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Passengers Flow Analysis of Public Transit Service in Pokhara

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Abstract

The motive of the study is to evaluate the existing public transportation system and propose recommendations for Pokhara public transportation to enhance its efficiency and effectiveness. In urban locations, a well-managed public transportation system is unquestionably required. According to the previous study, passengers faced various issues on their journey, such as delays in reaching their destination, bus congestion, an inappropriate time of departure, lane stoppage, and more. (Duwadi, et al., 2019) The primary and secondary data collected from fieldwork and the Yatayat Bibhag, respectively, were used in the research for the analysis. The volumes of passenger flows on ten different routes were analyzed. Mapping and modeling were done using GIS and CAD. Results show that the service frequency did not match the actual swings in consumer demand, resulting in increased time delays. It is recommended that well-managed loading areas be needed in areas with the highest person capacity of more than 3000 per stop per hour, such as Chipledhunga, Mahendrapool, Srijanachowk, and more. A practical operation schedule and service frequency, including 10% for backup and maintenance, were recommended. Demand for passengers on various routes and the number of years the capacity can fulfill the demand is calculated.

Keywords: Public transportation, Capacity, Loading area, Service Frequency

1. Introduction

1.1. Background

Public transportation, also known as public transit, which is often administered on a schedule, operated on fix routes, and charges a posted price for each journey, is a system of transport for passengers via group travel systems available for use by the general public. Buses, mini buses, micro buses, railroads, and taxis are examples of modes of public transportation. Public transportation is the most affordable means of transportation for the average person. One significant advantage of taking public transportation is that it reduces the number of vehicles on the road, which progressively reduces pollution. Pokhara has a privately maintained public transit system that runs throughout the city and outlying townships and villages. A good regional-level policy and good-quality service have become essential to improving the public transportation sector in Pokhara. For this, a thorough study of public transit should be done. Some study articles on the person's capacity in traffic have been published,

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with the goal of understanding the most significant number of people that may be accommodated within a transportation system while maintaining a reasonable Level of Service. Level of Service is a tool which helps cities to determine whether to construct new highways or expand existing ones. Those studies have helped to understand traffic flow dynamics and transportation engineering. One major element used for analysis of passenger flow is the route's person capacity. The person capacity of a bus route is the maximum number of people that can be carried past a given location during a given period under specified operating conditions. It is based on the number of vehicles that are or may be operated on the facility, as well as the design passenger capacity of those vehicles. Person capacity is the product of vehicles per hour and vehicle passenger capacity. It is well known that vehicle capacity has a direct impact on passenger capacity**.** Dwell time refers to the time a transit vehicle stops at a station or stop to allow passengers to board and alight. Factors impacting dwell time include passenger behavior, vehicle design, station design, scheduling and routing, fare payment systems, and weather conditions. A long dwell time can result in increased transit service delays, reduced reliability, and decreased passenger satisfaction. Dwell time is the time required to serve passengers at the busiest door plus the time required to open and close the doors. A value of 2 to 5 seconds for door opening and closing is reasonable for normal operations. (National Academies of Sciences, Engineering, and Medicine., 2013) A loading area is proposed where Dwell time is at its maximum. An increase in operation hours can undoubtedly ease the passenger's travel. However, with more frequent operation, the maintenance and running costs may increase, which may directly impact the economic viability of the public buses and lead to passenger dissatisfaction. So, there must be a balance between the economic operation of buses and the running costs imposed on passengers. (Duwadi, et al., 2019)A detailed study of the Ring Road has been done in order to identify the existing problems of public transit in Kathmandu Valley. The study included the analysis of time, delay, and speed, the effectiveness of existing bus stops along with the selection of bus stops, corridor capacity, economic analysis, and analysis for the reduction of emissions of air pollutants. (Tiwari, et al., n.d.) Washington State Department of Transportation (WSDOT) did the comprehensive study on the corridor capacity to guide the engineers and policy decision-makers for future planning. (Millar , 2016) An Interactive Multiple Model-Based Pattern Hybrid (IMMPH) technique to predict short-term passenger demand has been used previously. By constructing knowledge from pattern models using historical data and improving the interaction between them using real-time observations, the technique maximizes the effective information content. The ability to accurately forecast demand in public transportation aims to reduce operating costs and enhance bus service quality by allocating limited resources more effectively. (Ma, et al., 2014)

1.2. Objectives

The objectives of this study are:

- To analyze passengers flow and evaluate corridor capacity, service frequency and effective time interval.
- To calculate passenger capacity and forecast the potentiality of routes to serve the increasing demand.

