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Temporal Analysis of Off-Street Parking Patterns and Occupancy Dynamics: Evidence from Kathmandu Valley, Nepal

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Abstract

Kathmandu valley is a fast-growing metropolitan city experiencing rapid growth in population and vehicles. Already congested narrow roads and haphazard driving and parking has made the matter worse. To combat this issue, the off- street car parking systems has been considered as one of the alternative solution by experts in the field. The unregulated on-street car parking system in the valley makes the study difficult and very unreliable. The study of off-street car parking systems provides us with a much reliable indicators. This study analyzes off-street car parking lots in the Kathmandu Valley, focusing on three parking lots within the city: New Baneshwor, Labim Mall, and Bishal Bazzar, over three days (Friday to Sunday). The analysis identifies distinct hourly parking patterns: left-skewed in New Baneshwor, right-skewed in Labim Mall, and uniform in Bishal Bazzar.

***Keywords** : Off-street car parking system, Parking patterns, Occupancy, Accumulation curves, Smart parking systems.*

Introduction

Car parking is one of the major problem that is created by the increased road traffic. It is an impact of transport development. The less space available in the cities has increased the high demand for the car parking systems. Before taking any measures for the betterment of conditions, data regarding availability of parking space, extent of its usage and parking demand is essential. Parking surveys are intended to provide all this information (IITB,, 2025). Smart Parking System which is considered as a solution to the parking problems is in its infancy in an under developed countries like Nepal. The recent work of the Kathmandu Municipality in forcing the buildings in areas near New Baneshwor to create space for under-ground parking has improved the situation a bit. In addition to this, the management of roads to enforce footpath to pedestrians has created a feeling that Kathmandu Valley thinks about the development of roads and parking spaces to be an important matter. We don't need to go far away from few years, it would had been difficult to find a path to walk due to many cars, vehicles being parked in the main road itself. However, there has been reductions in such scenarios in Kathmandu valley as people and local government has put an end to curb car parking and there has been increasing numbering of off-street or underground car parking system in Kathmandu Valley.

If we look at the roads of the US and European countries, we not only get mesmerized with the cleanness, tidiness and the beautiful scenery around the roads, we can hardly find curb car parking. If we somehow locate a car being parked in such roads, it is with a high parking fee where a driver can afford to pay for it. And those fees are usually used in the development of the roads and for the betterment of traffic condition in the same locality (Shoup, 2024). Developed nations have already implemented huge number of sensors to manage the parking system in their busiest cities. Electronics based on sensors has moved from the chip factory to the roads and to the parking spaces in those developed countries. Few of the countries like Australia even provide the data gathered from their parking sensors for the general research work in their website. Australian Capital Territory (ACT) province in Australia have published the data obtained from the massive number of sensors in the public domain (ACT Government (ACT), 2019). The analysis of these huge datasets is a great way to look into the contents of the smart data obtained from the smart parking system. Such public data are not available from the parking systems available in the Kathmandu valley. Country like Nepal can hardly afford to put such sensors in the roads or the parking lot to locate them and make better use of them. Maybe in future, the country can afford to do that. In such a case, Nepal also can generate huge datasets from those parking sensors and that data can be used to find out any patterns available in those datasets collected. Such data are important for the implementation of the smart city. The car parking data are private to the owner of the parking system. Public car parking dataset is unheard of in Nepal. Without a standard car parking data, parking pattern cannot be identified in Nepal and specially within Kathmandu Valley. A brief study of data analysis of car parking lots is done in (Parajuli, 2020). This research work looks into the car parking lots information collected manually to see if any parking pattern can be deduced or some other insights can be derived.

Statement of the Problem

Parking space in urban area in Kathmandu valley is limited and expensive on the other hand. Traffic management is becoming more complicated due to unmanaged on-street parking and some parking their vehicles on the footpaths. The enforcement authorities in the Kathmandu valley are having a very hard time in the management of on-street parking lots. Off-street parking facilities are the probable remedial solution for the reduction of the current chaotic urban traffic.

Before taking any measures for the betterment of parking conditions, data regarding parking lots, its extent of usage and parking demand is essential. Such as hourly car parking pattern, parking accumulation, parking duration and parking occupancy are indicators for parking scenario. However, these data regarding parking are not found in an authorized way. Also, the effect of Information and Technology (IT) on the usage of parking lot is a new frontier that needs analysis.

