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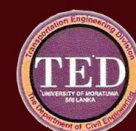


TRANSPORT RESEARCH FORUM

2010



UNIVERSITY
OF
MORATUWA



TRANSPORTATION
ENGINEERING
DIVISION

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Determination of an Effective Laying Pattern and Best Block Shape for Concrete Block Pavement Based on Field Performance

Senadeera A.A., Mampearachchi W. K.

Significance of problem

There has been an intensive process of urbanization which has brought about need for rapid construction of roads and related infrastructure during the end of the last century. Therefore development of economical road construction methods is a high priority for a developing country like Sri Lanka. Concrete block paving is one of the predominant road construction method used in most of the developing counties due to economic adaptability and this has emerged as a cost effective road construction method suitable for certain local conditions. But in Sri Lanka this technique is yet to be developed to a fully fledged road construction method. This can be attributed to a dearth of the technical expertise and knowledge. As a result, there is a great need to develop knowledge and establish proper methods of block paving.

The performance of concrete block pavements vary with block shape, thickness, size of the block, compressive strength, laying pattern, bedding sand and sub grade conditions. Therefore, considerable amount of research has been done recently with Concrete Block Pavement models in order to analysis their performance with respect to various factors. But most of the researches on CBP have been done in laboratory models and very low traffic roads and these tests may not simulate real situation. This research will cover the real ground situation and the behavior and the effects of blocks due to traffic weights.

Objective

- 1 determine most suitable individual block shape for CBP roads
- 2 determine effective laying pattern for CBP roads

Method/design

This research was covered the real ground situation and the behavior and the effects of blocks due to traffic weights with high percentage of heavy truck and buses.. Under this study, concrete blocks were cast according to the specifications in predetermined shapes and paving was done with different block shapes and patterns in a road which contains vehicular traffic.

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Selected 100m road length was divided to 10 equal parts and blocks were paved according to selected pattern and block shapes in each different section.

Deflection was measured by using Benkelman instrument and block displacement were measured by using venire caliper. The most effective block shape and pattern were selected comparing deflection and block displacement in each combination of block shape and patterns.

Findings

The analysis of results show that the following results

Most effective block shape is Uni style

Most effective block paving patterns are Stretcher and Herring. Both show similarly good results.

The effective laying angles are 0 and 90 degrees. Here again both angles show good results.

Conclusions

Under this study, concrete block paving road was constructed. Concrete blocks were cast according to the specifications in predetermined shapes and paving was done with different block shapes and patterns. Then the performances of the block paving were observed after allowing traffic. The data were collected to determine the most effective block shape and pattern.

The most effective combination of variables for cement concrete block laying are Uni style block shape, Stretcher and Herring block pattern and zero or 90 degree block angle can be recommended for new CBP roads.

Economical Mix Design for Interlocking Block Paving for Sri Lanka

Pilnavithana U. S., Perera P. S., Appuhami R. S. B. R., Mampearachchi W. K.

Rocketed trend of world wide Concrete Block Paving (CBP) adherence to the road network has already influenced the Sri Lanka as a well performing alternative for the rigid concrete pavements which caused many issues over past decades. Even though CBP in larger Production level, significant Standards and Guidelines for basic properties and manufacturing in the Sri Lankan conditions have not been introduced yet. Especially in application of CBP in trafficked road ways seems to be declined as it is not deeply concerned by the authorities due to lack of guidance. In that case the requirement of study in concrete mix design of CBP for roads phenomena was come across.

In an attempt to find the a economical mix design for concrete block paving optimized combination of cementitious and aggregate materials has been developed, which contains cement, sand, quarry dust and chips in intended for the production of interlocked concrete blocks for paving in road pavement. The main purpose was to achieve optimized Concrete Blocks with fulfilling the requirements in road by using alternative aggregates, admixtures and the production cost via materials.

The initial mix design was developed with the use of literature review and besides that other mix proportions were introduced by altering the initial design. First series of blocks were produced by using above mix designs by varying the aggregate-cement ratio (A/C) and water-cement ratio (W/C) between 0.25 – 0.40. Optimized value was selected considering the Compressive strength, Surface texture and Shape (edges). Next series was casted from the selected mix design and sand was replaced by quarry dust in proportion to the total fine aggregate weight. Final mix design was developed with those results and it showed significant high energy requirement compared to the first series.

Seven days Compressive strength of CBP with out quarry dust was varied between 52 N/mm² – 34 N/mm² with in the W/C of 0.25-0.40. It was given 41 N/mm² – 46 N/mm² variations for the W/C of 0.30 after replacing the quarry dust with sand. This has satisfied the required strength of 35 N/mm² for the commercial vehicles. All mix designs produced zero slumps. Compressive Strength has correlations with the A/C, W/C, Density and Sand Percentage. W/C inversely affects the shape and texture.

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In conclusion, Sand can be replaced by quarry dust as a successful alternative aggregate with a unique proportion. W/C ratio plays major role while restricting to upper limit to fulfill surface texture and shape. Quarry dust improves strength with a unique proportion of sand while acquiring more energy in production.

Key Words: Concrete mix design, Concrete block paving, slump, Quarry dust, compressive strength

Finite Element Model Analysis to Determine Improved Support Condition for Concrete Block Paved Low Volume Roads.

Gunarathna, W.P.H., Mampearachchi W.K

The intensive process of urbanization in the last century has caused a need for rapid construction of roads and related infrastructure in Sri Lanka. The rapid demand for better roads and services required the designers and the builders to introduce suitable construction methods in order to economize the construction as well as increase the durability. In Sri Lanka, large percentage of low volume roads has been constructed using gravel, concrete or bitumen as the primary material. Due to lack of maintenance of the roads in rural sector, Engineers are trying to find alternative cost effective pavement construction techniques.

Concrete block paving (CBP) is one of the predominant road construction methods used in most of the developing countries due to economic adaptability. This method can be emerged as a cost effective road construction method suitable for different ground conditions with low life cycle cost. However, this technique yet to be developed to a fully fledged road construction method in Sri Lanka. Therefore, standard set of guide lines are needed to maintain consistency and construction quality of block paving technology.

The aim of this research is to evaluate the state of support conditions for low volume roads and effective block laying patterns which can be used to obtain best performance from concrete block paving. Therefore verified three-dimensional (3-D) finite element model (using SAP2000 structural analysis software) was used to measure elastic deflection behavior of concrete block pavement for low volume roads. Developed design chart can be used for subgrade improvements for low volume roads condition and find best laying arrangement in the concrete block paving to obtain most excellent interlocking action.

Key words: Finite Element Model, Concrete block paving, low volume roads, Elastic behavior, Surface Deflection, Block laying Pattern

Simulation of Thermal Behavior of Ground Concrete Slab Exposed to Solar Radiation

Karunarathne A.M.A.N., .Mampearachchi W.K., Nanayakkara S.M.A.

Rate of heat flux from solar radiation, thermal properties of concrete and heat loss from concrete due to convection parameters of surrounding influence the temperature variation of an exposed concrete slab. Literature review has shown that a wide range of views on heat generation in concrete during the setting time and early age. This paper describes a method to incorporate the temperature variation of a concrete slab due to solar radiation to estimate the relevant deformation of concrete using finite element model (FEM) approach.

Variation of the temperature profile across a slab is well known fact and it cause differential thermal stresses and differential deformation of concrete structures. These stresses are very savior in rigid pavements in tropical countries. Deformation of slabs and pavements can lead to structural failures, efficiency drop downs, etc. Pre determination of ultimate deformation is important to taking relevant precautions.

ANSYS version 12 used to develop the FEM which was verified by a laboratory scale slab. It is one of the best non-linear analysis software to illustrate the thermal behavior of concrete. FEM gives temperature values at each location and hence the deformation also can be obtained. Prototype model constructed and measured the daily temperature variation at various points. Temperature profile at the centre was measured by thermocouples set across the thickness. Temperature variations were compared in the same points in FEM and the prototype for the verification.

The research provides a verified method to obtain temperature values at any location in a concrete slab which exposed to solar radiation. The deformation values at the particular locations can be obtained from FEM for varies thicknesses. Outcome is important in designing of expansion joints and load transfer non-dowelled joints in rigid pavements. Amount of curling and warping of pavements can be obtained using the FEM for varies lengths. The FEM approach is very helpful for proper designing of rigid pavements with less faulting, cracking and other distresses.

