

Sustainability Impact Analysis of Intelligent Transportation System

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Abstract

Traffic Congestion is increasing in extensive manner globally as a result of inadequate road development, increasing number of vehicles, decreasing speed, increasing in accident rate, increasing fuel consumption rate etc. It increases the necessity for the concept of intelligence transportation system (ITS) for the conventional transportation system. ITS have a major role to play in developing countries economy, increasing driver's safety, enhancing mobility and convenience, bring environmental benefit, increasing productive economic and employment growth. In this paper, comparative study of intelligent transportation system with conventional transportation system is done with the help of some analytical equations. And the impact analysis and sustainability of ITS and sustainable transportation system is done, in which different ITS is compared using some fraction unit in terms of value of time, emissions and safety values. By using urban mobility report calculations can be easily performed for emerging metropolitan cities. In this paper equations are proposed for calculating annual congestion cost, value of time benefit, value of emission savings and the safety savings.

Keywords: Annual Congestion Cost, Time Benefit, Emission Savings, Safety Savings

I. INTRODUCTION

Transportation is necessary for the movement of people and goods. The productive adequacy of urban areas is maintained when mobility requirements in the cities are fully met. With the advancement of cities, demand for transportation grows with the growing business and deal all over the world. Thus urban transport plan one of the most important components of urban development. A good network of roads and a profitable transport system make a extraordinary contribution to the working efficiency of a city. The evolution of industrial development calls for an enlargement of transportation systems to procure to the increasing demand.

Most of the population and economic growth in the world is appearing in developing countries. The Situation of rapid urbanization in the world has created the movement of people from rural areas to metropolitan areas. Rapid urbanization is leading by an alarming rate of increase in the number of vehicles. In fact, the manufacturing of vehicles has been rising at a faster rate in terms of percentage in comparison to the population. There is a high growth of auto ownership in cities for better convenience. Besides, in many of the developing countries car owning is a trend. With this, there is greater demand for the use of transportation facilities.

However transport infrastructure development and arrangement of public transport facilities have slow growth rate as compared to the demand. Road networks in cities are obstructed by the increasing of personalized vehicle and have resulted in high traffic congestion, deeply increasing number of accidents and levels of pollution. Process of urbanization with an inappropriate controlled planning has resulted in unbalanced spatial distribution of population and economic activities needed large-scale inter-city movement of people, goods and vehicles.

Thus sustainable transportation involve with the impacts of transportation developments on economic efficiency, environmental factors, resource consumption, land use, and equity. It includes the application of systems, management and technologies, which would help achieve the continuous economic development without having adverse effect on environmental and human resources. It aims at the efficiency of transport of goods, services and distribution systems with least accessibility problems. Sustainable transportation system aims at designing of congestion free planning, with bicycle and pedestrian friendly areas. It focuses on moving people and not only the vehicles, which reduces air pollution as well as the increasing congestion problem. Sustainability can be attained with the change in behavioural aspects of people. When people understand the impacts of transportation, they can make choices that reduce the need for resources and thus minimize the negative impacts.

In existing transportation system there are certain problems like environmental problems, economical problems, social factors etc. Due to these problems transportation system becomes inefficient for public users. Due to inadequate public transportation use of private vehicle trend is increasing which leads to congestion problems, increasing of road accidents, emission of greenhouse gases which causes environmental pollution and many more problems in existing transportation system. To overcome from all these problems we proposed the sustainability analysis for existing and intelligent transportation system, in which comparison made on the basis of basic factors such as environmental, social, economic and safety parameters.

II. LITERATURE REVIEW

It is an analytical report of the information connected to the particular topic. Literature review offers description, summary and analysis of journal paper referred for the study. Literature review includes actual finding, as well as theoretical and methodological explanation about particular topic.

Dhingra S.L et al. (2004) gives the case study of Mumbai city and proposed some sustainable solution for the mobility, as the failure of the existing system to meet the transportation requirement for the present scenario and considering the future expansion of the city, there has been a constant urge to look for an alternative technology. A system which would integrate the existing the existing rail and bus transport along with a sustainable solution, is desired which has been proposed in this paper, the system would comprise: 1. Twin Railway Corridor 2. Existing BEST bus Route 3. New concept of sky bus metro 4. Environment Friendly battery powered electronic vehicle.

Elizabeth Deakin (2013) examines strategies for sustainable transportation as a principle component of sustainability. A variety of the strategies have been identified for potentially increasing transportation sustainability. In this paper Author proposed the following methodology for sustainable transportation development.