Research Objectives

The main objective of the research work is to analyze the off-street car parking data for the benefit of the parking authorities and managers. The specific objectives of the study are:

- To analyze an hourly car parking pattern of cars in selected locations in Kathmandu Valley.
- To find out an existing car parking accumulation and parking occupancy.

Literature Review

As per the Department of transport management (DoTM) data, the number of the cars are in an increasing order every year (Parajuli, 2020). With only limited space available in the Kathmandu Valley, the analysis of the car parking data can provide the transport authority with an insight to manage the car traffic in the future. This research work is one such initiative. The car parking data in three commercial area has been used and analyzed to determine the pattern of parking.

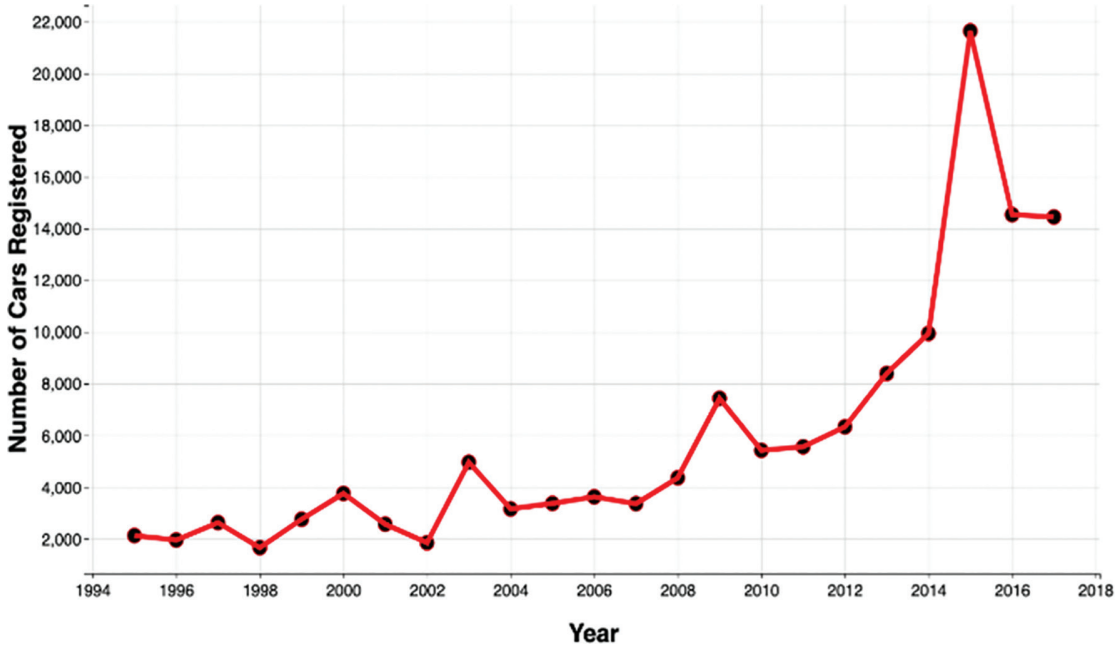

Figure 1: Car Registration Data in Kathmandu Valley

The plot of car registration data within Kathmandu valley shows almost an exponential increase in the number of the cars (Parajuli, 2020). The DoTM data is not easily available and is extracted from their website as upto 2018.The department provides the registration data in a pdf format in their annual report. The department still need to believe in thinking that such data are needed for transport professionals. This indicate how much lagging we are behind the developed US and European transport department bodies. The massive increase in car numbers brings us into the importance of the other events related to it. Accidents data, parking data, traffic data etc has become a buzz word at the moment. And this study is mainly concentrated on the use of the car parking data. Now, lets look at the recent studies that have been done throughout the globe in regard to the car registration, parking and parking fees.