Key words: Radiation, temperature, deformation, FEM, verification

Rigid Pavement Design with Recycled Concrete Aggregate for Low Volume Roads

Gayani J. K. U., Mampearachchi W. K.

The main consideration of any pavement design is to provide structural alternatives that are feasible both technically and economically. This can be achieved by specifying pavement layer thickness with proper types of materials based on the extent traffic, environmental conditions and life cycle cost analysis.

Since traffic is regarded as the key design parameter, traffic analysis was done for seventeen provincial roads. That analysis was carried out to find vehicle composition, magnitude of the axle loads, axle configuration and frequency of load repetitions. In rigid pavement construction main component is concrete slab. Proper types of material should be selected for the concrete slab. In this project, it was determined the strength characteristic of recycled aggregates that can be used as an alternative material for rigid pavement construction instead of natural aggregate in concrete.

An experimental campaign was implemented in order to monitor the recycled aggregate properties before utilizing them as a rigid pavement construction material. Properties of recycled aggregate were determined in terms of (i) particle size distribution (ii) particle density (iii) porosity and absorption (IV) particle shape (v) strength and toughness.

In this study, various physical and mechanical properties of concretes were examined. The concrete properties were determined by doing the workability test, compressive test, flexural strength and modulus of elasticity test. Plating admixture was added to recycled aggregate concrete with the aim of improving its properties.

Suitable dimensions were proposed for provincial roads based on the traffic volume and the recycled aggregate concrete properties. Fatigue analysis (to control fatigue cracking) and erosion analysis (to control foundation and shoulder erosion, pumping and faulting) are the two design criteria in rigid pavement design. Fatigue analysis will usually control the design of light – traffic pavements while erosion analysis controls the design of medium-and heavy traffic pavement. Therefore erosion analysis was not considered to propose a pavement thickness for provincial roads. Fatigue analysis was regarded as the main parameter to propose a suitable thickness for rigid pavement in provincial roads

Geometric Design Standards for Narrow Curves in Hilly Terrain of Sri Lanka

Suneth Thushara Salawavidana, Mampearachchi W.K

The geometric design standards of roads in Sri Lanka are primarily based on the 'Geometric Design Standards of Roads (GDSR) of Road Development Authority, 1998. The GDSR is a complete set of guidelines that the Highway Design Division of RDA is following to design new roads and rehabilitate existing roads. However, the problem identified in this research with this glorious manual is the lack of design details for the horizontal curves whose radii are below 25m. As a design engineer, a main problem one faces in designing the roads in Sri Lanka is the financial constraints imposed with the design. Even though one is obliged to follow the GDSR in designing roads, it is common to find places where the minimum curve radius 25m is not possible at all without significantly increasing the cost. The aim of this research is to find out a set of guidelines for the geometric design standards for these narrow curves.

The main objectives considered are; to find out the horizontal design standards, in the context of design speed and superelevation that are adoptable to the curves whose radii are below 25 m, to find out the appropriate vertical design standards to cater the above situation and to find out the different physical measures to enforce these design standards.

The Factor of Safety (FOS) was assessed in each of the speeds from 100kmph to 30kmph as used in GDSR. □A representative FOS was taken to use in design speeds lesser than 30kmph. The maximum superelevation was assessed subjected to the practical maximum of 10% as per the findings from the literature review. Side Friction Factor (F_{max}) was taken as 0.21 in conformity with the findings from the literature. Minimum radii for each of the superelevation values from 2.5% to 10% were determined against speeds of 25kmph, 20kmph, 15kmph and 10kmph. □The practical minimum radius of 13m was adhered to cater for the design vehicles.

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It is shown that the derived design standards can be used for the narrow curves up to 13m, which are not covered by the GDSR and they should be accompanied with suitable vertical design standards. The practical minimum design radius should be 13m.

Guideline for the Selection of Appropriate Specifications for Low Volume Roads

Wannige E.P., Abeywardena H.S.T , Haththotuwa H.M.D.S, J.M.S.J. Bandara

The paper presents the research carried out to prepare a set of guidelines for the selection of appropriate specifications for low volume roads. It is an essential requirement to have such a guideline because lack of such guideline has resulted in waste of valuable resource in road construction work. This research finding are very important to Sri Lanka as there are many problems associated in the low volume roads due to lack of technical knowhow of the majority of people involved in the low volume road construction and maintenance. This paper describe the work is carried out in order to provide a guideline to minimize existing problems.

For the purpose of selecting suitable specifications for low volume roads a wide range of data base was needed. Areas selected for data collection were Badulla, Diyathalawa and Mahiyanganaya Engineering divisions in Uva Province. With the purpose of having a good database for analysis, data was collected through both discussions with engineers in provincial Road Development Department in Uva Provincial Council and observed data through field visits. Practice of low volume road planning, design and material selection, construction and maintenance were discussed with engineers and important road sections for visits were identified. Through field visits data on various parameters affecting the road condition were collected including all road types such as DBST, gravel, concrete and metalled & tar.

The data collected was statistically analyzed using SPSS software to identify significant relationships are present between parameters identified as important. The identified important parameters were drainage condition, traffic volume, terrain, land use, material used and carriage way width. Crosstab analysis was carried out between two parameters and also in between more than two parameters using layer option available in SPSS. Results of the data analysis were used for producing the set of guidelines for planning, design and material selection, and construction and maintenance phases.

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A GIS map was also produced to indicate the existing road conditions as a tool for identifying access needs during planning process of roads. A sample inventory of road infrastructure is presented to demonstrate how to use collected information during planning, design, and construction and operation stages of low volume roads.

Key Words: Low Volume Roads, Specifications, guidelines, SPSS, Crosstab

Identification of Suitable Decision Support System for Planning Programming and Economic Evaluation of Road Investment Projects for Sri Lanka

Sumugan V.S., Kulasooriya K.A.S.A, Bandara J.M.S.J.

Project evaluation, especially road investment project evaluations need to be handled carefully, since the initial capital outlay for such projects is considerably higher than other projects and it is highly essential for the national development. In Sri Lanka we can observe a lack of data for the evaluation process and the absence of suitable decision support systems although we have observed some developments such as the HDM-4, PREM model, and information systems such as TransPlan which are used widely. This research targets at identifying the current trends in the evaluation process and to identify critical parameters which affect the evaluation to further improve the quality of decision making in the sector.

The paper first identify the economic and engineering evaluation techniques currently used in the industry. NPV, IRR and Cost Benefit Analysis were the primary economic indicators used. Based on these and the available data it was decided to identify critical parameters that affect these indicators and to identify suitable evaluation methods. For this purpose HDM-4 was used.

HDM-4 (Highway Design and Maintenance Standards Model) was developed by the World Bank. It combines the technical and economic appraisals of road investment projects and is highly reliable. The application has a single drawback with respect to the local environment, i.e. it requires a high amount of data. Therefore in order to comply with the standards a sensitivity analysis was carried out to identify the most critical parameters that will affect the output significantly.

Several data sets were used with input data such as drainage condition, traffic data, pavement condition (Roughness, CBR etc.) and others to identify the impact of these factors in the evaluation process. Using the results produced over a range of input data, this paper identifies critical factors that need to be measured accurately to minimize significant deviations in results with respect to the actual situation. Furthermore it also targets at identifying a way to coordinate the existing information systems present to aid in the evaluation process. The

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result expected is a much better, accurate, reliable and transparent decision making process than at present in the local context.

Key Words: Road Improvements, Economic Evaluation, HDM 4

Selection Criteria for Provincial Road Development

Upali Liyanage, Mampearachchi W.K

Road network is playing an important role in the development of any country. With the present development in Sri Lanka its road network, consisting of national, provincial and rural roads are developing rapidly. Government allocates a considerable amount of money out of its annual budget for road development. In this environment there is a necessity to spend this money with the maximum benefit to the country. This research was done to develop criteria for the selection of roads for development in the provincial sector with maximum benefit to the country.

