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THE LIFE CYCLE APPROACH FOR STRATEGIC TRANSPORTATION PLANNING

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Abstract: Fossil fuel consumption and related environmental and socioeconomic impacts from the transportation sector are growing as more and more people become dependent on daily transportation. Thus, it is crucial that transportation planning and investments be carried out in a strategically holistic manner to meet optimum travel needs, promote economic prosperity and environmental preservation and enhance the integrity of natural resource systems. The life cycle approach in transportation planning and development involves planning a system based on environmental, economic and social considerations in a cradle to grave perspective. Such efforts can promote resource efficiency and energy conservation, while reducing pollution and offering initiatives and solutions toward achieving sustainable development. The paper introduces life cycle approach (LCA) and life cycle management (LCM) in a transportation perspective and sets out a broad strategic and policy framework under which policy makers and planners can cooperatively make decisions and take actions.

Key Words: Strategic Transportation Planning, Life Cycle Approach, Sustainable Development.

1. INTRODUCTION

Transportation system planning, implementation and maintenance will affect the manner and efficiency in which people and goods are transported and subsequently the daily life of all inhabitants in a town, city or even country. More people are driving further with more frequency, creating smog, global warming and traffic congestion. Ironically, we often attempt to build our way out of a jam with more roads, leading to more problems in stead of focusing on long term traffic management.

The main stakeholders in a transportation system can be grouped into residents, business and ecosystems (the environment). It is crucial that the interests of these three groups are all equally integrated into the transportation system as they are all essential parameters in society. The lack of a holistic and flexible focus in the planning strategies will inevitably lead to an unsustainable system causing havoc with a decade.

The development of sustainable transportation systems that enhance, not entrap, life in the urban and rural areas is very crucial. For example, it was found that upgrading existing roadways, rather

than building a new highway is in many cases more cost effective and more environmentally friendly. With better planning for roadways, more mass transit, modern railway networks, and smart solutions for traffic problems, our cities and rural areas can be healthier places to live and work for everyone.

1.1 Objective

The objective of this paper is to introduce the concepts of life cycle approach (LCA) and life cycle management (LCM) as a holistic and flexible inventory and planning tool in transportation management.

2. IDENTIFYING THE PROBLEM

The pollution resulting from the traffic congestion can cause humans inhaling high levels of particulates, hydrocarbons, lead, and NO_X in concentrations violating the World Health Organization standards.

The rapidly growing motor vehicle fleets in cities with road infrastructure designed for only a fraction of the current fleet is the number one reason for daily traffic congestions and the severe pollution that follows. Motor vehicle ownership grows faster than GNP in most developing countries. Pollution is worse than in industrialized country cities with higher levels of motor vehicle ownership, not only because of the worse congestion, but also because of older vehicle fleets, lack of emissions regulation and enforcement, lack of vehicle inspection and maintenance, low grade fuels, and the prevalence of two-stroke engine vehicles. In some countries, motorcycles account for 70% of the total vehicle fleets, and are responsible for a large share of total air pollution.

The main courses of the overpopulated streets leading to traffic congestions and massive exhaust gas emission are (not necessarily in the correct order of importance):

- Inconsiderate driving: Everybody wants to get to their destination as fast as possible and thus many drivers cut lanes at will to get to a faster lane and try to squeeze into the lines just before an exit. This behavior significantly decreases the flow of the traffic and leads to longer engine running time and more gearshifts/acceleration, which ultimately increases the fuel consumption and the exhaust emissions.
- Low vehicle capacity of many main roads.
- Inadequate public transportation: The public transport system in Klang Valley includes busses, commuter, LRT, monorail and taxis. The existing rail transport is well functioning and reliable, but it has a relatively limited range and most passengers need busses to take them to and from the railways. Busses, however, are scarce, poorly maintained and unreliable with no functioning time table and no route charts. There is also a general lack of integration between busses and trains. Further more the public transport passengers are just as inconsiderate as the drivers. Lining up is a practically unknown phenomenon making it difficult to get in and out of trains and busses. Using public transportation is frustrating and time consuming.

- No bus lanes or cyclist lanes to enhance the ease of public or non-fossil fuel transportation. (Observations, 2004 and Singh, 2004).

