DEVELOPMENT OF AN ECONOMICAL LEVEL OF SERVICE ESTIMATION MODEL USING GPS DATA IN A MIXED TRAFFIC CONDITION

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This research presents the development of an economical Level-of-Service (LOS) estimation model using GPS data in a mixed traffic condition, with a specific focus on defining clusters based on the categories within the existing Highway Capacity Manual (HCM) definitions of motorised LOS, for practical application. The study aims to enhance the representation of Sri Lankan traffic conditions, predominantly observed on 2-lane roads, particularly within the LOS D and E categories where the majority of typical Sri Lankan traffic situations occur. The data collection scope encompasses the entirety of Sri Lanka to ensure the generation of more representative values for the defined clusters. As clusterisation parameters, Average Travel Speed which is a reflection of mobility, Percentage Time Spent Following another vehicle and the Percentage Free Flow Speed which is a ratio of current speed to the posted speed limit were used in the same manner as HCM 2016 - 15-2.

It showcases the utilisation of two CNN based image processing models developed, one for assessing the 'following' and 'non-following' states and the other to assess the types of road (road classes), using the Google Colaboratory platform, for the analysis of geo-tagged video collected through the Transcend DrivePro 250 and their combination with 1 Hz GPS data collected by the Qtravel GPS device, which includes parameters such as speed, heading local date and time. Additionally, application of unsupervised K means clustering, which finds k centroids and then assigns each data point to the closest cluster while minimising the size of the centroids, to define clusters corresponding to the HCM definitions. The proposed methodology and model aim to provide an improved representation of LOS in Sri Lanka's traffic conditions, considering the unique characteristics of the road network and the predominant traffic scenarios observed in the country. The research findings, produce a table containing parameters similar to HCM 15-2 (Motorised LOS parameters for 2 lane roads) but in a practical sense instead of a planning tool.

Cluster	Road Class			
	Class 01		Class 02	Class 03
	ATS (mi/h)	PTSF (%)	PTSF (%)	PFFS (%)
01	> 44	< 33	< 50	>100
02	34 – 44	33 – 55	50 – 70	76 – 100
03	24 – 34	55 – 72	70 – 84	48 – 76
04	11 – 24	72 – 88	84 – 94	18 – 48
05	< 11	> 88	> 94	< 18

PFFS exceeded 100% due to speed limit choice (50 km/h) for class 03 roads and FCD non-compliance. Cluster 5 needs to be checked against road capacity levels. Adjusting limits in the clustering model can eliminate any potential issues. However, the primary objective has been achieved for representative LOS clusterisation from GPS and geo-tagged video data.

Keywords: Level of Service (LOS), GPS data, CNN, KMeans Clustering, Highway Capacity Manual (HCM)