The existing methods used for selecting roads for improvement are different in different organizations. Road Development Authority, who manages the national road network in the country has there own data base necessary in doing this selections using HDM4 which can make reasonably accurate selections. But due to the limited trained staff, equipments and allocation such systems are not available in provincial or rural road organizations.

he research propose to make initial allocation of road length for development in each province and subsequently make the candidate road list in a province in a priority according to the social and economic benefits to the area of road development The provincial allocation to be done considering the poverty level, road density, vehicle fleet and population of each province with different weightings to those parameters. Poverty level of the province was given the highest weighting and the provinces with the roads already improved by any project were given a negative weighting. The assessment of benefit due to each road development was done based on a cost benefit analysis. The cost assessment was done mainly based on the cost for the improvement and the maintenance cost. The benefits were assessed under economic benefits and social benefits due to road development. During the assessment the economic parameters were given 70% weighting and social parameters were given 30% weighting. The social benefits were assessed under the benefits at the vicinity of the road (25m belt) and the benefits within the Divisional Secretaries area of the road development.

The cost for the pavement construction was done based on the pavement design criteria according to Road note 31. The type of pavement was designed according to the traffic loading during the design period and the value of CBR in road base. As the CBR value for a

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road base is a fixed value the pavement design is based on the predicted traffic loading of the road. This was assessed according to the present traffic volume and the predicted traffic growth rates during the design period. It was revealed that the traffic growth rates used for this assessment in PERM was incorrect and the assessment of ESA values used for pavement design was incorrect. The other main factor affecting to the traffic loading to the road is the damaging factor of the overloaded vehicles. Most of roads improved in provincial councils are damaged before the expected life of the road due to overloaded vehicles. This situation Leads to loose the expected benefits due to this road development and the bad thing happening behind this is the road network is suffering due to lack of additional money for the improvement of these roads before the expected life of them. It is observed that this situation has not considered in designing the road pavements in provincial councils. During the research it is propose to use vehicle damaged factors developed by RDA for the provincial council roads as there may not be a big difference of damaging effect of overloaded vehicles in national or provincial council roads. The damaging factors were calculated according to the traffic counting and classification data for each road. The other observation made during research is the necessity of conducting the ROW data assessment at the stage of project implementation. During the period of the preliminary assessment and the project implementation this may have changed and the actual cost for shifting utilities and demolishing work in ROW to be used in cost assessment for the project and the maintenance cost for the road during operation with and without the project has to include for assessment.

Benefit assessment was done based on the saving of the vehicle operating cost due to road improvement and the cost saving due to the saving of travel time..

The finding of this research will help to select provincial roads for development with maximum return to the money spending for them.

Effectiveness of Traffic Forecasting on Pavement Designs in Sri Lankan Roads

Gunasinghe P.H., Mampearachchi W.K.

Since the pavement design plays an important role in any improvement or rehabilitation, it is a responsibility of the road design Engineer to ensure that he has come up with an effective design, so that it will last for the design life. This effectiveness or the optimization is very important as otherwise it could lead to financial implications. If it is under design, it will not last till the end of design life, thereby incurring huge sum of money for the early rehabilitation and maintenance. And if it is over designed, that would also be undesirable fact, as the cost over run on this could have been utilized to improve another few kilometers of road.

The method adopted for the design of selected flexible pavements was the TRL, Road Note 31. The two main parameters considered in the design of the pavements under Road Note 31 are CNSA (i.e. Traffic Class) and the sub-grade strength (i.e. CBR% class).

In this research study, flexible pavement designs of recently rehabilitated or improved set of roads were analyzed to check the effectiveness of the traffic forecasting on pavement design. As the sub-grade strength of the pavements is a fixed parameter in all the cases, the only possible variable is the Traffic Class relevant to predicted CNSA.

It was found in the study that the actual traffic growth rates of different modes of traffic which travels along the selected roads is different to the predicted rates at the time of design. It has also been shown and statistically proved that the ESA values actually applied on these pavements by large trucks / heavy goods vehicles are significantly high, compared to the ESA values recorded at the design stage. Authors have proposed a methodology to evaluate the effectiveness of traffic forecasting on pavement designs. And improvements to the present practice of pavement designs carried out by RDA and its presentation.

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Key Words:

TRL – Transport Research Laboratory

CNSA – Cumulative Number of Standard Axles

CBR – California Bearing Ratio

ESA – Equivalent Standard Axles

RDA – Road Development Authority

Quality Control Aspects of Asphalt Concrete Surface Regularity

Gnanasekaran S., Mampearachchi W.K.

Standard Specifications for Construction & Maintenance of Roads and Bridges in Sri Lanka do not specify the allowable limit of road roughness for newly constructed roads or rehabilitated roads. But, the specification outlines the maximum permissible undulations for various types of constructions, that can be measured using straight edge. For asphalt surfacing the maximum permissible undulation is 6 mm longitudinally and 4 mm transversely. Hence, Road Authorities, which use the current Sri Lankan Road Specification, are unable to set an allowable road roughness for newly constructed roads or rehabilitated roads. So, the contractor is entitled to get his full payment, if the straightedge criterion is satisfied.

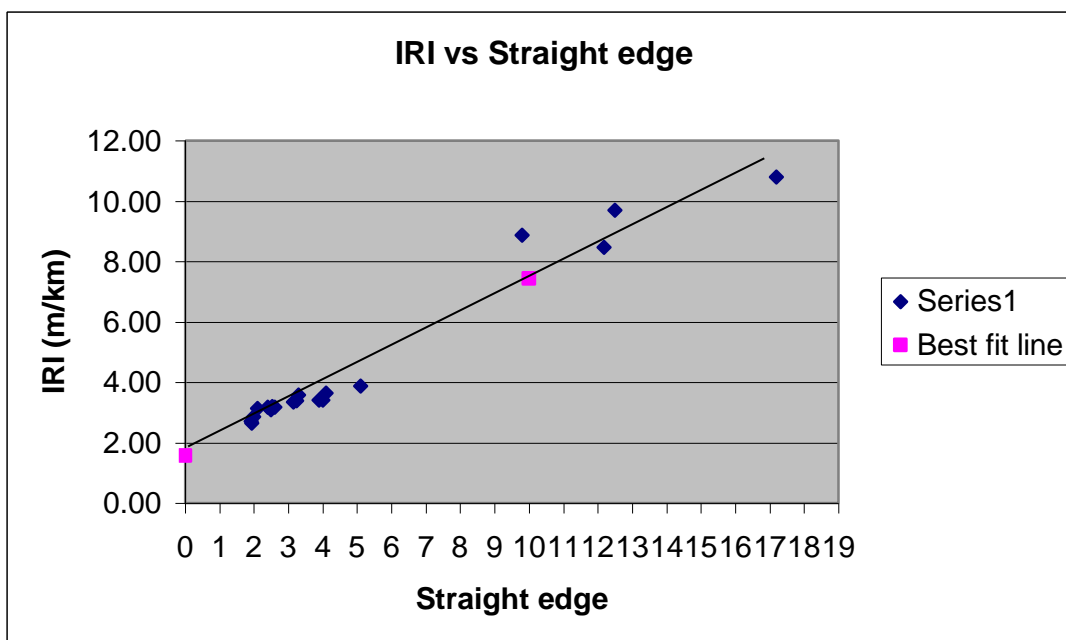
The main objective of this research is to find out an acceptable road roughness value for newly overlaid asphalt surface roads and to get an acceptable value at the end of the Defects Liability Period. The other requirement is to find an approximate IRI value when the maximum undulation is 6 mm within each and every three meter length of road. This can be obtained using a correlation equation between IRI values and Straight edge readings. Then it is possible to predict an approximate IRI value when the straight edge measurement gives its maximum acceptable value as per SSCM of Roads and bridge published in 1989.

Recently constructed roads in various areas of the country were selected to observe their initial roughness values using vehicle mounted bump integrators. Further, the roughness values of the selected roads were monitored to find out the variation of roughness with time, especially for a shorter period. The idea is to check whether the roughness varies drastically around one year time that is within the Defects Liability Period of the Contract. Though many countries have already adopted initial roughness requirement in their specifications, it is essential to check the practicability of adopting it in Sri Lanka. Setting a target which is impossible or it causes remarkably higher project cost does not give any benefit to the nation.