In Japan, the owner of the car will need to provide garage certification from police to be able to register their cars (Barter, 2021). Even if the drivers corrupt the police officer and manage to get around the car registration, it is illegal to on-start park their cars in Japan. This way, the government have made sure without a garage , it is not possible to buy a car in Japan. This will lead to more off-street car parking and hence provide more parking space to other needing it on an urgent basis. In an another study carried out in an European city (T&E, 2026) predicts that the increase in the size of the car can harm the already less available on-street car parking spaces. Few parking lot studies are centered around on-street parking while few others are focused on off-street parking lots. The worsening condition of city traffic and car parking spaces in Kathmandu Valley is dealt with in some respect in (Khatry, 2022). The author argues that the accidents and death of pedestrians by car has been spiking in Kathmandu as the owner of the cars have parked their cars on the footpaths and the general public are forced to walk in the middle of the road. Thus resulting in the accidents. If car parking spaces are not managed well, the author argues that death related to vehicles/cars will definitely rise in the Kathmandu Valley. An important task carried out by Kathmandu Metropolitan City (KMC) to reclaim the enchroached space by huge building owners infront of their buildings or their underground floor has been described in (TRN Online, 2022). The article says that by forcing the huge building owners to use the parking seen in their blueprint will clearly help in reducing the traffic jam or find

a place in the private car parking lots around the Kathmandu Valley.Then current mayor of the KMC, Balen Shah had been praised for that impressive work carried out to perform the major reform in the transportation sector in Nepal.

The periodic off-street parking system data has been studied in (Yifei Cai, 2025). In their study, the authors have analyzed the data from Ningbo Yongcheng parking platform. As per them, the off-street parking data pattern can have convex characteristics or they can have double or triple peaks. The periodic parking in their studies shows temporal and spatial imbalances. The author has worked hard in the sense that they have manipulated the data obtained from the parking platform and have plotted those dataset to visualize some insightful patterns needed for the parking or city authorities.

The difficulty of finding an authorized off-street car parking data is indicted in (Bopp, 2026). The author have used aerial images of Hamburg and Munich, Germany to build a model for their analysis. Their analysis is mainly focused on residential area and the authors indicate that such study could be carried out in a commercial area to view the pattern in a better way. From this research , we can allude that much of the recent studies on transportation , authors have given importance to the statistical analysis of the car parking data. Now, the car parking data is not only a transportation problem, it is an issue of broader context like data analysis and employee or employer enrichment in most of the countries around the world.

One good study of an on-street car parking system in Hong Kong has been carried out in (Fan Wu, 2022). The study is of great importance in a highly dense city like Hong Kong. Though, the study is focused on on-street car parking system, lessons from this study and their data analysis carried out in their research work carries a huge important role in transportation and data analysis sector.The study of predictive parking management sourced from multisource data inputs has been carried out in (Katerina Vakrinou, 2026). The authors analyze the data from different sources in Greece and have concluded that performance based parking management could be done by the parking management authority to utilize the parking area to its optimum level. From this research, we can say that car parking data can be further utilized in gaining more insightful ideas needed for the society.

Different models to analyze car parking data from China has been studied in (Ziyao Zhao, 2020). The research focusses on the long-term and mid-term performance based parking feasibilities with the data sourced from four different places in the country.A case study in Taipei which includes 346 parking spaces has been documented in (Pei-Fen Kuo, 2024). The research work analyzes the 24 hrs data at massive number of parking spaces. The study categorizes the parking spaces into three categories : one in which parking data decreases during datytime, remains stable during daytime and increases gradually during daytime. The research work uses different models to analyze the parking data characteristics. As we travel from the North America to Europe and final to Asia, the depth of car parking analysis has decreased a bit due to unavailability of the consistent and authorized car parking data. The researches have been making use of Sophicasted tools on R / Python to simple data collection and rendering those data in a very rudimentary level in the Asian research.

All these recent research and studies point us towards the use of off-street/on-street parking data and their further analysis to deduce some implications. With the recent use of electronic sensors in many cities in the world to track parking data, car parking data analysis has become an important topic in the recent days. And more and more research is being carried out in this regard in the field of transportation, computer vision, data analytics, and parking management. While much has been studied in the use of sensors and technology to make car parking easy, few insightful research also has been carried out about how car traffic in the roads can be minimized. One such is the work from (Shoup, 2024). Here the author argues that in a big city like New York City, car parking space can be utilized to a great extent if employer cashes out money instead of

subsidizing the car parking fee of their employees . According to him, few employee have the possibility to take the cash and come by public transportation or by carpooling . Hence giving out the possibility of car parking space that can be utilized by the other needed person.

