An R based automated model to perform the transportation route assignment

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Abstract

The urban growth in the Sri Lankan major cities is taking place at a rate of 18.2%. Similarly, in the world, more than 54% of the population is living in urban areas by 2014. This drastic level of transformation leads towards unforeseen problems since the degree of adaptation of the communities is not compatible with urban transformation. In this case, a proper combination of land use distribution will be able to optimize the Vehicle Miles Travelled (VMT) to reduce the transportation-related energy consumption and city congestion. The objective of this research study is to develop a model and a computer-aided automated tool to calculate the congestion in each road segment in a given area based on the land use distribution which is known as "route assignment". In this research, the R programming platform is used to develop the tool which can automate the entire route assignment process. The data required for the analysis are information on the road network and intersections, trip generation and trip attraction amounts at each intersection based on its Traffic Analysis Zone (TAZ). The gravity model is used to perform the trip distribution and the result is gained through several iterations and generalized with a K-factor. Using the graph theory, shortest paths are identified where, a minimum amount of intersections are passed between two given intersections. The path is weighted from the length of the bypassed links to get the minimum length. The trip distribution is assigned to the road network based on the identified shortest paths. The main outputs of the tool are the congestion values of each road segment and the balanced trip generation and trip attraction values for each intersection which balances the congestion value to the capacity level of the segment. The importance of this methodology is that the TAZs are formulated based on the land use categories and the proximity to the respective intersection. Therefore, the contribution of each land use category for the congestion of respective road segments can be identified in quantities. This finding leads towards the formulation of trip balancing strategies which ultimately can be implemented in the regional level land use management projects.

Keywords: Job-house ratio, Land use - transport simulation model, Motorized trip distribution, R programming, Route assignment

1. Introduction

1.1. Use of computer aided models in urban planning

The computer aided models have been used in urban planning since 1960s (Lowry 1965). The automated simulation models are widely adopted in land use change detection, traffic and transportation studies, remote sensing studies, flood modelling, human movements modelling and many other urban planning related aspects. The automation in modelling studies enables the client to view and estimate the impacts of the predicted scenarios.

A combination of real time virtual simulations, spatial modelling and GIS has been able to allow the urban planners to work on the situation beforehand it is practically implemented on the ground. The computer aided simulation modelling creates the situation which is likely to happen in the context of its implementation thus, saves the time taken to perform manual calculations and saves the expense on contingency. Further, the ability to identify the implications of the projects at their planning stage allows the urban planners to pitch the project more practically in the context and make the implementation of the projects more effective. However, irrespective of the convenience of the use of automated tools, the products started to release as exclusive licensed versions. The products were oriented at commercial purposes rather than serving the need of the planners. At this stage (1991) the use of free licensed software became popular and advanced in technology. QGIS can be considered as the biggest license free software in the planning

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context which is being widely adopted in the planning analyses. The computer aided tool introduced in this research is developed using another open source platform known as R programming. The research question led to the development of this tool is the imbalanced distribution of employment and resident locations in the Colombo district of Sri Lanka which ultimately causes for a massive traffic congestion in the major transportation corridors.

The objective of the research study is to develop a computer aided tool to identify an organized employment and resident distribution for a considered planning region to achieve a congestion free environment in the major transportation corridors. The study is based on optimizing the home based work trips which accounts for a larger percentage in the Colombo district traffic congestion. It is assumed that the major proportion of the traffic in the Colombo district is led by home based work trips. Further, it is assumed the trip generation takes place from residential units and the trip attraction takes place from employment locations.

