various options, depend on:

- Differences in activity type (hence trip purpose)
- Consequent shift in modal split per road-use hour
 - Differentiate between age groups
 - Differentiate by socio-economic groups

The modal split can be measured by observing use of modes by trip makers (if possible distinguishing socio-economic classes, age, gender) on a stretch of road or in an area (cordon study) and calculating the relative distribution of modes (unit [%])

Travel Cost and Travel Earning-Time

The differences in travel cost and travel earning-time, resulting from the various options, depend on:

- Differences in modal split per road-use hour,
- Average travel cost/hour for each of the various travel modes
- Average wage/hour in the region

Road Safety

When assessing differences in road safety resulting from a shift in modal split, it is important to consider not only the risk for the road users in question, but also the danger they present to other road users.

The differences in road safety, resulting from the various options, depends on:

- Differences in modal split per road-use hour,
 - Differentiate between age groups
- Average involvement/hour in serious road accidents (i.e. risk for yourself + danger to others)
 - Differentiate between the various road-use modes
 - Differentiate between age groups

- Differentiate between gender
- Differentiate between socio-economic classes

When changing design and/or management of roads and intersections (like changing the lay out, or implementing of a specific road safety policy), the changes affect not only the consumers which shifted their travel mode, but all road users. In such a case one needs:

- Total number of road-use hours, and vehicle hours
 - Differentiate between the various road-use modes
 - Differentiate between age groups
 - Differentiate between gender
 - Differentiate between socio-economic classes
- Risk estimates (expressed in relation to the average involvement/hour) for trips under similar (relatively safe/unsafe) circumstances

Liveability, Social Safety, Social Cohesion, and Health

The influence of differences in walking and cycling on Liveability, Social Safety, Social Cohesion, and Health is complicated.

People walking, or cycling may be extra vulnerable to robbery and sexual assault on certain places. But the enhancement of liveability, social safety and social cohesion, on the other hand, asks for the presence of non motorised adults on the street.

Moreover physical exercise, like walking or cycling, helps to enhance ones health. All these effects, resulting from the various options, depend on

- Differences in hours walking, and hours cycling on the street
 - Differentiate between age groups

Infrastructure may also serve as an barrier to non-users of the road, interrupting social cohesion for example. To measure these, infrastructure as a barrier to certain groups of people needs to be mapped. E.g. People may not cycle even if a good cycling provision is offered along the route if a barrier (such as a 2x2 lanes main arterial with fences in the middle) is physically obstructing safe passage.

Noise, Air Pollution, and Contribution to Climate Change

The differences in impact on these aspects depends largely on:

- Differences in motorised vehicle hours resulting from the various options
 - Differentiate between road-use modes
 - Differentiate between gender
 - Differentiate between socio-economic classes
- Average expulsion per vehicle hour of noise, and emissions of various harmful substances
 - Differentiate between road-use modes
 - Differentiate between gender
 - Differentiate between socio-economic classes

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