It should be quite clear that much has been carried out with respect to car parking studies throughout the world. Thus, sooner or later, government of Nepal also will need to make a formal study in this regard. It might take time, it is going to happen as the economic status of Nepalese has increased during the last few years time.

Methodology

The car parking data has to be collected in the first step. Manual plus data is obtained from the parking authority in an authorized manner. In a manual process, car parking data is collected manually and tabulated in a spreadsheet. In second category type, data is obtained from the authority by a formal request. In this type of data, underreporting of the car parking data can be prevalent. New Baneshwor, Labim mall, and Bishal Bazzar parking lots are selected in this work as the study area.

Why these areas for this study and research ? This can come to mind of many of us! Yes, these are the main place of importance to the people of the Kathmandu Valley and country as a whole. Also it can be seen in *Figure 2*, three locations are located at three corners of Maithighar-Thapathali junction and thus almost cover general parking pattern inside busy area of Kathmandu Valley in a short analysis. To anonymize the collected data at New Baneshwor parking area, the parking lot name is not identified in this research work to protect the privacy and avoid copyright information of the parking lot authority. Manual collection was carried out at New Baneshwor parking lot. While recorded dataset were obtained for the case of Bishal Bazzar and Labim Mall area parking lot.

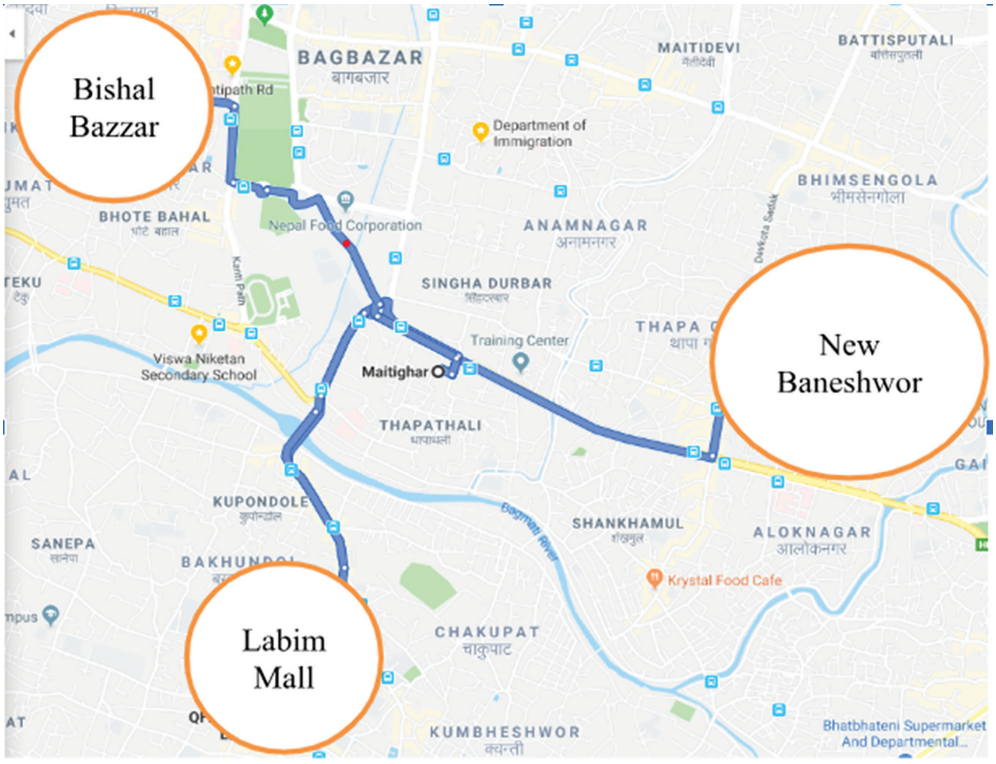

Figure 2: Area of concern for this research work traced over Google Maps

The other main reasons to select these three locations are:

- New Baneshwor area is a hub for big corporations like banks, hospitals, and hotels, and colleges. Their employees and clients are likely to have cars. There is a great possibility to find a parked car around this area. Also upto recent times, there was the building for Nepalese parliament in New Baneshwor center. This made this area of good interest to be included in this research work.
- Lalitpur area is a great place for foreign dignitaries from around the world. There are lot of INGO's around Labim Mall area, so it is selected as an important parking lot. After, Kathmandu Municipality, Lalitpur Municipality almost comes to its rivalry. Thus , selecting another location at Labim Mall was very strsaighforward.
- New Road area is a shopping destination for most of the wealthiest persons in Kathmandu valley, Bishal Bazzar parking lot is selected in this area.

