A Parking Study at Malabe Campus, SLIIT

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Abstract: Legally provided surface parking lots were merely not sufficient to accommodate the current demand for parking inside the Malabe campus, SLIIT tempting commuters to park in illegal areas and student playground of the campus. Therefore, this study evaluated the operational and safety issues of the existing facility by means of four surveys. Parking inventory survey was conducted to enumerate existing parking facility and its characteristics. Using a Metro Count roadside unit, vehicle inflow-outflow data were obtained through six months to study parking accumulation characteristics. Vehicle count surveys were conducted to determine parking characteristics such as parking accumulation profile, parking demand, number of users, average parking durations and turnover. Feedback from users regarding parking problem was collected from interview survey. Recommendations were proposed to supply total parking spaces for 399 cars, 365 bikes and 10 buses to meet the demand in 2025 while ensuring the safety and efficiency of parking.

Keywords: Parking study; University campus; Parking demand; Parking problem

1. INTRODUCTION

Sri Lanka is a developing country with more than 20 million population. After the end of three decades of civil conflict in May 2009, country was set on the path of development. Since then rapid development took place in all sectors. As a result, the living standards and income of people has increased over the past years. Number of people using personal vehicles for commuting has also increased. Figure 1 shows the variation of vehicle population from 2009 to 2015 (DMT, 2019).

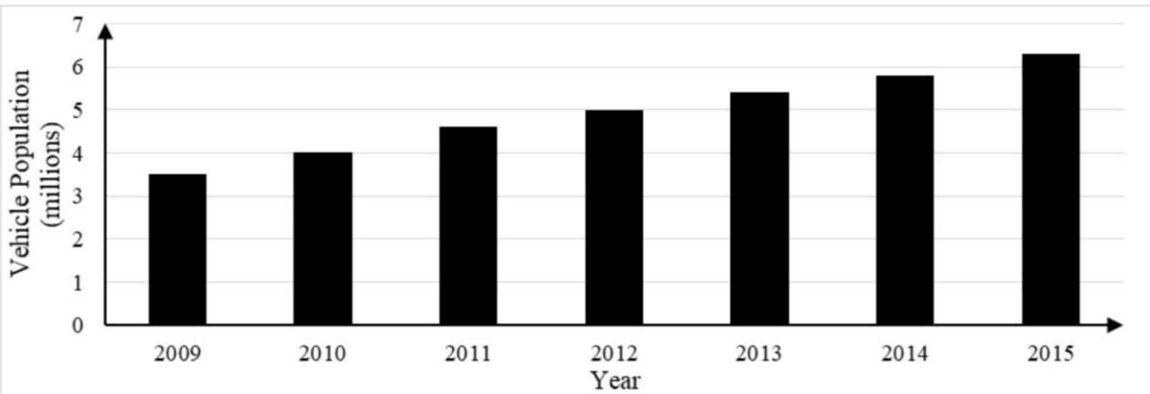

Figure: 1 Vehicle Population Variation from 2009 to 2015 in Sri Lanka

It has increased from 3.5 million vehicles in 2009 to 6.3 million in 2015 with an average annual growth of 9.3% according to the department of motor vehicles in Sri Lanka. When vehicles population increase, number of vehicles per household also increase and the number of people using personal vehicles for daily commuting also increase. Hence, the demand for parking facilities at trip destinations simultaneously increase.

1.1. Problem Statement

Sri Lanka Institute of Information Technology (SLIIT) is a non-state university in Sri Lanka offers courses in undergraduate and post-graduate level. Since founded in 1999 with 400 students, institute has expanded its horizons in the fields of computing, business, engineering, and architecture studies with over 7,000 students studying at several campuses and centers in Kollupitiya, Kandy, Mathara, Jaffna, and Kurunegala while Malabe campus being the educational and administrative center of the campus network, currently accommodating approximately 7,000 students, academic and non-academic staff. With the recent economic development of the country during past decades and growth of the university, the number of students and staff members using personal vehicles for making commute trips to the campus has been increased.

Legal parking facilities provided in Malabe campus can be divided as on-street parking facilities and off-street parking facilities. On-street parking facilities are parking bays alongside the edge of the road on either one or both sides of the road and also known as curb facilities. However, majority of the legal on-street parking facilities are unmarked undivided areas with permitted to park only one side of the road. There are two types off-street parking areas provided at Malabe campus of which majority of the facilities are surface parking lots for students and staff while garage type of off-street parking is provided for the campus administration staff. However, due to the increased demand for parking users are often tempted to park in illegal areas and the playground of the campus as shown in Figure 2. Even though parking in the campus playground was temporary allowed by the administration, considerable number of users seemed to be tempted to use other illegal parking areas.

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Figure 2: Vehicles parked in campus playground

Other types of illegal parking areas noticed during the study were near business faculty, on road to engineering faculty, parking in back alleys at engineering faculty building, parking near ongoing construction areas near new academic building, parking in steep slopes, parking blocking the access roads, parking at junctions, and parking at sharp horizontal curves. An example for illegal parking blocking the access road to the engineering faculty can be seen in Figure 3. With the increasing demand, limited supply and illegal parking, the probability of crisis being occurred has also increased. This can endanger the safety of properties and all involved stakeholders. Incidents of tree branches falling on top of vehicles parked at illegal area causing minor damages to the vehicles.

Figure 3: Illegal parking blocking access to engineering faculty

In addition to the existing infrastructure at Malabe campus, construction of a new 14 story academic building is currently underway and will increase the capacity of the campus by approximately 4,500 of students and staff once the facility is fully operational for academic activities, according to the administration. This expansion of student population will increase the number of personal vehicle commuters and the demand for parking will significantly increase in very short period of time and will overcrowd the capacity of existing parking facilities and illegal parking lots unless more surface parking lots are not provided. Thus, the effect of new trips generated by the new building also needs to be considered for the parking study to propose a sustainable solution.

2. LITERATURE REVIEW

During planning of a research study, it is necessary to consider as many approaches as possible to explore the horizons of the study and to come up with a unique outcome. During literature review, several publications were reviewed and extracted the approaches and methodologies that used to achieve objectives in each study.

