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USES OF ITS INCLUDING CONSIDERATION OF PLANNING FOR FUTURE IMPROVEMENTS, UPGRADES AND THE ECONOMY

Technical Committee 2.1 *Road Network Operations*
World Road Association

WORLD ROAD ASSOCIATION
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STATEMENTS

The World Road Association (PIARC) is a nonprofit organisation established in 1909 to improve international co-operation and to foster progress in the field of roads and road transport.

The study that is the subject of this report was defined in the PIARC Strategic Plan 2012 – 2015 and approved by the Council of the World Road Association, whose members are representatives of the member national governments. The members of the Technical Committee responsible for this report were nominated by the member national governments for their special competences.

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AUTHORS/ACKNOWLEDGMENTS

This report has been prepared by *Work Group 2.1.2 of the Technical Committee 2.1* Road Network Operations. The report covers a general overview of uses of ITS, examines in some detail the cost benefit analyses considerations for ITS deployments, and explores the use of ITS in developing countries.

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EXECUTIVE SUMMARY

2016R10EN

USES OF ITS INCLUDING CONSIDERATION OF PLANNING FOR FUTURE IMPROVEMENTS, UPGRADES AND THE ECONOMY

Economic growth typically results in an increase of both freight and passenger traffic. This generally compounds the problems in transportation systems. ITS technologies have been widely used to mitigate many of these transportation challenges and will continue to play an increasingly important role in securing the future of sustainable mobility. *Sections 1 and 2* of this report deal with the primary factors that contribute to a sustainable transportation system. It also explores the ITS services employed in improving traffic safety and security, enhancing mobility and network operations.

Section 3 of the report deals in some detail with Cost and Benefit Analysis (CBA) in the transport sector. The CBA allows for a determination of the value of a project by dividing the incremental monetised benefits related to a project by the incremental costs of that project. Given the general scarcity of public funds for the implementation of projects in the public sector, authorities must act prudently in the allocation of such funds for feasible transportation projects. The CBA is thus widely used in the transport sector, all over the world, to conduct such evaluations and assessments. The benefit/cost ratio is regarded as an easy indicator as to whether an investment is economically feasible or not. It also provides a basis upon which to compare ITS investments with other investments, in a generally accepted manner.

The key processes involved in the CBA, as well as full life cycle costing, are discussed in detail. Considerations for CBA that are relevant for developing countries are also explored. The section concludes with a discussion of lessons learnt from various analyses performed and recommendations when conducting the CBA.

The final section, *section 4* of the report deals with ITS considerations in developing countries. Road network infrastructure and transportation systems are amongst the key strategic economic assets of countries across the world. These take on particular significance in the developing world as an enabler for economic development and poverty reduction in facilitating the movement of goods and services for society at large.

Governments in these countries are increasingly aware of the society-wide benefits of ITS deployments and interventions in addressing the commonplace transportation issues such as improving road safety and mobility for people and freight, reducing congestion and managing road network demand. These benefits accrue directly to society at large, through improved reliability in travel and greater efficiency and security in the transportation system.

This part of the report focuses on examining the key challenges faced by developing countries in respect of transportation infrastructure and ITS deployment, a discussion of some the key enabling factors for ITS deployment, and looks at areas where such deployments may find the greatest benefit.

CONTENTS

INTRODUCTION

The Strategic Plan 2012-2015 of the World Road Association (PIARC) contains goals, issues, strategies and outcomes for all Strategic Themes and Technical Committees. The goal for Strategic Theme 2 (Access and Mobility) is to encourage the improvement of access and mobility provided to the community and industry by improving road network operations and increasing integration with other transport modes.

It is recognised that road authorities provide many road network operation services to society. In this area of technology and services there is a need for knowledge-sharing in the experiences of cost-benefit analyses and life-cycle costing in the area of Intelligent Transportation Systems (ITS). In addition to this, a very prevalent issue for many member countries is the maximisation of the benefits derived from road network infrastructure. From a road user perspective, it is particularly important for transportation reliability and sustainability, through leveraging ITS technologies and interfacing such with all transport modes. Working Group 2.1.2 focused on these issues and included an emphasis on developing countries.

As an output, it had to:

1. produce information about more efficient and effective use of ITS from the perspective of the cost and benefit analysis (CBA) considering initial investment in early stage, operating costs and future maintenance cost (full life cycle analysis);
2. explore the particular transportation challenges faced by developing countries; investigate applications of ITS technologies and the areas of focus for ITS in developing countries;
3. update and upgrade the Association's RNO-ITS Web Resource.

1. MAIN CONSIDERATIONS OF ITS

Intelligent Transport Systems and Services (ITS) can be described as the application of information and communication systems and services to transport and related infrastructure (ITS Terminology 2012). ITS cover all transport modes and considers all elements of the transportation system - the vehicle, the infrastructure and the driver or user. Many ITS tools are based on the collection, processing and integration of data and supply of information. ITS based information is used by transportation professionals to improve the overall mobility of people and goods as well as by the public for individual transport needs. ITS applications are used for improving traffic safety and security, helping to relieve congestion and improving the efficiency of the transportation system by addressing all modes of transportation in a sustainable and user friendly way.

Generally, traffic and transportation volumes have risen very rapidly during the last decades all over the world, especially in metropolitan areas and in developing countries. The growth of the economy typically results in an increase of both freight and passenger traffic. This generally compounds the problems in transportation system. ITS have been used to mitigate many of these transportation challenges and it will play an increasingly important role in securing the future of sustainable mobility. One driver for this is that building conventional infrastructure is very expensive and in many cases there is not more space for transport infrastructure enlargement. From the perspective of the transportation system, ITS may be seen as enabling a more efficient use of various transport modes based on real-time information gathering and allowing for more fluent traffic flows. This is enabled by efficient signalling systems in urban areas and freeway management systems on highways. Travel Demand Management is also useful in reducing the level of traffic congestion. It is widely acknowledged that economic growth requires a high-quality transportation network and management system that efficiently connects people and goods.

1.1. ITS FOR A SMOOTHER, SAFER AND MORE SUSTAINABLE TRANSPORTATION SYSTEM

ITS are used to make transportation systems safer. Variable speed limit systems and automatic enforcement can be used to constrain driving speeds and speeding on highways, as well as driving against red traffic lights in urban areas. Decreasing speed plays a big role in mitigating traffic accidents.

ITS is used for better and sustainable mobility. ITS tools differ from urban and metropolitan areas to highways. Travel Demand Management plays a major role in managing traffic volumes to levels the road network can sustain. High-quality real-time traffic information and an efficient public transport system enable people to make accurate decisions to meet their travelling needs.

ITS are used for more effective road network operations. Comprehensive traffic and road weather monitoring systems are essential tools for traffic management centre operators and road maintenance contractors. Traffic information services and automatic operations of traffic control systems for road traffic are based on these monitoring systems. The expectations for the depth of expertise regarding transportation and human behaviour for the traffic management centre operators, is continuously increasing. ITS technologies are also critical in traffic management during incidents and emergency situations.

ITS are used for sustainable mobility. The journey planners and real-time public transport information systems enable more efficient, comfortable and user friendly journeys nowadays. Use of public transport instead of private cars, when possible, eases traffic congestion and reduces GHG emissions at the same time. New ways of multimodal travelling like “Mobility as a service” are coming into use too. With these ITS solutions, people can make the best choice for each trip.

2. TARGETS FOR THE USE OF ITS

An efficient transport system must provide for improved traffic safety and security, less congestion and GHG emissions, in a satisfactory manner for the customers of transportation services. There is a pressing need to reduce the amount of traffic accidents and mitigate the consequences of accidents. Transport should consume less energy, use clean energy and efficiently exploit multimodal, interconnected intelligent transport networks, but without having to restrict mobility [28].

Smooth traffic flow and traffic safety are functionally important targets of transport systems. ITS provides tools to meet these expectations by influencing transportation decisions. Real-time information regarding traffic, road weather forecasts and road conditions can be used for making better decisions regarding travel mode, route and timing for journey planning. ITS is typically based on real-time information of the prevailing traffic conditions and hence there is an expectation of high accuracy of the data.

People tend to follow real-time traffic management more closely than traditional traffic control. To ensure the reliability of the traffic management systems, it must operate efficiently and as planned. Any changes in land use or traffic circumstances must be analysed to update traffic management systems on the area. Without updates, the traffic management systems will lose its credibility very soon. The life-cycle of the components of traffic management systems varies a lot and it is remarkable shorter compared to roads and bridges.

2.1. SYSTEM ARCHITECTURE OF ITS

ITS utilisation is becoming widespread and ITS solutions have to be interoperable with each other. The ITS architecture creates a framework for standard and reliable ITS solutions. The development of an ITS architecture is usually made in cooperation with several stakeholders. The ITS architecture defines the functions that are required for ITS, the physical entities or subsystems where these functions reside and the information flows and data flows that connect these functions and physical subsystems together into an integrated system (National ITS Architecture, US DOT).

2.2. ITS SERVICES

ITS are based on monitoring of prevailing traffic conditions including weather and road weather monitoring. The gathered data is used for better road network operations in traffic management centres and road maintenance centres. Traffic management and road maintenance operations will be put into operation based on information from these centres. Traffic information services and journey planners are typical and widely-used in ITS solutions for all travellers. On the road network different traffic control systems are used, including traffic signalling, variable speed limits and variable sign messaging. Nowadays there are various ways to implement travel demand management systems e.g. open road tolling.

2.2.1. Services for better traffic safety and security

Relevant ITS services (according to PIARC ITS Handbook) include:

- intelligent speed adaptation;
- assistance for vulnerable road users;
- weather and road condition monitoring and information;
- incident detection and warning systems;
- collision warning systems;
- emergency vehicle priority;
- driver monitoring systems;
- speed and traffic signal enforcement;
- hazardous load monitoring;
- cargo screening;
- driver vision enhancement systems;
- evacuation route signing and priority;
- homeland security initiatives such as deployed in USA;
- people with a disability will benefit from better visual and audio presentation of information.

2.2.2. Mobility services

Relevant ITS services for travel demand management (according to PIARC ITS Handbook) include:

- access control;
- road user charging;
- congestion charging.

Relevant ITS services to encourage modal shift (according to PIARC ITS Handbook) include:

- journey planning;
- real-time passenger information systems;
- bus/tram traffic priority.

2.2.3. Network operation services

Relevant ITS services for better efficiency of transportation network (according to PIARC ITS Handbook) include:

- area-wide traffic control;
- long-distance traffic management;
- rerouting guidance;
- variable speed controls;
- ramp metering;
- incident detection and management;
- driver information.

3. THE EFFECTIVE AND EFFICIENT USE OF ITS – COST AND BENEFIT ANALYSIS (CBA) CONSIDERATIONS

3.1. THE NEED AND LIMITATIONS OF CBA METHODS (FOR DECISION MAKERS)

Use of increasingly scarce public funds and the implementation of projects in the public sector for critical users are the responsible tasks of authorities. The authorities have to act in a sensible and sensitive way, taking into account the demands of financial audits and governmental/parliamentary committees. Consequently, evaluation serves as a first step to convincing decision makers on the rationale for project investments. For the pre-investment decision, the assessment allows a clear justification of the future expenditure of money based on generally accepted evaluation procedures and criteria. Afterwards, evaluation will produce an “after the fact” feedback on the investment’s success with the purpose to confirm or modify how and which investments will be made in further ongoing actions and programs. The decision-making process cannot ignore the results of these evaluations without coming to a conflict with the surrounding public representatives.

Cost and Benefit Analysis (CBA) is widely used in the transport sector all over the world to compile the results of such evaluations and assessments. The benefit/cost ratio is regarded as an easy indicator on whether an investment is economically feasible or not. The ratio will also give an indicator with which to compare the ITS investment to other investment in a generally accepted manner. The analysis also clearly indicates the main benefits and costs of the project or investment, while also revealing who will bear the costs and who will reap the benefits. The analysis also provides the cash flows for both costs and benefits during the project's life-cycle.

Examples of the use of CBA can be found for instance in Baum, Geissler, Westerkamp and Vitale (2008) [12] for in-vehicle systems, and in Sisiopoku (2012) for roadside systems

The main limitation to CBA is that not all benefits can be included in the calculations due to the difficulty in valuating these benefits in money. This deals for instance with comfort benefits. An especially important drawback is the difficulty to describe the value of being informed, which has been discussed quite comprehensively [14]. The benefit-cost assessment should cover all relevant benefits and costs of the investment in question, and failure to do so makes the benefit/cost ratio quite useless as a support for decision making and comparisons.