In 2001 there were 4.4 million private cars registered in Malaysia. They shared our roads with 5.5 million motorcycles and 800.000 other vehicles, including taxis, buses and commercial trucks, which works out to a total of 10.7 million vehicles. This total represents an increase of almost 300% compared to 3.6 million vehicles in 1987 or an average annual increase of 9%.

9.9 million of the 10.7 million Malaysian vehicles are privately owned, a ratio of 2.5 people to every vehicle. Amazingly enough, there are only 8.7 million licensed vehicle drivers/riders in Malaysia i.e. there are more private vehicles in Malaysia than there are people licensed to operate them.

Table 1: No. of Motor Vehicles in Malaysia by Type and State up to 31 July, 2001

TYPES OF VEHICLES	**PRIVATE VEHICLES**		**PUBLIC TRANSPORTATION**		**RENTAL CARS**	**COMMERCIAL VEHICLES**
STATES	MOTORCYCLES	CARS	BUSES	TAXIS		
Perlis	31,740	8,633	156	164	0	1,585
Kedah	393,087	137,956	2,737	2,900	272	28,321
Penang	693,224	416,893	3,932	2,496	377	37,897
Perak	697,470	330,996	3,774	3,960	54	47,415
Selangor	630,955	596,788	4,380	3,870	188	87,357
W/Persekutuan	728,467	1,239,921	10,906	18,896	7,103	149,034
N/Sembilan	281,397	150,961	2,219	1,709	12	28,946
Melaka	229,202	126,699	1,698	1,424	59	17,712
Johor	835,578	559,273	6,896	10,031	162	84,766
Pahang	249,063	154,233	1,744	2,429	10	30,144
Terengganu	144,358	76,304	897	965	17	15,800
Kelantan	214,160	110,525	1,583	1,963	12	20,298
Sabah	78,930	210,317	5,850	3,997	1,394	83,335
Sarawak	305,285	253,463	2,484	1,576	363	47,560
TOTAL	**5,512,916**	**4,372,962**	**49,256**	**56,280**	**10,023**	**680,170**

Source: Ministry of Transport Malaysia, 2001

According to the Malaysia Automotive Association, total sales grew 10% in the first half year of 2001. Low interest rate, the easing of car financing terms, introduction of new car models and the government move to stimulate consumer spending helps to keep car sales stable. The sales of motor vehicles in Malaysia and three other major ASEAN markets are tabulated in Table 2. Malaysia's vehicle sales for the period between January to June 2001 grew by 10 percent, which is less that that of the reference countries, but Malaysia still has the largest marked despite housing the smallest population among the four.

To deal with the severe traffic problems in KL, the transportation planners will have to look to solutions to their woes, such as implementing a much delayed exclusive bus system, and promoting the increased use of cycling and walking in areas where this would be viable.

Table 2: Sales of Motor Vehicles in Four Major ASEAN Markets

Country	Volume (January - June)		Growth (%)
	2001	2000	
Malaysia	182,222	163,721	11
Indonesia	148,491	126,934	17
Thailand	140,018	122,339	14
Philippines	35,379	41,523	-15
TOTAL	506,110	454,517	11

Source: New Straits Times, July 26, 2001

2.1 Environmental impacts from transportation

The impact of transportation on quality of life is perhaps most easily seen in environmental degradation. The auto-oriented Malaysian transportation system pollutes the air, contaminates oceans and rivers, consumes open space and wildlife habitat, hastens climate change, and depletes fossil fuel resources. Transport has been identified as a priority area for action not least because of its impact on the environment, EC (2001a, §27),COM (2001, p.4), DE (2002, p.177ff).

The wide-ranging environmental impacts from transport are summarized in Table 3.