The parking problem at the public zone of the Beijing University of aeronautics and astronautics was significantly increased after the changes done in campus property utilization and eventual growth of communications with the community (Shang et al., 2007). Goals of the study were to find the general features and weaknesses existing in the campus parking system and to make suggestions for further improvements. Methods used for study were the surveys and analysis conducted to quantify the inflow and outflow of vehicles by collecting vehicle entrance and leaving times along with the last three digits of its number plate. Available locations of parking lots and the corresponding capacities were evaluated by observing occupancy rates during walking tours at 0.5-hour intervals. Analysis of the study was done by computing the number vehicles entering the premises at a given time, variations of demand for parking spaces with time, average parking duration and use of turnovers of some parking areas. Outcomes of the study were the identifying weaknesses and causes of traffic of the current parking facility and suggesting improvements such as introducing a toll system to limit parking of parties neither employed by university nor the students of the university.

Chulalongkorn University in Bangkok, Thailand experienced significant improvement of number of students commute to the campus by car from 5 percent 20 years ago to 20 percent today as the university expanded and the uplift of national economy and limitations of on-campus housing. With recently provided paid parking facilities, Ampansirirat and Chalermpong (2011) motivated to conduct a study to develop a model for parking demand identify possibilities of attracting users from free of charge on-street parking around the campus into the paid parking facility provided. The goal of this study was to examine Chulalongkorn university campus parking demand in order to inform policy making concerning appropriate parking pricing as well as other service dimensions which could lead to improved utilization of parking facility. The researchers conducted interview surveys with drivers who regularly park their cars on-street during morning peak hours and data such as type of user, faculty enrolled, expecting parking attributes and preferred type of payment were collected. The data were analyzed using the method known as discrete choice framework to generate maximum likelihood estimations of the binary choice model. The final outcome of study reflected that parking choice of commuters depends not only on price but also on characteristics of commuters such as arrival and departure times, time restrictions, security, cover, and parking availability. Thus, the researchers came to the conclusion that most effective incentive to increase utilization of developed paid parking facility is not to reduce hourly rate of tariffs but to provide discounts in the form of semester passes.

While the rapid development of university campuses in China, the number of teachers and students increases continuously while the on-campus dormitories and housing is far less causing increment of personal vehicle commuters to the campuses. Wang et al. (2014) identified that most of the studies done in tragedy of commons of campus parking problems were addressed based on statistical analysis of laws governing the operation of the campus parking system while less attention was paid on the fact that people is the most important element to examine the campus parking problem. Thus, they focused on filling the research gap of addressing the traveler’s perspective to understand the causes of parking problem. The game theory was used to analyze the process of interaction between travelers and explore the intensified parking problem. Conclusions of the study suggested that charging teachers and students parking fees, issue annual subsidy to faculty members who do not use seldom vehicles and introducing alternative modes of transportation. However, researchers suggested to use risk-dominant Pareto inferior solution when introducing or increasing tariffs for university campus parking to avoid tragedy.

It was identified by Barata et al. (2011) that the parking facilities inside the University of Colombia (UC) Polo I campus was underpriced and overcrowding. Thus, the importance of adopting integrated parking management policies that ensure more rational use of the available parking spaces, evenly balancing supply and demand, bringing in revenues to cover the parking facilities costs, and improve attractiveness towards alternative transport modes were highlighted. The goal of the study was to address their socioeconomic implications by conducting a survey regarding the characterization of campus commuters and their travel options. First, the analysis was done to identify existing places availability for parking, their location, and characteristics. The inflow and outflow of vehicles were counted at entrance and exit gates per 10-minute intervals during morning peak time from 7:30-10:00 am for five consecutive working days and inflow and outflow volumes were computed in order to assess the quantity of the demand for parking inside the campus. The volume of vehicles coming in and out, in articulation with the parking average occupancy rates were used to evaluate the number of vehicles potentially benefiting from a specific type of parking place on campus at a given time. A survey with 68 questions per participant was conducted to evaluate attitude of the commuter, mobility characteristics and the nature of respondent him/herself. Conclusions were made regarding the willingness of users to pay a parking fee, eliminate on-street parking and encouraging commuters towards alternative transport solutions. Recommendations for implementing this research for other parties outside UC campus were made.

Necessity of developing a viable solution for parking spaces in Tudor Vladimirescu University campus in Iasi, Romania was identified (Maftei et al., 2016a). During past years demand and frequency for parking grew and lead commuters to face difficulties regarding road traffic, ease of travel and lack of parking spaces inside the campus. Objective of the study was very diverse from improved traffic safety inside the campus to infrastructure protection and improving conditions for the users. For the study, researchers considered the traffic volumes in adjacent access roads in addition to the traffic inside the campus. Methodology of the research was to determine the number of vehicles to define the maximum number of parking spaces, determine the incline in regards with the terrain where parking lot is built, marking the surface regards according to the actual architectural design and model of transversal section. On a chosen day with clear weather at around midnight time, the vehicles parked inside campus were numbered and counted according to correct or incorrect parking mode. Suitable locations for use of parking were identified and plans were proposed for increasing parking spaces. Though the proposals were made only to meet demand in near future, it was identified that further expansions of parking facilities will be viable without reducing the dedicated green spaces. In conclusion, with the proposed arrangements, it was expected to increase the number of parking spaces by about 93 slots.

In Beijing Jiao tong University campus, bicycles were mainly used for trips within the campus teaching and office districts where most of the classrooms, laboratories, and library facilities were located (Xu et al., 2012). According to the type of utilization of building, it was found that parking demand for bicycles during peak times were very high and parking facilities were not adequate. Thus, goal of the study was to analyze the bicycle parking demand and corresponding influence factors to forecast bicycle parking demand using a combination of parking generation rate model and a traffic – parking demand model. Number of bicycles parked in each parking space was counted at 15-minute consecutive intervals during data collection and distribution graphs of timeline vs. occupancy were plotted to illustrate the variation of demand. Peak times for each parking space was identified and observed that different parking facilities have different peak times as their purpose varies. In order to account the turnovers occurring at each parking lot, parking duration of bicycles were surveyed and summarized into durations and average parking times and probabilities were calculated. Parking demand – supply forecast model was used to predict the requirement of the construction of parking facilities. The study was concluded with obtaining bicycle parking demand within the length of peak time, parking duration, the rate of utilization and turnover in the campus teaching and office district.