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The road surfaces with different undulations were measured for IRI and the same locations were measured using straight edge. The road sections were carefully selected such that the road surface does not have sharp undulations such as potholes. Then approximate correlation equation is found.

In this study the maximum undulation for every 3m was taken and it is plotted against the IRI for the corresponding section as shown in figure 1. Using the correlation, IRI value is found for the straight reading of 6mm. This comes to an IRI value of around 5m/km. This is the minimum IRI value for the corresponding straight edge reading as the analysis is carried out for the maximum straight edge readings. That is to say, for average straight edge reading the IRI is greater than 5 m/km.



It is found that the implementation of smoothness specification in Sri Lanka, in terms of IRI, is essential. The bonus and penalty system appears to convince the contractors to produce smoother road pavements. This has resulted reduced life cycle costs. It is practicable to set a maximum initial road roughness in terms of IRI, when the measurements are being made using vehicle mounted bump integrators.

The change of IRI with time for a shorter period is not significant. So, it is not essential to set a roughness value at the end of defects liability period. The maximum tolerance of surface regularity given in the standard Specifications for Construction and Maintenance of Roads and Bridges published in 1989 results a higher initial IRI value.

Review of Grading Systems for Asphalt Binders in Hot Mix Asphalt Pavements

Mihirani G.S., Binduhewa B.W.P., Lalithya G.D.D., Mampearachchi W.K.

Asphalt binders are typically categorized by one or more grading systems according to the physical characteristics. Traditional grading systems such as penetration and viscosity grading system and the new method, Superpave grading system are available currently.

While some developed countries are using the latest Superpave grading system, most of the other countries are still rely on the empirical Penetration grading system. Sri Lanka also has not moved even to the Viscosity grading system. Some developed countries such as USA, UK are conducting many researches under those areas. India has developed their own grading system to comply with their climatic conditions as well as its location. A study relevant to the Sri Lankan conditions based on pavement performances, currently using grading system and binder grades, the suitable binder grades will be carried out herein.

A road investigation on pavement distresses is carried out to evaluate the pavement performances with the change of climate and the binder grade used. Current practice in the industry when dealing with asphalt binder including the property variations, temperature susceptibility, testing methods, etc is evaluated with the test reports collected from the industry and a survey conducted. The suitable binder grades for different areas of the country are identified then, according to the climatic conditions especially the Superpave prediction algorithms, used to convert the air temperatures into pavement temperatures are verified to Sri Lankan climatic conditions.

The research identified that binder grade using for the construction make a significant effect on pavement distresses. Even though the literature, reviews that the Superpave grading system is most suitable, Sri Lanka has many restrictions to move even to the Viscosity grading system. The research clearly shows that industry do not maintain even the current using Penetration Grading system. From the analysis of binder grades for different areas, the requirement of different binder grades for different zones are identified. Moving to a better binder grading system while maintaining its standards and changing the binder grade with the climatic conditions as identified is recommended here in.

Key words: Asphalt Binder, Grading, Pavement Temperature, Performances, Penetration, Viscosity, Superpave

Effects of Super pave Specifies Aggregate Gradation on Marshall Mix Parameters

Fernando P. R. D., Mampearachchi W.K.

Standard specification for roads and bridges (SSCM) includes gradation master band in which upper and lower percent passing has been specified for most sieve sizes. These limits tend to make finer gradation in the asphalt concrete than Superpave specifies aggregate gradation. The objective of this research is to evaluate the effect of Superpave aggregate gradations on Marshall Mix parameters (heavy traffic condition) while types of asphalt binder and type of aggregate remain unchanged

The method was very similar as Marshall Mix design procedure that SSCM are described for Sri Lankan conditions, except Superpave guides was used to develop the design-blended aggregate envelopes. Locally available crushed granite and 60-70 penetration grade bitumen were identified and collected to prepare different test samples. Individual properties of asphalt binder and aggregate were tested to determine that they are met relevant specifications as mentioned in SSCM.

The different hot bin aggregate samples were combined to make aggregate mixtures that comply with the Superpave conditions. The coarse side (plus 4.75 mm) of the grading curve remained almost unchanged, while the fine side (minus 4.75 mm) was varied in order to pass through, above, and below the restricted zone specified in superpave aggregate gradation. The blended aggregate envelopes were categorized as follows:

- Over Restricted Zone (ORZ) with comply to control points.
- Through Restricted Zone (TRZ) with comply to control points.
- Below Restricted Zone (BRZ) with comply to control points.

It was observed from the research that all Superpave specifies aggregates blends were satisfied the SSCM specified Marshall Criteria. Superpave restricted zone was not affected on Marshall criteria under local conditions and specifications. Optimum binder content (OBC) and Binder Tolerance (BT) were reduced when aggregate blend becomes coarser. Average Film Thickness (AFT) was increased when aggregate blend become coarser.

Further, Marshall Stability and Void in Mineral Aggregate (VMA) are not any significance differences when compare three gradation envelopes (ORZ, TRZ & BRZ). There was no significance different of Marshall Flow of ORZ & TRZ, while BRZ showed some lesser value than ORZ & TRZ. Air Voids (Va) value was increased when the aggregate blends become coarse.

Evaluating Suitability of Soil Stabilization Methods for Local Road Construction Industry

Herath H.M.S.M., Mampearachchi W.K.

Soil stabilization is defined as any treatment applied to improve its strength and reduce its vulnerability to water. With the rapid development of local infrastructure industry, there is a scarcity of good quality soils which causes to delay of projects, increase of cost as well as decrease the quality of the final product. Therefore it is essential to find out reason for non popularity of soil stabilization and develop some guidelines to effectively used in road construction sites. *A survey was conducted among professional in road industry* Survey result revealed that only 35% of the participants had a fair knowledge and experience on soil stabilization but 72% and 56 % of participants were skeptical on quality control and the cost respectively.

Engineering properties of soil Sample collected from different places were determined and same soil has being used to determine the properties after stabilizing according to the available guideline, with locally available stabilizers (Cement and Lime).Laboratory test results indicates that both stabilizer improve soil properties in considerable amount and Degree of Pulverization (DOP), mixing time are important parameters in soil stabilizing .Further, field tests are conducted to measure the applicability of stabilization technology using locally available materials and machineries

According to the laboratory test results shows 80% degree of pulverization (DOP) is required to gain a higher compressive strength of cement and lime stabilized soil. The effect of delayed compaction showed a strength reduction of 22% for cement and 12% for lime at the OMC. Lime and cement stabilizers increase OMC and therefore compaction should be carried at higher moisture content. .Breaking action is more effective rather than rolling action in soil - stabilizing. So, rotaries may be more effective than motor grader or backhoe (which are presently use)

Key Words: soil stabilization , OMC, DOP,

Estimation of ESAL Values for Low Volume Roads in Provincial Sector

Kinigama L., Mampearachi W.K.

The demands for the improvement of provincial roads are ever increasing and GOSL has given priority for the upliftment of rural economy through the improvement of rural road network. Funding agencies have shown interest in providing financial assistance for this task. Road design engineers require reliable traffic data and design specifications for detailed design of provincial roads. One of the basic inputs required for the pavement design is the ESAL values for each vehicle category in each road.

The most common method used for the estimation of ESAL values for trucks is the static axle load survey conducted by Road Development Authority (RDA) for national roads however the axle load surveys are rarely done for provincial roads.

Sophisticated equipment and methods are not suitable for the provincial sector as their capacities are limited. Primary objective of this study is to formulate a simple but reliable method to estimate axle loads on provincial roads.

The most important and core analysis of this study is to find out how the vehicle load is distributed among axles. The vehicle load can be estimated using vehicle dimensions, type of material and loading condition. Then this estimated load should be distributed among each axle in a rational manner. Again for the buses, LGVs and Farm vehicles, the average distribution of loads were analyzed irrespective of the type of loading material. This is simply because the, loading type for buses are passengers only, and for farm tractors, it is mostly grains and agricultural products. There is no large variation of load distribution for different type of material in the case of LGVs.

But for the MGV & HGV types, the distributions of load among axles are very sensitive to type of material. Therefore the same analysis was extended for each material type.