- Vehicle/fuel technological changes.
- Road vehicle operation improvement.
- Modal substitution.
- Telecommunication substitution.

American Association for State Highway and Transport Official (AASHTO), this report which proposed by AASHTO, they give the brief description about the sustainable transportation. In this paper authors described the parameters for sustainable transportation development by taking the three key factors that are Economic, Social and Environmental. There is some Parameter proposed for sustainable transportation development such as:

- Policies for climate changing.
- Revenue policies and pricing strategies.
- Strategies for land use plan
- Strategies for freight management.
- Sustainably plan

Dr Aashish Verma (2013) described the sustainable transportation system for the Indian cities, in this article author first described the problems in existing transportation system in India then by taking key factors of sustainable transportation author proposed some methodology of sustainable transportation system for Indian scenario. Author proposed parameters like public transit, mobility management, residential development, parking system and transportation management.

M.A Mosaberpanah et al. (2012) explain the Factors of Sustainable transportation system and a brief description about sustainability. In this paper author proposed the strategies for sustainable transportation in roadway system. In this, author gives the strategies according to the vehicle, road and human. Strategies are such as improved efficiency of conventional vehicles, new vehicle/fuel technology, traffic flow improvement, ITS improvement, modal substitution, pricing strategies etc.

Todd Litman (2008) explains the sustainability factors i.e. social, economic, and environmental. And further explain the role of sustainability in transportation planning by selecting some sustainable parameters. Author also gives the brief description about the Triple Bottom Line methodology in his research.

III. METHODOLOGY

In today's era as whole world is concern about the global warming and increasing pollution and congestion. Most of the part of pollution is related with the industries and the transportation system. To control this pollution excess research is necessary and is going on now a day. In transportation system, to convert existing transportation system into sustainable transportation system, there are various methods proposed by the researchers, such methods are mentioned in the literature review. In this paper we propose some analytical formulas for assessment of sustainable and intelligent transportation system. In which economic, environmental and social factors are considered. To overcome from the given problems existing transportation should convert to sustainable and ITS. But we can't directly replace the whole system; we have to make some analysis for the existing and the converting system (ITS and sustainable system). For which we proposed some analytical equations to analyse the sustainability impact on society.

In given flow chart (Fig.1), first of all it is mention that one have to invest some sustainable and ITS investments as primary investment. In which there are some inputs given such as initial cost of the system, operating and maintenance cost of ITS system. After that we have to apply particular method for sustainability assessment such as Fuzzy data Envelopment analysis (Fuzzy DEA) or Triple Bottom Line methodology (TBL) to the inputs we given to intelligent transportation system. After process of ITS investment as a result there is reduction in delay of vehicles and fuel savings which directly or indirectly affect the factors such as environmental, social and economic. In environmental factors there are certain parameters which get affected by ITS and sustainable system i.e. reduction in greenhouse gases, energy consumption or effective use of energy, minimizing of toxic releases, reduction in water consumption and ecologic footprint. There are certain socio-economic factors also affect by ITS and sustainable system such as public from public transport system, as people prefer public transit over private vehicles. Employment increases

due to increase in public transport system. Import in goods increase as people prefer government mode of transport and reduction taxes as private vehicles minimizes.

Now we briefly describe the methods for assessment of sustainability impact on society due to ITS and sustainable transportation system in metropolitan cities.