Saptarshi et al. (2016) identified that lack of off-street parking forced the Indian road users towards on-street parking and with increasing vehicle ownership and poor-quality transit system lead to increase demand in on-street parking. Gariahat, Kolkata was selected as the case study area for the study since it represented a suitable sample in a metropolitan shopping area with high intensity of activity and poor parking availability and the accumulation profile, current parking demand and future demand were chosen to be addressed in the study.

Methodology used for estimating accumulation profile and determining occupancy of parking spaces was in-out vehicle survey whereas for estimating the parking demand a questionnaire survey with over 100 respondents was used. The objective of this study was to find out parking accumulation profile and to compute present and future parking demand. During analysis, the number of vehicles parked at a given time interval in each parking lot was plotted and identified as the occupancy/efficiency of that particular lot which led to determine how effectively the parking spaces were utilized. Since the study area was occupied by mostly shopping interests, the peak accumulation was identified between 18:00 – 19:00 hours though it can be highly affected by climate and social practices such as holidays and festivals. Estimated parking demand revealed that the occupancy rate to be more than 100% concluding that parking demand was higher than the available parking spaces and estimated to be doubled in 10years time. Thus, the study concluded that the given solution just fulfills current demand and will not be sufficient while a long-term solution should be considered.

Campuses located in urban locations required to maintain adequate provision of parking with the high land constraints and increasing vehicle trips to the campus. Riggs (2017) identified the research gap left by the popular studies based on mode of transportation as static variable and aimed to address dynamic variables to see how parking price reforms, traveler information systems and incentives affect an increase in the use of public transit. Research was conducted at taken University of California, Berkeley campus to address the issues related to parking and evaluates the UC Berkeley campus using descriptive statistics, crosstabs and logistic regression to analyze the factors most likely to influence driving behavior at parking lots. Data for the survey was obtained via an email questionnaire. GIS software was used to calculate alternative transportation modes availability. Researchers implied that rather than trying to meet growing demand for parking, it was more viable for planners to look for ways to reduce number of vehicles which will result in increased accessibility. Furthermore, researchers emphasize the importance of conducting in-depth surveys to make much more strategic decisions balancing sustainability and capital costs.

A similar study was conducted in the Qatar University for solving the parking problem by Azzali and Sabour (2018). Demographic data, number of parking spaces, and daily traffic at the university gate were collected. The direct systematic observations were made in a specific time in each day. Also, questionnaire survey was conducted among both students and staff. Based on the collected data, an optimized and comprehensive mobility system was proposed for Qatar University, by introducing new services and assessing the use of services which were already in place. It was recommended to conduct further studies to applicability of this system.

Dell'Olio et al. (2019) conducted a study on effect of parking policy on user mobility choices using the data collected through revealed and stated preferences survey. Mixed logit model was used to estimate the importance of different variables on choice of mobility when parking policies are changed. Using this method, optimum parking fare could be calculated minimizing the number of free spaces. A case study was conducted at University of Cantabria, Spain and the optimum parking fare was calculated that would maximize the income obtained from the parking spaces.

3. METHOD

In order to fulfill the objectives defined for the study, following methodology was followed to investigate the magnitude and characteristics of parking problem. Before getting into the methodology itself, few key technical parameters to be defined which were used throughout the study (Garber and Hoel, 2009).

Space-hour: a unit used to quantify parking which defined as the use of single parking space designated to a specific vehicle class for a period of 1 hour.

Parking capacity: maximum number of vehicles that can be safely parked in a specified area with sufficient area per each vehicle according to its class.

Parking volume: total number of vehicles parked in a specified area during a specific length of time (usually a day).

Parking accumulation: number of vehicles parked in a specified area at a specified time.

Parking load: area under the curve of parking accumulation versus time graph for specific duration.

Occupancy rate: ratio between parking accumulation to parking capacity at a specified time in a specified study area.

Parking duration: time duration of a vehicle parked for at a parking bay.

Turnover: rate of use of a parking space. Obtained by dividing the parking volume by the parking capacity.

This parking study followed a conventional approach with four key stages. First an inventory of existing parking facilities was generated. During this stage, areas used by users to park vehicles both legal on-street and off-street parking and illegal were identified and evaluated. At Malabe campus, 19 different parking areas were identified as shown in Figure 4.