Even the values, which can be valued in money, differ by nature. Some are real money, cash transferred from one stakeholder to another whereas some reflect the money that persons are willing to pay for avoiding a specific outcome like a traffic related injury or willing to accept as a compensation for an outcome.

Cost-benefit analysis is not the only tool available for comprehensive evaluation of transport projects. A number of tools exist for multiple-criteria decision making (MCDM) and multiple-criteria decision analysis (MCDA). MCDM aims to structure and solve decision and planning problems involving multiple criteria in order to support decision makers facing such problems. Often, a unique optimal solution does not exist for such problems and it is necessary to use decision maker's preferences to differentiate between solutions. These preferences can be brought into the analysis, for example, in the form of weights given to some of the criteria used in comparing different alternative solutions. Tools for MCDA include Analytic Hierarchy Process (AHP), Analytic Network Process (ANP), Preference Ranking Organization METHod for Enrichment Evaluation (PROMETHEE), etc.

Cost-effectiveness analysis (CEA) compares the relative costs and outcomes (effects) of two or more courses of action. This is useful in cases where specific effects and performances are being sought for, and one wishes to obtain these effects with as low costs as possible.

While Cost-Benefit Analysis is widely used by public sector stakeholders for socio-economic assessment from the society point of view, it is seldom used by the private sector stakeholders. The private sector stakeholders use different methods for profitability analysis focusing on the direct and indirect economical impacts of the investment on their own company only. For the private stakeholders, profit percentage or ROI are key indicators for decision making.

3.2. COST-BENEFIT ANALYSIS - STEPS OF CBA

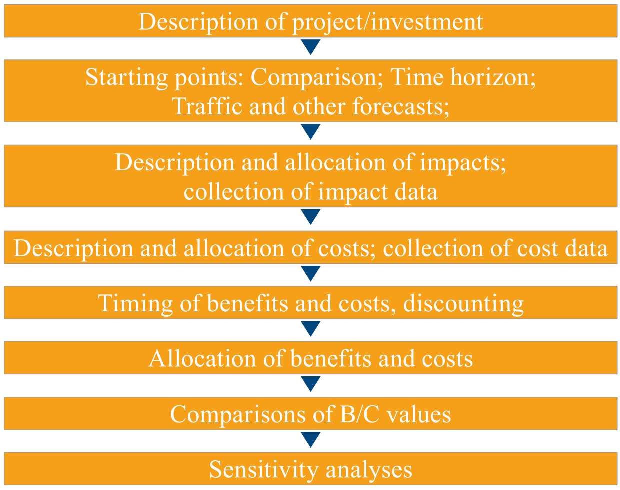

Illustration 1 - The different steps of CBA

The first step is to describe the investment or project in sufficient detail in order to understand why the investment is being considered (what is the problem to be solved?), and the actual content of the investment or project (what exactly is being deployed or implemented?).

Next the starting points need to be clarified. What is the base situation what the measure is being compared to? Usually it is the current situation with no measures, often denoted as "*0*" (zero) situation. Sometimes the situation may be improved somewhat with a routine upgrading or renewal action, the result of which can be used as a comparison "*0+*". In some cases, the situation can be forecasted to be worsening, for instance due to increasing traffic demand and thereby increasing traffic problems. This could be used as "*0-*" situation. The use of any other situation than "*0*" should, however, always be well grounded and explained.

Another starting point is the time horizon for analysis. This is usually related to the life span of the investment, and should cover at least that. An important starting point is also the choice of traffic related forecasts including forecasts of traffic demand, mode choice and volumes, congestion and delays, road accidents and their consequences, exhaust emissions and other environmental impacts, etc. Naturally, the collection of current basic traffic-related data also belongs to this phase.

The next phase deals with the description of the impacts of the investments. This includes the identification and selection of impacts, both direct and indirect so that all relevant impacts will be covered. It is often useful to specifically allocate the impacts to the various stakeholders. The indicators and criteria to be used for the different impacts are selected, and the data on impacts is collected and estimated via the means available.

The next phase carries out a similar procedure for all relevant costs related to the investment. At least the following costs are included:

- investment costs;
- operating and maintenance (O&M) costs.

The valuation of impacts is carried out in the next phase with the help of unit costs, which have been agreed upon nationally. See Maibach et al (2008) and the updated handbook on external costs [16], [34] for a discussion of this. The following impact values or costs are usually included:

- change in accident costs;
- change in time costs;
- change in vehicle operating costs;
- change in environmental costs;
- market-price impacts on the economic status of private persons (e.g. changes in service prices), on corporate economy, and on costs – not project-related – of transport infrastructure operators.

In the next phase, all benefits (revenues) and costs are estimated for each year of the life span of the investment (see illustration below), and then discounted. Discounting is carried out using the standard discounting rate used for all transport investments nationally.

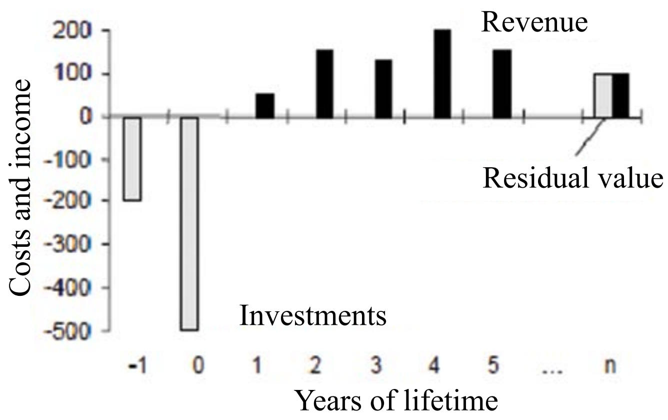

Illustration 2 - Example of the timing of the expenses and revenue of an its project (kulmala et al 2004)

When calculating the sums of the benefits and costs, the Benefit/Cost ratio or B/C is calculated as: (socio-economic benefits - O&M costs) / investment costs. In this case, the benefit/cost ratio is calculated using the net principle, which means that the overall socio-economic impact is divided by the investment costs. The system's operating and maintenance costs are thus subtracted from the overall benefits, and the residual value is seen as profit.

Next, the benefits and costs may be allocated to different stakeholders, if this is relevant for the decision makers or the users of the analysis.

Finally, the B/C values are compared to those of feasible alternatives or other investments. If there are no other investments to be compared to, the B/C ratio should be at least 1 or more.

The last phase contains sensitivity analyses, if any. These should be made of the main uncertainty factors of the benefit/cost ratio. These uncertainty factors include traffic forecasts, the budget and any uncertainties associated with impact evaluations. Sensitivity analyses also have to examine the risks involved with the realisation of cost components, such as the financing risk. Sensitivity analyses are often especially necessary when similar projects have not been implemented before, making the uncertainty associated with the impacts particularly great. One good example of sensitivity analyses is the FHWA study from 2009 [29], where the amount of benefits were estimated using different assumptions to check how sensitive they were to the assumptions made.

3.3. KEY COMPONENTS OF CBA (WHAT CAN BE MEASURED)

There are three kinds of indicators, these being:

Direct benefits and costs: These are direct after-effects of the project, or effects of the direct use of the project. Typical examples are travel time savings, accident costs, vehicle operating costs, investment costs; maintenance and operating costs.

Indirect benefits and costs: These are effects, caused to other persons and not to the direct beneficiaries of the project (additional production or cost reduction, and prevention of damages). The external costs of transport are typical examples of these groups. These can be additional health cost due to noise and air pollution, damages to material and the biosphere.

Intangible benefits and costs: This group of indicators cannot be monetised or measured in a cardinal scale (e.g. how beautiful is a landscape or what the amenity value of a street for relaxation is).

The CBA requires that all indicator values are transformed into a monetary value. This means the indicator must be monetisable and it must be able to measure the indicator in a cardinal scale. Therefore, intangible benefits and costs cannot be included into the CBA. It is only possible to include them as additional arguments by changing the order of alternatives, with the order of alternatives being the result of the cost/benefit ratio.

The direct and indirect benefits and costs can be translated into monetary terms by using approaches such as, cost of damages, avoidance of costs and opportunity costs. The costs of damages can be analysed by using several methods:

- the assessment of the dose-effect relationship analysis, the damages which are caused by pollutants, noise emissions, etc. The costs are allocated to damages;
- the assessment of restoration costs is calculating the costs necessary to restore the damages to health, goods, materials, etc.;
- the concept of willingness to pay is evaluating how much the persons concerned are willing to pay for e.g. environmental improvements. The willingness to accept is using the opposite method. It is assessed by how much one has to pay to the persons concerned so that they accept e.g. certain levels of pollution and the resulting impairment of their quality of life.

The approach costs of avoidance involves analysing the costs necessary to avoid the damages. It calculates the costs, which will arise, for example, to prevent certain levels of emission. The amount of avoidance costs depends highly on the level of reduction. The amount increases with rising reduction levels. The monetisation can also be done by calculating the costs of the alternative use of a scarce factor. This method is called opportunity costs.

All approaches use very different concepts for calculating the monetary value. This means that the same indicator value, translated with different monetisation methods, will deliver different monetary values. As an example, a high air emission level will deliver a high monetary value if the dose-effect relationship methods (cost of damages) will be used. However, the monetary value will be low if the costs of avoidance with a low avoidance level are used. This problem makes it critical to combine indicators, which are translated with different monetisation approaches because they describe different economic concepts.

Typical components of benefit and cost items are presented in *Table 1* below.

TABLE 1. BENEFIT AND COST CATEGORIES AND ELEMENTS [8]		
Agency benefits/costs	User benefits/costs associated with TSMO and RWM Projects	Externalities (non-user impacts, if applicable)
• design and engineering; • land acquisition; • construction; • reconstruction/rehabilitation; • preservation; • routine maintenance; • mitigation (e.g., noise barriers).	• travel time and delay; • reliability; • crashes; • vehicule operating cost.	• emissions; • noise; • other societal impacts.

The impacts of a particular alternative do not always fall neatly into benefit or cost categories. An alternative may reduce agency costs, which is a benefit. Similarly, an alternative may reduce crash rates (a benefit) relative to the base case while another alternative may increase crash rates (a cost, also called a negative benefit or disbenefit) relative to the base case. Care must be taken to ensure that all costs and benefits of each alternative are fully and accurately accounted for.

Tolls, taxes, and other user charges for transportation projects constitute important potential revenue sources to agencies for financing transportation projects. However, these revenue sources are not “benefits” of a project as measured by economic analysis such as CBA. Rather, these charges represent a means by which some of the benefits to the users of the transportation project (as measured by their implicit willingness to pay for reduced travel time or improved safety) can be transferred in whole or in part (in the form of cash payments by the users) to the state or private agency that operates the facility. Adding toll or tax revenues to the value of travel time, safety, and vehicle operating cost benefits already included in the CBA would be double-counting benefits [8].

The valuation of each of the major elements listed above is described below, mostly based on FHWA guidelines.

The assignment of monetary values to the design and construction of a project is perhaps the easiest valuation concept to understand. Engineers estimate these costs based on past experience, bid prices, design specifications, materials costs, and other information. Care must be taken to make a complete capital cost estimation, including contingencies and administrative expenses such as internal staff planning and overhead costs. A common error in economic analysis and budgeting is the underestimation of project construction and development costs. Particular care should be used when costing large or complicated projects.

Expenses associated with a project’s financing, such as depreciation and interest payments, are not included in the CBA. The equivalent value of such expenses is already captured through the application of the discount rate to the agency cost of the project. Adding depreciation or interest expenses to agency costs in a CBA in most cases would lead to double counting costs.

Concerning travel time, delay, and reliability, an hour of travel associated with a business trip or commerce is usually valued at the average traveller's wage plus overhead—representing the cost to the traveller's employer. Personal travel time (either for commuting or leisure) is usually valued as a percentage of average personal wage or through estimates of what travellers would be willing to pay to reduce travel time. Recently researchers have identified another important benefit: travel time reliability. Due to uncertainty in travel time, travellers add "buffer time" to their trips to ensure they arrive at their destination on time. The "buffer time" impacts should also be included in CBA.