2. Methodology

2.1. Study Area

Pokhara Metropolitan City, with an area of 464.24 km^2, is Nepal's largest metropolitan city by area. According to CBS 2021, the population of Pokhara city is 513,504. (National Statistics Office, 2021) This study consists of ten different routes on Pokhara's public transportation system. So, this study is focused on studying the passengers' flow on these routes. Pokhara Yatayat Pvt. Ltd., Lekhnath Yatayat, Bindabashini Yatayat, and Fewa Bus are the central local public transportation service providers on these routes.

The figure below shows the map of the study area along with the studied routes.

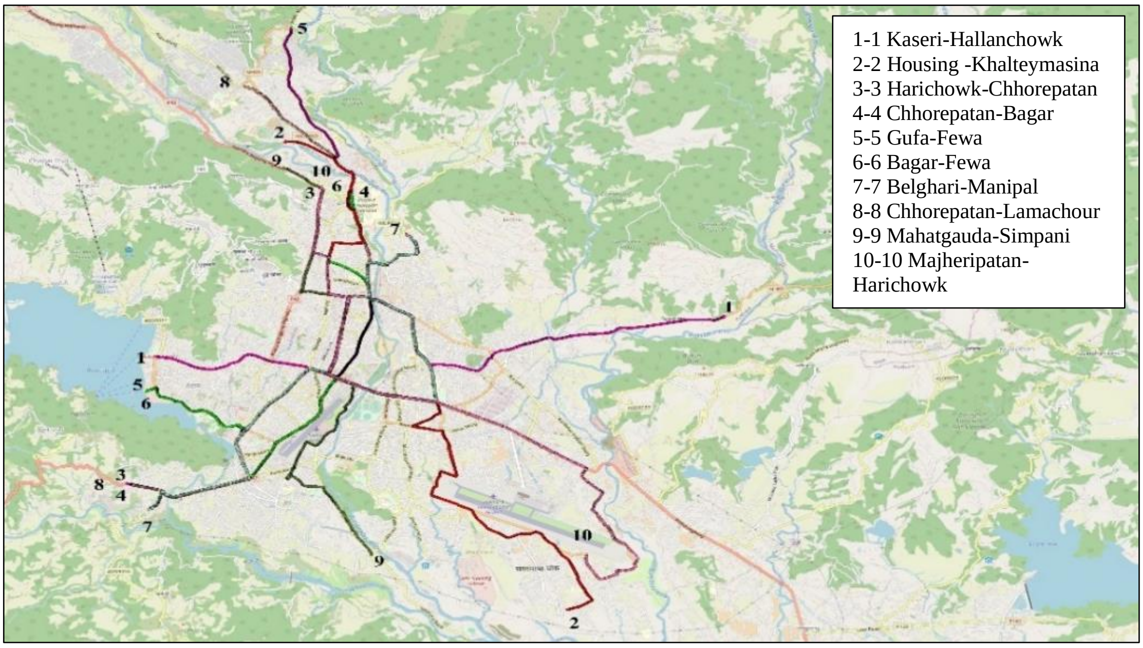

Figure 1. Pokhara Metropolitan City

2.2. Data Collection

2.2.1. Primary Data Collection

The primary data collected during the study consists of public transportation trip characteristics, i.e., journey time, delay time, passenger volume, and existing bus stations and shelters. An on-board Survey was used to collect primary data. While traveling, the number of passengers getting on or off the bus at each station is recorded, as is the total time elapsed to cover the entire route. Using GPS, surveyed routes were traced along with bus stops and shelters. The trips were taken at peak and off-peak hours in each direction. On working days, 58 data set are collected on all ten routes during peak hours (8:30 AM–11:30 AM and 3:30 PM–6:30 PM) and off-peak hours.

2.2.2. Secondary Data Collection

Secondary data, such as the number of vehicles operated by the operators on these routes, their timetables, bus fare, public vehicle routes, and frequency were collected from these bus operators operating on these routes.

3. Data Analysis

3.1. Average number of passengers

The table below shows the total number of passengers on all ten routes in different shifts, along with the average number of passengers during peak hours and off-peak hours.