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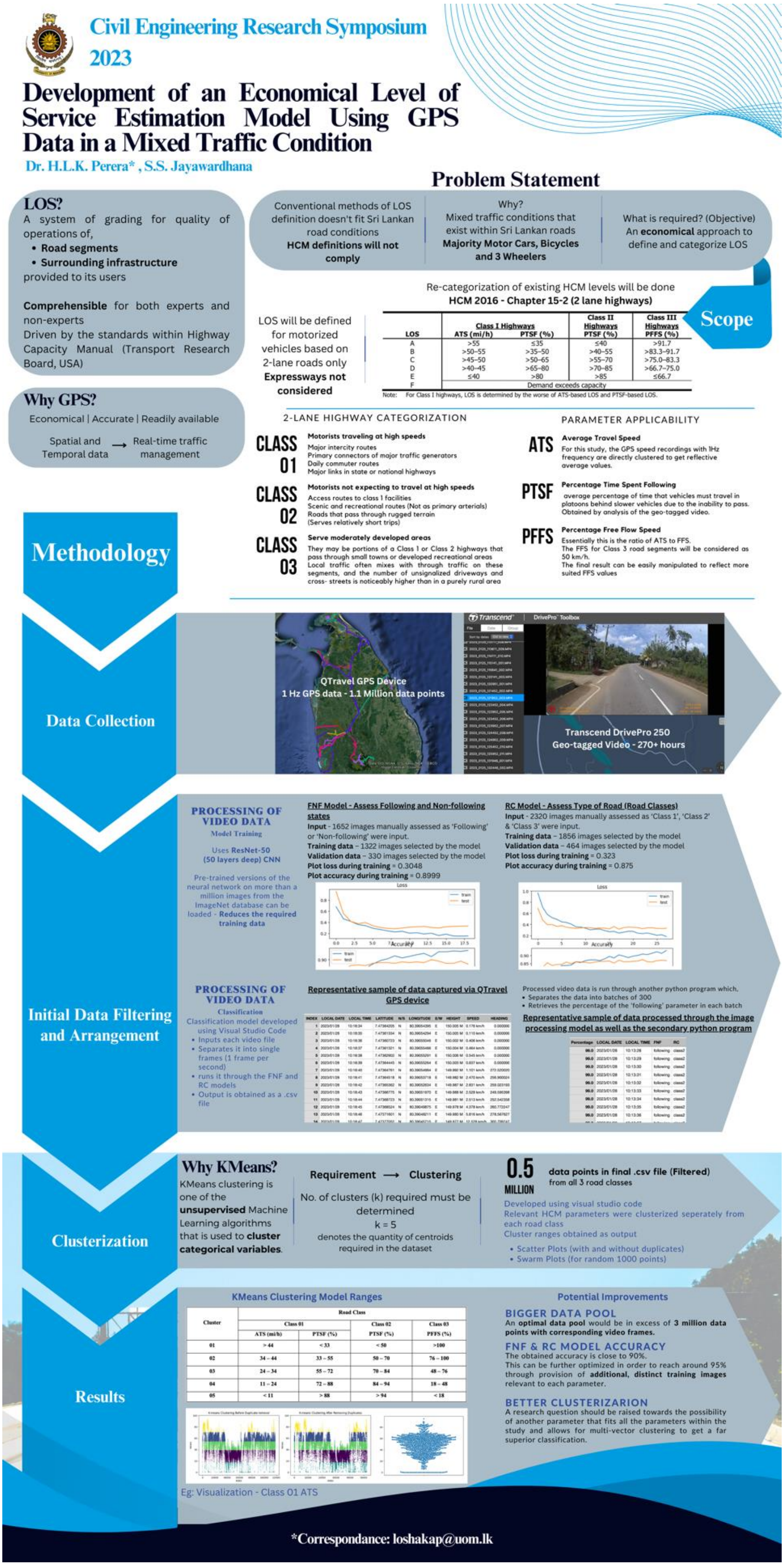
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Development of an Economical Level of Service Estimation Model Using GPS Data in a Mixed Traffic Condition
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Problem Statement
LOS?
A system of grading for quality of operations of,
• Road segments
• Surrounding infrastructure
provided to its users
Comprehensible for both experts and non-experts
Driven by the standards within Highway Capacity Manual (Transport Research Board, USA)
Why GPS?
Economical | Accurate | Readily available
Spatial and Temporal data → Real-time traffic management
Conventional methods of LOS definition doesn't fit Sri Lankan road conditions
HCM definitions will not comply
Why?
Mixed traffic conditions that exist within Sri Lankan roads
Majority Motor Cars, Bicycles and 3 Wheelers
What is required? (Objective)
An economical approach to define and categorize LOS
Re-categorization of existing HCM levels will be done
HCM 2016 - Chapter 15-2 (2 lane highways)
Scope
LOS will be defined for motorized vehicles based on 2-lane roads only
Expressways not considered
LOS | Class I Highways ATS (mi/h) | Class I Highways PTSF (%) | Class II Highways PTSF (%) | Class III Highways PFFS (%)
A | >55 | ≤35 | ≤40 | >91.7
B | >50–55 | >35–50 | >40–55 | >83.3–91.7
C | >45–50 | >50–65 | >55–70 | >75.0–83.3
D | >40–45 | >65–80 | >70–85 | >66.7–75.0
E | ≤40 | >80 | >85 | ≤66.7
F | Demand exceeds capacity
Note: For Class I highways, LOS is determined by the worse of ATS-based LOS and PTSF-based LOS.
2-LANE HIGHWAY CATEGORIZATION
CLASS 01
Motorists traveling at high speeds
Major intercity routes
Primary connectors of major traffic generators
Daily commuter routes
Major links in state or national highways
CLASS 02
Motorists not expecting to travel at high speeds
Access routes to class 1 facilities
Scenic and recreational routes (Not as primary arterials)
Roads that pass through rugged terrain
(Serves relatively short trips)
CLASS 03
Serve moderately developed areas
They may be portions of a Class 1 or Class 2 highways that pass through small towns or developed recreational areas
Local traffic often mixes with through traffic on these segments, and the number of unsignalized driveways and cross- streets is noticeably higher than in a purely rural area
PARAMETER APPLICABILITY
ATS
Average Travel Speed
For this study, the GPS speed recordings with 1Hz frequency are directly clustered to get reflective average values.
PTSF
Percentage Time Spent Following
average percentage of time that vehicles must travel in platoons behind slower vehicles due to the inability to pass. Obtained by analysis of the geo-tagged video.
PFFS
Percentage Free Flow Speed
Essentially this is the ratio of ATS to FFS.
The FFS for Class 3 road segments will be considered as 50 km/h.
The final result can be easily manipulated to reflect more suited FFS values
Methodology
Data Collection
QTravel GPS Device
1 Hz GPS data - 1.1 Million data points
Transcend
DrivePro Toolbox
Transcend DrivePro 250
Geo-tagged Video - 270+ hours
Initial Data Filtering and Arrangement