The assignment of monetary values to changes in crash rates or severities can provoke controversy because crashes often involve injury or loss of life. The use of reasonable crash values is critical, however, to avoid underinvesting in highway safety. Economists often use the dollar amounts that travellers are willing to pay to reduce their risk of injury or death to estimate monetary values for fatalities and injuries associated with crashes. Medical, property, legal, and other crash-related costs are also calculated and added to these amounts. U.S. DOT offers guidance on this subject in its guidance on treatment of the economic Value of Statistical Life (VSL) [7].

Concerning vehicle operating costs, the cost of owning and operating vehicles can be affected by a project due to the changes that it causes in highway speeds, traffic congestion, pavement surface, and other conditions that affect vehicle fuel consumption and wear and tear. Accurate calculations of a project's effects on vehicle operating costs require good information on the relationship of vehicle performance to highway conditions and clear assumptions about future vehicle fleet fuel efficiency and performance. Benefits attributable to lower vehicle operating costs are usually not a major component of a project's benefit stream [17].

One of the more challenging areas of CBA is the treatment and valuation of the "externalities" of transportation projects. In economics, an externality is the uncompensated impact of one person's actions on the well-being of a bystander. In the case of transportation investments, "bystanders" are the nonusers of the project. When the impact benefits the nonuser, this is called a positive externality. When the impact is adverse, this is called a negative externality. Often, when there is talk about externalities of highways, the focus is on negative externalities. Negative externalities include the undesirable effects of a project on air and water quality, noise and construction disruptions, and various community and aesthetic impacts. Positive externalities, however, also exist. A project may serve to reduce air or noise pollution from previously existing or projected levels.

Several methods exist for including externalities in a CBA. In some cases, scientific and economic studies have revealed per-unit costs for air pollutants, for example, that can be incorporated directly into the CBA. Much uncertainty surrounds these valuations, however. Values can vary from project to project due to location, climate, and pre-existing environmental conditions. Risk analysis techniques can yield helpful information about the sensitivity of results to these uncertain values. Externalities are specifically dealt with in environmental assessments required by governments, e.g. the National Environmental Policy Act in the USA. Where adverse impacts are identified, mitigation is required to avoid, minimize, or compensate for them. Required mitigation is part of the environmental decision, and the costs of mitigation will become "internalized" in the project's cost in the CBA. The CBA effort should be coordinated closely with the environmental assessment.

When an externality cannot be put into dollar terms, it can often be dealt with on a qualitative basis relative to other, monetized components of the CBA. If the measurable net benefits of a project are highly positive, the presence of minor unquantified externalities can be tolerated from an economic standpoint even if they are perceived to be negative. On the other hand, if the net benefits are very low, then the existence of significant unquantified negative externalities may tip the economic balance against the project [17], [15].

Externalities considered in a CBA are the uncompensated direct impacts of the project on non-users of the project. These effects are additive to other direct costs and benefits (such as the value of time saving or reduced crashes and saved lives) measured in the CBA. Direct effects, however, usually lead to indirect effects on the regional economy through the actions of the marketplace. Indirect impacts of a transportation project could include local changes in employment or land use. The value of indirect effects is not often additional to that of direct effects measured in CBA; rather, indirect effects are often a restatement or transfer to other parties of the value of direct effects. Projects can also have indirect effects that can be included in the analysis, but these need to be specified carefully in order to eliminate double counting.

Another aspect receiving increasing attention is the internalisation of external costs (especially negative externalities) to make such effects part of the decision making process of transport users. According to the welfare theory approach, internalisation of external costs through the use of market-based instruments may lead to a more efficient use of infrastructure, reduce the negative side effects of transport activity and improve the fairness between transport users.

In contrast to the benefits, the costs of these effects of transport are not fully borne by transport users and without policy intervention, they may not be taken into account by transport users when they make travel decisions. Transport users are thus faced with incorrect incentives, leading to welfare losses.

Externality impact categories included the following:

1. congestion;
2. accidents;
3. noise;
4. air pollution;
5. climate change;
6. other environmental impacts (costs of up- and downstream processes);
7. infrastructure wear and tear for road and rail.

As indicated in the preceding paragraphs, although the estimation of external can be quite challenging due to several uncertainties, there is at least consensus on the major methodological issues for determining the costs.

The best practice estimation of congestion costs is based on speed-flow relations, value of time and demand elasticity. For air pollution and noise costs, the impact pathway (or damage cost) approach is broadly acknowledged as the preferred methodology. The valuation of the respective health effects is based on the willingness to pay concept. Marginal accident cost can be estimated by the risk elasticity approach, using values of statistical life. Given long-term reduction targets for GHG emissions, the abatement cost approach (in contrast to the damage cost approach used for other environmental impacts) is the best practice for estimating climate cost. Other external costs exist, e.g. costs related to energy dependency, but there is for the time being no scientific consensus on the methods to value them. [34]

Table 2 below provides an indication of the typical benefits and costs for an ITS intervention using a wind warning system and reflects the primary direct costs for the impacts.

TABLE 2. BENEFIT COST CALCULATIONS FOR AUTOMATED WIND WARNING SYSTEMS [8]

	South Coast		Yaquina Bay Bridge	
	Average*	High**	Average*	High**
Number of closures per year	5	10	30	30
Benefits				
Direct savings from non-closure	$5,135	$10,270	$11,940	$17,910
Delay reductions from non-closure	$41,715	$73,725	$242,570	$46,200
Delay reductions from quicker deactivation	$2,980	$5,275	$18,960	$35,350
Costs				
initial installation costs (non-recurring)	$90,000		$90,000	
power, communication and maintenance (recurring)	$3,000		$3,500	
B/C ratio* **				
direct benefits alone	0.87		1.46	
direct and indirect benefits	4.13		22.80	
Number of years before benefits exceed costs				
direct benefits alone	12 years		7 years	
direct and indirect benefits	3 years		1 years	

* « *Average* » scenario includes average number of wind events and average traffic volumes.
** « *High* » scenario includes high number of wind events and high traffic volumes.
*** B/C ratio is calculated based on « *average* » benefits.

3.4. OBJECTIVES AND BENEFITS FOR THE PROJECTS

ITS will solve a multitude of problems, and help to meet a number of different public, political, economical, technical, and social objectives. *Table 3* below illustrates the typical policy objectives affected by the various types of ITS services.

TABLE 3. TYPICAL OBJECTIVES AFFECTED BY ITS SERVICE TYPES

Service	Network and its costs	Fleet and its costs	Accessibility	Travel time	Traffic safety	Environ-nement	valuations, comfort
Traffic information			Major impact	Some impact	Some impact		Major impact
Demand mgmt	Major impact	Some impact	Some impact	Some impact		Some impact	Some impact
Traffic control	Some impact			Major impact	Major impact	Some impact	Some impact
Incident mgmt				Major impact	Some impact	Some impact	Some impact
Freight&fleet mgmt		Major impact		Major impact		Some impact	
Driver support			Some impact	Some impact	Major impact	Some impact	Major impact
Enforcement	Some impact	Some impact		Major impact	Major impact	Some impact	Some impact

SOME IMPACT (light green) — MAJOR IMPACT (dark green)

Naturally, individual ITS services will each have its own impacts. For instance, eco-driving support systems will primarily have environmental effects although typically driver support systems are safety and comfort systems. A number of reviews of impacts, benefits and costs have been made to compile the impacts and socio-economic profitability of different ITS systems. The table below provides one such compilation from Europe.

TABLE 4. ESTIMATED IMPACTS OF SELECTED ITS SERVICES ON SAFETY, CONGESTION AND GHG AND ESTIMATES OF THEIR BENEFIT-COST RATIOS.

Travel information services	Impact on fatalities/ injuries	Impact on congestion	Impact on CO2	Benefit/ Cost
Travel information services				
RT (Real Time) event information	-	- 1...- 15 %	- 1...- 10 %	1...2,5
RT traffic condition information	-	- 1...- 15 %	- 1...- 10 %	2...6
Travel time information	-	- 1...- 15 %	- 1...- 10 %	2...6
Weather information	- 2...- 4 %	-	-	3...8
Speed limit information	- 2...- 10 %	- 2...- 10 %	- 2...- 10 %	
Parking information and guidance	0	-	-	
Local hazard warning	- 2...- 10 %	- 2...- 10 %	-	
Multimodal traffic information	-	-	-	10...72
Predictive traffic conditions info	-	- 1...- 15 %	- 1...- 10 %	
Dynamic route guidance	-	- -	- -	
Emergency vehicle warning	-	-	-	
Wrong way driving warning	-	-	-	
Limited access warn., detour notif.	-	-	-	
Traffic Management services				
TM of sensitive road segments	- 6...- 30 %	- 5...- 10 %	-	0,7...12
Incident Management	-	- 5...- 20 %	- 5...- 15 %	2-4
Road user charging	--	- 10...- 20 %	- 10...- 20 %	> 1
TM services/systems, e.g. ramp ctrl	- 10...- 20 %	- 10...- 30 %	- 10...- 30 %	4...27
Strategic corridor/network TM	-	- -	-	2...15
Recommended speed profiles	-	- -	- -	
Priority lane	0	- -	-	
Requesting green/signal priorities	-	- 1...- 2 %	- 1...- 3 %	0,7...7,5
Freight and logistic services				
Intelligent truck parking	-	-	-	
Other services				
ECall	- 1...- 8 %	- 0,5...- 3 %	-	0,5...3
Intelligent Speed Adaptation (ISA)	- 10...- 20 %	- 2...- 10 %	- 2...- 10 %	5-17

NB: In the absence of quantitative estimates, a small expected reduction is denoted by "-" and a considerable expected reduction by "- -" [30]

Note that impacts are for the drivers of the vehicles or for the road sections equipped with the systems or services, also that the CO_2 impacts are closely related to energy efficiency impacts.

3.5. LIFE CYCLE COSTS

There is a wide array of ITS solutions to address nearly every transportation challenge. Many ITS solution developers agree that the most advanced challenge is not the technology, but rather the organisation itself. This is typically the consequence of misunderstood expectations regarding costs to plan, design, implement, and operate a functioning system. These challenges can be overcome through the development of cost estimates that consider the full life cycle of the system.

The development of life cycle costs involves more than the summation of costs for all the field devices, communications, and systems integration. Systems engineering enables a process for mitigating all the risks. If we could accurately predict the future, it would be easy to avoid mistakes and problems. However, in real life, we need to deal with uncertainty and risk. Systems engineering focuses on three aspects of uncertainty and risk management: identification, analysis and mitigation of risks.

The team considering the ITS implementation needs to consider the importance of each issue and problem and determine what is known. One way to analyse the issues and problems is to rank-order them according to their importance and the degree of uncertainty in the knowledge about them. This organises them into a 3x3 matrix (shown below) that establishes clarity on your needs so that you can avoid expensive re-design costs.

Cost if Event Occurs				
	High	3	6	9
	Medium	2	4	6
	Low	1	2	3
		Low	**Medium**	**High**
		Probability of Occurrence		

Illustration 3 - Assessment of importance vs. Uncertainty [17]

Implementation is an extremely critical stage because, once the system concepts are embodied in the system products, making changes becomes much more expensive. The table below illustrates the experience software development organizations have had with the relative cost of making changes in software-intensive systems. By their nature, ITS systems are software-intensive.