Table 3: Selected Environmental Effects of Principal Transport Modes

	Air	Water	Land Resources	Solid Waste	Noise	Risks of Accidents	Other Impacts
Marine and Inland Water Transport		Modification of water systems during portconstruction and canal cutting and dredging	Land taken infrastructure; dereliction of obsolete port facilities and canals	Vessels and craft withdrawn from service		Bulk transport of hazardous substances	
Rail Transport			Land taken for rights of way and terminals; dereliction of obsolete facilities	Abandoned lines, equipment and rolling stock	Noise and vibration around terminals and along railway lines	Derailment or collision of freight carrying hazardous substances	Partition or destruction of neighbourhoods, farmland and wildlife habitats
Road Transport	Air pollution (CO,HC,NOx, particulates and fuel additives such as lead) Global Pollution (CO2, CFC)	Pollution of surface water and ground water by surface run-off; modification of water systems by road building	Land taken for infrastucture; extraction of road building materilas	Abandoned spoil tips and rubble from road works; road vehicles withdrawn from service; waste oil	Noise and vibration from cars, motorcycles and lorries in cities, and along main roads	Deaths, injuries and property damaged from road accidents; risk of transport of hazardous substances, risks of structural failure in old or worn road facilities	Partition or descruction of neighbourhoods, farmland and wildlife habitats; congestion
Air Transport	Air pollution	Modification of water tables, river courses, and field drainage in airport construction	Land taken for infrastructures, dereliction of obsolete facilities	Aircraft withdrawn from service	Noise around airports		

Source: Linster (1990)

As illustrated in, Malaysia's per capita CO_2 emissions from fuel combustion are relatively high compared to Indonesia, India and Thailand. However, the number is relatively lower for Malaysia compared to Singapore. About one fourth of the total CO_2 emissions from Malaysia can be attributed to transport.

Table 4: Per capita Emissions by Sector in 1998 (kg CO_2/capita)

Country	Total CO_2 Emission from Fuel Combustion	Public Electricity and Heat Production	Unallocated Auto-producers	Other Energy Industry	Manufacturing Industries & Construction	Transport	Other Sectors
India	892	384	61	26	237	120	64
Indonesia	1112	240	8	174	203	278	210
Malaysia	4166	1254	51	479	1122	1079	181
Singapore	13736	5390	-	3233	920	4160	34
Thailand	2420	894	-	118	482	771	154

Source: International Energy Agency

Transportation causes impacts in five major environmental areas. The impacts are discussed below.

1. Significant Source of Air Pollution due to Transportation

- More people around the world are living in areas with unacceptable air pollution. Asthma, lung and respiratory illnesses, and heart diseases are also exacerbated by air pollution. Economically disadvantaged communities tend to be disproportionately affected by these public health problems. In addition to negative impacts on human health and environmental justice, air pollution in the form of smog and acid rain is known to kill or harm agricultural crops and damage buildings at a cost of between $2 and $3 billion annually worldwide.
- Motor vehicles are the largest source of urban air pollution, generating more than two-thirds of the carbon monoxide released to the atmosphere, a third of the nitrogen oxides (which react to form smog), and a quarter of the hydrocarbons (which also form smog). Some pollutants emitted by cars and trucks are known or likely to cause cancer, including toxic substances such as soot (fine particulates), benzene, arsenic compounds, and formaldehyde.
- Whereas all fossil fuel combustion processes will produce CO_2, the properties of the engines determine the quantities of other harmful substances. Especially old and poorly maintained vehicles in densely populated areas cause alarming human health risks. In Malaysia CO_2 emissions from transport constituted 28% of the 29 million tons of national CO_2 emissions in 1999 (Earthtrends, 2003) and in UK other health hazard emissions such as NO_X and CO, transport were responsible for more that half of the national emissions in 2001 (UK DFT, 2004). Even minor savings in transportation emissions will thus have effects on a national level.
- Emissions from vehicles contain Carbon Dioxide (CO2), Hydrocarbon (HC), Carbon Monoxide (CO), Nitrogen Oxide (NOx), Sulfur Oxide (Sox), Particulate Matter (PM) and other chemicals. Emission of pollutants from transportation and other sectors is given in Table 5.