2. Literature review

In the present world 54% of the population is considered as urban population and it is estimated that within next 30 years the urban population in world will be grown by 2.5 billion (UN, Department of Economic and Social Affairs 2014). Similarly in Sri Lankan context, the coastal cities can be identified as the most urbanized areas whereas Western Province can be identified as the highest (38.8%) urbanized province in Sri Lanka. The urbanization rate in overall is 18.4% (Census of Population and Housing Sri Lanka 2012). “The main reason for congestion was poor city planning, inappropriate public transport facilities and insufficient traffic system, which leads to waste of time, fuel and wear and tear of vehicles,” (Kumarage 2013). In this situation a balanced job-housing locations will create a proper structure for a city. In this way the Vehicle Miles Travelled (VMT) in a city can be configured to reduce the energy consumption in transportation and congestion. Job-House ratio has been widely considered in the world’s planning context. The research studies of the University of Wisconsin, USA has identified, the Job-House ratio directly influences the home based work VMT in a region and a planned ratio can manipulates the region’s travel behaviour. As a land use policy, balancing job-house ratio based on the region’s travel behaviour can mitigate road related congestion and environmental impacts (Peng 1997). Sri Lanka is losing 1.5% of its annual GDP due to traffic congestion. Not only the economic loss but also the loss in man hours due to the traffic congestion is higher in the urban context (Kumarage 2013). In terms of energy efficiency high density multinuclear urban forms have been identified as better configurations (Shim et al. 2006). The concept of closeness centrality and betweeness centrality are another widely adopted methods in estimating the accessibility levels in cities. It is identified that the centrality parameters are directly related to the traffic behaviours and can be modelled to identify the quantities (Jayasinghe, Sano, and Nishiuchi 2015). It is comprehensively applied based on the space syntax concept and the results of the study in Colombo, Sri Lanka has proved a thorough relationship (R2 > 0.75) between centrality measures and trip attraction (Jayasinghe, Sano, and Rattanaporn 2017). The job-housing balance concept refers to the geographic relationship of the ratio of jobs to the households available within a considered spatial region. The balanced job-housing ratio can be achieved when the employees can approach to the working places within a reasonable travel distance. In 1994 the entropy index was used to identify the level of heterogeneity among land uses. The entropy index involves the land use characteristics such as family members, offices, level of services, institutional and industrial areas. The highly mobile employment locations and residential locations keeps the job housing ratio balanced over time (Peng, 1997).

The commonly used programming platforms in the urban studies are ArcPy, Python, R programming, Java, PHP, Pig and there are several other database management platforms such as MySQL, PostgreSQL, MongoDB. Python is one of the advanced programming platforms used in many of the urban analysis software (Ex: ArcGIS, QGIS). ArcPy is a Python package that provides a useful way to carryout geographic data analysis, data management, and map automation with Python (Eubank 2014). R is an open source programming language as well as software atmosphere for statistical computing plus graphics. The source code for the R atmosphere is developed mainly in C, FORTRAN, + R. R is openly accessible under the GNU-General Community License. R programming language is useful for geostatistical, data science, and geospatial study. QGIS and ArcGIS consist of script printed in R (Kelley, Lai, and Wu 2008).

Visual programming languages are also commonly used in geographic analysis. The visual programming introduces a method of illustrating the steps of spatial analysis in a work flow on geometric data. ArcGIS software provides the opportunity of exporting the analysis model to Python programming language. An output script in Python can be used as a start point of the algorithmic solution (Dobesova 2011). In spatial modelling and simulation cellular automata concept has been widely incorporated with the programming platforms. Open source platform for Urban Simulation and UrbanSim are developed in Python, using optimized matrix manipulation packages developed in C++ to manage inner loop computations. The system is open source, under the GNU public license (Davis et al. 2006).

Open Source (OS) philosophy provides important solutions not only in the design processes but also in the professional role of developers. According to OS philosophy, anyone can collaborate in improving the source code, independently of its position, profession or academic grade (Pardo-García 2018). Therefore, the open source software development became dominant within the users and developers.

The automated tool developed in this research is programmed using R-programming platform. R is a powerful free software environment for statistical computing and graphics. It is widely adopted in data science, big data, statistical modelling and simulation projects (Kelley, Lai, and Wu 2008). The advantage of using R is the capability of handling a large amount of data in a minimum processing time. Further, there are useful libraries (ex: igraph, shortest.paths) particularly dedicated to urban analyses. The programming platform is intuitive and compatible with database systems. In this research, MySQL and MS excel are used as a database storage for the output result. The initial data layers and tables are prepared using QGIS. The tool was initially developed and tested using several other programming platforms. (Excel, Python, VB macro) However, the processing time was not as efficient as it is processed in R. Further, the R platform can be used to visually interpret the output using the inbuilt libraries. There are plotting options (Ex: tkplot, ggplot) in aid for the visualization process.