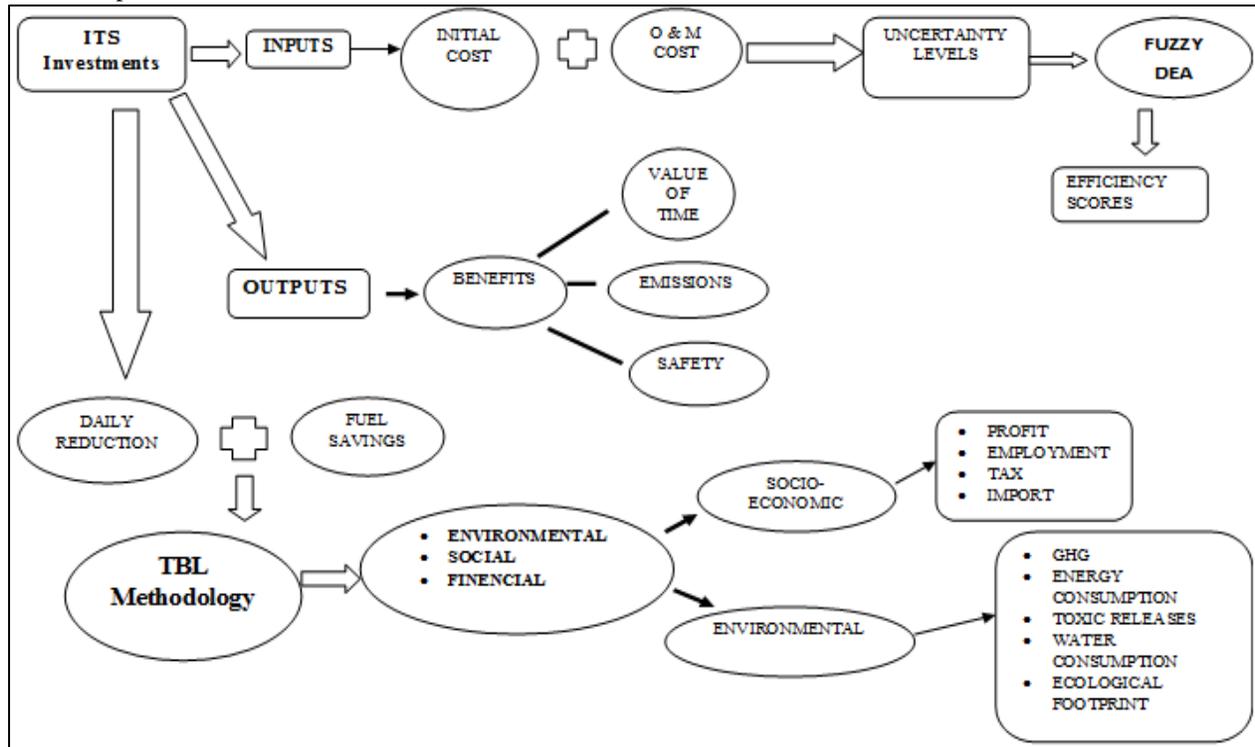


Fig. 1: Sustainability analysis and efficiency impacts of ITS

IV. ANALYTICAL ANALYSIS FOR SUSTAINABLE AND ITS RELATED TRAFFIC CONGESTION RELIEF SAVINGS

A. Annual Congestion Cost

All the information i.e. congestion related traffic information is gathered from a report which is related to that particular city is known as urban mobility report (UMR) or draft plan. From that report congestion related information such as wasted time, value of fuel, operational treatment related time and fuel savings. This analysis creates conditions that how traffic affects if there is no sustainable and intelligent transportation system on the roads in congested areas of emerging metropolitan cities compared with the congested areas with the use of sustainable and intelligent transportation system on the road networks. Total cost of congestion is the sum of annual delay hour and wasted fuel cost, as shown in equation (1) below.

$$C_{AC} = [C_{PVD} + C_{PVF}] + [C_{CVD} + C_{CVF}]$$

C_{AC} - Annual congestion cost
 C_{PVD} - Annual passenger vehicle delay cost
 C_{PVF} - Annual passenger vehicle Fuel cost
 C_{CVD} - Annual commercial vehicle delay cost
 C_{CVF} - Annual commercial vehicle fuel cost

In this equation(1) every component has its own parameters such as average passenger and commercial vehicle in percentage on roads, average fuel cost, fuel saved or wasted annually, occupancy rate of passenger and commercial vehicle, time value of commercial and passenger vehicle. From these parameters and components the cost of congestion or cost savings due to ITS and sustainable transportation system can be easily calculated.

B. Time Benefits

The analysis of sustainable and intelligent transportation system considers few components related traffic congestion relief benefits i.e. time value, emission of gases, and safety of commuters. In time benefit value, time represented in money saved by the sustainable and ITS investment for public annually. The time benefit value is more for commercial vehicle and less for the passenger vehicle. The equation (2) showed below represented the time benefit value.

$$B_T = [S_{CRT} * V_{PHP} * V_{OPV}] + [S_{CRT} * V_{PHC} * V_{OCV}] \quad (2)$$

Where,

B_T - Time Benefit Value

S_{CRT} – Congestion relief related time Savings (person hour)
 V_{PHP} – Value of each person hour for commuter for passenger vehicle
 V_{PHC} - Value of each person hour for commercial vehicle
 V_{OPV} – Vehicle occupancy of passenger vehicle
 V_{OCV} - Vehicle occupancy of commercial vehicle

In above equation (2) the time value is in money for person hour fraction, then it multiplied with the vehicle occupancy, then after this it again multiplied with the actual time saving in a year. Mostly working days i.e. 250 or 260 days are considers for this calculation.