Table 1. Average number of passengers

Routes	Morning		Day		Evening		Average no. of passengers	
	1	2	1	2	1	2	Peak hour	Off-peak hour
Lamachour-Chhorepatan	74	49	66	41	63	45	58	54
Harichowk-Majeripatan	39	57	49	48	57	45	50	49
Manipal- Belghari	53	63	47	29	62	54	58	38
Housing-Khaltey Masina	57	52	33	29	64	38	53	31
Gufa-Fewa Lake	28	62	42	44	42	62	49	43
Simpani-Mahatgauda	41	40	23	52	-	-	41	38
Kaseri-Hallanchowk	40	57	34	31	46	41	46	33
Bagar -Fewalake	24	28	49	50	72	73	50	50
Chhorepatan-Bagar	32	50	72	55	68	50	50	64
Harichowk-Chhorepatan	49	26	71	40	24	37	34	56

1= Forward Direction 2= Reverse Direction

3.2. Time and Speed Analysis

The table below shows the calculation of time and speed for the routes Gufa-Fewa Lake and Simpani-Mahatgauda. The time and speed analysis of the remaining eight routes were also calculated.

Table 2. Time and Speed Analysis

Routes	Gufa-Fewa Lake						Simpani-Mahatgauda			
Shifts	Morning		Day		Evening		Morning		Day	
Journey Time (Min)	40.00	63.00	46.00	65.00	50.00	66.00	63.00	68.00	58.00	62.00
Delay Time (Min)	4.00	16.00	5.00	8.00	6.00	14.00	19.00	29.00	14.00	37.00
Running Time (Min)	36.00	47.00	41.00	57.00	44.00	52.00	44.00	39.00	44.00	25.00
Journey Speed (Kmph)	17.70	11.24	15.39	10.89	14.16	10.73	10.29	10.59	12.41	11.61
Running Speed (Kmph)	19.67	15.06	17.27	12.42	16.09	13.62	14.73	18.46	16.36	28.80

3.3. Person Capacity at Loading Area

Person Capacity (Ps) refers to the number of passengers per stop every hour or the maximum number of passengers that our suggested loading area could service. The loading area was proposed in the reverse and forward directions, where the dwell time is the maximum. It was computed using the provided equation 1. Equation 2 was used to compute the vehicle capacity of a bus per hour (B_s). Three loading zones were proposed at stations, so the value of Number of effective loading areas (N_{eb}) is taken as 2.45 while calculating vehicle capacity of a bus per hour (B_s). In addition, equation 3 was used to calculate the maximum number of buses per loading area per hour (B_{bb}). (National Academies of Sciences, Engineering, and Medicine., 2013)

$$P_s = B_s \times P_{15} \quad \text{(Equation 1)}$$

$$B_s = N_{eb} \times B_{bb} \quad \text{(Equation 2)}$$

$$B_{bb} = \frac{3600\left(\frac{g}{C}\right)}{t_C + \left(\frac{g}{C}\right)t_d + z_a C_v t_d} \quad \text{(Equation 3)}$$

Where:
P_{15} = Peak 15-minute passenger interchange per bus;
B_{bb} = maximum number of buses per loading area per hour;
g/C = ratio of effective green time to total traffic signal cycle length (1.0 for a stop not at a signalized intersection);
t_c = clearance time between successive buses (s);
t_d = average (mean) dwell time (s);
Z_a = one-tail normal variate corresponding to the probability that queues will not form behind the bus stop;
c_v = coefficient of variation of dwell times.

The g/c ratio was set to one since the traffic signals did not interrupt bus and the probability factor was set to 1.4 as the buses moved towards the loading area from the lane for alighting and boarding passengers. (National Academies of Sciences, Engineering, and Medicine., 2013)

The table below shows the Person capacity of loading area in forward and reverse directions.

Table 3. Person capacity of loading area in forward and reverse direction

Forward Direction		Reverse Direction	
Station	Person Capacity (P_s)	Station	Person Capacity (P_s)
Chipledhunga	6302	Fewa lake	6302
Bagar	4649	Chipledhunga	3315
Prithivichowk (Bus-park)	4545	Bagar	3404
Amar Singh	4654	Sabhagriha	7603
Srijanachowk	6541	Mahendrapool	4000
		Ranipauwa	4887
		Chhorepatan	7740
		Birauta	4077