3. Methodology

3.1. System Development Life Cycle (SDLC)

SDLC is a process followed for a software development. It demonstrates a detailed process on how to develop, maintain, replace and improve or alter specific software. The life cycle assists a methodology for enhancing the quality of the software and the overall process. There are various SDLC models defined and followed during the software development process. Each model follows a series of unique steps of its own to ensure accuracy in the process of software development. Following are the most popular SDLC models followed in software development; Waterfall Model, Iterative Model, Spiral Model, V-Model, Big Bang Model.

The steps in the V-model was followed to develop and test the automated tool developed in this research.

3.2. Software design and architecture

3.2.1. Requirement Analysis:

The process of route assignment is one of the fundamental requirement in any transportation analysis. The result of the route assignment process can be used to identify the level of service in road segments and eventually it can be used in road and transportation planning and regional zoning demarcation. However, the route assignment process (if performed manually) is a tiring process and gets complicated as the number of nodes and segments becomes more. Therefore, it has been a wide requirement to develop an automated tool which can perform the transportation route assignment and calculate the congestion levels. The similar kind of study was carried out in different software applications (MS Excel, VB Macro, and Python). However, the mentioned platform were not successful in delivering the required result in terms of time efficiency and the data managing capacity.

3.2.2. System design and architecture

The objective of this research is to develop a computer aided system to perform the transportation route assignment and identify the congestion factors in the road segments in the study area. The system intends to calculate the road segment traffic congestion levels based on the trip generation at residential locations as origins and trip attraction at the employment locations as destinations. The tool further provides the facility to identify the required level in the congestion factor and the amount of trips to be balanced in each road segment.

The calculation of trip generation and trip attraction to the respective node is identified based on the demarcation of Traffic Analysis Zone (TAZ). The demarcation of the TAZs are performed using the Theissen Polygon tool in QGIS software. The Theissen Polygons are constructed based on the Delaunay triangulation network theory. The centroids for the demarcation of TAZs are considered as the intersections of the road network.

The following models (1), (2) are used to calculate the trip generation and trip attraction values with respective to each TAZ. Base on the assumption of calculating the home based work trips, the economically active population and the employment opportunities at each TAZ was identified as input data to the models.

Zonal Trip generation Model
Ln (Trips Produced) = 1.0229 x Ln (Population) (1)

Zonal trip attraction model
Ln (Trips Attraction) = 0.9384 x Ln (Employment) + 0.96 (2)

(Gulden, Goates, & Ewing, 2013)

Input data – Road network with segment lengths, nodes with trip generation and trip attraction values (Table 01, Table 02).

Table 01: Input data 1, Road segment length

from	to	length
1	25	38.6752

Table 02: Input data 2, Trip information at each node

node	trip generation	trip attraction
1	232668	225684

Method – Data insertion into the system is done using .CSV file format (Figure 01). It is required to insert the pair of nodes at start and end location of each segment with their respective distance, trip attraction and trip generation values at each node and the series of node pairs available in the data system.

```
file <- read.csv("Feature_vp_join.csv", sep=",")
file2 <- read.csv("tatg.csv", sep=",")
file3 <- read.csv("pairs.csv", sep=",")
```

Figure 01: Data insertion into the tool

The system then calculates the shortest paths among each nodes. This action is performed using an inbuilt library in the R platform named “library (igraph)”. The igraph package is a powerful tool for neatwork analysis and graph model development. In the tool development the package was specifically used to identify the network links and length of the shortest paths. The “plot” option can be used to visualize the network links (Figure 02).

```
from <- file$from
to <- file$to
c.from<-as.character(from)
c.to<-as.character(to)
pair <- c(matrix(c(c.from,c.to), nrow=2, byrow=TRUE))
graph <- graph(pair)
plot(graph, edge.arrow.size=.5, vertex.color="gold",
vertex.size=5,
vertex.frame.color="gray", vertex.label.color="black",
vertex.label.cex=0.8, vertex.label.dist=2,
edge.curved=0.1)
```

