1. INTRODUCTION

Affordable, reliable and sustainable rural mobility provision is a vital element that influences the socio-economic status of rural poor. Rural mobility provision is considered as the entry point for poverty alleviation and already there is a growing body of empirical evidence, that links transport investments to the improved well being of the rural poor [4]. For a long time governments of developing countries have been spending heavily on building and improving roads in rural areas believing that it would solve the transport burden of rural people, promote economic and social development and will reduce poverty. But this school of thought i.e. provision only the accessibility has not so far been able to uplift the socio-economic status of rural poor. In fact provision only a good and a wide road would not be effective, unless the associated mobility means and services are not provided. Derivation of appropriate rural mobility solutions needs a holistic understanding of the whole mechanism, through which mobility services are provided. Rural mobility provision is influenced by elements such as user demands, patterns, mobility means, service options, infrastructure options, status of local authority governance. Literature survey confirms even the current decision making practices pertaining to provision of rural transport services do not consider integrated approaches (Mbara, et al[10], Malczewski[9], Han[5]). It has now been increasingly realized, that without an integrated approach, affordable, reliable and sustainable rural mobility solutions could not be developed. Accordingly for the provision of affordable, reliable and sustainable rural mobility solutions, an integrated approach is needed, but such one approach has not yet been practiced in developing countries, particularly those in South Asia (Lebo[7]). The objective of this paper is to present a conceptual framework for an integrated decision support system enabling local authorities to derive and implement sustainable and affordable rural mobility interventions so that rural socio-economic aspirations and as a result poverty alleviation targets expected from such interventions could be achieved.

Key words: Characterization, Integration, rural mobility attributes, socio-economic parameters,
conventional transport planning tools are based on extrapolating current demands, and one basic assumption is that generated traffic/demand is a small incremental increase over the existing usage, but in the context of rural mobility planning there is a particular challenging situation. Current level of mobility services at village levels is low or in most cases zero. The rural transport market, characterized with small sizes and low demands, by default does not provide a competitive operating environment for service providers. But if we could convinced the rural commuters that affordable and reliable services are available, then for example farmers will start to invest on additional crops, villagers will apply for jobs in town, and young people will start to attend for evening courses available in town etc., thus gradually forming a critical mass of end users [3]. This means on the first hand we need to have appropriate, affordable and reliable mobility solutions in place i.e. conventional planning tools are not designed to address such situations, only an integrated approach could provide affordable, reliable and sustainable interventions, this way we could optimize the gap between demand and supply, eventually enabling self reliance in providing rural mobility solutions.

2. RURAL MOBILITY PROVISION - AN OVERVIEW

Today developing countries are facing increasing diversity of challenges in providing affordable, reliable and sustainable mobility solutions for the rural communities to assist in their basic socio-economic mobility needs and thereby to reduce the poverty incidence. Obvious deficiencies are the poor status of accessibility and non-availability of reliable mobility means and services. On the other hand as Ellis[2] has stated rural areas anywhere in the world tend to have lower population densities and lengthy rural road networks, thus causing difficulties in providing and maintaining viable transport services. In contrast, though we have a wide spectrum of available rural mobility options, much rural transport still relies on either, walking, cycling or use of private vehicles. It means that the potentials of modes such as public transport and the use of Intermediate Mode of Transport (IMTs) have not yet been fully investigated and practiced.

It has been an inherent feature of the rural transport provision that for many developing countries, elements of the provision are addressed in isolation. Infrastructure conditions, status of services and governance are conventionally inferior due to multi-facet of reasons such as unreliability of services, financial restrictions, and extremely poor quality consciousness during construction, inappropriate designs, and poor governance. In general the current rural transport development scenarios followed by local authorities, for the provision of rural mobility solutions keep on aggravating inequality and worsening the socio-economic status of rural poor day by day. According to the personal communications had with MAGA NAGUMA unit of Ministry of Ports and Highways, in Sri Lanka rural transport development initiatives have always been limited only to provide and

![Figure 1](image1.png)

Figure 1: Status of rural roads improvements program-Year 2004-2010, Sri Lanka.