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The method introduced for the estimation of ESAL is very straight forward and simple. High technical inputs are not required for the implementation. High-tech equipments are not required. It is quick and easy, therefore large amount of trucks can be measured during the field survey. The survey can be carried out for several days for the same road to see all the traffic variations and seasonal changes. And it can be used for all roads and then CNSA for each individual road can be found.

The accuracy of the findings was checked using actual axle load survey data. It was found that results can be accepted at 95% confidence level. The ESAL is usually estimated based on the sample data. Hence, the proposed method can be used to estimate ESAL values for each vehicle category on all provincial roads with reasonable accuracy.

Method to identify Potential Safety Deficiencies at Identified Accident Black Spots

Gayani Jayawardena, Bandara J.M.S.J.

Accidents Black spots are the locations or road sections where accidents are common. Highway engineers and Traffic police generally know of the tendency for road accidents to cluster together at certain locations, commonly termed “accident black spots”. It is possible to identify these black spots of the road network, so that appropriate remedial measures can be undertaken to reduce the likelihood and severity of accidents at those locations. Although the improvement of accident black spots is a very important area requiring attention it has so far received little priority in Sri Lanka.

Traffic accidents are a serious issue in Sri Lanka around 2,000 people are killed in traffic accidents every year. As a result of ever increasing number of vehicles and insufficient safety precautions the traffic accidents in Sri Lanka shows an ever increasing trend and the alarming numbers of fatalities.

The objective of this paper is to provide a clear guidance on how to enhance the road safety at identified accident black spots by identifying potential safety deficiencies in Sri Lankan road network. At present, Sri Lanka Police Department keep records of traffic accidents, but this information does not carry adequate information on accident prone locations or information is not properly transferred to road authorities who design and install road safety facilities. It is not clear who is the primary agency to formulate road safety policy and strategy and design and implement road safety measures.

Paper identifies five major issues and their sub issues which caused to accidents in Sri Lankan road network. The five issues are i) Road markings, ii) Signing and lighting, iii) Layout geometric details and road surface, iv) Pedestrians and related facilities, v) Overtaking opportunities and land use either side of the road. Significance of these issues can be change depending on the location and the environment. Method has been proposed to priorities these major issue, as most of our organizations are not in a position to rectify all identified problems, due to restricted/lack of funds. Furthermore, under each issue it is

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identified sub factors which can enhance the accident situation. The above major issues and sub issues are gathered in a questionnaire format.

Major contributing factor can be identified using the said questionnaire for a particular problematic location. As mention above the questionnaire has been based on five different issues with their individual sub components which has been identified as the important safety factors in Sri Lankan Road Network. The questionnaire needs to be answered by different people at the conflict location (Safety Audit). It is advisable to do this Safety Audit by the persons who have some knowledge regarding the road conditions and road situations.

The next step is to allocate weights to individual issues. Depending on the location and the importance of the individual issues weights can be defined. As the aim is to improve road safety at identified black spot another third person who has experience in road safety improvement has to decide the weights considering the relative importance of the five issues in that particular accident black spot. Defined weights could be justified using the analytical hierarchy process. The basic idea of the approach is to convert subjective assessments of relative importance to a set of overall scores or weights. Then by normalizing the issues most critical issue for the particular location could be identified out of five issues. Subsequently most appropriate traffic safety measures could be implemented successfully. The proposed method will enhance the road safety at identified accident black spots with less cost but effective safety measures resulting more economic benefits to the society.

Key words: Road Safety, Accident Black Spot

Development of Shortest Path Network with Minimum Nodes for the National Roads to Maximize the Accessibility using Breadth-first search algorithm

Harshana W. Sellahandi, Mampearachchi W.K.

Sri Lanka, as a developing country, needs data also in the form of classification for things like reservoirs, irrigation schemes, roads etc. Most of the infrastructure facilities in Sri Lanka have been built; nevertheless, they have not been classified fully into categories for further advanced studies in its own field. Roads in Sri Lanka are such as instance.

Most of the Sri Lankan roads have been classified as class A, class B, class C and class D roads. Among them class A and B roads have a clear definition, whereas, class C and D roads have failed. Over the time these roads are upgraded by the government when such a demand, due to the development and increase in traffic, is faced by the relevant authorities.

Sri Lankan government has made great achievement in economic and social development. One of the most important policies of Sri Lankan government has been sticking to is to prioritize infrastructures construction, including transportation, energy and telecommunication, among which, transportation especially road network was realized as vital of economic development by Sri Lankan government.

However, in Sri Lanka, road of total length 72000 km are in the state of unclassified. The reason is, the objective found in constructing such road was to just connect villages and small community centers. As the time permitted us to the next stage from this level, classification of these roads is of concern.

The paper is focused on development of a low volume road classification system based on minimum node shortest path concept in network analysis

The sample road network was selected in Kesbewa DSD for the study. In creating the road network, all junctions were defined as nodes and all road sectors were defined as edges. Find the all minimum paths to specific goal node. This process will be continued several times. Ultimately this will come up with the most important shortest paths. According to this shortest path, the sample road network can be divided into sub networks. Breadth-first search algorithm is uses to identity the minimum node path in a subnet work.

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All the nodes in Class A, B, roads are marked as goal nodes in the sub network and a start node is selected from the rest. In the (Breadth-first search algorithm) program is executed and the shortest minimum node paths can be found. This process is continued to all nodes in the region excepting goal nodes. The minimum nodes path in the sub network are arranged by the descending order depend on number of minimum nodes in those minimum paths and weights are assigned to road links according to the survey data analysis. The links are ranked according to the weight range they fall in.

This analysis will help to identify the most important link in a network to improve the accessibility to National road network.

Key words: Breadth-first search algorithm, minimum paths, minimum node paths.

Methodology to Determine the Optimum Logistics Cost Cluster Size of Multiple Facility and Server System

Perera K.P.H., Bandara J.M.S.J

Majority of suppliers of material required for construction are concentrated in to a particular area to handle their facilities due to the location of existing customers, existing supplying capacity and the locations of their key requirements such as raw material suppliers or sites. The market demand for a particular facility can be exceeded due to the existing demand and due to the growth of facility consumers. So the competition of the market can also be increased. This will encourage the forming of new facilities or plants and also increasing the supplying capacity of existing facilities or plants. With time facility providers can be scattered over a large area with continuous growth of the facility consumers and there is a need to determine the optimum location for new facilities.

This type of problems is usually handled by using clustering method to improve the convenience and the efficiency of operation. The usual practice is to consider the geographic basis or arbitrarily based on suppliers and consumers. When there are interactions among the clustered facilities and/or between the facilities and a central server, the cost of transport & logistics operations would be a significant component that affects the efficiency of the system. The problem of locating regional facilities and allocating customers to optimize the cost of transportation covers the core topics of optimums logistic cost cluster model.

This paper describes a mathematical model that can be used to determine the optimum location and cluster size for a given facility. This model can be applied in to transportation requirements which based on direct shipment network type such as construction sites of contractor, distribution network of retail stores and serves etc. Transportation problem theories and center of gravity methods were used to develop the model. The cost of transportation was assumed to be proportionate to the distances between the origin and destination. This was later relaxed by using an individual time factor which user can define according to the average speed of the particular road. Operation requirements also introduced to enhance the model accuracy and efficiency such as the concrete delivery time of concrete transportation etc.

Key Words: Facility location, Cluster size, Transport network, Optimization

Methodology to Find Alternative Paths Using GIS

Silva S.A., Bandara J.M.S.J

In recent years Sri Lanka has experienced a high growth in urban population and the number of private vehicles. Most evident feature of such a trend is urban road congestion; roads in some areas are also facing unexpectedly high traffic flow which causes a lot of time waste in transit and huge losses to the economy of the country. Therefore, it is important to find alternative routes during times of traffic congestion. GIS technology can be used for this purpose, to find alternative paths between two nodes and graphically represent it. This will not only help manage the existing highways efficiently but will also help traffic planning studies.

Alternative path between two nodes can be node independent or link independent. Furthermore, the meaning of the node independent path is path which cannot go through specific node or nodes in its best path. The route which is not use a particular link or links of its best path can be defined as link independent path. These paths are important for transport engineers and urban planners in accessibility studies, disaster management and traffic management work. Best path between any two nodes can be found using minimum path algorithms. TransPlan model developed by the Transportation Engineering Division of the University of Moratuwa facilitate finding best paths between any two nodes on the National Road network in Sri Lanka. It is not possible to find alternative paths between two nodes using TransPlan.