Figure 02: Graph plotting in the tool

The Graph theory is used for the routing analysis and shortest network analysis (Figure 03). In this study the application of minimum cost flow solution is used to identify the shortest possible paths among the intersections (Monteiro, Robertson, and Atkinson 2014). The path is weighted from the length of the passed links to get the total length.

```
g <- graph.data.frame(file, directed=FALSE)
g.shortest_paths<-get.shortest.paths(g, a,
weights=E(g)$length)
g.shortest_length <-shortest.paths(g, a,
weights=E(g)$length
nb_of_sp <- length(g.shortest_paths[1][[1]])
```

Figure 03: Calculation of shortest paths and length

The gravity model (3) is used to perform the trip distribution and the result is gained through several iterations and generalized with a K-factor. The Gravity Model (GM) is formulated based on Newton’s concept of gravity (Figure 04). The model assumes that the trips being transferred among zones in an area is dependent based on the relative attraction and the geographic distance between them. The role of spatial distance adjusts the relative attraction of zones for its capacity. The trip distribution is then assigned to the road network based on the identified shortest links which is known as *Route Assignment* (Figure 05).

$$T_{i-j} = K\ P_i\ A_j /\ d_{ij}^n \ (3)$$

T_{i-j} = Trips between zone i and j
P_i = Trips produced in zone i
A_j = Trips produced in zone j
d_{ij}^n = Distance between zone i and zone j
K = Constant independent of i
n = an exponential constant (varies between 1 and 3) (Kadiyali, 2013)

```
#gravity model--------------------------------
if (g.shortest_length[e]=="0") {
x[e,c]<-paste(0)}
else if (g.shortest_length[e]!=0) {
x[e,c]<-
paste(round((as.double(tg_r[a])*as.double(ta_r[nsp]))/(
(as.double(g.shortest_length[e]))^2),digits=4))}
for (ps in 1:p) {
for (sl in 1:as.numeric(s.l)) {
if (as.character(s.p1[sl])==as.character(pairs.s[ps])) {
x[e,ps+2]<-paste(v.a)}
else if
(revstring(as.character(s.p1[sl]))==as.character(pairs.
[ps])) { x[e,ps+2]<-paste(v.a)}}}
#sum of calculation column x----------------------------
filex <- read.csv("x.csv", sep=",")
sumx<-sum(filex$V36)
#k factor--------------------------------
kfac <- as.double(tot.pop)/as.numeric(sumx)
kfac
```

Figure 04: Application of Gravity Model and trip distribution

The output of the route assignment provides the congestion values of the road link segments. At this stage it is identified in specific, the segments which already have exceeded the carrying capacity (1500 passenger car units (PCU) per lane) of the road segments and the segments where more trips can be accommodated (National Research Council (U.S.), 2000).

The quality of the traffic in the road network is divided into six categories ranging from level A to Level F (Level A being the best quality and Level F being the worst quality). The main criteria considered in the LoS measure are speed and travel time, density, and delay. In planning practices the Volume to Capacity ratio (V/C also known as congestion factor) is used to assess the result of LoS. In V/C ratio, volume (demand) is divided by the estimated capacity of each road segment during the peak time period. In conclusion, the LOS is used to evaluate the traffic service quality compared to a given flow rate of traffic. The VMT is calculated by multiplying the number of trips transferred through the shortest path by their respective length.

Based on the V/C ratio the roads are categorized and identified in order of their quality of traffic level. Further, decisions can be made where the quality has to be improved or can be maintained. Accordingly, a moderated value for V/C ratio is identified based on its context and percentage contribution for overall traffic volume (Figure 06).

```
for (a in 1:n){
e=0
x<-matrix(ncol=p+2, nrow=n)
for (b in 1:n) {
e=e+1
r.n=r.n+1
setTxtProgressBar(pb, r.n)
if (r.n == 30976) cat("Done!\n")
s.p <- filex[r.n,2:31]
s.p1 <- as.data.frame.array(s.p)
v9 <- filex$V36
s.l <- filex$V33[r.n]
x[e,1] <- paste(a,b,sep = "_")
v.a <- round((as.numeric(v9[r.n]))*kfac,digits=4)
x[e,2]<- paste(v.a)
for (ps in 1:p) {
for (sl in 1:as.numeric(s.l)) {
if (as.character(s.p1[sl])==as.character(pairs.s[ps])) {
x[e,ps+2]<-paste(v.a)}
else if
(revstring(as.character(s.p1[sl]))==as.character(pairs.s
[ps])) {
x[e,ps+2]<-paste(v.a)
}}}}
```