![Figure 2](image2.png)

Figure 2: Expenses incurred during -Year 2004-2010 for rural roads developments, Sri Lanka

Lanka rural transport development initiatives have always been limited only to provide and
improve accessibility, under one such initiative government decided to implement a rural road concreting program. Knowing that concrete pavements will last long, program was commenced countrywide in year 2005 but mainly due to poor governance the program had an unsuccessful termination in year 2009 after completing only 2650km with an expenditure of 13.44B Rs, still completing only 4.16% of the total rural road network of the country. Figure 1 clearly indicates the gradual termination of the concreting program and Figure 2 further indicates the reduction of budgetary provisions. No concerns over the status of mobility means and services have been considered.

According to the personal communications had, India has a very ambitious rural roads development program under implementation at the moment. The program is popularly known as “Prime Minister’s Rural Road Program” PMGSY, and its main objective is to provide all weather accessibility to all habitations with inhabitants ≥ 500. This initiative too, solely considers only the provision of accessibility, no concerns over the status of “mobility means”, “service options”, considered.

According to the personal communications had, in Bangladesh rural transport development initiatives have been the responsibility of Upazila and Union Parishads both elected political administrative bodies. To prioritize limited investments over rural roads provision, these Parishads consider the number of inhabitants, degree of connectivity and allocations done in previous year, but still they do not consider associated other elements of the mobility provision.

Beside above, when providing accessibility local authorities pay a high-level of concern over to the desires of motorists, because of this reason the accessibility provision has not been in commensurate with the exact demands and aspirations of rural communities, thus making the majority worse off and gradually decreasing the “social equity”. This automobile dependency denies the right to have mobility provisions of under deserved communities (Litman[8]).

2.1 STATUS OF MOBILITY MEANS

Though there is a wide spectrum of mobility means, we have been using limited number of options, such as head loading, cycling, animal hauling, carts, 3-wheelers, motor bikes. There is a wide variety of local transport options that are intermediate in scale and may involve different forms of lower technology, often referred as intermediate means of transport, they increase local transport capacity and reduce drudgery at relatively low cost. They are most commonly used for relatively short distances of up to 20km. Some are non-motorized (handcarts, bicycles, animal powered transport) while others have small motors (motorcycles, power tiller trailer) equivalent intermediate water based means of transport include canoes, rafts and other smaller boats. For each mode, a most matching infrastructure option is associated, for example bicycles work best in flat terrain, with hard surfaces.

For many developing countries alternatives such as public transport and non-motorized transport have not yet explicitly integrated into the planning and decision making process, but these could form the primary modes of transport for the majority of rural populations. Figure 3 provides an overview of modal choices used by the rural inhabitants of HIGURALA, a smallest administrative unit (GN division) of western province, Sri Lanka.

![Figure 3: Main modes of transport to work- HIGURALA GN division](image)

Accordingly HIGURALA GN-division in which 518 families live, the majority of inhabitants are compelled; either to select “walking” or “hire a three wheeler” both are not the desired/appropriate modal choices for the community.
Figure 4 shows the typical nature of rural public transport in Sri Lanka and Figure 5 shows an example for a non-motorized means of transport used in rural Bangladesh, suitable for flat terrain.

According to the household surveys carried out in year 2011, these options are not in commensurate with the socio-economic parameters of the poor inhabitants.

2.2 STATUS OF SERVICES

Status of rural transport services in most developing countries are underdeveloped and in most cases unreliable, unavailable, expensive posing a serious impediment to reaping the benefits of accessibility improvements. In general transport service operators include both public and private companies/associations and individuals. Companies tend to operate medium to large buses, which require significant investments and government concessions and support. Individuals provide services using minibuses, pickups, three wheelers, mainly driving by themselves, or by employing drivers. The mini-bus services are normally demand driven, only operates when a critical mass is available, so services do not operate to a time table, hence not reliable. In TALAWA GN division in DERANIYAGALA, groups of village commuters used to hire vans on weekly POLA day to return to villages. One other important and influential parameter is the status of road infrastructure, once these are deteriorated beyond a certain limit mini-bus services and public bus services get terminated compelling rural commuters either to walk or to hire a three wheeler at high cost. On other hand because of the deteriorated status three wheelers are guaranteed with trips. In Sri Lanka three wheelers are mainly driven by owners. Because of non-existence of fare regulations in force hiring charges are very high. For the first kilometer distance it will be SLR 60.00 (0.53US$) at current market rates.