TABLE 5. COMPARISON OF RELATIVE COSTS BY SYSTEM LIFE CYCLE STAGE [10]

System Stage	Minimum Cost	Maximum Cost
Requirements Analysis	$1	$1
Design	$3	$6
Implementation	$10	$40
Integration and Testing	$30	$70
Operation and Maintenance	$40	$1,000

TABLE 6. UNDERSTANDING THE LONGEVITY OF THE TOOLS IS ALSO A FACTOR IN DEVELOPING THE LIFE CYCLE COSTS [17]

Subsystem	Lifetime (Years)
Roadside Telecommunications (RS-TC)	
DS3 Communication Line	20
Wireless Communications, High Usage	20
Call Box	10
Roadside Detection (RS-D)	
Inductive Loop Surveillance on Corridor	5
Remote Traffic Microwave Sensor on Corridor	10
Remote Traffic Microwave Sensor at Intersection	10
CCTV Video Camera	10
CCTV Video Camera Tower	20
Environmental Sensing Station (Weather Station)	25

Subsystem	Lifetime (Years)
Roadside Control (RS-C)	
Signal Controller Upgrade for Signal Control	20
Signal Pre-emption Receiver	5
Signal Controller Upgrade for Signal Pre-emption	10
Ramp Meter	5
Software for Lane Control	20
Lane Control Gates	20
Fixed Lane Signal	20
Roadside Information (RS-I)	
Roadside Message Sign	20
Wire line to Roadside Message Sign	20
Variable Message Sign	20
Variable Message Sign Tower	20
Variable Message Sign – Portable	14
Highway Advisory Radio	20
Highway Advisory Radio Sign	10
Roadside Probe Beacon	5
LED Count-down Signal	10
Roadside Rail Crossing (R-RC)	
Rail Crossing 4-Quad Gate, Signals	20
Rail Crossing Train Detector	20
Rail Crossing Controller	10
Rail Crossing Pedestrian Warning Signal, Gates	20
Rail Crossing Trapped Vehicle Detector	10
Parking Management (PM)	
Entrance/Exit Ramp Meters	10
Tag Readers	10
Database and Software for Billing & Pricing	10
Parking Monitoring System	10
Hardware	5
Toll Plaza (TP)	
Electronic Toll Reader	10
High-Speed Camera	10
Electronic Toll Collection Software	10
Electronic Toll Collection Structure	20
Remote Location (RM)	
CCTV Camera	10
Integration of Camera with Existing Systems	10
Informational Kiosk	7
Integration of Kiosk with Existing Systems	7
Kiosk Upgrade for Interactive Usage	5
Kiosk Software Upgrade for Interactive Usage	5
Transit Status Information Sign	10
Smart Card Vending Machine	5
Software, Integration for Smart Card Vending	20
Emergency Response Centre (ER)	
Emergency Response Hardware	10
Emergency Response Software	10
Emergency Management Communications Software	20
Hardware, Software Upgrade for E-911 and Mayday	10
800 MHz. 2-way Radio	5
Transportation Management Centre	
Hardware for Signal Control	5
Software, Integration for Signal Control	5
Hardware, Software for Traffic Surveillance	20
Integration for Traffic Surveillance	20
Hardware for Freeway Control	5
Software, Integration for Freeway Control	5

Subsystem	Lifetime (Years)
Hardware for Lane Control	5
Software, Integration for Lane Control	10
Software, Integration for Regional Control	10
Video Monitors, Wall for Incident Detection	5
Hardware for Incident Detection	5
Integration for Incident Detection	20
Transit Management Centre	
Transit Centre Hardware	10
Transit Centre Software, Integration	20
Upgrade for Auto. Scheduling, Run Cutting, or Fare Payment	20
Integration for Auto. Scheduling, Run Cutting, or Fare Payment	20
Further Software Upgrade for E-Fare Payment	20
Vehicle Location Interface	20
Video Monitors for Security System	10
Hardware for Security System	10
Integration of Security System with Existing Systems	20
Commercial Vehicle Check Station (CC)	
Check Station Structure	20
Signal Board	10
Signal Indicator	20
Roadside Beacon	10
Wire line to Roadside Beacon	20
Check Station Software, Integration	20
Check Station Hardware	10
Detection System	10
Software Upgrade for Safety Inspection	20
Handheld Safety Devices	5
Software Upgrade for Citation and Accident Recording	20
Weigh-In-Motion Facility	10
Wire line to Weigh-In-Motion Facility	10
Wire line to Weigh-In-Motion Facility	10

3.6. EVALUATION TOOLS AND REPOSITORIES

Evaluations are critical to ensuring progress toward the vision of integrated intelligent transportation systems and achieving ITS deployment goals. Evaluations are also critical to an understanding of the value, effectiveness, and impacts of the ITS Program activities and to allow for the continual refinement of the ITS Program's strategy.

Evaluation should be considered an integral part of the project development process, and be considered in each phase: strategy formulation, detailed planning, system design, system implementation, data collection, data analysis, and reporting of results. Evaluations should be performed by an independent party who has no vested interest or stake in the project itself.

Tracking of both program outputs and outcomes is valuable for designing an effective evaluation. Program outputs track the progress of a program (e.g. the number of toll plazas equipped with electronic toll collection capability). Program outcomes track the benefits of a program from the perspective of the end-user (e.g. reduction in delay waiting to pay tolls). Another activity is outreach, where evaluation results are communicated to select target audiences in ways that are meaningful to them. In addition, under ITS Evaluation sponsorship, in-depth studies are conducted concerning modelling and simulation of the impact of ITS deployments, estimating the costs and benefits of ITS technologies, determining user acceptance of ITS products and services, and investigating institutional and policy issues related to ITS.

The ITS Knowledge Resource website [15] presents information on the benefits, costs, deployment levels, and lessons learned regarding ITS deployment and operations. These Knowledge Resources were developed by the U.S. DOT's ITS Joint Program Office (JPO) evaluation program to support informed decision making regarding ITS investments by tracking the effectiveness of deployed ITS. The Knowledge Resources contain over fifteen years of summaries of the benefits, costs, lessons learned, and deployment status of specific ITS implementations, drawn primarily from written sources such as ITS evaluation studies, research syntheses, handbooks, journal articles, and conference papers.

TABLE 7. THE ITS KNOWLEDGE RESOURCES SITE INFORMATION (AS OF OCTOBER 2014)

Database	Number of Entries	Number of Source Materials
Benefits	838	565
Costs	302 (System Cost) 4,142 (Unit Cost)	246
Lessons Learned	587	

ITS Benefits Database entries are short summaries of ITS evaluations and their findings with regard to the effect of ITS on transportation operations. The database organizes these findings into six goals of ITS deployment identified by the U.S. Department of Transportation - safety, mobility, efficiency, productivity, energy and environmental impacts, and customer satisfaction.

A typical entry includes three elements:

- system Description;
- evaluation Techniques;
- findings.

The ITS Costs Database contains two types of entries: unit costs and system cost summaries. Unit costs are the costs associated with an individual ITS element, such as a video camera for traffic surveillance or a dynamic message sign. A range of costs (e.g. $500 - $1,000) is presented for the capital cost and annual operations and maintenance cost of each element as well as an estimate of the length in years of its usable life. System cost summaries are the costs of an ITS project or portion of an ITS project such as the cost of expanding a state-wide road weather information system or the detailed costs for a signal interconnect project.

A lesson learned is the knowledge gained through experience or study. It is a reflection on what was done right, what one would do differently, and how one could be more effective in the future. An ITS stakeholder experience of what worked and what did not work in the procurement of traffic management systems software is a valid candidate for the Lessons Learned Knowledge Resource. Each lesson captured in the ITS Lessons Learned Knowledge Resource is described in a concise format.

3.7. CONSIDERATIONS FOR DEVELOPING COUNTRIES

Prior to initiating any analysis, practitioners are encouraged to carefully weigh the factors influencing the analysis approach. Careful assessment of the analysis needs and mapping to an appropriate analysis method or tool will provide for a better use of scarce analysis resources, and help minimize the possibility of discovering that the selected analysis method is incapable of successfully completing the analysis when the evaluation is half-finished.

The factors below present expanded discussion of multiple factors that should be considered in selecting a methodology and customizing an analysis approach. These factors include:

Geographic scope - Some strategies may be deployed and influence only a limited geographic area, such as an intersection, a freeway interchange, or a single corridor. Other strategies may be deployed on multiple corridors or even region wide (e.g., traveler information systems). Prior to developing the analysis approach, practitioners should carefully assess the possible impacts of the operations strategy to be analyzed, and determine the likely geographic extents of the impacts to various regional facilities. It is important that the analysis be designed to fully capture not only the impacts at facilities immediately adjacent to the proposed deployment, but also capture broader network impacts due to likely traveler changes in route mode or time of travel. For example, an analysis of a ramp metering deployment should not only attempt to assess the change in roadway performance within the immediate merge area, but also should attempt to include an assessment of conditions in the ramp queue, at adjacent intersections, and possibly on parallel arterials or freeway facilities, if they are likely to be impacted by the deployment. Failure to include all the likely facilities and modes likely to be impact by a strategy risks understating or overstating the benefits of the strategy.

Types of strategies - The type of strategy, or combinations of strategies, to be analyzed and compared within the CBA analysis is a key factor in determining the analysis approach. At the most basic level, the analyst should first determine if the analysis would need to:

- only evaluate and prioritize operations strategies compared with each other;
- compare operations strategies alongside alternative scenarios with more traditional capacity enhancements; or
- evaluate various alternative scenarios containing combinations of operations and more traditional capacity enhancements.

Need/purpose of study - In early planning phases, for example the preliminary screening of alternatives, there is often a need to quickly conduct high-level, order-of-magnitude analysis of a large number of alternative scenarios. This analysis would likely require an approach that could be quickly implemented and repeated for a number of scenarios; however, the level of detail in the analysis may not be as critical. Alternatively, at the other end of the planning spectrum during the final alternative prioritization and design process, there may be the need to conduct very detailed analysis of a small number of scenarios.

Desired Measures Of Effectiveness (MOE) - Different operations strategies often may have impacts on different MOEs. Likewise, different regions may place a higher priority on particular MOEs. For example, a region that is in non-compliance for a particular emissions category may have requirements that an assessment of that measure be included in all regional analysis.

Therefore, the analyst should carefully consider the MOEs to be used in the analysis when setting up the approach and making decisions on applicable analysis tools.

Required level of confidence in results - While the level of confidence in the results is largely a product of the analysis tool or method selected, it is also related to the amount of effort put into customizing, calibrating, and validating the various tools. For very simple analysis requiring order-of-magnitude detail, practitioners may choose to simply apply parameters, impact measures, and benefit values based on national averages. As the need for greater confidence in the level of accuracy increases, practitioners will want to place greater effort on identifying and applying customized analysis parameters within the selected method/tool that more closely match the local experience and traffic conditions.

Available analysis resources - The analysts and their managers should then carefully weigh the needs of the analysis with the projected costs. The estimate of resources should also consider the contingency costs of conducting any additional analysis, or evaluating new alternatives that may arise during the project prioritization process. If, during this assessment, the project needs and the available resources are found to not be aligned, then the analysts and their managers need to seek a balanced resolution, but either cutting scope and/or requirements from the analysis (e.g. lessening the number of alternatives to be analyzed or reducing the complexity of the analysis); or by increasing the available resources to meet the needs of the analysis. Failure to do so will result in either a cost overrun, a poorly conducted analysis that does not meet its original intent, or both.

The table below estimates a "typical" analysis. Actual time and budget resources would be dependent on the number of alternatives, geographic scope, and effort required to compile the appropriate input data

TABLE 8. TYPICAL ANALYSIS COSTS [31]

Method/Tool	Resources Required
Sketch planning	Budget – Low ($1K to $25K)
	Schedule – 1 week to 8 weeks
	Staff Expertise – Medium
	Data Availability – Low
Post-processing methods	Budget – Medium/High ($5,000 to $50,000)
	Schedule – 2 months to 1-year
	Staff Expertise – Medium/High
	Data Availability – Medium
Multi-resolution/multi-scenario	Budget – High ($50,000 to $1.5 million)
	Schedule – 3-months to 1.5-years
	Staff Expertise – High
	Data Availability – High

The factors presented above often comprise the most critical determinants in identifying and planning a successful analysis approach. There is often the need to carefully balance the tradeoffs between the various factors (e.g., more robust analysis often requires additional resources to complete) in the final selection of an appropriate analysis approach.

3.8. LESSONS LEARNT

The strength of CBAs lies within the easiness and comprehensibility of their results to all levels of stakeholders. However, the simplification and normalisation of elements of such a diverse nature also creates several disadvantages that make a thorough CBA difficult to conduct.

On the prediction stage of benefits, side-effects and secondary benefits are difficult to assess in an accurate way. In many cases the working mechanisms are too complicated or subjective to be approximated by mathematical methods, or they are simply not fully understood. Especially if simulations are used to predict impacts and benefits, the extent of the models necessary to capture all secondary effects becomes too large and uneconomical.

In the monetisation process, cost rates have to be multiplied with benefit indicator values. Those rates are determined by assuming either the willingness of people to pay for those benefits or the economic damage caused by their absence. The rates are often given in guidelines provided by public authorities. In either case they are based on assumptions or average value evaluations and thus lack adaptability to local requirements of the ITS application area. Intangible benefits are in most cases neglected in the monetization. Also during the composition of a final benefit value, weights are being introduced in order to allow stakeholders to control the process according to their own policy premises. Thus, an overall useful instrument reduces the comparability of different case studies and affects the transparency of the analysis towards third parties.