Figure 05: Route assignment

Table 03: Classification of Level of Service

LOS main roads	Volume	Capacity (PCU)	Travel speed	V/C	State of improvement
A	2100	6000	65	0.35	Possible to accommodate more vehicles
B	3300	6000	60	0.55	Quality should be maintained
C	4620	6000	55	0.77	Quality should be maintained
D	5520	6000	50	0.92	Quality improvements are required
E	6000	6000	40	1.0	Quality improvements are required
F	>6000	6000	20	> 1.0	Quality improvements are required

(National Research Council (U.S.), 2000)

Using the following formula (4) the values can be resolved to a ratio which can be applied to the respective analysis zones in terms of mobilizing the population and employment to maintain a traffic congestion free road environment.

$$Job - House\ Ratio = \frac{Available\ Employment\ Opportunities}{Labour\ Force\ Population}$$

(4) (Peng, 1997)

```
x<-matrix(ncol=p+2, nrow = 5)
n.r <- 0
rownames(x) <- c('LoS', 'LoS Requirement', 'LoS Gap',
'trip balance', 'trip balance per unit')
for (n.r in 1:p) {
LoS <-
paste(filexassign[30977,n.r+2]/filexassign[30978,n.r+2]
)
x[1,n.r+1] <- LoS
 x[2,n.r+1] <- paste('0.85')LoSgap <- 0.85 -
as.double(LoS)
trpb <- as.double(LoSgap)*6000
x[4, n.r+1] <- trpb
if (filexassign[30977,n.r+2] != 0) {
x[5, n.r+1] <- as.double(trpb)/filexassign[30977,n.r+2]}
else if (filexassign[30977,n.r+2] == 0) {
x[5, n.r+1] <- paste(0)}
if (is.na(filexassign[c.n,r.n+2]) == TRUE) {
x[1,r.n+1] <- paste(0)}
else if (is.na(filexassign[c.n,r.n+2]) == FALSE) {
x[1,r.n+1] <-
(filexassign[c.n,r.n+2]*filexassign[30983,r.n+2])+filexa
ssign[c.n,r.n+2]}
```

Figure 06: Calculation of Congestion Factor and balancing requirement

The Figure 07 demonstrates the procedure of developing the result into an OD matrix.

```
#OD matrix--------------------------------
trpbl <- read.csv("xtripbalanced.csv", sep=",")
x<-matrix(ncol=n+2, nrow = 0)
#rownames(x) <- c(coln[1])
colnames(x) <- c('OD', 1:176, 'Sum')
write.table(x, file = "OD.csv", row.names=F, col.names=T,
na="", append=F, sep=",")
for (r.n in 1:176) {
x<-matrix(ncol=n+2, nrow = 1)
for (n.c in 1:176) {
e = e+1
x[1,1] <- r.n
x[1,n.c+1] <- trpbl[e,287]
x[1,178] <- paste(sum(as.double(x[2:177])))}
write.table(x, file = "OD.csv", row.names=F, col.names=F,
na="", append=T, sep=",")}
od <- read.csv("od.csv", sep=",")
x<-matrix(ncol=n+1, nrow = 1)
for (n.c in 1:176) {
x[1,1] <- 'Sum'
x[1,n.c+1] <- sum(od[n.c+1])}
write.table(x, file = "OD.csv", row.names=F, col.names=F,
na="", append=T, sep=",")
```

Figure 07: Composition of OD matrix

3.2.3. System requirements:

The tool coding arrangement can be viewed using R software. The system should be consisted of R, MS Excel, MySQL software and can be performed in Windows 7, 8 or 10 versions.

4. Analysis

4.1. Data selection and case study location

The Colombo district as mentioned previously is liable for the highest agglomeration point of Sri Lanka (Figure 08). Since its significance of the geographic location, Sri Lanka's international relationships are initiated at this point. The infrastructure concentration has caused to increase its accessibility and therefore the people's retention rate has risen within the district.