2.3 STATUS OF GOVERNANCE

In the context of provision of rural mobility solutions, local governance has so far been unable to follow holistic and transparent approaches in arriving at mobility development initiatives. Further local authorities responsible for managing the roads nationally, regionally or locally, are greatly overstuffed, and may lack the specialist technical staff and professional managers needed to make the best decisions and to ensure that limited financial resources for rural transport provision is effectively utilized.

3. LITERATURE REVIEW- CURRENT PRACTICES AND ISSUES

For a long time “need for transport” in general has been considered exclusively as a derived need, that is to satisfy primary needs. In recent years studies published in many circumstances affirms that mobility has a positive intrinsic utility or in other words, demand for mobility has a non-derived component (Colonna[1]). This idea is persistent in some secondary lines of research and confirmed by the everyday experiences, but it is often ignored by the current scientific paradigm. In the context of rural mobility, based on a pilot household survey carried out by authors in 2011, demands exclusively for non-derived needs were not encountered, but non-derived needs are considerable within urban sector, hence the literature survey was confined to explore the approaches currently
in practice for the provision of derived mobility needs of rural sector.

Conventional transport planning tools developed based on motorized travel demand couldn’t be used in the context of rural transport planning, mainly because of heterogeneity in modal compositions and the very low trip intensities. Further these standard transport planning tools ignore the status of widely varying needs and aspirations for mobility by age, gender, purpose, locally available mobility options and services, hence unable to provide affordable and reliable solutions.

Current transportation planning systems and land use development strategies tend to be relatively “Automobile dependent” meaning that they provide a relatively high level of service and concern to motorists, but inferior facilities for other modes. Hence physically, economically and socially disadvantaged, i.e. those who have limited ability to drive, the automobile dependency culture tends to make them even worse off, particularly in the context of rural mobility provision (Litman [8]).

Integrated Rural Accessibility Planning (IRAP) tool emerged in 1980 was used in number of countries such as Tanzania, Philippines, Bangladesh, Malawi and Zimbabwe (Sarkar, et al [12]).

The IRAP tool uses a bottom-up approach involving communities at different stages of the planning process. However IRAP remains focused mainly on the provision of accessibility, not all elements of the rural mobility provision are considered (Mbara, et al [10]).

Though the participatory approaches are very popular, on the other hand they do not consider the multi-systems nature of the rural mobility provision instead consider elements in isolation.

The existing latest asset management models such as Highway Development and Management Model (HDM-4) and Roads Economics Decision Model (RED) do not consider all dimensions of system; instead consider provision and management of accessibility [6].

In addition one most important drawback of both HDM-4 and RED models is that they assume that effective maintenance is always in place within the rural transport assets management process, which is not the exact scenario in reality in developing countries.

The application of GIS capabilities in the context of rural transport planning in general has been limited to visualization of spatial relationships of entities and no direct GIS based application is found to derive optimum rural mobility solutions (Malczewski, [9]). Han, [5]) presented a Decision Support System (DSS) for execution of bridge planning programs. The proposed system supplemented existing bridge management system (BMS) to determine the “optimum execution order”. Han, [5]) described a Transit Asset Management System (TAMS) intended to support decision making for rural and small urban transit systems. Main objective of TAMS was to derive cost effective maintenance strategies to sustain or improve vehicle conditions. Han, [5]) presented a methodology using “multi-criteria decision making” tool that involved tradeoff analysis between candidate projects and optimal projects selection in highway asset management under alternative scenarios of certainty, risk and uncertainty. This was an effective highway asset management tool.

Accordingly an integrated approach for the provision of reliable, affordable and sustainable rural mobility solutions has not yet practiced in general in developing countries and in particular in Sri Lanka. It has now been understood the need to have a more holistic approach towards the provision of rural mobility solutions, so that all demands, supply and infrastructure related attributes could be integrated to derive out affordable and reliable solutions. An integrated, multi-criteria approach will help to provide a wider spectrum of mobility solutions, for rural communities, hence will reduce the automobile dependency so could substantially increase “social equity”. Further integrated approach will help to fulfill the concept of “inclusiveness” to the maximum extent possible.
Apart from above, today growing concerns over green house gas contributions, low carbon mobility solutions, the increasing fuel scarcity, energy costs and environmental constraints will create a complex and a difficult decision making environment in providing affordable and sustainable rural transport solutions in near future.