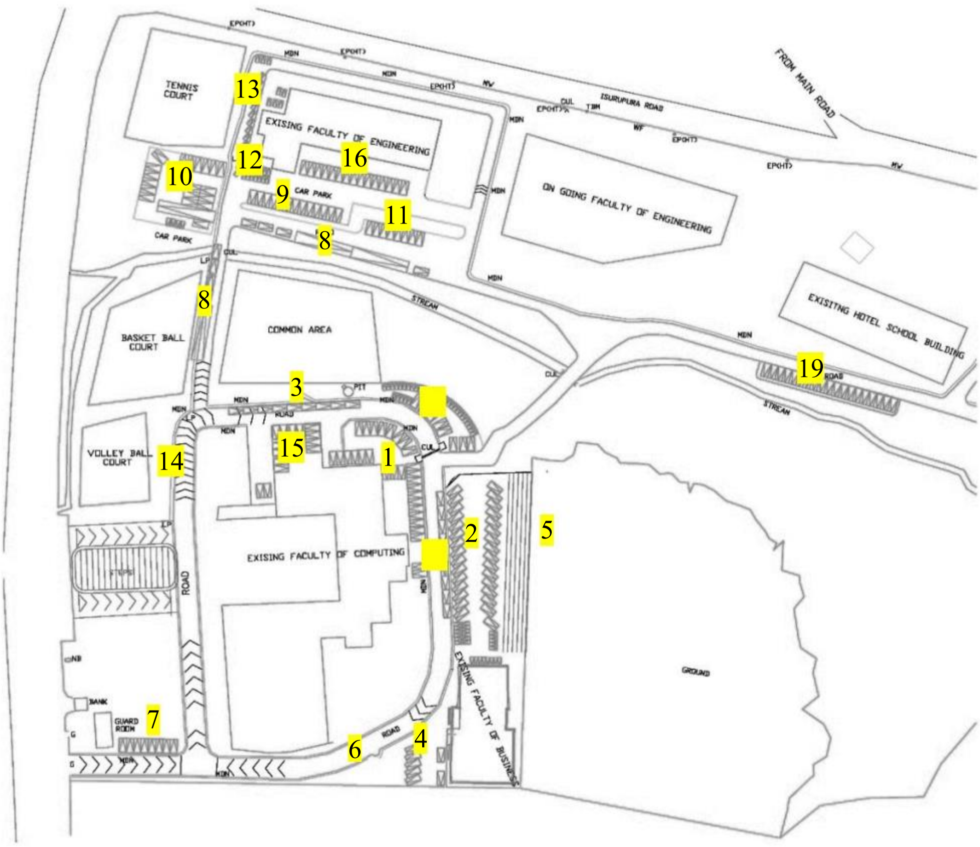

Figure 4: Locations of parking areas in Malabe campus

Then the characteristics of each area such as available number of parking spaces for each vehicle class, restrictions of use, type of parking provided, dimensions and other remarks were recorded. Using these data, the parking capacity of each parking area was calculated and summarized as shown in the Table 1. Parking spaces available in illegal parking areas were plotted by observing the typical pattern of users' parking behavior in order to obtain the current capacity of those parking lots.

The second stage of the parking study was to collect data on daily vehicle flow, parking accumulation, occupancy rate, parking turnover and parking duration. Daily vehicle flow was obtained using a Metro count pneumatic tube roadside unit installed at the entrance of the campus. Data collection using pneumatic tubes was carried out for 6 months from March to September 2017 to obtain a more refined average data. Data collection for parking accumulation and occupancy rates were obtained by 36 hours of vehicle count survey done at all identified parking areas on average days from 07:00am to 07:00pm with hourly counting cycles for three days. For each parking area, the number of vehicles was recorded in each vehicle class in each hour. Selected three days for 36-hour vehicle counting survey were 4th of May, 20th of July, and 08th of August in 2017. All selected days were chosen on weekdays avoiding any special events, academic holidays or special activities with clear sunny weather to obtain typical parking data on an average day. The selected sample size was considered adequate to obtain average values to represent the present parking conditions qualitatively and quantitatively considering the available manpower and time.

Table 1: Parking areas identified and its characteristics

Area No.	Area Name	Legal / Illegal	Surface Parking / On-street	Existing Parking Capacity		
				Car	Bike	Bus
1	IT Staff parking	Legal	Surface	24	0	0
2	IT Student main parking	Legal	Surface	31	25	0
3	IT On-street parking	Illegal	Street	9	0	0
4	BM Parking	Legal	Surface	7	0	0
5	Playground parking	Illegal	Surface	N/A	N/A	N/A
6	Unpermitted parking near BM	Illegal	Street	N/A	N/A	N/A
7	Visitors Parking	Legal	Surface	8	0	0
8	EN Roadside parking	Illegal	Street	8	0	3
9	EN Student park 1	Legal	Surface	13	0	0
10	EN Student park 2	Illegal	Surface	19	4	2
11	EN Student park 3	Legal	Surface	8	0	0
12	EN Bike parking	Legal	Surface	0	14	0
13	EN Back alley parking	Illegal	Street	1	22	0
14	Unpermitted parking – other	Illegal	Street	N/A	N/A	N/A
15	IT Administration parking	Legal	Surface	20	0	1
16	EN Staff parking	Legal	Surface	15	0	0
17	IT On-street parking 2	Illegal	Street	9	0	0
18	IT Student parking 2	Legal	Surface	8	33	0
19	CAHM Parking	Legal	Surface	15	20	N/A
	Total			**180**	**98**	**6**

To determine information on turnover and parking duration, 12 hours of manual data collection survey was carried out from 07:00am to 07:00pm with hourly counting cycles on an average day for the selected legal surface parking areas which were “2 - IT student main parking”, “16 – EN Staff parking”, “9 – EN student parking 1”, “10 – EN student parking 2”, and “11 – EN student parking 3” which is shown in Table 1. Number plates of the vehicles parked in above specified areas were videotaped during each cycle and the data were extracted and recorded in post to minimize the cycle time. Recorded data were used to identify individual vehicle and corresponding parking durations which were used to determine the turnover rate at each parking lot using Equation 1.

Turnover= (number of different vehicles parked)/(number of parking spaces) *(1)*

In third stage, sources of parking generators and factors influencing the choice of parking spots were identified. Prepared standard set of questionnaires was provided to parking users targeting to reach as many parking facility users as possible to obtain necessary information. In the final stage of the study, the collected data were analyzed to determine above mentioned parameters in each stage in addition to the results from the interview surveys and necessary solutions were proposed.

4. RESULTS

Collected data were analyzed to determine the current parking demand and then to forecast the future parking demand. Data obtained from user interview survey was used to obtain an insight to user opinions. Improvements were proposed for the parking infrastructure in accordance with local regulations related to parking.

4.1. Current Parking Demand

First, the data obtained from “MetroCount” roadside unit was used to determine the vehicle inflow outflow variation during an average week using data tables obtained from “Weekly Vehicle Counts (Virtual Week)” function of Metro Count “MC Report” application. The report profile of MC Report software was customized as shown in Figure 5 to only consider incoming vehicles by using the directional modifier “only A-B vehicles”. Similarly, only considering outgoing vehicles using “only B-A vehicles” directional modifier the results were obtained for outgoing vehicles.