PROCESSING OF VIDEO DATA
Model Training
Uses ResNet-50 (50 layers deep) CNN
Pre-trained versions of the neural network on more than a million images from the ImageNet database can be loaded - Reduces the required training data
FNF Model - Assess Following and Non-following states
Input - 1652 images manually assessed as 'Following' or 'Non-following' were input.
Training data – 1322 images selected by the model
Validation data – 330 images selected by the model
Plot loss during training = 0.3048
Plot accuracy during training = 0.8999
RC Model - Assess Type of Road (Road Classes)
Input - 2320 images manually assessed as 'Class 1', 'Class 2' & 'Class 3' were input.
Training data – 1856 images selected by the model
Validation data – 464 images selected by the model
Plot loss during training = 0.323
Plot accuracy during training = 0.875
Loss
Accuracy
train
test
PROCESSING OF VIDEO DATA
Classification
Classification model developed using Visual Studio Code
• Inputs each video file
• Separates it into single frames (1 frame per second)
• runs it through the FNF and RC models
• Output is obtained as a .csv file
Representative sample of data captured via QTravel GPS device
INDEX | LOCAL DATE | LOCAL TIME | LATITUDE | N/S | LONGITUDE | E/W | HEIGHT | SPEED | HEADING
Processed video data is run through another python program which,
• Separates the data into batches of 300
• Retrieves the percentage of the 'following' parameter in each batch
Representative sample of data processed through the image processing model as well as the secondary python program
Percentage | LOCAL DATE | LOCAL TIME | FNF | RC
Clusterization
Why KMeans?
KMeans clustering is one of the unsupervised Machine Learning algorithms that is used to cluster categorical variables.
Requirement → Clustering
No. of clusters (k) required must be determined
k = 5
denotes the quantity of centroids required in the dataset
0.5 MILLION data points in final .csv file (Filtered) from all 3 road classes
Developed using visual studio code
Relevant HCM parameters were clusterized seperately from each road class
Cluster ranges obtained as output
• Scatter Plots (with and without duplicates)
• Swarm Plots (for random 1000 points)
Results
KMeans Clustering Model Ranges
Cluster | Road Class: Class 01 ATS (mi/h) | Class 01 PTSF (%) | Class 02 PTSF (%) | Class 03 PFFS (%)
01 | > 44 | < 33 | < 50 | >100
02 | 34 – 44 | 33 – 55 | 50 – 70 | 76 – 100
03 | 24 – 34 | 55 – 72 | 70 – 84 | 48 – 76
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Eg: Visualization - Class 01 ATS
Potential Improvements
BIGGER DATA POOL
An optimal data pool would be in excess of 3 million data points with corresponding video frames.
FNF & RC MODEL ACCURACY
The obtained accuracy is close to 90%.
This can be further optimized in order to reach around 95% through provision of additional, distinct training images relevant to each parameter.
BETTER CLUSTERIZARION
A research question should be raised towards the possibility of another parameter that fits all the parameters within the study and allows for multi-vector clustering to get a far superior classification.
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