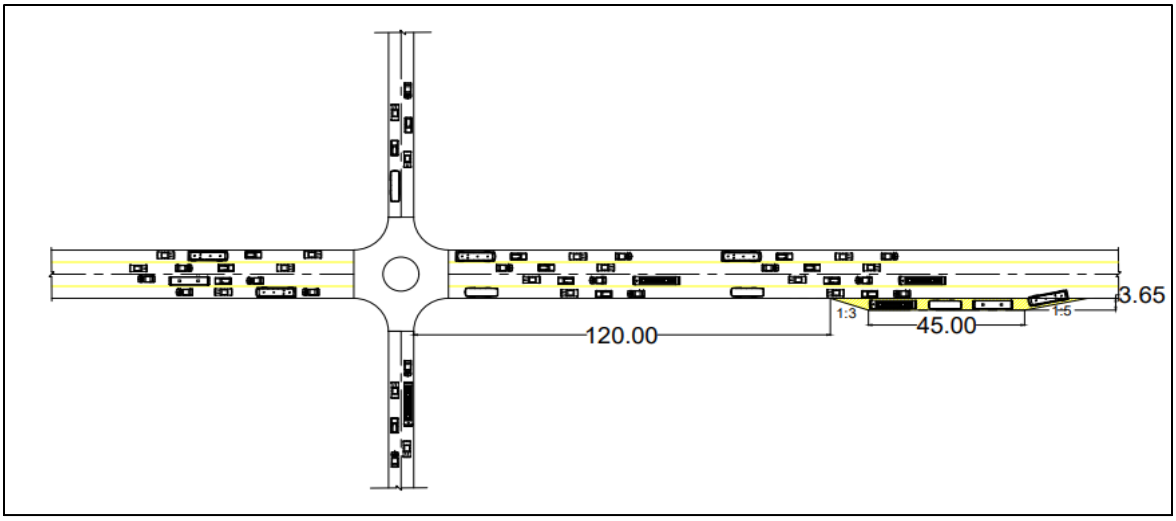

Figure 2 . Model of Proposed Loading Area

The above figure shows the loading area between Sabhagriha Chowk and Srijanachowk. The loading area's one end is 120 meters away from Srijanachowk, and its width is the same as the width of one road lane. The length of the loading area is 45 m, with a 5:1 longitudinal to transverse merging or re-entry taper and a 3:1 taper for the deceleration lane. It is only a proposed sample, prepared following the NRS 2070. (Department of Road, 2013)

The loading areas were proposed at Chipledhunga, Bagar, Amarsingh Chowk, Prithivichowk, Ranipauwa, and Srijanachowk on the forward direction, while on the reverse direction at Fewa Lake, Chhorepatan, Sabhagriha, Chipledhunga, Mahendrapool, Ranipauwa, and Bagar with person capacity (P_s) ranging from 3000-7000 per stop per hour, which is sufficient for future traffic growth. The figure below shows the coordinates of the loading area in both forward and reverse directions.