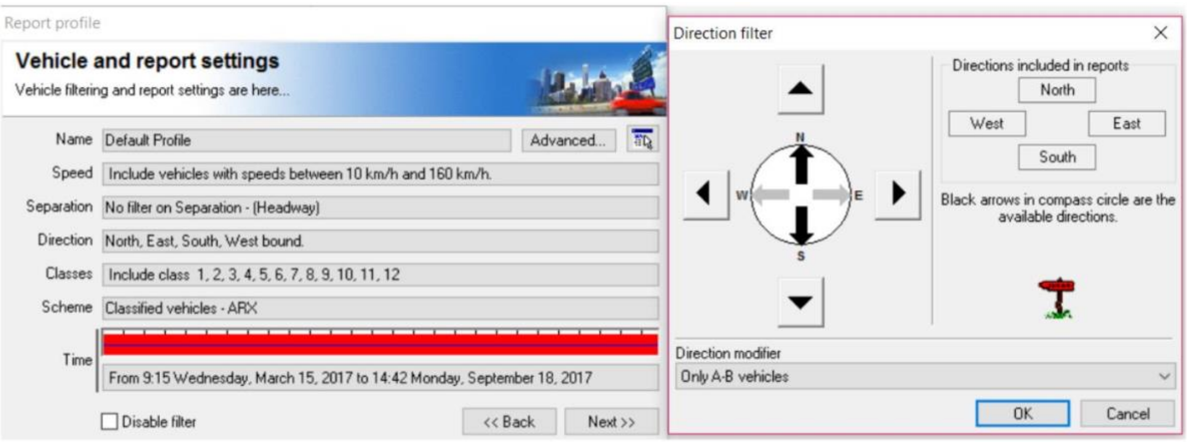

Figure 5: Metro-count report profile customization

Variation of averaged values of hourly inflow and outflow data for weekdays was plotted as shown in Figure 6. Results indicated morning peak at 08:00 hours and evening peak at 17:00 hours for outflow vehicles with a mild peak at 13:00 hours. Inflow vehicle count also recorded morning peak at 08:00 hours. However, it indicated two noticeable evening peaks at 13:00 hours and 17:00 hours. Figure 6 also indicated that the vehicle inflow before 11:00 hours was higher than outflow which resulted in increase of demand for parking. Outflow after 11:00 hours was higher than inflow resulting decrease of parked vehicles.

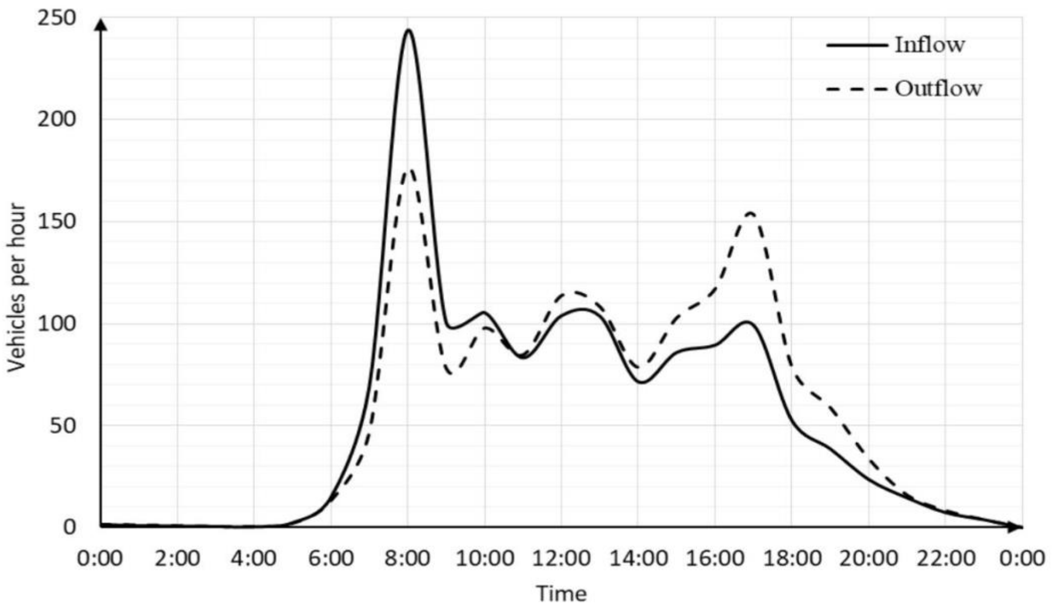

Figure: 6 Vehicle Inflow - Outflow Variation on an average day

Then the vehicle count data of parked vehicles obtained from 36 hours of survey was used to obtain average parking accumulation profile for 12 hours duration by calculating average number of vehicles parked in each hour against time. The accumulation data were summarized by vehicle class and plotted as shown in Figure 7. Parking accumulation profile exhibited downwardly concaved shape with two peaks with a trough in the middle at 13:00 hours which was during the lunch break hour. The maximum parking accumulation was peaked as 414 total vehicles parked at 14:00 hours and a second maximum of 407 total vehicles peaked at 11:00 hours.

Averaged data of parking accumulation was then used in conjunction with current parking capacity data acquired from parking inventory survey in Table 1 to obtain variation of occupancy rate in each parking lot with respect to vehicle class. Parking lot no. 1, 2, 9, 10, 12, 16, 17, 18 and 19 were identified as critical as they exceeded occupancy rate over 100%. Results indicated that the parking lots stated above were also identified as fully occupied from visual inspection. However, some parking lots with lower occupancy rates than 100% were also identified as fully occupied during visual inspections. This may be due to improper parking habits and lack of marked parking spaces causing users to occupy more surface area than dimensions specified in guidelines.

Data from 12-hour vehicle count survey was tabulated for each class of each parking lot. Total space hours of parking supply and demand, total number of users, average parking duration per user, and turnover of each vehicle class for each selected parking lot was estimated and summarized in Figure 8. Overall average parking time for student parking lot users was 5 hours and 3 minutes while it was 7 hours and 42 minutes for staff parking lot users.