The objective of this study is to develop a method to find the node independent and link independent alternate paths using Geographic Information System (GIS) and make a model to find the alternative paths of A, B and selected main roads within City of Colombo by customizing the ArcGIS network analysis tool using Visual Basic 6.0. Method used and examples of application are presented in the paper.

Key Words: Alternative path, GIS, Customize the GIS using VB6

Methodology to Identify the Optimum Network for an Integrated Urban Rail System

Malkanthi L.P.S. , Bandara J.M.S.J.

Planning of railway network is very important in case of new railway systems such as urban Light Rail Transit (LRT) and Mass Rapid Transit (MRT). The general objectives of a railway network development are minimizing total cost that includes construction and operation costs, maximizing social welfare and profit and minimizing travel time and negative environmental impacts. The question in transport network design is to determine a network that has an optimal performance given a specific design objective.

According to the previous research studies, a methodology has been developed to identify the optimum railway network, by considering the factors related to the construction cost and the passenger demand. Although the network can be optimized by considering those two factors, it is not completed until the operational stage costs are considered. Therefore it is very much important to consider the operational costs in developing methodologies to identify the optimum railway network.

This paper is on finding an improved methodology to determine the optimum rail road network considering the fleet cost in addition to the construction cost. Optimum route network is generated so that optimizes the fleet because fleet is mainly depending on the route network.

Initially, ten locations from the Colombo Metropolitan Region are selected as station locations and two networks are identified based on two scenarios. First scenario is to generate a primary route network considering the demands between nodes. Routes are assigned for highest demands until all the nodes are connected at least by one route. In second scenario, all the demand values between nodes are assigned along their shortest paths and add them up to calculate the total demand for each link. Primary network is generated by linking the highest demand links until all the nodes are connected. Routes are assigned for the network considering the highest demand.

The two route networks are checked for fleet cost. Route networks are fine tuned using a set of algorithms for route merging, adding links and route sprouting. Fine tuned route networks are also checked for fleet cost and compared. Network with least fleet cost value and least changes for fleet cost with route network changes is selected as the best network. That means the best network should not be changed considerably in the later stages of operation due to demand variations apart from adding links or changing route network. The method to generate the best network is considered as the methodology to find the optimum network.

Critical Issues on Motor Insurance Claims

Edirmanne I.A.G., Bandara J.M.S.J.

Insurance acts as an important tool providing security to the society. As the premium paid by people are part of their savings, insurance acts in promoting savings and investments. This paper is focused on motor insurance and its critical issues in settling claims of road accidents victims. The deficiencies in transport related insurance claims, particularly, the fatal accidents, accidents at road construction sites and the growing problem of hit and run accidents are being discussed.

The aim of this paper is to educate the victims of road accidents and the general public that they need not silently suffer the damages/injuries caused due to someone else's negligence as they can always be compensated for such losses/damages through insurance claims. At the same time it creates an opportunity for insurers too, to expand their services to cover many important areas that are being highlighted.

A motor vehicle accident can disrupt one's life on many ways. This will create financial problems and emotional strain for the victim of motor accident and his/her family members. The paper identifies problems in motor insurance claims, such as;

- The stress of dealing with the insurance companies responsible for covering damages
- The insurer's attitude to pay the minimum when settling claims
- Non availability of specific guide lines in settling claims among the insurers
- Denying policy holders' claims
- Obtaining insurance policies only to satisfy the legal requirement under Motor Traffic Act
- People are unaware that claims have to be filed within the specified time if not, they have no claims
- The victims of road accidents at construction sites and hit and run accidents could also make claims against the parties responsible, though, this is not happening in practice.

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The paper will also discuss the critical issues in insurance claims such as disputes between the Insurer and the Insured, obligations of the Insurer - to explain the main benefits /before the contract is entered into, exclusion of claims treatment of policy holders, legal action required to recover damage, rigid litigation procedures, responsibility of road construction contractors and safety violations, deficiencies in Hit & Run Accident Claims and benefits for victims of pain and mental sufferings.

The following recommendations are identified as vital in promoting motor insurance not only among people live in urban areas but also among people in rural areas.

- Awareness programs to educate the motorists. Consumer education is also important to provide the motorists with the correct state of mind for careful driving to prevent accidents. The public should also be educated on how they should report traffic accidents and also be educated on insurance matters.
- Driver training and testing programs
- Introduction of New Laws and Regulations
- Proper guide lines and procedures in settlement of claims
- Consideration of claims for pain and mental sufferings
- Awareness programs regarding insurance claims for victims at road construction sites
- New Payment plan for road accident victims younger than 18 years and over 65 years of age. This is a serious issue since these groups of people are not covered as they have no earning capacity.
- Keep in view the no-fault claims – No fault claim should be kept in view as it has its merits and drawbacks.
- On line information to minimize delays in obtaining insurance claims and to find information for people who are interested in insurance.
- The successful implementation of the above recommendations depends on the cooperation of all stakeholders to play their part responsibly to deal with the issues.

Freight Vehicle Movement Pattern on National Roads in Sri Lanka

Priyadarshani G.A.C., Bandara J.M.S.J.

Transportation in Sri Lanka is mainly based on the road network which is centered on Sri Lanka's capital, Colombo. It is reported that over 95% of the freight movements are taking place on roads. However, majority of the studies focuses on passenger transportation and minimal literature available on freight transportation in Sri Lanka. Objective of this paper is to analyze the freight vehicle movements in Sri Lanka in various aspects such as vehicle type, type of commodity, load and capacity.

This study uses the roadside origin and destination survey data collected from 35 locations all over the country by the Transportation Engineering Division of University of Moratuwa. First the data from the 35 locations were analyzed qualitatively and quantitatively to find which type of vehicle mostly uses for freight transportation and the type of commodity highly distributed and find whether there is any correlation between commodity type and the type of vehicle and loading patterns.

Next part is, preparing a combined origin and destination matrix to find the freight trip distribution pattern. When preparing combined origin and destination matrix at Divisional Secretariat Division (DSD) level, it is found that most of the cell values are zero. It may be due to inadequacy of sample sizes or there is no freight trips during the time of data collection or those trip may not be going through the selected survey locations.

Hence, the combined origin and destination matrix was prepared for District level, It is found that 69% of the freight vehicles are medium goods vehicles while light goods vehicles and multi-axel goods are 19% and 6% respectively and remaining 5% are heavy goods and tractors.

Except within the Colombo district trips most of the medium goods vehicles trips are moving from Gampaha district to Colombo district.

When considering the commodity type it is found that 38% are empty goods vehicles, 10% are construction materials the remaining 14% are perishable and other agricultural products and the remaining 38% are other types of goods.

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It is also found that 46% are empty loaded vehicles, 25% are fully loaded and remaining 29% are 1/2 loaded, 1/4 loaded and overloaded vehicles.

With respect to the total freight vehicle combined matrix, it is found that 36.9% trips are generated from Colombo district and 53.2% trips are attracted to Colombo districts.

Finally it is found that most of the perishable goods are fully loaded and medium goods vehicles are mostly used to transport the perishable goods.

Key words: freight vehicles, Origin and Destination, Goods transport by road, Types of freight vehicles, Commodity types

Preparation of Time, Bus and Crew Schedules for a Selected Passenger Transport Bus Company

Karunaratne K.A.C., Amal S. Kumarage

In Sri Lanka, passenger transport services are provided by both private sector and government sector. Government sector buses are operated by Sri Lanka Transport Board. This board is a well organizing institute. This institute has time table to operate their buses and there are bus and crew schedules system.

However, such organization cannot be seen in the private sector. Private sector buses are operated by individual operators and the permits are issued to these buses to operate only on one route. This ownership structure makes lot of difficulties in the passenger transport service such as less Average Vehicle Utilization, illegal operators, overloading, speeding and high accident rate, lack of time tables, unqualified and dissatisfied bus crews without job security, loss of revenue, high operating cost. As the solution for above difficulties National Transport Commission (NTC) has introduced Coordinated Rotated Timetables System to operate the government and private sector buses. If bus operations are carried out according to proper timetable there cannot be excess supply or demand, either overcrowding or lingering. Also, buses waiting at terminal for hours and hours and buses chasing behind each other on the road can be eliminated.