Car Parking Data

The primary data for this work consists of an actual survey. The data of three days (Friday, Saturday, and Sunday) from three locations are collected from 7:00 hrs to 19:00 hrs. The following information are collected:"IN time","OUT time" ,"Location" and "Date". The recorded data are tabulated and then later on processed by an algorithm to do some pre-determined statistical analysis on the recorded data. It should be noted that the time range beyond the mentioned was not considered in this research as people in this part of the world are usually active in between this time duration range.

Data analysis

Data visualization is then carried out and detailed analysis is done in this section of the dataset. The algorithm that is used is as follows.

- Data samples of field survey is read as a data frame.
- The data frame is categorized as per three locations: New Baneshwor, Labim Mall, and Bishal Bazzar and three different data frames are created.
- Each of these sub-data frames are classified according to date to get nine different smaller subsets of data frames.
- Each subset of data frames is cleaned and converted so that the "date" was formatted across the x-axis.
- The "parking duration" was calculated by subtracting "OUT" time from "IN" time.
- The "date" and "parking duration"are plotted to get an hourly parking pattern in a scatter plot format.
- Each data frames are again used to derive the car accumulation number.
- Accumulation curve are plotted for each area.

The algorithm used to derive an accumulation number as mentioned in step VII is presented as follows. This step during an accumulation curve generation is the most important part of this research work. The algorithm model takes the survey data as an input, it then automatically processes to plot nine parking patterns and the three accumulation curves. The accumulation curve represents the number of cars that are parked at the instant of the time that is being considered. Most of the research that have been done, do so by counting the cars being parked manually in most part of the Asian country. In this study, the counting is carried out automatically by a code and is more accurate than the one being done in most of the cases.

Algorithm/Model

if (the **IN** time is greater than 7:00 AM and less than 7:30 AM) &&

(the **OUT** time is greater than 7:00 AM and less than 7:30 AM)

{

increment **IN** number

increment **OUT** number

accumulation number <= **IN** number - **OUT** number

}

else

{

update the counter to check for next interval between 7:30 AM to 8:00 AM and so on until 07:00 PM

}

End

Findings and Interpretations

The hourly car carking pattern is derived for each parking lot for consecutive three days to see different pattern behavior. Friday, Saturday and Sunday data analysis shows the pattern as shown in *Figure 3*. The three days are considered here as the traffic pattern can change on weekday with respect to to weekends. Hence, by considering Friday, Saturday and Sunday in a research, it is possible that we can find out the difference between the patterns on the weekdays and the weekends. In the plot, on the x-axis is taken the time of interest. It is taken from 07:00 AM to 19:00 PM. By considering these time interval , we can be sure that people wake up in the morning and go for their home in the late afternoon after finishing their normal tasks. The y-axis is taken as the car parking duration in hours . It is the number equal to the amount the car has parked in the parking space. By putting this value on the y-axis, it is possible to glance at a single sight how long the car parked in the parking lot of interest to us. In the parking lot of New Baneshwor, the high value of duration on the left side of the plot on the top three figures shows that the cars that were parked in the morning usually tended to stay upto far in the late afternoon. The pattern was slightly different on Saturdy. The car that were parked in the morning left the parking lot fast. And the car that were parked in around mid-afternoon tended to satay upto evening. And if we look at the pattern for Sudnay, it usually is similar to the one on the Friday. The car parked in the morning around 07:00 AM tended to stay upto little bit late. We can thus clearly interpret by looking at this hourly car parking pattern that a user behaviour can be found out from this scatter/line plot of the hourly car parking plot. If we now focus on the middle three plots in Figure 3, there is a little bit difference between the first one on the top. The car parked in this parking lot has stayed in the lots for longer duration around the mid-afternoon. This is quite in contrast to the pattern observed in the New Baneshwor parking lot. Also, the pattern of Friday and Saturday is similar. However, the hourly car parking pattern of Sunday is slightly different than the one from on Friday or Saturday. From this, we should conclude that , Sunday is a different day than Friday or Saturday to the people with cars who have parked their cars in the Labim Mall. This is the power of data analytics that is being used in plotting/

visualizing the data of car parking lots.