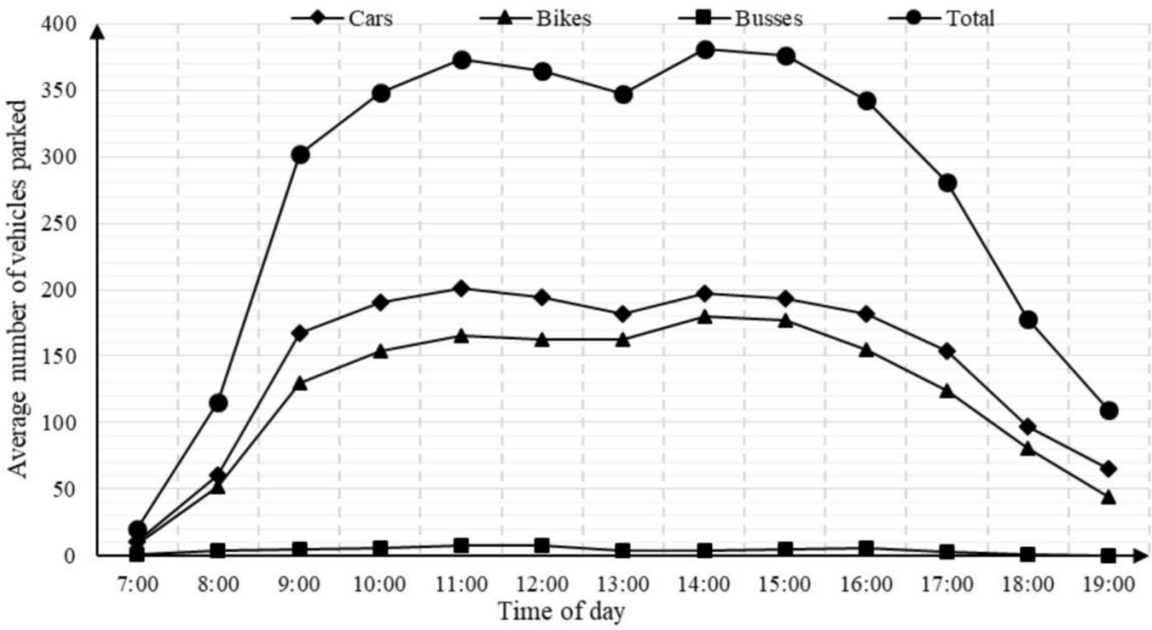

Figure: 7 Parking Accumulation Profile by Class in average weekday

		Parking Supply (spots)			Parking Supply (Space hours)			Parking Demand (Space		
Lot No.	Lot ID	Cars	Bikes	Buses	Cars	Bikes	Buses	Cars	Bikes	Buses
2	IT Student main parking	31.00	25.00		297.60	240.00		275.00	333.00	
9	EN Student park 1	13.00			124.80			118.00		
10	EN Student park 2	19.00	4.00	2.00	182.40	38.40	19.20	177.00	16.00	19.00
11	EN Student park 3	8.00			76.80			67.00		
12	EN Bike parking		14.00			134.40			170.00	
16	EN Staff parking	15.00			144.00			154.00		
Total		**86.00**	**43.00**	**2.00**	**825.60**	**412.80**	**19.20**	**791.00**	**519.00**	**19.00**

		Total Number of Users			Average Parking Duration			Turnover		
Lot No.	Lot ID	Cars	Bikes	Buses	Cars	Bikes	Buses	Cars	Bikes	Buses
2	IT Student main parking	58.00	67.00		4.74	4.97		1.87	2.68	
9	EN Student park 1	23.00			5.13			1.77		
10	EN Student park 2	31.00	4.00	2.00	5.71	4.00	9.50	1.63	1.00	1.00
11	EN Student park 3	10.00			6.70			1.25		
12	EN Bike parking		36.00			4.72			2.57	
16	EN Staff parking	20.00			7.70			1.33		
		142.00	**107.00**	**2.00**	**5.57**	**4.85**	**9.50**	**1.68**	**2.58**	**1.00**
					Avg.Duration (student)		5.05			
					Avg.Duration (staff)		7.70			

Figure 8: Summary of Parking Supply, Demand, Duration & Turnover from 12-Hour Survey

Area under the parking accumulation curve represents the total parking demand in space hours. Hence the parking demand for each class was obtained. Parking capacity data from inventory survey (Table 1) used in conjunction with the current parking demand data to calculate the number of additional parking spaces required in each class to meet the current demand considering parking efficiency factor of 0.8 as show in the Table 2. Negative values got for additional space required meant the existing facilities were sufficient.

Table 2: Calculating additional parking spots required for current demand

Field	Cars	Bikes	Buses
Total Parking Demand (space hours)	1827.00	1550.33	51.00
Total Parking Spots Available	180.00	98.00	6.00
Total Parking Supply (space hours)	1728.00	940.80	57.60
Current Excess Demand (space hours)	99.00	609.53	-6.60
Additional Spots Required (current)	10	63	-1

4.2 Future Parking Demand

The increment in parking facility users' due to upcoming new academic building was investigated by assuming current population to be 6,000 users and population increased by 100 users annually to calculate the population of Malabe campus in year 2025 plus the estimated 4,500 additional students and staff to obtain the total population of Malabe campus in year 2025. Historical data on student population growth is required in order to conduct a more accurate analysis to determine the growth. Due to Malabe campus's institutional policy toward revealing such data with sensitive corporate information, author's request for the historic population information was declined by management authority. Hence, current population and growth rates were estimated with publicly available information and educated assumptions. However, the contribution and value of the study upholds as in order to implement the study for practical applications, the implementing party can use its historical information to accurately calculate population.

Number of current parking facility users in each class was divided by current population of campus to obtain percentage of personal car users and assumed to be a constant ratio till year 2025. Assuming the percentage of personal car users in the campus till 2025 will remain constant is not realistic given the state rapid economic development of the country. However, factors such as not only more users will be able to afford personal vehicles for their commuters will increase, but also more new users who will be able to afford paid education will increase as well. Also, development in a country is associated with the development of its transportation infrastructure and with better public transport, commuter's choice of mode of transport could also change by 2025. Specially, new developments such as upcoming Light Rail Transit (LRT) system connecting the Malabe area to the capital of Colombo and its public transportations hotspots. All these factors make it require a very comprehensive study into the variation of parking user's percentage by 2025. It was not feasible to incorporate such sophisticated investigation within the scope of this study.

Total population in 2025 was multiplied by percentage of personal car users in each class to calculate number of parking facility users in 2025.Average parking duration of each vehicle class was multiplied by number of users in 2025 to calculate the total space hours of parking demand in 2025 and then existing space hours of parking demand was subtracted from it to calculate excess parking demand in 2025. Then the number of additional parking spots required in 2025 was estimated and given in Table 3 considering the parking efficiency factor to be 0.8. Results indicated additional 216 of car parking spaces, 252 of bike parking spaces and 4 of bus parking spaces were required.