To cope with these uncertainties, alternative assessment methods, as already partly outlined above, have to be considered. Costly large scale deployments might still require classical CBAs, however the decision making process can become more transparent and controllable by providing an adjusted methodology. The problem of the complex secondary benefits can be solved by maintaining a narrower consideration and focussing primarily on the direct impacts of the application. Given the distinct target of ITS, a large scale benefit analysis might rather blur out the actual value of the applications.

The monetisation process is also an element of the analysis that can be omitted, especially if intangible benefits play an important role for the application. One alternative is the so called cost-effectiveness-analysis that involves a more descriptive presentation of benefits. A flexibility that on the other hand introduces elements of subjectivity in the decision making process.

Issues with the transparency of the analysis can be solved by abstaining from simplifications and presenting a more diverse scope of benefits. Alternative methods are the "multiple criteria decision analysis" and the so-called "balancing and discussion". The criteria consist of primary and secondary benefits as well as costs. The methodologies also allow conflicts between the criteria e.g. between efficiency and cost. The consideration is more difficult compared to the one-value CBA. However, through balancing and discussion, decisions upon multiple alternatives can become manageable and transparent.

Apart from the important task to thoroughly select the most suitable and most sensitive method for a comparative (ex-ante or ex-post) evaluation of ITS implementations, there is increasing need for an internationally harmonized terminology and agreed definition of ITS, ITS subsystems and ITS measures. A few approaches to that task were undertaken over the last years, when ITS became more widely used. Although there is still some variation in the details, the main aspects are meanwhile consistently understood. The PIARC ITS Handbook together with its web based version (which is produced within the PIARC cycle 2014-2017), reflects the latest status in that aspect and should be taken as reference, if possible.

A further necessity, aside from selecting methodology and agreeing on ITS-definitions, is the choice of meaningful Key Performance Indicators (KPI). These KPI in most cases need to be collected (observation, measurement, interrogation, etc.) over longer time intervals, where the preconditions should be carefully considered and fixed in time, otherwise it will not be able to achieve statistical significance and validity of conclusions.

If a comparison with other, comparable ITS installations is intended, benchmarks and knowledge databases are useful. A few international projects and initiatives over the last years did start to address this aspect, e.g. the European FP7-project CONDUITS, the European POLIS initiative of larger cities and the FHWA driven initiative of the ITS-knowledge Resource website (see examples above). In parallel, several national documents and handbooks reflect the specific national definitions, requirements and experiences are available, e.g. US HCM, German HBS.

With respect to specific areas of ITS deployments, the highest productivity impacts in terms of cost savings, cost-benefit ratio, or cost-effectiveness measures, are found in commercial vehicle operations, intermodal freight, road weather management systems, freeway management, traffic incident management, transit management and traveller information evaluations [33].

3.9. CBA BEST PRACTICES AND RECOMMENDATIONS

For making decisions on the deployment of ITS, reliable information is needed on the benefits and costs of the ITS service or system in question. In order to have that information and knowledge, the aspects detailed hereunder are important.

1. the conducting of ex-post evaluation studies to assess the impacts of ITS deployment is an important step. This is especially relevant when not enough knowledge and information of the ITS service in the current use context has been accumulated;
2. ex-post evaluations with an appropriate experimental design to eliminate the bias of any confounding factors must be conducted. There must be sufficient data collection carried out to ensure statistically reliable estimations of the effects;
3. the evaluation of impacts, benefits and costs should also always be accompanied with a study on the technical performance of the ITS service or system. This is essential since it is known that a good quality service, one with high technical performance, will have more impacts, benefits and costs than a service of poorer quality. Hence, the magnitude of the impacts, benefits, and costs are always closely linked to the technical performance of the service, and the technical performance information should thereby always accompany the impact, benefit and cost information;
4. widely used KPIs to measure and describe the impacts of ITS must be employed. This facilitates the comparison, combination and synthesis of results from different studies to reach a more reliable estimate of the magnitude of the impacts;
5. the attachment of widely agreed monetary values to all relevant ITS impacts (those having established value to users), must be adopted. The most important of such is the value of being informed. People are clearly willing to pay for being kept informed, but thus far, allocating a monetary value to this type of impact, has proved elusive. Further research is needed to develop this;
6. the transferability for any results on impacts and benefits/costs must be clearly described so that the users of the results can immediately determine whether the results will apply to their specific use context and operating environment.

4. ITS CONSIDERATIONS FOR DEVELOPING COUNTRIES

4.1. INTRODUCTION

Road network infrastructure and transportation systems are amongst the key strategic economic assets of countries across the world. These take on particular significance in the developing world as an enabler for economic development and poverty reduction in facilitating the movement of goods and services for society at large.

This part of the report thus focuses on examining the key challenges faced by developing countries in respect of transportation infrastructure and ITS deployment, a discussion of some the key enabling factors for ITS deployment, and looks at areas where such deployments may find the greatest benefit.

Governments in these countries are increasingly cognisant of the society-wide benefits of ITS deployments and interventions in addressing the commonplace transportation issues such as improving road safety and mobility for people and freight, reducing congestion and managing road network demand. Concomitant benefits also accrue directly to society at large, through improved reliability in travel and greater efficiency and security in the transportation system.

There is currently no formal paradigm for the definition of “developed” and “developing” countries or areas in the United Nations system, according to the United Nations Statistics Division. Indeed, there are differences in the metrics and criterion employed by various international organisations, including the Bretton Woods institutions, in assessing the levels of growth and the maturity of a country’s economy.

For the purposes of this report and in keeping with the PIARC guidelines, the World Bank classification of countries into income groups will be used in the representation of developing countries. In this metric, economies are measured according to Gross National Income (GNI) per capita, which is reflective of the average income of a country’s citizens. Countries with GNI per capita up to USD4,036 (2011 UN data) fall into the low to lower middle income range of economies and are classified as ‘developing economies’ by the World Bank.

The countries, for which ITS deployments are considered in this report, fall primarily into the low and middle income categories. Specific case studies were considered and reviewed in workgroup 2.1.2 for South Africa, Mali, Philippines and Argentina. Literature was further reviewed for ITS deployments in several other countries in Africa, Asia, the Americas and Eastern Europe.

4.2. CHALLENGES FACING DEVELOPING COUNTRIES – TRANSPORTATION INFRASTRUCTURE AND ITS PERSPECTIVE

In relative terms there is significant diversity within and between the world’s developing countries. There may be large regional differences e.g. São Paulo has a much higher per capita income and per capita vehicle ownership than the Brazilian national average. Differences in economic and transport levels over time can be significant - several eastern European and Asian countries have experienced significant increases in per capita income and huge improvements in their road networks. There is also considerable diversity in economic systems, per capita income, human resources, road development and traffic modal composition. Given these diversities, there is a school of thought that urges caution in identifying commonalities among developing countries. However, as trends have become evident over the past decade, there are in principal, several areas of commonality which differ perhaps only in scale, severity and in some cases ubiquity. It is thus apropos to pursue an analysis of these factors.

4.2.1. Political Environment and Fiscal Constraints

More so than upper income countries, developing countries are often faced with severe demands on fiscal policy to alleviate social problems such as poverty, education, medical care, social welfare and high levels of unemployment. Unemployment levels in many developing countries often exceed 25%, which is around six times the level of most developed countries. This often results in transportation infrastructure being underfunded, with spending on ITS infrastructure in many instances considered low priority.

From a political perspective, it is thus difficult to obtain consensus to allow for expenditure on projects that are technologically advanced. It is therefore essential to lobby decision makers on the manifold societal, economic, safety, security and law enforcement benefits of such deployments.

To this end, there are several studies that indicate a causal link between investment in infrastructure and GDP growth as well as public sector employment. As an example, for the period 1960-2009 in South Africa, economic studies [18] have established that a strong causality exists between economic infrastructure investment and GDP growth. Economic infrastructure investment drives economic growth with the latter feeding back into enhanced investment in the former. The empirical finding on the long term causal relationship between economic infrastructure investment and economic growth is in line with previous empirical studies both for South Africa and elsewhere. It also found a strong two way causal relationship between economic infrastructure investment and public sector employment reflecting the role of such investments on job creation through construction, maintenance and the actual operational activities, while increased employment could in turn contribute to further infrastructure investments indirectly through the multiplier effects across the economy.

However, with the severe fiscal constraints of lower income countries, amidst more pressing competing areas of expenditure, this will be a large impediment to significant deployment of ITS in the lower income countries.

4.2.2. Functional Road Networks

The percentage of paved roads in the least developed countries, per United Nations classification was measured at a typical average of less than 20.78% during 2009. In order to implement a road network management system, functional network systems should be available. For many developing countries, such networks are not in place. Road networks in urban areas are in a poor condition (road pavements), non continuous, or not connected. Therefore, as a first challenge, a continuous road network should be developed that will create an interconnected network of freeways, arterials, trunk and feeder roads.

Such a network, properly designed to incorporate telecommunication and ITS infrastructure for road management from the outset, will allow for more efficient management of the network and offers the advantage of avoiding the retrofitting of such technologies.

4.2.3. Vehicular Mix

In many African and Asian countries, there is a diverse range of vehicular traffic on public roads – both non-motorised (pedestrian, bicycle, animal drawn carts) and conventional motorised transport. This composition of vehicles and disparate vehicle speeds on roads, coupled with high population density makes the adoption of developed country ITS architecture difficult to deploy.

India has been developing solutions to cater for these unique conditions by making use of smart phone capabilities - GPS, microphone, and camera and communication via Wi-Fi to profile the traffic mix, predict traffic conditions and travel times [4].

4.2.4. Theft and Vandalism of Infrastructure

This is a problem which is ubiquitous. Developing countries are particularly vulnerable, due to prevailing poverty and the high value of copper and electronic equipment. The risks of theft and vandalism should be identified for each design component, and mitigating measures incorporated in the design. Retrofitting is expensive and should be avoided as far as possible.

In South Africa, copper cabling is routinely encased in concrete during the build phase on ITS deployments to prevent theft. This is an expensive undertaking, but has proven to be a successful countermeasure. The prevention of cable theft using cost effective and innovative measures would greatly assist developing countries in sustaining ITS deployments.

4.2.5. Rapid Urbanisation and Traffic Congestion

As living standards in developing countries increase however, there has been high growth of the vehicle population and greater demand for transportation infrastructure.

An increasingly prevalent, and in some cases entrenched development, as a consequence of rapid urbanization and economic growth in especially urban areas, several developing countries in the middle income GNI per capita range such as Chile, Argentina and South Africa face very much the same transportation challenges as in the developed world. The challenges however are more acute given the greater fiscal constraints of developing countries.

The mega cities of developing countries face road congestion at much lower levels of car ownership. Although most developing countries have less than 100 cars per thousand people as compared to 400 or more in the industrialised world, the relationship between income growth and car ownership is similar. Congestion in major cities of the developing countries is due to the concentration of population and income in the cities. In many African and Asian cities the capital city is more than 40 times as large as the second city. The primacy index for Malaysia was 0.29 in 2000 and a similar situation is prevalent in many other cities of Asia. Vehicle ownership and use is growing even faster than the population, with ownership growth rates of 15–20% per year not uncommon in developing countries. However, growth of road infrastructure has not been able to keep pace with the vehicle growth [32].

Illustrative of this problem is India, currently the second most populous country in the world. According to the Indian Ministry of Urban Development, from 1981 to 2001, the population in six major Indian cities increased twofold while motor vehicles increased eightfold. Cities in India are already considered congested today, and are going to be even more congested in the coming years. The rate of urbanisation in India in 2006 was only 29% and is expected to grow to 41% by 2030 [4]. Such rapid growth in vehicles without a comparable growth in transportation infrastructure leads to increasing traffic congestion.

Increasing urbanisation with the proportion of the world population living in cities rising from 50% to 70% between 2010 and 2050, is a phenomenon mainly driven by the developing world.

A rising share of urban dwellers and faster growth in urban areas leads to strong concentration of GDP in cities. 74% of global growth between 2010 and 2025 is expected to occur in urban agglomerations in developing countries (McKinsey Global Institute, 2012).