Table 5: Estimated Emission of Pollutants by Sources ('000 MT) 1998

Emission	Mobile Sources	Stationary Source				Open Burning Practice	
		Power Station	Industrial Fuel	Domestic	Industrial Process	Municipal Disposal	Industrial Waste
PM	17.40	13.89	25.87	1.20	75.43	3.36	1.96
SOx	38.30	171.23	185.81	16.45	1.95	0.21	0.29
NOx	236.60	100.82	52.08	3.53	0.59	1.26	0.22
CO	1998.50	3.85	11.66	0.83	1.69	17.00	17.69
HC	111.30	0.61	8.04	0.33	4.42	6.30	1.81

Source: Department of Environment, Annual Environmental Quality Report, 2003

2. Major Source of Water Pollution

- Transportation also has a significant impact on water quality. Runoff from roads, bridges, parking lots and other impervious surfaces can pollute drinking water and lead to changes in water chemistry that degrade habitat quality. This significant non-point pollution source deposits road salt, dirt and dust, fertilizers, pesticides, antifreeze, engine oil, rubber and metal deposits, litter and other pollutants into aquifers, lakes, rivers, streams and oceans. One study shows that when more than ten percent of the acreage of a watershed is covered in roads, parking lots, rooftops, and other impervious surfaces, the rivers and streams within the watershed become seriously degraded. Groundwater contamination is also attributed to underground gasoline storage tanks (UST) which leak. One example is the gasoline additive MTBE, which has been linked to hyperactivity, convulsions, kidney damage, and possibly cancer.
- Finally, the necessity of moving millions of cubic meters of oil to serve motor vehicles has consequences for water quality in the form of marine oil spills. The infamous Exxon Valdez spill in Alaska was only one of thousands of oil spills reported annually.

3. Threat on Wildlife and Habitat

- More than 1 million animals are killed on highways every day. Besides that by altering, degrading, and destroying wildlife habitat, and by encouraging additional development, roads have helped bring dozens of species to the brink of extinction. For example the estimates of oil resources in the Arctic National Wildlife Refuge, which range from 3 billion barrels of oil to 16 billion barrels of oil, will put this natural habitat at risk.

4. Transportation Contributes to Climate Change

- According to the Intergovernmental Panel on Climate Change (IPCC), the 1990s were the hottest decade of the 20th century. The IPCC further predicts that the earth's average temperature will increase by as much as 6°C during the next century, leading to record heat waves, droughts, an increase in frequency of severe storms, rising sea levels, and the migration of insect-borne tropical diseases like malaria.
- Carbon dioxide (CO_2) is the largest contributor to climate change and the transportation sector is one of the largest sources of CO_2. Cars and light trucks can normally emit 20 percent of a nation's CO_2 pollution. Each liter of gasoline burned pumps 13 kg of CO_2 into the atmosphere – 9 from the tailpipe and 4 pounds from upstream refining, transporting and refueling. The world is getting hotter as the result of global warming, one of the major causes of which is vehicle emissions.

5. High Energy Consumption

- The transportation sector is over 95 percent dependent on oil. In 2000, cars and trucks use 120 billion liters of gasoline and an additional 125 billion liters of diesel and other special fuels. Cars and light trucks consume more energy than domestic oil producers extract in Malaysia. This trend is expected to worsen.

3. MANAGEMENT STRATEGIES

3.1 Strategic Transportation Planning (STP)

Transportation is not just roads and rails. The transportation systems affect the quality of our lives in many ways beyond the time we spend commuting. The efficiency of the local and regional transportation systems can affect the value of our homes, the safety of our children, the quality of the air we breathe and many other intangible positive and negative consequences.

Strategic and integrated transportation planning involves developing safe, efficient and affordable transportation systems for a country or an area. A committee structure should ensure that citizens, interest groups, elected officials and public and private agencies are included in the transportation planning process. In a STP, various considerations can be implemented to integrate and enhance the transport system, for example:

1. Mixed-Use Development
   - Mixed-use developments, which combine residential, shopping and office amenities takes up less space and provide easier access between home, work and recreational destinations. They also reduce traffic congestion by cutting trip lengths and catering to pedestrian traffic.

2. Set Transportation Development Patterns
   - New highways can facilitate higher levels of population growth. Investment in rail infrastructure often results in more mixed-use development, which occupies less land.

3. Governments Role
   - From land-purchasing programs, to transferable development rights, to more environmentally sensitive zoning standards, local, county and state officials can adopt a variety of coordinated policies to stem the loss of forest and open space.