However, an integrated timetable system may have some shortcomings. Some of the major shortcomings are the majority of buses are operated by individual operators. As a result vehicle and crew assignment has to be integrated among the individual operators. Buses are authorized to operate only on routes assigned by the authorities, which issues them a permit. Therefore, the buses cannot be deployed on different routes according to passenger demand. It was effected to create lack of Average Vehicle Utility, less Reliability (Early morning and night trips), Overlapping, and Oversupply buses of the route

Due to this reasons National Transport Commission looked for further development. As a result, National Transport Commission has introduced *Passenger Transport Bus Companies*.

The aim of this study was to introduce an efficient scheduling system to the private passenger transport companies and analyze how to minimize the above shortcomings by the formation of Bus Company rather than individual operators:

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When considering the percentages improvements of this study, operated km per bus per day (AVU), average trips per bus per full operating day and average revenue hours were increased, while idle time, required buses per day, required bus fleet, average crew working hours, required drivers and conductors, total trips per day by all buses in routes, platform hours were reduced. According to that, the main objectives of the research are successfully achieved. It is evident that a proper timetable method can address all the problems identified in a passenger bus transport system, such as less Average Vehicle Utilization, illegal operators, overloading, speeding and high accident rate, lack of time tables, unqualified and dissatisfied bus crews without job security, loss of revenue, high operating cost etc. Considering these economic and social advantages it can be concluded that schedule efficiency and resources utilization can be maximized by preparing time, bus and crew schedules for bus companies rather than individual bus operators.

Rail Bus Integration for Commuter Traffic in Colombo City

Hirani Thenuwara,. Bandara J.M.S.J

Despite commuters often use more than one mode of transport even in a single journey, an intermodal coordination and organizational facilities of public transport service in Sri Lanka is yet to be developed. Transport Integration means coordination of two or more modes with an appropriately coordinated time table. Developing integration between transport modes is difficult in Sri Lanka as a number of stakeholders separately involve in a decentralized, sector fragmented transport service. In this context implementing an intermodal connectivity in the public transport system is a high priority requirement to improve the quality of the service.

Many of the passengers travel through Colombo city whenever they need to travel to other suburban areas within the Colombo Metropolitan Region. Consequence is unnecessary traffic congestion in the city which leads environmental pollution as well as disutility to passengers such as long trip length and travel time etc. Passengers who use rail are not facilitated with an intermodal connection up to their final destinations and hence they often have to walk over 200 m distance to get into buses. This may discourage passengers' use of railway. The railway transport carries only a 10% of the total demand in and around Colombo. Therefore a well coordinated Rail/Bus integrated system will be a cost effective strategy to overcome above problems as compared to more expensive road widening and highway infrastructure development etc. In this aspect rail stations closer to main roads such as Dematagoda, Bambalapitiya, Slave Island, Nugegoda, Dehiwala, Panadura, etc and surrounding bus stops could be taken as platforms to implement bus/rail integration.

In this paper the possibility of rail & bus integration within Colombo city limit to reduce the difficulties of public transport passengers is investigated. Dematagoda railway station and adjoining bus stops were taken as a case study to identify the current situation and the need of the connectivity in between Dematagoda station and bus stop especially towards Borella. Data from a comprehensive travel survey that has been conducted during the period from June to August 2009 is used for the analysis. The paper identify the travel characteristics of passengers, demand for intermodal connectivity of the rail & bus passengers and their travel requirements to minimize the difficulties of their journeys.

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It is found that 66% of railway passengers use bus as their access mode to railway and 63% bus passengers use railway as the access mode at the Dematagoda railway station. A higher percentage of bus and rail passengers have home based work trips. However, there is no significant difference in trip purposes between rail and bus passengers. The railway can therefore, be expected to attract all types of trips.

It is shown that there is a potential to improve the quality of the public transport service for commuter satisfaction by providing proper integration between the two modes. To achieve the desired results it is necessary to provide a rail/road based public transport network for feeder routes. The urban and suburban public transport system could be planned and developed focusing on rail-based transport corridors.

Possible Improvements to Existing Bus Fare Structure to Achieve Better Service

Iftthikar B.M. , Bandara J.M.S.J.

Bus fare is one of the most important factors regarding profit maximization in the industry as well as providing a quality service to the passengers. In the economic point of view the price of the commodity decided by the market mechanism of demand and supply basis. But in the case of service sector the price deciding approach is different than the market mechanism. Most of the cases service provider is deciding the price according to his cost. But in the case of bus operation the service provider in terms of bus operator don't have an opportunity to decide the fare for his bus service as the fare is decided by the regulatory authority.

There was no scientific method for bus fare revisions till 2002. Due to the unavailability of scientific method bus fare was revised under the tight pressure of bus owners and this created anomalies in the structure. Therefore the bus industry almost every time needed a policy for bus fare and guidelines which use now for fare revisions comes to affect as policy in 2002. Anyhow there is a question arises that the rate which decided to revise the bus fare earlier and after introducing the policy, is comparatively reasonable with other economic indicators. It is also important to examine that the rate which decided to revise the fare is equally applied to the individual fare stages which consist different segment of distance.

One of the main objectives of the study is to get the historical view of the fare structure. Before nationalization bus fare was revised few times and available data of that are insufficient to analyze. The existing fare structure came to effect in 1958 with nationalization of the bus transport in the same year. The bus fare was revised in 25 times since 1958 under the different institutional structure. One objective of this study is to identify the equity of the fare structure. Parameters such as fare revising rate, fare/km, and cost/revenue can be used to this purpose. To observe the passenger attitudes is another objective where the survey data of the passenger behavior used to identify the passenger attitudes on bus transport under present fare level. It is seen that the short distance fare was overpriced and long distance services were under priced. This situation badly affected to the industry where the quality of the services are not improved comparatively with the increase of bus fare. Therefore it highly needed a proposal to develop the existing fare structure as another objective of the study.

The unsystematic fare structure causes to lower the quality of the services especially in the long distance services. Due to the low fare in the long distance services they try to scouting the short distance passenger where it is profitable and easy to recover the cost level. This condition must create

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an overloading situation in the long distance services as well increase travel time of the journey due to scouting of the short distance passenger all over the journey.

To avoid this situation it is important to introduce a new boarding fare for long distance services to discourage short distance passengers to get in long distance busses, in the same way it needs to increase the fare/km in the long distance services to recover the operating cost.

Develop an Evaluation Criterion to Assess Pedestrian Facilities in Urban Environments at Micro Level

Dias T.W.K.I.M, Bandara J.M.S.J.

In urban design, facilities available for the pedestrians and the convenience of walking are the measure of the overall walking conditions in an area. The concept of walkability has been used to assess these factors. That is to measure the extent to which the built environment is friendly to the presence of people living, shopping, visiting, enjoying or spending time in an area. A walkability index is a method to evaluate the facilities available for walking. Evaluating walkability is challenging because it requires the consideration of many subjective factors. Some factors are; land use modal conflict, security, crossing safety, motorist behavior, pedestrian amenities, disability infrastructure, side walk width, obstructions, maintenance and cleanliness. There are some indices used internationally and all of them assess the effectiveness of the facilities qualitatively. In this paper it is proposed to develop a criterion to compare two roads at micro level to evaluate ease of walking with an improved walkability index. An attempt has been made to incorporate more quantitative parameters that will minimize individual biasness.

It is expected that having an evaluation criterion will generate awareness on walkability as an important issue in developing cities. This will help the relevant authorities to identify the areas where the pedestrian facilities are to be enhanced. Some of the walkability indices have been evaluated and their shortcomings and limitations are being identified.

For the current indices that are in use, roads environment need to be categorized in to specific types such as a high-income neighborhood with mostly housing; a low income neighborhood with mostly housing, a transport hub (e.g., rail station), and a commercial district. A survey was carried out in the Colombo city limits with a road length of 35 km. During that survey it was realized that a similar sampling method cannot be adopted and road stretches should not be greater than 500 m. to avoid loss of homogeneity since the land use is not much organized in developing country such as Sri Lanka. In order to accommodate different land use types along the road it is proposed to use the land use percentages. There is a need to incorporate

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the height of the buildings or walls by the road side. The effects on weather on the walkability measures were not seen in any walkability index. Evaluation need consider both rain and sun shine. This paper summarizes the findings of the walkability survey carried out and highlight the improvements need to minimize biasness.