As a consequence, global mobility trends will be increasingly defined by urban mobility outcomes, particularly in developing countries. Urban mobility policy will therefore be increasingly influential on the achievement of national and global sustainability goals. Due to higher density of demand, the scope for relying on public transport to meet mobility needs is broader in cities than elsewhere. Higher congestion levels also reduce the benefits of using private transport compared to situations where its use is less constrained by capacity limits. Urbanisation hence can result in a lower share of cars in meeting transport demand even if urban incomes are higher. However, realising this potential requires supporting policy. Incomes in cities in the developing world will remain below those in developed economies, Reducing poverty will remain a challenge but increasing demand will put pressure on infrastructure provision. The impact of infrastructure provision on transport volumes has to be factored into the outlook

In such instances, developing countries are increasingly adopting similar solutions (with local variations) to developed countries in addressing these problems. Freeway Management Systems and Electronic Toll Collection for instance are now commonplace in these areas.

4.2.6. ITS Skill Shortage and Technical Competence

There is a considerable dearth of suitable ITS technical expertise in many developing countries. Most ITS implementations in these countries have proceeded with assistance of technical advisors from developed countries. However, for ITS deployments to be sustainable, a local knowledge base must be developed and fostered [1].

To this end, many of the developing countries in Europe, Asia, and Latin America have created ITS promotion organisations akin to ITS America, ITS Japan, and ERTICO/ITS Europe. Attempts have also been made to foster such entities with the assistance of ITS South Africa, in other African countries, including Nigeria and Ethiopia. Such organisations can actively promote ITS education and training through formal institutes of learning as well as technical centres of excellence.

They also play an important role in facilitating public-private partnerships thus allowing capital investment from the private sector to be secured for ITS projects.

4.2.7. Road Safety

Approximately 1.24 million people die every year on the world's roads, and another 20 to 50 million sustain nonfatal injuries as a result of road traffic crashes. Road traffic injuries are the eighth leading cause of death globally, and the leading cause of death for young people aged 15–29. It is estimated that road traffic injuries cost low and middle-income countries between 1% and 2% of their gross national product – more than they receive in development aid [26].

In 2010, the United Nations General Assembly adopted resolution 64/2551, which proclaimed a Decade of Action for Road Safety. The goal of the Decade (2011–2020) is to stabilize and reduce the increasing trend in road traffic fatalities, saving an estimated 5 million lives over the period. Key risk factors; speed, drink–driving, motorcycle helmets, seat-belts and child restraints were targeted to reduce road traffic fatalities and injuries. The overall global road traffic fatality rate is 18 per 100 000 population. However, middle-income countries have the highest annual road traffic fatality rates, at 20.1 per 100 000, while the rate in high-income countries is lowest, at 8.7 per 100 000. Eighty per cent of road traffic deaths occur in middle-income countries, which account for 72% of the world's population, but only 52% of the world's registered vehicles [26]. This indicates that these countries bear a disproportionately high burden of road traffic deaths relative to their level of motorisation. The risk of dying as a result of a road traffic injury is highest in the African Region (24.1 per 100 000 population), as shown in *illustrations 1 and 2* below.

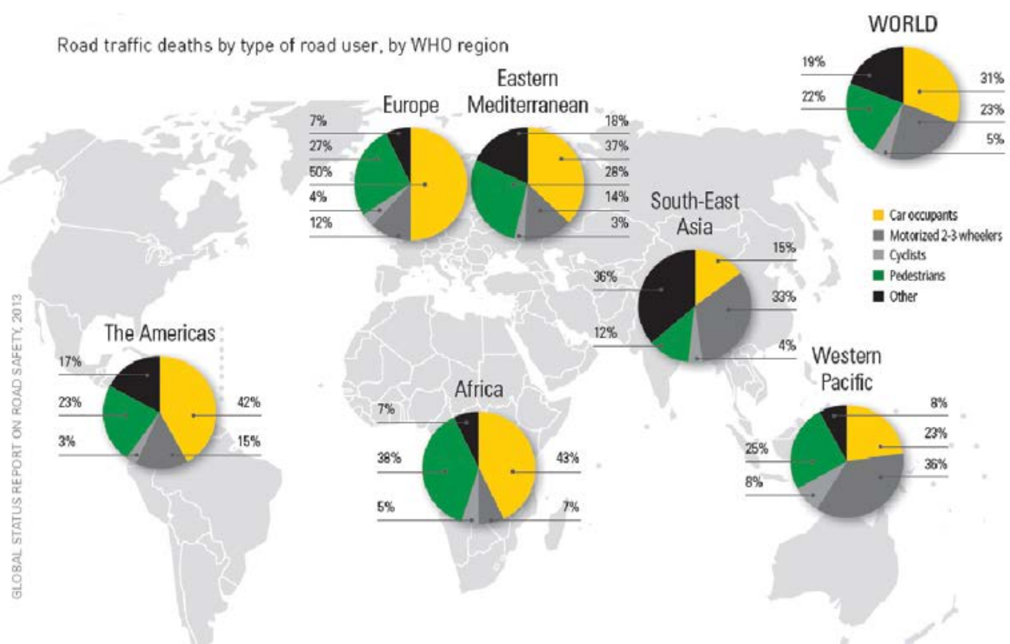

Illustration 4 . Road Traffic Deaths by Type of Road User, by WHO Region [26]

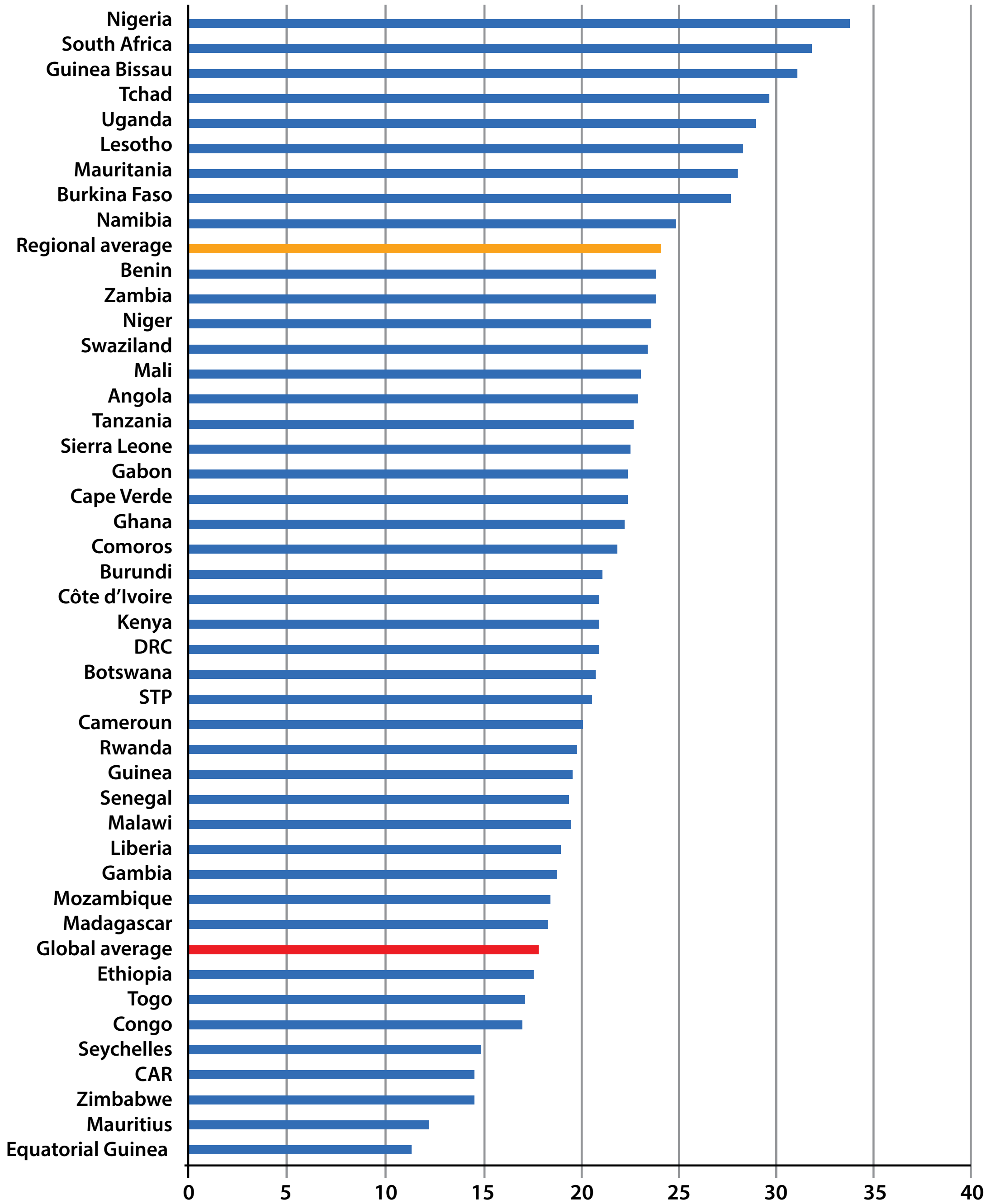

Illustration 5. Road Death Rates in 2010 (per 100,000 population) [27]

In low and middle-income countries, a third of all road traffic deaths occur among pedestrians and cyclists. As the world continues to motorise, walking and cycling need to be made safe and promoted as healthy and less expensive mobility options. There has been some progress in implementing national or sub national policies to promote walking and cycling, with 68 countries having such policies (compared to 57 in 2008) [26]. Many countries attempting to encourage walking and cycling as viable alternatives to motorised transport, however, do not have infrastructure policies in place to ensure that walking and cycling are safe. Infrastructure measures separating road users are important to protect motorcyclists as well and are thus highly relevant to many low and middle-income countries with high proportions of deaths among these road users. For example, a third of road traffic deaths in the Western Pacific Region occur among motorcycle users, yet only 36% of this region's Member States have policies in place to protect motorcyclists by separating them from high-speed traffic.

ITS technologies can be useful in undertaking observations and measurements of pedestrian activities on freeways [1]. Pedestrian bridges at hotspots have been useful in alleviating the problem of pedestrians crossing freeways. Continuous law enforcement and education and awareness campaigns must be implemented to make inroads in mitigating the problem.

4.3. ENABLING FACTORS CONTRIBUTING TO ITS DEPLOYMENT

Enabling factors contributing to ITS deployments such as improvment reactions to traffic congestion, road safety concerns (crashes), urban traffic control, incident management and the like have had extensive coverage in numerous publications and case studies, including the current PIARC ITS Handbook. This is also well attested to in the Workgroup 2.1.2 case studies from Mali, Argentina, South Africa and Philippines

Two interesting aspects, about which not much has been written about is discussed in this section.

4.3.1. Major Event Hosting

The prospect of hosting major events (sports, major political summits, etc) can be the impetus for massive infrastructure spend on infrastructure, including importantly, transportation infrastructure. This is conducive for significant ITS systems deployment.

Illustrative of this was the hosting of the 2010 FIFA Soccer World Cup in South Africa – the first time this biggest of sporting events was hosted on the African continent. Major event hosting comprises three phases. Firstly, the pre-event phase which consists of all the planning and procurement phases. The second phase is the expenditure phase, where expenditure is mainly geared towards the construction and improvement of infrastructure required to successfully host the event. The final phase is the post event phase where the sustainability and continued economic activity following from the infrastructure expenditure is assessed.

In particular focus on the pre-event phase, it has been shown that using a Computable General Equilibrium (CGE) model developed specifically for the South African economy, that the impact of the pre-event phase on the local economy had a marked positive impact on most macroeconomic variables, including GDP and employment

The results indicated that the contribution to real GDP was estimated to be in excess of R1 billion (2010 USD), with thousands of jobs created by the construction of new venues and upgrading of existing infrastructure. In addition, the improvement to the infrastructure of the country, especially the transport sector, benefits productivity in the longer term and further increases GDP [2].

An analysis should also be conducted of the recent hosting the 2014 FIFA Soccer World Cup in Brazil, to ascertain if these trends are similar.

4.3.2. Cross Border Cooperation in Fostering ITS deployments

Neighbouring countries may as a result of necessity be required in certain circumstances to implement measures involving ITS technologies to address pressing border control problems. In such instances such interventions become important ITS technology enablers.