4. Protection of Water Catchments and Wetlands
   - Encroachment on water catchments areas and naturally wet areas threatens both public water quality and private properties. Preserved wetlands and other natural habitats can serve as recreational attractions, which improve livability and provide a community with related commercial opportunities.
5. Enhancement of Mature Communities
   - Older, urbanized neighborhoods can capitalize on existing infrastructure to attract other development. But careful planning should take place to ensure that new development strengthens, rather than splits, the community's physical cohesion and urban identity.

3.2 Challenges

The gap between a country's transportation needs and available funding presents several challenges that must be addressed:

- Aggressively pursue both short and long term increases in needed capital funds to meet the country's transportation needs;
- Advance plan components to implementation, whether they are major projects, systems, policies, or strategies;
- Monitor the country's growth to ensure the plan stays abreast of the country's needs;
- Initiate feasibility studies for projects needed
- Create a flexible and integrated transportation system designed for periodical upgrading to meet future demands

Failure to address these challenges may result in deterioration of the transportation infrastructure, degradation in mobility, and harm to the economy and environment.

3.3 Transportation Management

Transportation management strategies are approaches that reduce and manage the demand for transportation projects. They also improve the operational characteristics of the transportation system. These strategies are designed to modify travel behavior and increase system efficiency without costly infrastructure improvements. A variety of transportation strategies are needed to meet the challenges we face today and will face in the future. The basic goals are to:

- Maintain and improve the capital infrastructure of the existing transportation system.
- Provide a transportation system that supports existing and future patterns of land development as recommended by locally adopted land use plans and adopted plans and policies already in place.
- Preserve the national transportation system to maximize people and goods carrying efficiency.
- Provide a safe and secure transportation system that allows for the movement of people and goods.
- Provide a transportation system that is sensitive to the quality of the environment and enhances the natural resources.

With this framework, the relevant implementing agencies responsible for maintaining the transportation system in the country should develop their programs. Besides those identified above, development programs should be in response to improvements requested by the public.

Basically, transportation management strategies consist of three interrelated components:

1. demand management;
2. system management;
3. technology applications.

Transportation demand management consists of strategies that manage the demand for transportation facilities by increasing transit share and lowering the overall growth in vehicle miles of travel, particularly single occupant vehicle trips. Transportation systems management consists of lower-cost capital projects and operational and institutional actions that improve the operating efficiency of facilities and serves to enhance the quality of service and promote transit use. Intelligent transportation systems consist of the deployment and use of technologies to improve, manage and share information; provide for the integration of transportation services; provide for improved incident response systems; and provide other system management and operational improvements that enhance efficiency and safety. It is important that the three components are viewed as equally important and as part of a holistic planning process. They should thus not be isolated.

4. DISCUSSION – LCA/LCM AS THE PROPOSED STRATEGY

One of the most pressing issues in transportation system design is long term planning. In order to be able to make long term decisions and optimize the management strategy, holistic tools must be introduced into the assessment and improvement of the system. Life cycle tools provide such features.

Life Cycle Approach (LCA) takes into account environmental, technical, and cost considerations in a planning and decision-making process. The basic approach is to create an inventory of the current system and identify improvement opportunities in target areas of the planning system, and then explore the environmental, technical, and cost implications of the resulting changes. The objective is to provide a holistic approach for improvement in concern to environmental and socioeconomic performance and to integrate the improvements fully into the system making sure that no areas of the transportation are isolated in the planning process.