District:	Colombo
Area:	679.6 Km2
No. of GN/DS Divisions:	558/13
Population:	1,820,445
Employment:	4,407,768
Floating Population:	1 million approx.
Trip Attraction Amount:	6,461,866
Trip Generation Amount:	2,202,898
Trip Length Per Capita:	23.74 km
Average Job House Ratio:	2.42
Net Migration Rate:	67.1

(Census of Population and Housing Sri Lanka 2012)

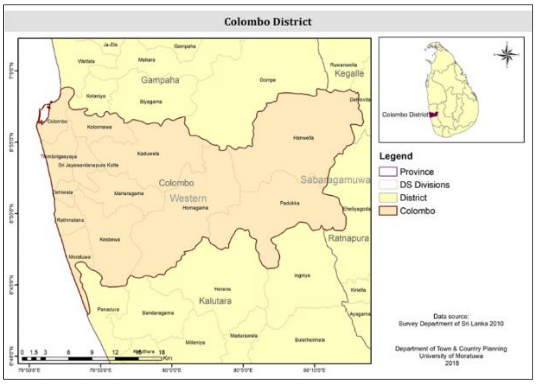


Figure 08: Study area

4.2. Input data

4.2.1. Road network including length information:

The road network is split into segments at nodes and the length of each segment is used as a weight in shortest path identification (Figure 09).

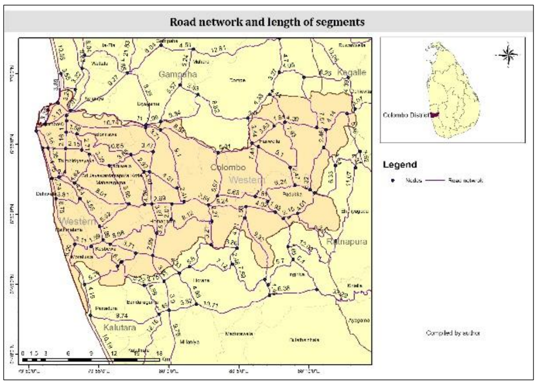


Figure 09: Road network information

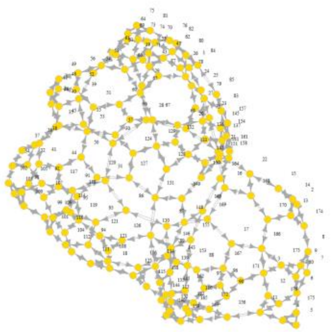
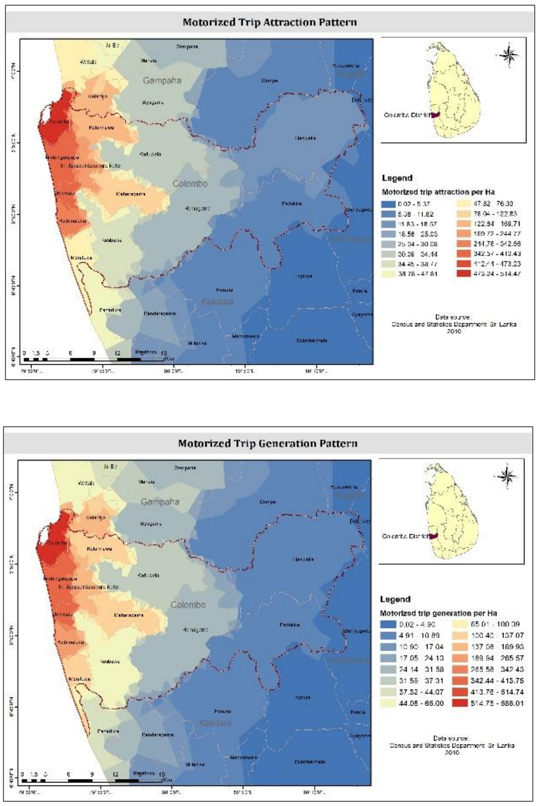


Figure 10: Road links plotting in the system

4.2.2. Trip generation and trip attraction values of each node:

The trip generation and trip attraction values are calculated based on the population and employment amounts concentrated in the respective TAZ. Using the Figure 11 (a), (b) it can be identified that the trip attraction values are 500 trips per Ha in Colombo city centre during a peak hour and the suburban areas generate high amount of trips compared to its trip attraction (ex: Kesbewa DSD, trip generation – 44-65 per Ha, trip attraction – 30-34 per Ha).