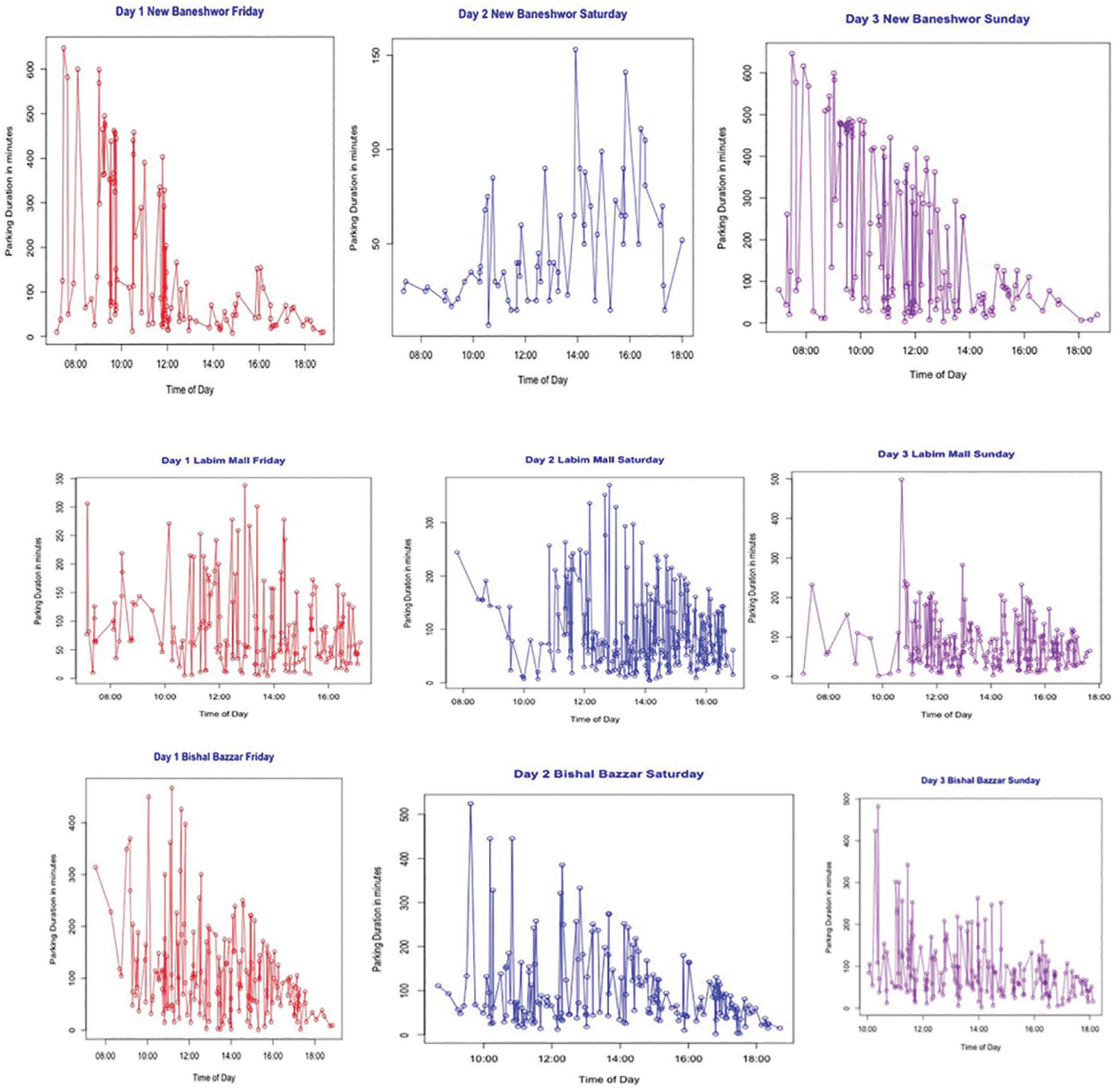

Figure 3: Hourly car parking pattern

Now, lets check at the bottom three plots in Figure 3. These are the datasets plots from New Road area , core area of Kathmandu Valley. The hourly car parking data from New Road or Bishal Bazzar parking lot is fairly flat from the morning hours to the late afternoon hours. The duration of the parked time for cars on hourly basis is almost constant for the three days: Friday,Saturday and Sunday. From this characteristics of the plot , we can tell that people whoever parks in New Road area park for fairly same amount of time. Also, we can tell that parking lot of this type can have an importance in one respect. The parking lot authorities can also impart the demand based parking fee in this type of parking lot as the drivers are ready to pay the fee as the demand can be seen flat throughout the day.