Key Words: Walkability, Pedestrian, Safety, Evaluation

Tool for Initial Environmental Assessment of Road Rehabilitation Projects

Ambalavanar J., Bandara N.J.G.J., Bandara J.M.S.J.

The environmental assessment process involves the prediction of changes over time in various environmental aspects as a result of a proposed project. The prediction of the nature, extent, and magnitude of environmental changes likely to result from a proposed project is aided by various tools and techniques, the choice of which depends upon the impacts of concern, data availability or lack thereof, and the appropriate specificity of quantitative models. However, the choice of the appropriate method for conducting an environmental assessment can only be guided by certain criteria, but no single method will meet all the necessary criteria.

The environmental assessment for development projects are mandatory requirement in Sri Lanka since 1993. The detailed assessments are required only for the projects fall under the category of prescribed projects of the National Environmental Act. The Road rehabilitation projects do not fall in to the above category unless it falls within sensitive areas or resettlements of more than hundred families are involved. However, for funding purposes foreign agencies have made this mandatory even though they exempted from the Environmental Assessment according to the NEA act. Therefore a quick alternative method for environmental assessment is essential for this purpose.

For these reasons, the present study was conducted to develop a checklist for initial environmental assessment of road rehabilitation projects which only consumes a week or so to carry out the environmental assessment. The checklist was generated from the information collected from literature survey, questionnaire surveys and field observation of six actual road rehabilitation projects from planning, construction and operational phases. It identifies activities, corresponding environmental impacts, suitable mitigation and the monitoring requirement for each component of road rehabilitation projects. Notwithstanding the lesser time it takes, it will certainly help Sri Lanka to absorb more foreign donors and aids with effective assessments and also to attract prospective donors. The checklist is user friendly as

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activities and impacts are predetermined and linked to each other and it could be used in any road rehabilitation projects by the subject experts in order to be effective and accurate.

Also the study discovered that to avoid opposition from the general public for the proposed development, the compensation should be paid at the planning stage and a strong monitoring system should be implemented during construction and operational phases. A search for new cost effective mitigation measures is recommended and the checklist has to be upgraded accordingly.

Key Words: Initial Environmental Assessment, Road Rehabilitation Projects, Mitigation Measures, Environmental Monitoring, Checklist for Initial Environmental Assessment

Development of Content Management System for Traffic Survey Reports

De Silva S.C.P., Bandara J.M.S.J.

Transportation has become one of the key development factors in Sri Lanka recently. More studies and research have been initiated relating to the transportation infrastructure development. The one of the essential parameter for these studies and research is the availability of traffic related information. Since traffic data is vital for any type of study or research in transportation, the traffic survey reports files should be stored efficiently in a suitable repository from for interested party to view or use them.

There are different types of surveys conducted to gather traffic related information. Efficient mechanism to store collected data and an easy access to past data is a growing requirement. Currently there are no proper ways of keeping all surveys results that have been conducted. This paper discusses the development of a content management system to handle traffic related information.

A development of Content Management System for managing all common types of traffic and transport surveys is discussed. A separate file server is configured to store digital copies of survey results while end user software is connected with server and give all information about surveys. The Users can download relevant data from the server. java technology was used in developing the software and relational database management concept was used to develop the data model.

The database schema is developed by identifying the basic information/data regarding to be stored from any survey type (O-D, MCC etc.) by applying the concept of relational database and EER modelling. The software development has gone through the basic steps defined in waterfall method.

The final system is user friendly and safe since all the information is gathered to one central server database. Using this central server any type of survey reports can be retrieved with details. The administrator who is responsible for the system can grant the privileges to other low level users to do their tasks separately.

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Both functional and non functional requirements have been considered in the development of this database. As functional requirement the main processes for the system have been considered. For non functional requirement the quality of the system; security, reliability, performance, resources etc. have been considered based on the software and hardware components.

A Methodology for Design of Pedestrian Crossing Facilities in Sri Lanka

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Accommodation of pedestrian should be an integral part of any transport infrastructure design project. Pedestrian facility comprises with walkways and pedestrian crossings. Pedestrians have a right to cross roads safely. Therefore road designers have a professional responsibility to plan, design and provide safe walking and crossing facilities in their designs.

Analyses of recent accident studies have identified that pedestrians comprise a significant proportion of serious injuries and fatalities while they were crossing the road without using a designated pedestrian crossing. Majority of pedestrian accidents occur while negotiating a road crossing, hence provision of safe and effective pedestrian crossing facilities are paramount.

Sight distance, level of service and delay to pedestrians are major parameters to be considered with warrants prior to installation of a pedestrian crossing. Introduction of a crossing without following a rational design approach would create additional delays and such a provision would even be hazardous.

It is important to recognize the correlation between pedestrian travel characteristics, with parameters such as speed, density, flow and space by conducting comprehensive pedestrian surveys.

Design of a pedestrian crossing requires basic understanding of related human behaviors, characteristics and capabilities which again depend on age, physical and mental condition of pedestrians, who are expecting to negotiate a crossing.

So the main objective of this study is to develop a guideline to assist in determining the appropriate crossing facility for a given location of a road based on the sight distance, Level of Service, delay to pedestrians and vehicles, pedestrian speed, density, flow and space in addition to the warrants.

Strategies to Minimize User Inconvenience During Road Rehabilitations

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Many of the nation's transport infrastructure reaches the end of its life cycle, work zones are becoming more and more prevalent on our roadways. This increased exposure to work zones increases likelihood for inconvenience to road users. Level of inconvenience and how they perceive will be changed according to the user category depending on their involvement as passengers, pedestrians, drivers, residence, commercial parties or others. It is important to identify user inconvenience and activities causing inconvenience to them and introduce strategies to eliminate or minimize the inconveniences.

Road construction activities can lead to make some negative impacts such as increasing air pollution, noise pollution, traffic delays, crashes, disturbing to access, disturbing to existing drainage system and water stream, disturbing to utility services, water pollution, increasing vehicle operating cost and vibration, etc. All of these have certain economic and social cost.

Aim of this paper is to identify how the users perceive the inconveniences due to road rehabilitation work and to propose strategies to minimize or eliminate them. Field surveys and user interviews were used to gather information relating to different types of inconveniences. Analysis shows that, air pollution, traffic delays, noise pollution, disturbing the accessibility, disturbance to water ways and drains and interruptions to utility services are mostly disturb the road users during road construction.

Air pollution is the most impacted inconvenience to road users. Air pollution occurs due to many construction activities. Roadway excavation, site clearing, barrow pits, road base and sub base constructions, paving and surfacing, stone crushing plants, asphalt mixing plants, machines and vehicles makes lot of dust and emissions to the environment.

Traffic delays are the next most impacted inconvenience to road users. Road construction projects can potentially cause significant delays to road users. During road rehabilitation, traffic is allowed to pass on existing road or divert to another route. Going through road construction sites require additional time due to many obstructions. Traffic diversions to alternative roads also need extra time causing traffic delays.

Noise pollution comes next that have many inconvenience to road users. The major sources of noise are blasting, compaction, travels of heavy equipment and machineries, generators and pile driving, etc. Disturbing the accessibility during road construction also has a higher value. Many of excavations, storing materials, parking machineries, forming new levels due to designs and road closures disturb accessibility of road users.

Many construction activities can lead to disturb water ways and drains during construction period and sometimes even after that. If un-compacted earth surfaces are left exposed and construction activities are carried out during the rainy seasons, erosion and siltation severely may occur. When excavated material within the trace is used as fill material, or if proper planning and management of cut and fill operation is not followed, large amount of materials need to be kept in temporary storage thereby causing environmental issues such as erosion, silting, landslides etc.

Road users are suffered due to interruption of utility services (water, electricity and telecommunication) during road construction. Normally service lines are damaged due to construction activities. During shifting of these service lines, failure of providing continuous service may be happened. Strategies are proposed for all of the above inconvenience with conclusions and recommendation.

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