As can be seen from Figure 1, life cycle management (LCM) takes into consideration both environment, efficiency, stakeholders and economy. And further more these considerations are made over the life cycle of the system thus creating long term solutions

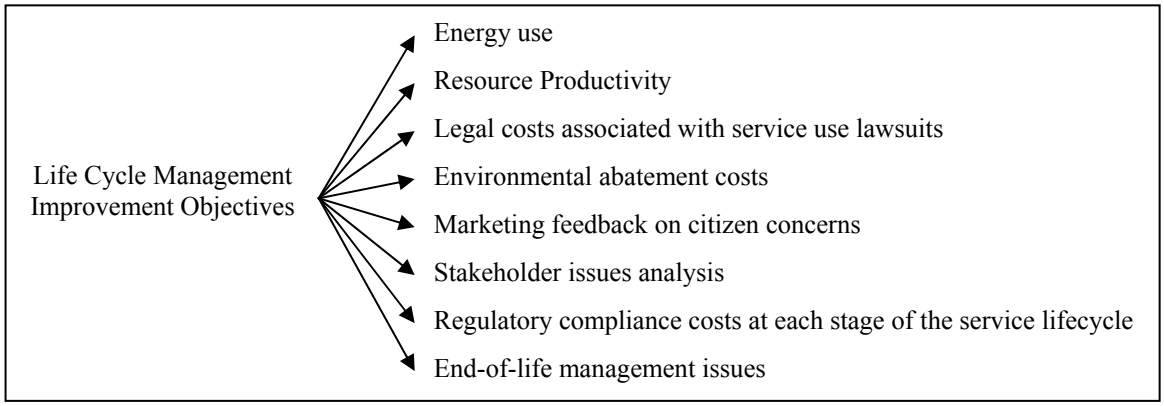

Figure 1: Examples of life-cycle management improvement objectives

4.1 Life Cycle Approach in Strategic Transportation Planning (LCASTP)

There are two main features of strategic transportation planning using life cycle approach for sustainable development:

- Consideration is needed in an integrated way, taking into account the wider economic, social and environmental implications of decisions and actions, the community and the biosphere
- The long-term rather than short-term view is adopted in decision making and actions.

By following a life cycle approach towards a sustainable path of development, we should be able to reduce serious environmental impacts arising from the transportation system. A life cycle approach will mean changes to our patterns of resource use, including improvements in the quality of our air, land and water and in the development of new, environmentally friendly transportation needs for the benefit of people and ecosystems.

The Guiding Principles of LCASTP are that -

- Decision making processes should effectively integrate both long and short-term economic, environmental social and equity considerations
- Where there are threats of serious or irreversible environmental damage, lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation
- The global dimension of environmental impacts of actions and policies should be recognized and considered
- Cost effective and flexible policy instruments should be adopted, such as improved valuation, pricing and incentive mechanisms
- Decisions and actions should provide for broad community involvement on issues, which affect them.

Providing a holistic overview, there are a number of parameters to be considered in a LCA based planning process. Figure 2 presents an overview of the main issues.

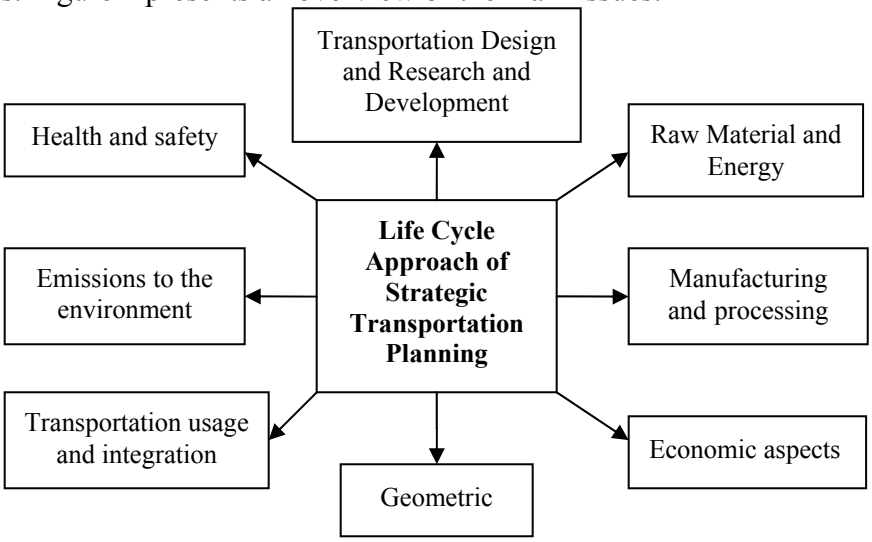

Figure 2: Issues to be considered in a Life Cycle Approach in Planning Strategies

4.2 LCA Planning Structure

One of the strengths of LCM is the total integration of environmental and economic aspects. Improvements in one aspect can not be made on the expense of the other.