Results and Discussions

Lets us now focus on what these characterisitics plots means to us. If we look at the top three plots on *Figure 3*, it is stikingly visible that we are able to see the left aligned plot in the first case of New Baneshwor parking lot. This meant the users or car driving person has managed to park their vehicle during th morning hours of the day. In the middle three plots of *Figure 3*, we can observe that the density of cars have increased around mid-afternoon at Labim Mall parking lot. By this, it is possible to interpret that the parking lots are more occupied during the mid-afternoons. Finally lets focus our study on the bottom part of *Figure 3* where the car parking number is observed to be almost uniform for the three days under study at Bishal Bazzar parking lot. This meant the parking spaces in this area of the valley is occupied for most of the time throughout the day indicting possible good revenue to the management authorities.

Parking Accumulation Curves

The current research finally calculates number of cars parked at a particular instant of the time. The number is referred to as a car accumulation. The car accumulation is plotted per hours as shown in *Figure 4*.

The accumulation curve shows that the parking accumulation during Saturday is very less indicating less usage of the parking lot. The Saturday accumulation pattern at two lots: New Baneshwor and Labim Mall matches to a similar extent. However, the Saturday accumulation (Day 2 in Figure 4)pattern of Bishal Bazzar parking lot is slightly different and is near most equal to that observed on the other days: Friday and Sunday.

Th car parking accumulation at New Baneshwor, Labim Mall and Bishal Bazzar on Friday (Day 1) all lie between that of the accumulation on Saturday and Sunday. This could mean that the car accumulation does vary with the day of the week in all of these three areas. And to say that it could be applied to other places in the country, more research will be needed to be carried out. The car accumulation on Sunday on all three parking lots displays almost highest peaks . This could mean that general public usually commutes more on Sunday which is the opening day of the week upto few months back. Now, since the government has provided a public holidays on Saturday and Sunday, more research will be needed to be carried out and the study data will need to be considered for consecutive four days. This could be a new topic for a future expolaration.

If we have a look at the car accumulation plots, one can notice few intersection points on Day1, Day2 and Day3. The intersections are less visible in New Baneshwor and Labim Mall. While, it is more consistent in the case of Bishal Bazzar car parking lot. There are nine such points observed in the plot of Bishal Bazzar parking lot. These points are not normal, the parking authorities could find them out and could make use of demand-based parking fee in such parking lots to derive out more benefit. However, more research will need to be carried out to make a conclusive remarks on this regards.