(a)



(b)

Figure 11: (a) Trip attraction pattern, (b) Trip generation pattern

4.2.3. Present Job-House Ratio:

The red coloured areas mentioned in the map (figure 12) shows the areas of high job-house ratio (Employment level is 9 times the resident economically active population). The blue colour areas shows a lower level of job-house ratio where a high amount of resident population is available than the employment availability. Within the study area the job-house ratio varies between 0.5 – 9.3 stating that the job-house ratio is considerably uneven. This uneven nature of job-house ratio causes for longer trips between the zones based on the people's willingness to travel. The implication of the varied job-house ratio can be identified as the people's willingness to travel for longer distances will become high in search of better employment opportunities. As per the findings the VMT per capita highly depends on the Job-house ratio (R^2= 0.593).

In conclusion, the high job-house ratio and low job-house ratio will cause for lengthier trip generations and eventually will contribute for the congestion of many segments.

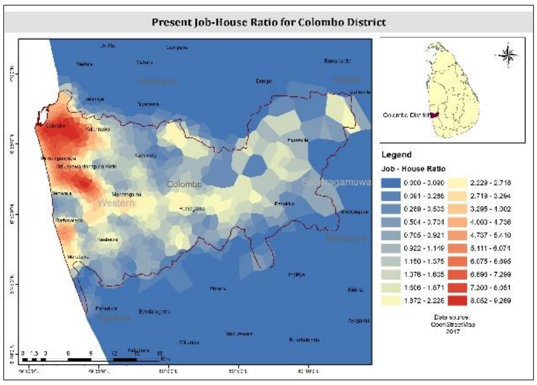


Figure 12. Present Job-house ratio

4.3. Output data and tables

4.3.1. Calculation of length of shortest paths and trip distribution

The first output of the tool is the table of shortest paths and the trip distribution values in each shortest path (Table 04). Using the table the user can view the number of segments in each shortest path and the number of trips being transferred through the considered link.

4.3.2. Route assignment

The second output of the tool is the route assignment table (Table 05). The trip distribution values are then assigned to the segments along the respective shortest path. The cumulative total under each segment provides the congestion at each segment (Figure 13).

4.3.3. Congestion factor and trip balancing requirement

Table 06 provides the final result of the entire process. The user can customize the PCU capacity of the segments based on the road type classification (Table 03). The tool calculates the congestion factor based on the amount of trips in each segment and finally the output will be given as the required trip balance per a PCU based on the user defined congestion factor. Therefore, the tool provides opportunity to maintain a context specific LoS in the study area (Figure 14).

The final output of the tool can be used to develop many spatial strategies. In transport planning, expressways, new bus lanes, railway lines can be developed based on the result as well as in land use planning different zonal demarcations can be identified using the result. Basically, the trip generation and trip attraction can be balanced based on the final output where the road segment congestion can be maintained at the user defined LoC. When compared the result of Figure 13 and Figure 14, most of the roads linked to Combo city are at the LoC of C, D & E and after the moderation the required reduction and addition for segments have been calculated compared to the present number of trips.

The Figure 15 demonstrates a proposed zonal strategy based on the output of the tool.