For instance, in Kenya, customs authority's uncovered rampant diversion and smuggling of transit goods destined for neighbouring countries in east Africa into the Kenyan market. These goods were imported through the port of Mombasa and hauled by road transport or railway networks to exit stations at the Kenyan border. However, some of these goods were falsely declared as transit goods with aims of selling them illicitly in the local market so as to evade payment of Customs' duties and other taxes and levies to the Kenyan government. To address the identified road transport haulage malpractices, an RFID based Electronic Cargo Tracking System (ECTS) to track transit container goods in Kenya was piloted. Results demonstrated the effectiveness of the solution in curbing the phenomena of road transport haulage diversion and also the reduction of turn-around times of transit vehicles and consignments.

The model of the Kenyan Revenue Authority's (KRA) ECTS is as illustrated *illustration 3* below. The model consists of a number of haulage cargo trucks operated by different hauliers in Kenya each fitted with RFID Seals and readers with event listeners. The position and activities of each truck is captured in real time by GPS and Satellite Systems and relayed or transmitted to a Universal Message Centre via wireless communication networks (GSM, GPRS, WiMAX, etc.). The Universal Message Centre which serves as both Application Business Logic and Data Base also functions as an interface device between the cargo trucks and Kenya's Customs check points and KRA's Control Room [3].

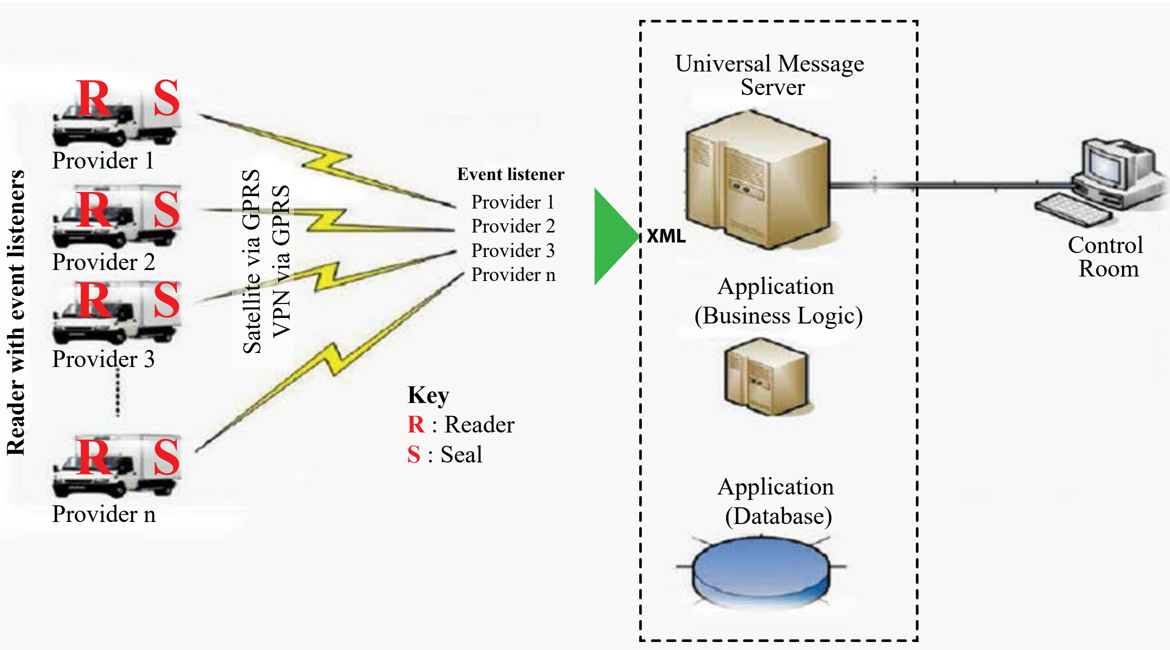

Illustration 6 . Model of Electronic Cargo Tracking System (ECTS) for Kenya Revenue Authorities. Source: Julius Musyoki (2012)

Cross border cooperation between Mali and its neighbours was also an important corollary in the EBEMI GPS truck tracking and monitoring project. To meet the convention requirements in terms of service in the adjacent country's convention perimeter, EBEMI deployments were put in place on each neighbouring international corridor of transit. A detailed treatment of this ITS application is provided in the Work Group 2.1.2 case study from Mali [1].

4.4. LESSONS LEARNED FROM OTHER COUNTRIES AND FROM INITIAL DEPLOYMENTS

4.4.1. Leap Frogging and Latecomers Advantage

As the World Bank Technical Notes for developing countries indicates, the developed countries went through a significant period of trial and error to get things right in ITS. The introduction of ITS can be significantly easier for countries that started to introduce ITS at a later stage. ITS equipment and systems are now cheaper and more refined than in the past. The technologies and standards especially on the electronic toll collection aspect are mature and well tested. Communications technologies and Internet services are spreading rapidly and independent of ITS. Their existence allows many kinds of ITS applications to be introduced without the need for significant investment in separate communications infrastructure.

In particular, mature DSRC standards for electronic toll collection, multi-level ETC interoperability and central transaction clearing on interoperable systems have culminated from numerous arduous attempts in the developed countries to promote and achieve this. Later deployments of open road tolling in Chile and South Africa have allowed for the implementation of advanced interoperability and in the latter case, central transaction clearing, thereby effectively leap frogging many intermediate and expensive steps.

4.4.2. Use of Smart Phone Technology

ITU reported figures indicate that in 2014 that 55% of the 2.3 billion mobile-broadband subscriptions is in the developing world. Mobile-cellular subscriptions at 7 billion, is increasing mostly due to growth in the developing world which accounts for 78% of the world's total. Africa and Asia-Pacific, where penetration would reach 69 per cent and 89 per cent are the regions with the strongest mobile-cellular growth. Some of the more innovative uses of smart phones as part of ITS deployments are highlighted in examples hereunder.

Given the large penetration of cellular networks in the developing world, the cost of investment in ITS infrastructure could be substantially less than a traditional ITS implementation. An evolution to using cellular networks for ITS applications, would for example, mean that instead of using the traditional road-based traffic sensors (loops and radar), vehicles with a smart phone or cellular tracking device, could be used as a probe to measure traffic flow, significantly reducing the financial and maintenance burden on road agencies [22]. Moreover, knowledge gained from the installation of cellular networks could be leveraged for ITS installations and applications. When one considers the cellular coverage maps of countries like Botswana, Nigeria, Zambia, or Kenya, it is clear that cellular coverage is most predominant in the large cities and along the main roads, which are predominantly the areas where one would need vehicular connectivity and other ITS services.

Traffic flows in cities of the developing regions, which comprise much of the world, tends to be much more complex owing to varied road conditions (e.g. potholed roads), chaotic traffic (e.g. a lot of braking and honking), and a heterogeneous mix of vehicles (2-wheelers, 3-wheelers, cars, buses, etc.) [24]. The use of smart phone technology has been finding use in an innovative way, especially in India to address such problems. Use of sensors such as GPS, microphone, Wi-Fi and camera in smart phones can be used to predict the traffic conditions. Installing the sensing infrastructure on roads can be costly and in particular instances restricted by space. The GPS functionality is finding use for hotspot detection and travel time estimation. Accelerometer sensors on smart phones are also being used to detect road and traffic events like bumps (potholes) and vehicle braking; with excessive braking indicative of traffic congestion [25].

4.4.3. Use of Systems Engineering approach

Various ITS components have been implemented at various locations in several developing countries with the help of consultants and vendors from different countries. Such piecemeal deployment of ITS is not generally advisable, except for very specific and strategic purposes. This is especially true in the case of complex systems that have many interrelated parts. The U.S. DOT recommends the use of Systems Engineering for deployment of ITS projects.

The Systems Engineering principle recommends the use of system architecture for complex systems. A system architecture is a framework that depicts how different sub-systems of ITS interrelate with each other and work collectively to deliver the required services to users of the system. The architecture defines the components as well as the interrelationships and information exchange among the components. Due to the complexity of integration of information systems in the field of transport, it is desirable to define and develop an ITS architecture at the national level, which will function as an overarching framework within which individual components or groups of components of ITS can be built. Such an approach will ensure that systems developed and implemented at different places and times are interoperable and compatible with each other.

To benefit fully from ITS, a nation needs to develop the ITS architecture at various levels - local, city, region, state, and national. Isolated development managed by disparate parties from around the world without any indigenous master framework to guide the work can lead to incompatible and non-interoperable systems that will hinder further development and expansion of ITS in any country. So the prevailing school of thought is that ITS development in developing countries should generally not proceed, until a national or regional architecture is in place. Small, strategic localized projects such as synchronization of traffic signals along a corridor, installation of some video surveillance for monitoring traffic at selected locations can, however, be undertaken.

4.5. FOCUS AREAS FOR ITS IN DEVELOPING COUNTRIES

Arguably one of the most, if not the most important focus area for developing countries, is the implementation, growth and sustainability of public transport infrastructure and functionality. Citizens in countries with low GNI per capita are unable to afford private vehicles and hence are dependent on some form of public transport. This mode of transport is envisaged to be the most widespread and ubiquitous for most of the people and also has the most scope to leverage ITS technologies to the benefit of the citizenry. Public transport, currently, in developing countries comprises mostly buses and mini-buses.

Public transport is an area that requires targeted strategic investment and ITS innovation to make it thrive. The societal benefits of well-established public transport systems are invaluable.

4.5.1. Public Transport as a Key Mode of Transport for Societal Benefit

A discussion of public transport initiatives in various developing countries is provided below.

In **Sub-Saharan Africa**, the informal taxi industry has sprawled into a vibrant industry and is a significant contributor to employment. In South Africa for instance, minibus taxis move 68% of the 5.4 million passengers on a daily basis [20]. The Taxi industry remains the most important part of the public transport system. The taxi industry is a $330 million (USD) per annum industry, with about 200 000 taxis, and provides approximately 300 000 job opportunities. It thus contributes immensely to the economy and is the transportation mode of choice, especially of the poor [19]. This is similar for other countries in Sub-Saharan Africa, for example the ubiquitous Dala-Dalas in Tanzania and Ndiaga Ndiaye in Senegal. A recent study by the Trans-Africa consortium found that Lagos alone had 80,000 informal minibuses. The study also pointed out that the majority of taxi owners manage to cover their operating costs, but cannot afford to adequately maintain and upgrade their fleets, thus compromising safety and quality. Both Senegal and South Africa have introduced fleet renewal programs, with varying levels of success [22].

In Kenya and neighbouring regions, the minibus taxi industry is more regulated, and the minibuses must adhere to minimum safety standards - fitted with seatbelts and speed governors. The matatu, as they are known, are privately owned and are the primary form of transport on the city. From December 2010, the Kenyan government began phasing out the minibus matatu in favour of larger, 25+ seat buses to improve transportation efficiency and safety.

Many of the vehicles in Sub-Saharan Africa, especially South Africa, have GSM and/or GPS enabled tracking devices fitted for vehicle-recovery purposes. The devices also capture acceleration and angular velocity in addition to speed and location, which can be used to monitor driver behaviour, which is especially useful in the informal public transport scenario. Models to specifically monitor minibus taxi driver behaviour using tracking devices have been developed [23] and can be used to alert the authorities of speed limit violations. The tracking devices on these vehicles, which have cellular connectivity and where a high ratio of vehicles can serve as active probes, can also be leveraged to provide accurate traffic flow information. The information regarding travel routing and travel times can then be used for road planning and targeted investment in infrastructure. Given the informal nature of the taxi industry in Sub-Saharan, where government agencies struggle to capture the travel patterns, this development could be very useful.

Ghana, like other developing countries, is facing rapid motorisation and increasing vehicle usage without commensurate development of roadway infrastructure. The situation is most acute in the national capital Accra, but is also prevalent in the other nine regional capital cities of Ghana [4].

Municipal planners and government agencies (in line with the concept of technology implementation theory) realised the need to apply ITS solutions to the overwhelming transportation bottlenecks. This prompted the search for feasible, sustainable and affordable solutions to mass transportation for Accra, and the other regional capitals. The search led to the identification of Bus Rapid Transit (BRT) as a transportation solution to meet the cities' public transport needs. The BRT is a public transportation mode designed to provide rapid transit services through an integrated system of ITS technologies that include priority treatments, dedicated or demarcated running ways, stations, vehicles and short service headways. The $45.4 million (USD) project officially commenced with a sod-cutting ceremony by the Vice-President, Mr John Dramani Mahama, in February 2011 [6].