4.3 User feedback

During the interview survey, total of 74 parking facility users were interviewed. The sample consisted of 63.5% students, 31.1% staff members and 5.4% other drivers such as student parents and campus owned vehicle drivers. Data collected were summarized using Google Forms. Average trip distance of a commuter was identified as 14.9 kilometers. Results indicated 40.5% of interviewees experiences their preferred parking area is not available most of the time. Preference order of qualities expected from a parking was selected as shade, safety and distance to the faculty by majority of the users in most to least important in given order. Collectively 64.9% of users expressed that the maximum tolerable walking distance from parking area to the respective faculty should be less than 200 meters. Though the preferred distance was less than 200m by majority, 86.5% of users chose free of charging parking 200 to 400 meters away from the faculty compared to paid-parking within 50 meters from faculty. To reduce the amount of personal vehicle commuters, users were asked to suggest a preferred bus route to introduce a new shuttle service from campus. About 14 users suggested Panadura as destination while six suggested Gampaha. However, 83.8% of users responded negatively to the suggestion of using shuttle service even, if it is available.

Table 3: Calculating Additional Parking Spaces Required in 2025

Field	Cars	Bikes	Busses
Total Parking Demand	2016.82	1783.15	51.00
Average Parking Duration	5.57	4.85	9.50
Average Turnover	1.68	2.58	1.00
Current Average Number of Parking Users	362.10	367.69	5.37
Current Number of Students and Staff	6000		
Percentage of Parking Users	6.03%	6.13%	0.09%
SLIIT Population Growth Rate	1.67%		
Growth of Current Population by 2025	6801.6		
Addition Due to New Building by 2025	4500		
Total Population by 2025	11301.6		
Total Parking Users by 2025	682.04	692.58	10.11
Parking Space Hours Required in 2025	3798.9	3358.7	96.1
Current Parking Supply (Space Hours)	1728.0	940.8	57.6
Excess Demand in 2025 (Space Hours)	2070.9	2417.9	38.5
Parking Efficiency Factor	0.8		
Additional Parking Spots Required in 2025	**216**	**252**	**4**

4.4 Proposed Improvements for Parking Infrastructure

Considering the results obtained from the study and feedback from the parking facility users, improved parking facility layout was proposed to meet the demand in 2025. Using AutoCAD software, existing layout of Malabe campus with roads, buildings, boundaries and other prominent elements was drawn. Then the improvements to current parking facilities and new parking facilities was proposed in accordance with Regulation 31 (2) to 31 (4) and form F of schedule III of 1994 amendment by Urban Development Authority (UDA) of Sri Lanka. Proper marking all parking areas was identified as a solution to improve occupancy rates. In addition, placing security personal near parking lots for a period of 4 to 6 weeks to guide users to in cooperate with the new parking practices was found necessary after marking the indicated parking spaces. As interview survey indicated, most users were disinclined to use parking facilities are not nearest to the respective faculties. Hence, the vehicles coming from Kaduwela side were proposed to restrict entering the campus from main entrance. Instead, providing a side entrance near new academic building via Isurupura road was proposed to be used by those users. This would also help to reduce traffic congestion near campus main entrance and users could utilize parking spaces provided towards the northeastward and east ward of the campus property. However, the number of nearby parking spaces also needed to be increased. Hence, parking area No. 3, 8, 10, 13 and 17 which were identified Illegal during parking inventory survey were proposed to be legalized and properly marked. Furthermore, parking area No. 3 was proposed to improve into a surface parking area. In addition, new parking area called "North East Parking" was proposed to introduce to serve commuters using Isurupura road side entrance. In order to maintain safety of pedestrians and parked vehicles, several roads were proposed to allow traffic flow in one direction only as indicated with arrows in proposed parking layout as shown in Figure 9. Overall, the proposed layout will supply 399 car parking spaces, 365 bike spaces and 10 bus parking spaces described in Table 4 to meet the total parking demand of 396 car parking spaces, 350 bike spaces and 10 bus parking spaces in year 2025.

Table 4: Characteristics of Improved Parking Facilities

Area Num.	Area Name	Legal / Illegal	Surface Parking / On-street	Existing Parking Capacity		
				Class 2	Class 1	Class 4/5
1	IT Staff parking	Legal	Surface	33	0	0
2	IT Student main parking	Legal	Surface	25	95	0
3	IT On-street parking	Legal	Street	16	0	0
4	BM Parking	Legal	Surface	8	0	0
5	Playground parking	Illegal	Surface	N/A	N/A	N/A
6	Unpermitted parking near BM	Illegal	Street	N/A	N/A	N/A
7	Visitors Parking	Legal	Surface	7	0	0
8	EN Roadside parking	Legal	Street	8	0	3
9	EN Student park 1	Legal	Surface	14	0	0
10	EN Student park 2	Legal	Surface	38	0	0
11	EN Student park 3	Legal	Surface	13	0	0
12	EN Bike parking	Illegal	Surface	N/A	N/A	N/A
13	EN Back alley parking	Legal	Street	11	160	0
14	Unpermitted parking – other	Illegal	Street	N/A	N/A	N/A
15	Administration parking	Legal	Surface	19	0	1
16	EN Staff parking	Legal	Surface	20	0	0
17	IT On-street parking 2	Legal	Street	10	0	0
18	IT Student parking 2	Legal	Surface	14	0	0
19	CAHM Parking	Legal	Surface	28	50	1
20	New Building Parking	Legal	Surface	45	60	0
21	North East Parking	Legal	Surface	90	0	5
	Total			**399**	**365**	**10**