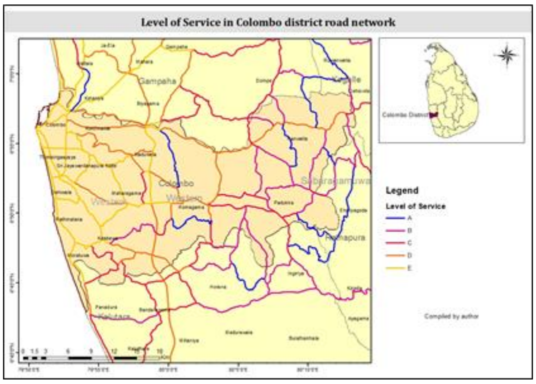


Figure 13. Present situation of the congestion level in the study area

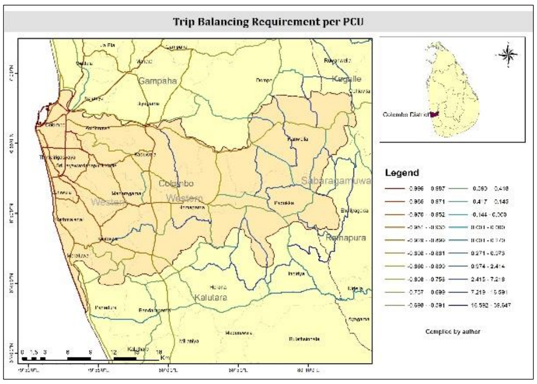


Figure 14. Trip balance requirement in each segment

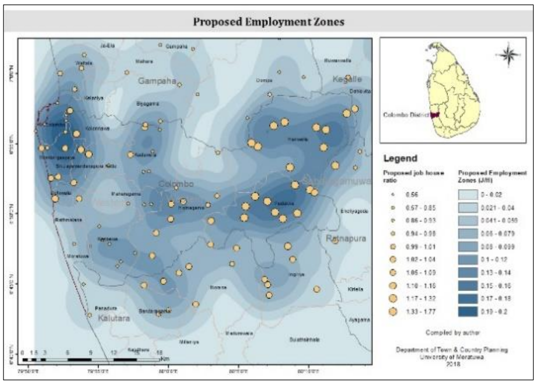


Figure 15. Proposed employment zones for the study area

Table 04: Length of the shortest path

OD Pair	Segments				Pair No.	No. of segments in shortest path	Length	Trips	Trips (K)
	Seg 1	Seg 2	Seg 3	Seg 4					
1_20	1_26	26_24	24_27	27_20	20	4	140.718	1.5E+10	759810.3

Table 05: Route assignment

OD Pair	No. of trips	Segments													
		1_25	1_26	1_62	2_14	2_15	145_154	146_148	146_155	147_152	147_162	148_149	148_160	149_150	150_151
151_146	13907.73							13907.73				13907.73		13907.73	13907.73

Table 06: Congestion factor and trip balancing requirement

OD Pair	Segments								
	1_25	1_26	1_62	2_14	2_15	2_174	3_12	3_166	3_171
Total Trips	0.00	4826.52	3724.71	843.60	0.00	125.47	7263.95	4101.33	17229.68
PCU Capacity	6000.00	6000.00	6000.00	6000.00	6000.00	6000.00	6000.00	6000.00	6000.00
LoS (Congestion Factor)	0.00	0.80	0.62	0.14	0.00	0.02	1.21	0.68	2.87
LoS Requirement	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85
LoS Gap	0.85	0.05	0.23	0.71	0.85	0.83	-0.36	0.17	-2.02
Trip balance	5100.00	273.48	1375.29	4256.40	5100.00	4974.53	-2163.95	998.67	-12129.70
Trip balance per PCU	0.00	0.06	0.37	5.05	0.00	39.65	-0.30	0.24	-0.70

5. Conclusion and recommendations

The R programming platform is a useful programming language in the urban studies since there are many spatial libraries available for easy data analysis and representation. The R based automated tool for transportation route assignment can be practiced mostly in regional planning activities to identify the suitable locations for employment clusters and residential clusters. Further, it can be manipulated to determine the transportation requirements and road planning. Similar to the results that are illustrated above the tool can be used to demarcate zones based on the employment and residential densities. Similar to the demonstration mentioned above, the present range of job-house ratio in Colombo district varies from 0.5-9.3 which creates a mismatch in the spatial distribution of employment and residential locations. As a result, the road network in the Colombo district becomes congested by the commuter population from suburban areas to Colombo central area (LoS identified as D, E and F). The analysis for the Colombo district was able to propose a new range of job-house ratio varies between 0.5 – 3.8 which promotes shorter distance travelling for home based work trips (13.9 km). This strategy maintains the LoS in the road network at A, B, and C levels.

The main recommendation of the research is the incorporation of job-house ratio can provide positive outcomes in regional planning and zonal demarcations. The R based transportation route assignment tool can automate the entire process of route assignment and develop the proposed spatial structure with balanced job-house ratio. Further, for the future development of the research focus, it is suggested to incorporate the agent based modelling into the system in order to model the micro level travel behaviours in the road network. This approach will increase the accuracy of the overall route assignment process. Also, the movement capacity in the junctions and intersections needs a thorough analysis since it influences the movement capacity in the connected segments.

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