Also in South Africa, with the emphasis on a modal shift to public transport, there are several initiatives throughout the country to implement bus rapid transport (BRT) systems [3]. Several deployments in 5 of the 9 provinces are currently underway. The integration of the minibus taxis into these systems is also being pursued. As part of this process, interoperable smart ticketing and billing as well as vehicle tracking is receiving attention. Further, in-vehicle surveillance monitoring of vehicles to improve safety and security is also being pursued.

In the 1990s, **Bogota, Columbia** was characterized by long travel times, congestion, high occurrence of accidents and poor road network and high levels of pollution. The government decided in 1998 to focus on the reconstruction and maintenance of sidewalks, cycle paths and campaign against the use of private motor vehicles and at the same time development of an efficient public transport system. As a result, Transmilenio, a bus rapid transit system was created in 2000.

The main features of the system include dedicated bus lanes, same-level loading and offloading of passengers, pre-selling of tickets and improvements in technology. The buses have a capacity of 160 passengers, are disabled friendly and meet Euro III emission standards. The system uses 165 articulated passenger buses and with clean diesel engines. A key advantage of Transmilenio is its low cost due to its innovative Transmilenio partnership. The system accounts for almost 1.3 million daily trips and the main line carries more than 40,000 passengers per hour. Transmilenio users save on an average 223 hours of travel annually and 9% of Transmilenio users have been diverted from commuting by private automobile [32].

In **India**, the proportion of buses of the total registered vehicles declined from 11.1% in 1951 to 1.1% in 2006. This indicates the steady decline in public transport modes with consequent vastly increased congestion in Indian cities.

The share of non motorized transport especially cycling has also declined in Indian cities to less than 11% from nearly 30% a decade ago. This has been due to a combination of increased purchasing power of the population and movement to private vehicles, declining investment and upkeep of non-motorised infrastructure.

However, attempts are being made to reverse the trend of deteriorating public transport in the country. Illustrative of this is **Indore**, a fast growing industrial city in the state of Madhya Pradesh. Like many other metropolitan cities across the developing world it faces the twin challenges of a growing population and increasing pressure on the existing urban transport system. In order to improve the accessibility levels in the city, popularise public transport and reduce the dependence on private vehicles, it started the process of improving its urban services in 2005.

The Indore Municipal Corporation, Indore Development Authority and the district administration jointly invested in the creation of a Special Purpose Vehicle (SPV) called the Indore City Transport Services Ltd. (ICTSL). A public private partnership model for creating and expanding urban bus services in Indore was structured. The investment in common structures like bus stops and office space was contributed by the ICTSL and the investment in rolling stock was made by the bus operators. The ICTSL finalised the routes for operation of the city buses and initiated a tendering proves for inviting private bus operators to bid for operating buses on predefined routes. The ICTSL also involved private parties in the provision of other services like bus passes, installing and operating GIS/PIS and advertising in the buses. The performance parameters for all the private entities are prescribed and monitored by the ICTSL [32].

Sustainable transport systems require a sound and efficient public transport system. Therefore, there is an urgent need to stem the decline of public road transport systems in developing countries. Many developing countries have state run bus services which are highly inefficient and a drain on the finances.. The performance of the state public transport system in terms of quality and efficiency should be improved and opens up the avenue to public private partnerships in delivering much needed infrastructure.

Safe public transport systems are increasingly viewed as important to improving mobility safety, particularly in urban areas with increasing traffic congestion. In many high-income cities, there has been strong political emphasis on decreasing individual car use through investments in public transport systems. Investing in safe public transport is also seen as a mechanism to encourage increased physical activity and thus promote health. However, a critical issue associated with promoting such measures is the need to ensure that these modes of transport are safe. Public transport is considerably safer than private car travel in most high-income countries, but in many low- and middle-income countries, this safety record is still to be realised [26]. Governments must thus ensure that public transport systems are safe, accessible and affordable. The necessary regulation, policies and enforcement of policies must be maintained to ensure successful implementations. In this way, reductions in congestion and improvements in mobility can be achieved concurrently with improvements in safety.

5. CONCLUSIONS, BEST PRACTICES AND RECOMMENDATIONS

5.1 ITS PLANNING AND ARCHITECTURE

Due to the complexity of integration of Information Systems (IS) in the field of ITS, it is desirable for developing countries to define and develop ITS architectures at the national level that will function as overarching frameworks within which individual components or groups of components of ITS can be deployed. Such approaches will ensure that systems developed and deployed at different places and times are interoperable and compatible with each other including existing ones, locally, regionally and globally.

Isolated development managed by disparate parties without any indigenous master framework to guide the work can lead to incompatible and non-interoperable systems that will hinder further development and expansion of ITS in the country [5].

Thus, countries with transitional economies which are yet to define their National or Regional ITS Architectures should not embark on full scale ITS deployment all at once [3]. Rather, to benefit fully from the potential of ITS technologies, overarching frameworks and ITS architectures should be developed first. ITS infrastructure should be gradually and systematically deployed, with due cognisance of the dynamic nature of ITS technologies.

5.2 ITS SKILLS SHORTAGE AND TECHNICAL COMPETENCE

There is a considerable lack of ITS technical expertise in many developing countries. However, for ITS deployments to be successful and sustainable, a local knowledge base must be developed and fostered [1].

Many of the developing countries in Europe, Asia, and Latin America have created ITS promotion organisations akin to ITS America, ITS Japan, and ERTICO/ITS Europe. Such organisations can actively promote ITS education and training through formal institutes of learning as well as technical centres of excellence. They also play an important role in facilitating public-private partnerships thus allowing capital investment from the private sector to be secured for ITS projects. Thus attempts are being made to foster the formation of such entities in developing countries. The launch of ITS Africa at the biennial ITS South Africa (ITSSA) i-transport conference in May 2015 conference is a major milestone in the creation of such entities and for advocacy of ITS in the region.

5.3 LOCAL ITS PILOT PROGRAMMES

The conducting of pilot tests and programmes to establish proof of concept and efficacy of the ITS solution that are bespoke to the particular conditions of the country is a highly recommended practice. It allows for an ascertainment of the success factors and failures, areas requiring adjustment to suit the specific conditions of the country, as well as practical 'lessons learned' from these test deployments [1]. These thus lay the foundations of successful future deployments.

5.4 ITS ENABLING FACTORS

The reactions to traffic congestion, road safety concerns (crashes), urban traffic control and incident management are generally well covered in numerous publications and case studies, including the current PIARC ITS Handbook. This is also attested to in the Workgroup 2.1.2 case studies from Mali, Argentina, South Africa and Philippines.

5.4.1 Road Safety

In addition to the recommendations cited in the above publications and in [1], the recommendations from the 2013 WHO reports [26] indicate that developing countries should advocate for a lead agency for road safety. This agency should have the authority to make decisions, manage resources and coordinate efforts of all participating governmental sectors, including those of health, transport, education and law enforcement.

Further the development of a national road safety strategy with precise targets and funding for implementation is a key element of sustained road traffic injury prevention efforts. Each country should have a road safety strategy that is multi-sectoral, involving agencies concerned with transport, health, law enforcement, education and other relevant sectors – and also multidisciplinary, involving both government and non-government stakeholders.

Setting targets to improve and assess road safety performance is increasingly important. Targets that are realistic, attainable and time-bound can motivate stakeholders and hold road safety leaders accountable for achieving defined results. Countries need to increase the adoption of comprehensive legislation relating to the key risk factors - speed, drink–driving, motorcycle helmets, seat-belts and child restraints, for road traffic if the targets of the United Nations General Assembly (UN Decade of Action for Road Safety 2011-2020) are to be met. Furthermore, enforcement of strong road safety laws is essential for success, with the use of strong social marketing campaigns playing an important role in fostering public understanding of and support for legislative measures.

Governments should also include targets on intermediate outcomes in their strategies (e.g. increases in helmet wearing, reductions in drink–driving). Setting interim targets can be very helpful in obtaining and sustaining community and political support for longer-term road safety measures as well as in identifying emerging issues.

ITS technologies can be useful contributor also in mitigating pedestrian accidents on roads through monitoring and measurement of pedestrian activities on freeways [1]. Pedestrian bridges at hotspots have been useful in alleviating the problem of pedestrians crossing freeways. Further, continuous law enforcement, education and awareness campaigns must be implemented to make inroads in mitigating the problem.

5.4.2 Cross Border Cooperation in Fostering ITS deployments

In addressing inter-regional border control problems, ITS technologies can be leveraged on as part of the broader solution and thus become important ITS infrastructure enablers.

The model of the Kenyan Revenue Authority's RFID based Electronic Cargo Tracking System (ECTS) to address haulage malpractices and tracking of transit container goods, as well as the EBEMI GPS truck tracking and monitoring undertaken in Mali, are exemplary of the use of ITS technologies in this manner.

These deployments have clearly demonstrated the effectiveness of ITS as an important contributor to the solution in curbing transport haulage diversion, fraudulent activities, and fostering cross border cooperation between neighbouring countries.

5.5 PUBLIC TRANSPORT

ITS patterns worth adopting and practicing by developing countries include the establishment of public policies to actively promote and sustain public transportation [3]. The most vulnerable road users in developing countries are the poor, who commonly are those walking, cycling, riding two-wheelers, old minibuses, or old and decrepit private vehicles. Having fewer financial resources, they also spend a greater percentage of their income on transport-related services. Both these factors contribute to intensifying urban inequality and therefore the promotion of public transport infrastructure is seen as a way of promoting equity in developing countries, especially in African cities.

Enabling actions should be undertaken as early as possible to develop consensus among the various stakeholders and as well as establishing effective public organisations for necessary administrative actions. An early behavioural shift to mass use of efficient, reliable and safe public transport will mitigate much of the traffic related problems associated with rapid urbanisation that beset developed countries. Governments must ensure however that public transport systems are safe, which is currently not the case in several developing countries. The necessary regulation, policies and enforcement of policies must be maintained to ensure successful implementations so that reductions in congestion and improvements in mobility can be achieved concurrently with improvements in safety.

As can be seen from the examples cited in item 4.5.1 of the report, from the vehicle tracking on minibuses in South Africa to the BRT systems deployed in Ghana, Columbia and India – ITS technologies can be harnessed as an important tool for successful deployments of public transportation systems.

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GLOSSARY

TERM	DEFINITION
AHP	Analytic Hierarchy Process
ALPR	Automatic License Plate Reader
API	Application Program Interface
ATCS	Adaptive Traffic Control Systems
ATDM	Active Traffic Demand Management
AVL	Automatic Vehicle Location
BRT	Bus Rapid Transit
CAD	Computer Aided Dispatch
CAN	Controller Area Network
CBA	Cost and Benefit Analysis
CCTV	Closed Circuit Television
CO	Carbon Monoxide
CO2	Carbon Dioxide
CEA	Cost-effectiveness analysis
CWS	Collision Warning Systems
DMS	Dynamic Message Signs
DSRC	Dedicated Short Range Communications
ESC	Electronic Stability Control
ETC	Electronic Toll Collection
FHWA	Federal Highway Administration
GHG	Greenhouse Gas
GPS	Global Positioning System
HAR	Highway Advisory Radio
HAZMAT	Hazardous material
HOT	High Occupancy Toll
HOV	High-Occupancy Vehicle
ISIG	Intelligent Traffic Signal System
ITS	Intelligent Transportation Systems

TERM	DEFINITION
KPI	Key Performance Indicator
LAN	Local Area Network
LNG	Liquefied Natural Gas
MCDA	Multiple-criteria decision analysis
MCDM	Multiple-criteria decision making
MDSS	Maintenance Decision Support System
MOE	Measure of Effectiveness
MOVES	MOtor Vehicle Emissions Simulator
MPG	Miles Per Gallon
MPO	Metropolitan Planning Organization
OBD	On-Board Device
OCR	Optical Character Recognition
O-D	Origin-Destination
PDA	Personal Digital Assistant
PROMETHEE	Preference Ranking Organization METHod for Enrichment Evaluation
RFID	Radio Frequency Identification
ROI	Return on Investment
RWIS	Road Weather Information Systems
RWM	Road Weather Management
TMC	Transportation Management Center
TOC	Transportation Operations Center
URL	Uniform Resource Link
USDOT	U.S. Department of Transportation
V2I	Vehicle-to-Infrastructure
V2V	Vehicle-to-Vehicle
VSL	Variable Speed Limit
WIM	Weigh-In-Motion

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