The integrated approach considered in this study has not considered above stated constraints, but the model will have the provision to accommodate these emerging constraints. Accordingly the objective of this paper is to present a conceptual decision support framework that could integrate attributes directly and in-directly related to demand and supply of rural mobility provision so that optimum solutions could be derived. The Figure 6 reveals the current status of planning and decision making environment characterized with multi-system and multi-stakeholder objectives.

4. THE CONCEPTUAL DECISION SUPPORT SYSTEM

Provision of reliable yet affordable rural mobility solutions need the interaction of many system elements, such as modal means, service options and appropriate infrastructure options. Optimum mobility solutions could be derived by integrating its system elements appropriately. On the other hand use of the proposed decision model does not fully eliminate human judgment; instead provide decision makers with insights regarding the decision process and will facilitate the application of human judgment in more holistic manner (Riggs, et al [11]). A board overview of the concept of integration is represented in Figure 7 In the context of rural mobility non-derived mobility needs have not been separately assessed and integrated in this study.
4.1 MAJOR COMPONENTS OF THE DECISION SUPPORT SYSTEM

The Figure 8 depicts the prototype of the main elements of the analytical framework of the integrated decision support system.

The integrated decision support system has two major elements i.e. a planning support system, basically knowledge databases, approaches for modeling the demands for mobility and a decision support system, which provides criterion for matching operations i.e., decision rules and the integration algorithms. Major elements of the decision support system are briefly described in following sections.

4.1.1 PLANNING SUPPORT SYSTEM – PSS

A Planning Support System (PSS) in the context of rural mobility provision is basically an organized knowledge data base. The PSS will analyze the primary and secondary data to establish correlations, patterns, trends and demands for rural mobility. PSS will comprise with following knowledge bases and attribute databases, thus will derive information needed to formulate the Decision Support System (DSS).

\[ V_m = V_o + \alpha P + \beta I + \chi D + \mu PD \]  

\( V_m \) = demand per household “walk-km” for dominant mobility needs

\( P \) = Impact due to population growth (+/-)

\( I \) = Impact due to income growth (+/-)

\( D \) = Impact due to ongoing developments

During this stage household data is used to model the demands, trends and patterns of rural mobility using suitably formulated econometric model, regression analysis and using other suitable tools. The demand projection is to be carried out for the next five years period. During this stage even, based on local knowledge and case based reasoning techniques it is possible to arrive at initial judgments on desirable solutions.

Modeling the demands for mobility is to be assessed using an econometric model, shown by equation 1.0, suitably formulated with following specification (Wadud et.al [13], modified)
PD = Impact due to the proposed integrated developments

V0 = constant for household

$\alpha, \beta, \chi$ & $\mu$ are parameters to be estimated using the household survey data and as well as the already available secondary data sets.

Motorized private vehicular ownership to be estimated using already established prediction models or using time series data of the specific area.

ii. Modal Splits-knowledgebase

Information on alternative modal splits such as possibility of using water ways, rails, and virtual modes are included in this knowledgebase.

iii. Mobility Means-knowledgebase

This knowledge base will comprise with basic characteristics and important requirements of various mobility means, and as well as holistically derived operating costs of each mobility mean for varying demands and hauling distances. For example, a bicycle would be desirable for loads up to 60kg for a hauling range of 20km at a nominal speed of 10km/hr on flat terrain (Lebo [7]).

iv. Mobility Service Options-knowledgebase

Objective is to formulate/identify realistic strategies, either to improve existing rural mobility services or to introduce new schemes. Sustainability of reliable and affordable service operations directly correlated to the availability of critical masses and the status of concession and support by local authorities, but on the other hand, if reliable and affordable transport services are not in place, densities of demands will be suppressed. This scenario has already been established by the pilot household survey data already collected. Hence this knowledgebase will include details of practically viable regulatory measures (encouragement and incentive formulas) to have enabling operating environments, but the scale of problem varies between geographical areas even within the same country. Figure 9 presents the sub-flow chart that illustrates the selection of optimum choices for mobility means and services.

v. Mobility Infrastructure options-knowledgebase

Objective is to ensure that optimum geometrics (cross section) and pavement options are selected to satisfy the projected volumes. Two important databases to be formulated at this stage are databases of geometrics and pavement options. Figure 10 presents the sub-flow chart that illustrates the selection of optimum choices for geometrics and pavements.

vi. Rural Land use- Attribute database

Objective is to provide information to facilitate decision making in the context of rural land use planning. For example, whether it is necessary to re-locate service facility centers or to establish new centers. Land use and road maps will provide this information.