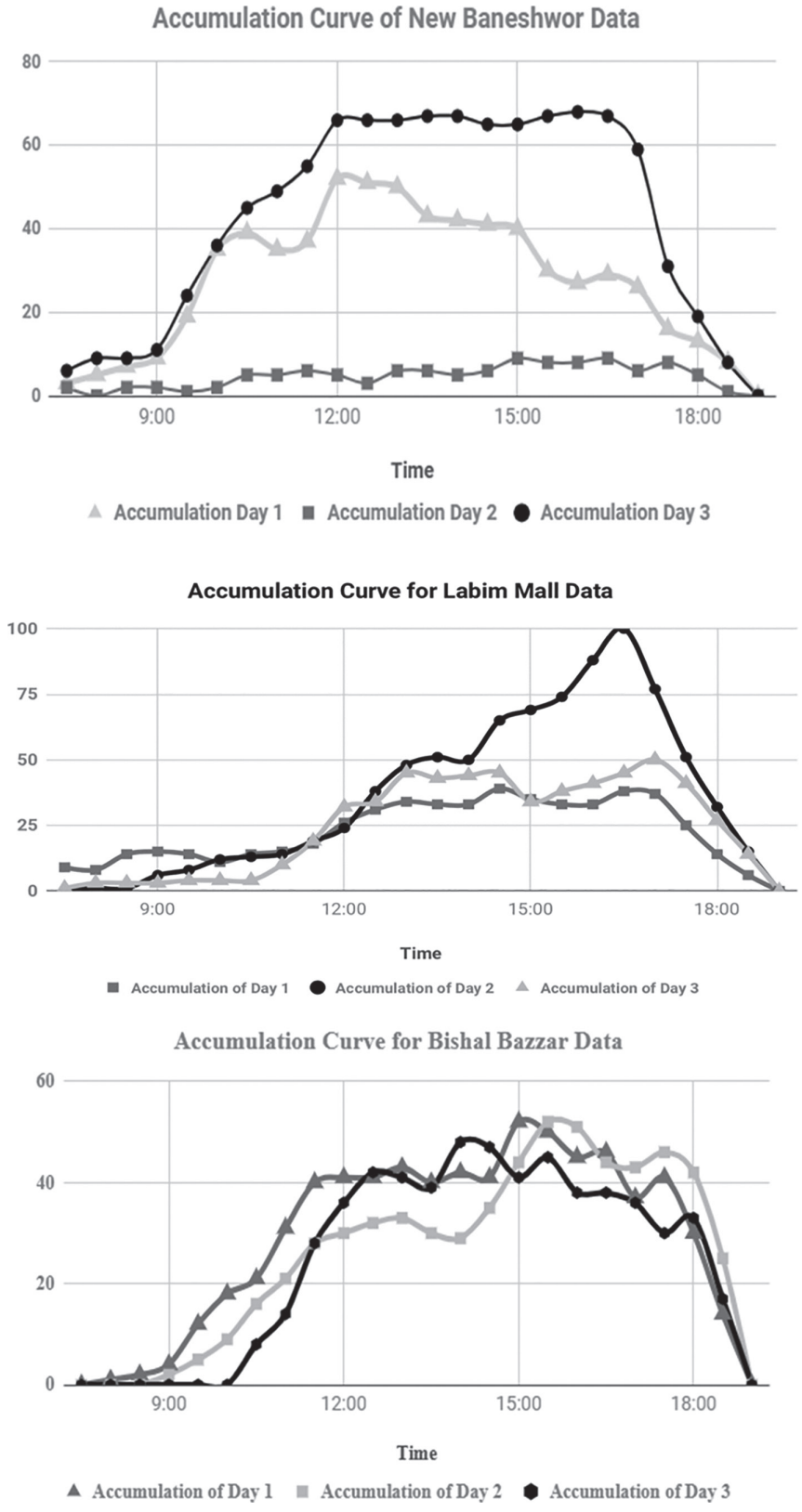

Figure 4: Car Parking Accumulation Curve

The curve is aligned towards right side in the Labim Mall parking lot indicating heavy usage of parking lot during the afternoon hours. And finally the car parking accumulation of Bishal Bazzar depicts the constant usage of the parking lot throughout the study duration. The left tilted data plots on New baneshwor indicates the busy time during morning hours.

Conclusions

More cars and less car parking space in an expensive city, Kathmandu has necessitated the study of car parking lots and behaviour of the parking drivers. For this type of detailed study, this research did a survey. Collected the car parking data and then used those data to plot the car parking hourly pattern and the car accumulation at all those three selected car parking lots. The collected data are analyzed and manipulated algorithmically to visualize the hourly car parking pattern and the car accumulation curves at the three important places we considered in this study. The hourly car parking pattern for each location is deduced with respect to parking duration. The hourly car parking information at three locations is found to be either tilted towards the left side, right side or center of the pattern. The pattern tilted towards left indicated the maximum use of parking area during the morning hours. The pattern tilted towards the right side indicated the maximum use of parking area during the evening hours. The steady or uniform pattern like that of the Bishal Bazzar parking area predicted the continuous use of parking area and constant dynamic nature of the city area.The data is further analyzed to generate the corresponding accumulation curves for each day and each parking lots. The accumulation curve indicated few intersection points which could be used for the implementation of performance-based fee.

The car parking pattern around the country can be studied. However, no guarantee can be provided about the type of the hourly pattern and the accumulation curves that are observed in these three cases. In addition to this, to understand much about the performance based parking fee, more analysis will be needed taking consideration about the car parking fee extracted during the parking time at the car parking spaces.

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