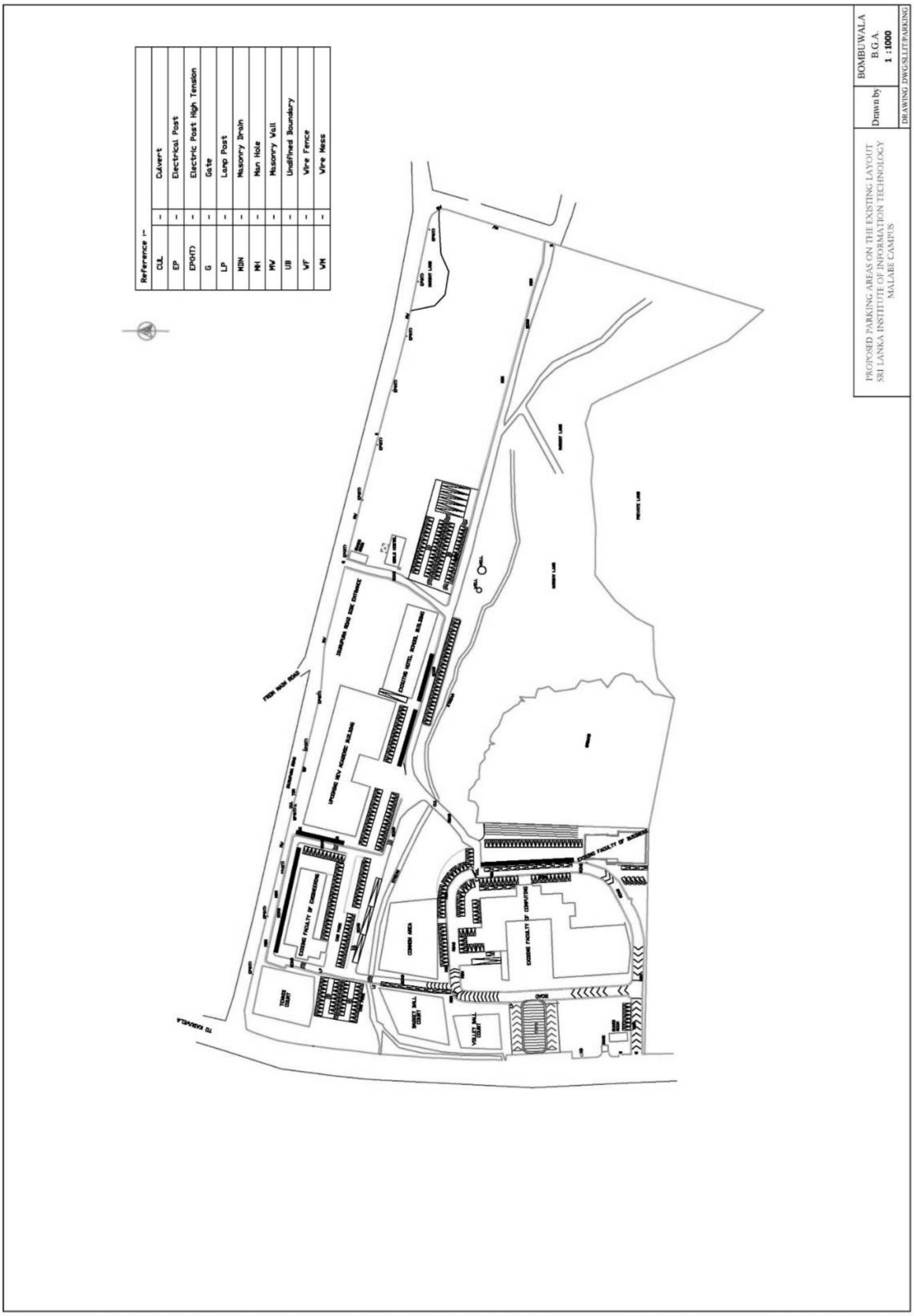

Figure 9: Proposed Improvements for Parking Infrastructure to Meet the Demand in 2025

5. CONCLUSIONS AND RECOMMENDATIONS

The study of parking problem at SLIIT, Malabe campus was identified as a necessity with the increased demand and limited supply of parking facilities. Literature of similar studies suggested various tools and techniques to approach the parking problem. Using four surveys, the magnitude of the existing parking problem was investigated. First the existing parking facilities were investigated, and parking capacity inventory was created. Data from vehicle inflow outflow pattern survey was used to identify parameters such as peak hours and inflow-outflow variation with time. The vehicle count survey of 36 hours was used to obtain parking accumulation profile, current space hours of parking demand and few other analogies respective to each vehicle class. Second vehicle count survey was conducted for 12 hours on selected legal surface parking lots. Data were analyzed to obtain parameters such as parking duration, number of vehicles parked and parking turnover. By using results from these analysis in conjunction, the current supply and demand of parking spots were obtained, and additional parking spaces required to meet the current demand in each vehicle class was calculated. The statistics of occupants of Malabe campus and above results were used to forecast the parking demand in year 2025 after upcoming new academic building is fully operational. Additional parking spaces required in each vehicle class to meet the demand in 2025 was predicted assuming percentage of personal vehicle users is constant. By providing additional 216 parking spaces for cars, 252 parking spaces for bikes and 4 parking spaces for buses, parking demand in year 2025 could be satisfied. Data from user interview survey were used to get an insight from users' perspective regarding problem and possible improvements. Majority of the users' responses reflected that the current parking supply was not enough, and the campus management should introduce more parking areas relatively close to the faculties without having to charge tolls for parking. AutoCAD drafting software was used to illustrate the proposed improvements in parking facilities for year 2025 to supply 399 car parking spaces, 365 bike spaces and 10 bus parking spaces to fulfill estimated total parking demand of 396 car parking spaces, 350 bike spaces and 10 bus parking spaces. Proposed parking facilities were proposed logically without sophisticated spatial effects analysis due to limitations of the scope and time of the study and suggested to be explored in future studies. Unmarked parking areas were identified as a reason for low parking efficiency. Properly marking indicated parking spots was proposed to increase the occupancy rates. In-depth research is recommended to be conducted in future studies to analyze spatial effects of parking spaces and other factors affecting parking behavior of the users to improve the parking space layouts and allocated areas. With these improvements, the study of parking problem at SLIIT, Malabe campus was able to propose a sustainable solution meeting the objectives of the study. However, when adopting this study for any other similar parking problems, the population data and growth data should be more comprehensively analyzed. Sample size and data collection durations should also be decided with relevance to the application. Overall, the study of this nature should always be unique to each problem yet could be used as basis for solving parking crisis of similar nature with careful implementation.

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