4.1.2 DECISION SUPPORT SYSTEM-DSS

The DSS in the context of rural mobility provision is considered as a computerized information system that supports local authorities in decision making process. The DSS is capable to compile, integrate all relevant information so that affordable, reliable and sustainable mobility solutions would be able to derive with increased transparency throughout the whole process. The DSS will comprise with decision rules based on already established knowledge and will use appropriate algorithms to facilitate the matching processes basically in spreadsheet environment.

In case more than one alternative solution is possible, the optimum solution is to be selected based on an assessment of economic viability of each alternative. Economic viability is to be assessed in terms of “walk time savings”.

For example, projected vehicle ownership and its composition in year 2016, will determine the cross-sectional geometry i.e. the width of the pavement, in case the design composition warrants the safe negotiation of two loaded motor bikes, then optimum width needed is 1.4m. Depending on location specific road...
engineering attributes and life cycle cost data
an optimum pavement too, is to be selected.
On the other hand, non-motorized users, for example, have an envelope of mobility means and service options. Hence, several alternatives...
have to be evaluated in order to arrive at an optimum solution. Selection criteria will be based on “walk distance” and “walk time” savings, for example one optimum solution would be to operate a public bus service up to and an identified hub on the core network, with a 3.3m width pavement made out of gravel.

The DSS is supposed to be user friendly tool that could be easily re-programmed to accommodate ever changing attributes of the decision environments.

4.2 MODEL CALIBRATION AND VALIDATION PROCESS

Model calibration and validation could be evaluated at two stages:

i. Calibration process

Model is applied for a GN division where at present rural mobility provisions are satisfactory and acceptable. Then model parameters are adjusted so that the outputs are in commensurate with these acceptable practices.

ii. Validation process

This is to be done by comparing the mean mobility costs and mean travel times for predominant movements at the end of the design life i.e. in 2016, presuming prevailing mobility providing scenarios are continued (
i.e. for example the ongoing rural roads concreting program) with the corresponding values due to the solutions derived by the DSS.

The projected socio-economic status due to the adaptation of the integrated mobility solutions as at the end of the design life are to be compared with corresponding socio-economic status projected, presuming the prevailing economic settings would have been continued throughout the design life. This could be done using appropriate rural development indices. Alternatively a household survey is to be carried out for post-evaluation of the socio-economic status, again using the same set of development indices.

5. CONCLUSION

For a long time building and improving roads in rural areas were considered as one of the main solutions, to promote economic and social development, and to reduce poverty through improved access to facility centers. However for many developing countries this school of thought has proven insufficient often because poor attention is paid to the provision of mobility services, as a result mobility services in most developing countries are under developed and in most cases unreliable, unavailable, and expensive posing a serious impediment to reaping the benefits of any accessibility improvement.

In the context of rural mobility there is a particular difficulty in assessing demands for mobility, following conventional transport planning tools. In villages, because status of existing mobility services are very low, unreliable or even zero, commuters have suppressed demands and desires, hence a single growth factor like for urban settings, could not be adopted instead the proposed DSS has taken an attempt to simulate rural mobility growth using an econometric model.

Deriving reliable and affordable mobility services requires a holistic understanding of the whole mechanism through which rural mobility services are provided and used in developing economies. Affordability, reliability, safety, efficiency, all these factors are at play in deriving appropriate mobility solutions. This is a challenging situation, i.e. to derive appropriate mobility solutions while optimizing the gap between demand and supply so that steady economic growth of end users is ensured. The proposed approach will yield out solutions that will eventually ensure self reliance in providing mobility services. The conceptual decision support framework presented here is to be practiced within selected GN divisions in SITHAWAKA and DERANIYAGALA and outputs are to be published in “ENGINEER” journal in December 2011.

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