C. Emission Savings

Time saving also related to the emission savings on traffic congestion, but it is not limited to the time savings because emission rates changes according to the number of acceleration and deceleration. Simulation models are generally used in studies for capturing emission savings related with congestion relief.

$$S_E = [S_{HC} * C_{HC}] + [S_{CO} * C_{CO}] + [S_{NOx} * C_{NOx}] \quad (3)$$

Where

S_E – Emission Savings
 S_{HC} – Amount of hydrocarbon savings
 S_{CO} - Amount of carbon monoxide savings
 S_{NOx} - Amount of nitrogen oxide savings
 C_{HC} – cost of hydrocarbon emission per kg
 C_{CO} - cost of carbon monoxide emission per kg
 C_{NOx} - cost of nitrogen oxide emission per kg

In this equation (3), we considers only three major components of vehicle related emissions i.e. Hydro carbons (HC) Carbon monoxide (CO) and volatile organic compound i.e. Nitrogen oxides (NO_x). These emissions are mostly releases in more quantity compare to other toxic releases which are nearby 30 in numbers which releases continuously from the driving vehicle. Each kilogram of HC, CO, NO_x and other emission cost money to the society. By using sustainable and intelligent transportation system we can easily reduce these emission which advantageous to future growth.

D. Safety Savings

Safety is the main parameter in transportation system. In any transportation system number of accidents decides the safety of that system. As existing transportation system is outdated or due to some disadvantages fulfilment to the public need and safety is not proper. Reduction or increase in the accidents presents the impact of that system on society. In this research paper comparative study is used such as before-after study or some simulation models to estimate safety impact on society. Safety saving is represented by the following equation (4).

$$S_S = C_R * C_A \quad (4)$$

Where,

S_S – Value of safety savings
 C_R – Crash Reduction Amount
 C_A – Average cost of an accidents

In this equation (4) accident data for different year is taken for the draft plan or urban mobility report. After calculating the accident portion numbers, it is then multiplied by the average cost of accident. In which it includes the cost of fatality, cost of serious injuries, and damage to property. It is only a predictable calculation as we can't measure the exact reason and nature of accidents. a average accidents cost is used to determine the safety benefits/ savings in the form of money.

V. CONCLUSION

Transportation is the most important foundation of metropolitan cities now days. There are certain problems come under the way of development of the emerging metropolitan cities. In which existing transportation is a key problem, due to existing transportation system, there are more environmental, social and economical problems, such as greenhouse gases effects increase day by day, safety problems, less economical, less profitable, low services provided in public transportation due to which interest of people from public transportation minimized and private vehicle trend increased.

In this research paper, analysis of sustainability with intelligent transportation is done by means of some analytical equations. A comparative study with existing transportation is done. In equation (1), congestion cost is calculated by taking passenger and commercial vehicle delay and fuel cost. This annual congestion cost is first calculated for existing/ conventional transportation system after that it is calculated for sustainable and ITS and compared both the system. ITS has long term sustainability impact as compare to the conventional transportation system.

In equation (2), time benefit is calculated by taking congestion related time saving, person hour for passenger and commercial vehicle occupancy rate. In conventional transportation system time spent in traffic is more as compared to the ITS and sustainable transportation system. Time benefit value shows difference in the form of money wasted or saved. BRT system is one of the

examples of ITS and sustainable transportation system, in which time of commuter is saved very much and in other hand in conventional system time wasted is more in traffic.

In equation (3) value of emission savings in the form of money is calculated. In which three major component i.e. hydrocarbons, carbon monoxide, and nitrogen oxides considers. Emission of these components in conventional transportation is more as compared to ITS and sustainable transportation system. Due to use of more private vehicle more emission of these components is happened which cause money to the society. But in sustainable transportation system more public transit is use which reduced the private vehicle trend and which also causes in reducing emission of toxic releases and make transportation system environment friendly.

In equation (4), this equation of safety savings is developed by taking crash reduction due to ITS, which is then multiplied with average cost of accident which gives us savings for safety for that system. In ITS and sustainable transportation system safety value is very much more as it is safe transportation system. In overall analysis of ITS and sustainable system, the three basic and main i.e. social, economical and environmental factors satisfies by using these analytical equations in ITS and sustainable system for analysis and sustainability impact on society.

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