The LCA/LCM planning structure is based on five main stages, namely –

1. Identification of the system and the scope/objectives
    a. The geographical system and the problems
    b. The goal, and scope including functional unit and borders (processes and compounds to include)
    c. In a transportation system, the functional unit could be impacts per person per km or impact per ton goods per km. The two functional units can be combined by setting a "price" on the transportation of persons and goods respectively. When defining the borders it must be decided what kind of vehicles to include, which stages of the lifecycle to include (e.g. should manufacturing and disposal of vehicles or construction of roads be included) and what kind of emissions to include.
2. Environmental and economic inventory
    a. All inputs and outputs are identified from all stages of the system
    b. Any assumptions made in the process are tested in a sensitivity analysis
3. Environmental and economic impact assessment
    a. The potential impacts from the inventory are assessed and debated. Preferred/ optimal areas of improvement are identified.
4. Setup and evaluation of alternative scenarios
    a. Qualified changes are made to the inventory in the preferred/optimal areas of improvement and the new impacts and costs are assessed. A scenario is chosen as the goal of the improvement project
    b. In a transportation system in a developing country, the costs of the improvements are very big issue and the optimal solution may not be available. It is thus of uttermost importance that the improvements are based on long term perspectives including the possibility of further upgrades at later stages. The alternative scenarios can assist in the long term gradual improvement planning.
5. Action plan formulation and implementations (including maintenance)
    a. The necessary institutional framework and committees are set up to prepare and implement action plans
    b. In a transportation system it is important to hold in mind the many stakeholders. It is thus important to include representatives from the industrial/commercial sector as well as the public.

When planning by the use of LCA/LCM three keywords must be kept in mind:

1. Transparency
2. Flexibility
3. Iterative Process

Being a holistic tool, the data quantities included in the process are generally immense and the overview, which is crucial in a planning process, may be lost if efforts are not made create a transparent data base and inventory. The flexibility and the iterative process are closely linked and also dependent on the transparency. The data collection and evaluation must be flexible to

allow for the iterative process to take place and to allow the new findings from the iterative process to substitute old data and thus change to focus back and forth between the respective processes of the system and or revise the system borders.

In developing countries, where transparency, flexibility and bottom-up initiatives in projects are not the norm, the LCM approach faces some obstacles. On the other hand, introducing LCM may also serve as a catalyst in changing the current bureaucratic project agenda to a more flexible and efficient mode.

4.3 Public Involvement

One of the goals of the LCASTP is a public involvement process, i.e. to develop and support an early, full and effective exchange of information and ideas among all transportation stakeholders. It should employ a wide range of techniques to promote citizen involvement, including direct mailings, open houses, public meetings in all parts of the region, and newspaper advertisements. Press briefings and media releases can also be used. One of the main premises of the updated public involvement process is commitment to increase public understanding of how transportation decisions are made and to encourage participation in the planning and implementation process. The public must be brought to understand the necessity of reducing private vehicles and enhance the use of public transportation.

5. CONCLUSIONS

Transport has a direct and well-understood history of environmental impacts and it is appropriate that guidelines and experiences be considered when formulating strategies and taking up new policies. The proper transportation planning and choice we make will represent new frontiers for development, and will have an impact on the shape and character of an area or country as a whole. Throughout the world, communities are struggling to reconcile the desire for economic development with concerns about rampant land consumption and environmental conservation.

The Life Cycle Approach is rapidly becoming recognized as a valuable approach that can allow focused environmental analysis and improvement of specific aspects of the overall transportation service system. Use of the LCA will undoubtedly result in a shift of the way the planners makes strategic and operational decisions, and subsequently probably improve the competitiveness in the long term, through being more effective in identifying improvement opportunities that may not have been previously obvious.

The LCA goes beyond being a technique for improving environmental performance. Through integration of environmental and financial parameters planners will be able to utilize this knowledge to identify novel improvement opportunities. This approach will provide most benefits when integrated into the planning, design and implementation when considering a national transportation system

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