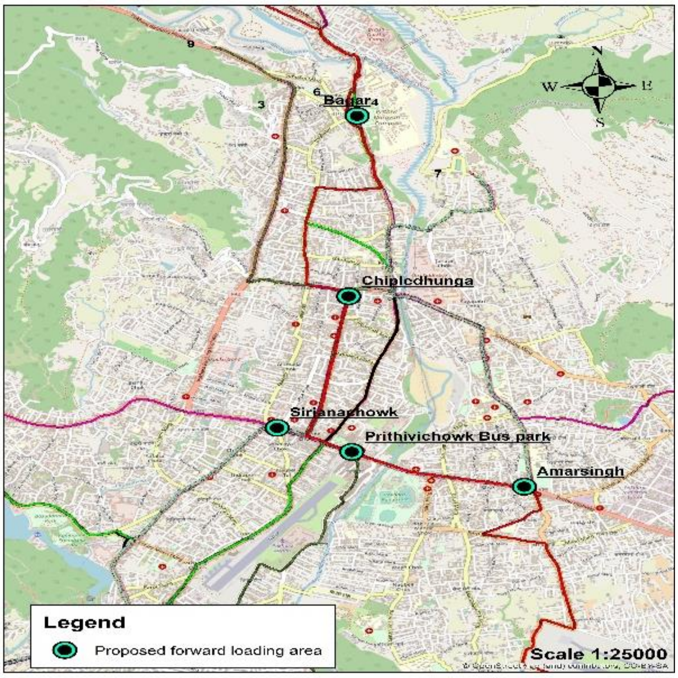

Figure 3. Proposed loading areas in forward direction

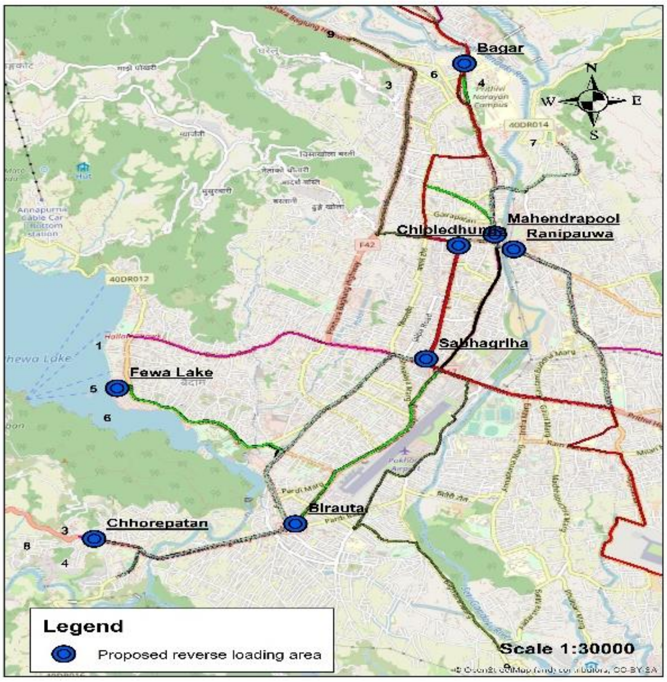

Figure 4. Proposed loading areas in reverse direction

3.4. Corridor Capacity

The corridor capacity was determined by multiplying the number of buses per hour by the number of passengers per hour. (Tiwari, et al., n.d.) There are four sets of corridor capacity, i.e., peak and off-peak hours in both directions. As service was being provided for 14 hours from 5:30 A.M. to 7:30 P.M.., the total number of passengers per day per direction was obtained, as shown in Table 4 and Table 5.

Table 4. Calculation of corridor capacity in the forward direction

Routes	Existing Service Frequency (Vech/hr)	No. of passengers per hour		Corridor capacity		No. of passengers per day per direction
		Peak	Off-Peak	Peak	Off-Peak	
Lamachour-Chhorepatan	12	71	71	850	849	11891
Harichowk-Majheripatan	4	48	41	192	166	2477
Manipal-Belghari	4	53	40	211	161	2553
Housing-Khaltey Masina	6	45	29	271	175	3021
Gufa-Fewa Lake	6	47	55	280	329	4310
Simpani-Mahatgauda	8	39	24	312	190	3397
Kaseri- Hallanchowk	8	54	53	432	423	5974
Bagar-Fewa Lake	3	69	72	208	215	2970
Chhorepatan-Bagar	6	50	79	300	474	5592
Harichowk- Chhorepatan	6	43	71	258	426	4954

Table 5. Calculation of corridor capacity in the reverse direction

Routes	Existing Service Frequency (Vech/hr)	No. of passengers per hour		Corridor capacity		No. of passengers per day per direction
		Peak	Off-Peak	Peak	Off-Peak	
Lamachour-Chhorepatan	12	41	43	494	518	7107
Harichowk-Majheripatan	4	54	46	215	186	2775
Manipal-Belghari	4	50	25	199	99	1990
Housing-Khaltey Masina	6	44	28	261	168	2915
Gufa-Fewa Lake	6	58	41	346	244	4026
Simpani-Mahatgauda	8	35	43	282	341	4419
Kaseri- Hallanchowk	8	45	35	362	281	4424
Bagar-Fewa Lake	3	56	35	167	105	1843
Chhorepatan-Bagar	6	57	55	342	330	4692
Harichowk- Chhorepatan	6	41	49	244	294	3814

3.5. Effective Service Frequency and Time Interval

By using equation 4, we calculated the service frequency, where the load factor was assumed to be 0.9, and the number of stopping bays in each station was 1. We have considered 10% backup and maintenance of the vehicle while calculating service frequency. (Tiwari, et al., n.d.) As we know, the vehicle capacity depends on seat capacity and standing capacity. 0.25 of the seating capacity is assumed to be the standing capacity. (Urban Bus Toolkit, 2011)

$$\text{Corridor Capacity} = \text{Vehicle capacity} \times \text{Load factor} \times \text{Service frequency} \times \text{No. of stopping Bays} \quad \text{(Equation 4)}$$

(Tiwari, et al., n.d.)

Table 6. Calculation of service frequency and time interval of 10 routes in the forward direction.

Routes	Corridor Capacity		Vehicle Capacity	Effective Service Frequency (Vech/Hr)		Time interval (min)	
	Peak hour	Off-peak Hour		Peak hour	Off-peak Hour	Peak hour	Off-peak Hour
Lamachour-Chhorepatan	850	849	46	22	22	2.94	2.94
Harichowk-Majheripatan	192	166	43	6	5	11.95	13.86
Manipal-Belghari	211	161	39	7	5	9.93	12.99
Housing-Khaltey Masina	271	175	36	9	6	7.24	11.20
Gufa-Fewa Lake	280	329	41	8	10	7.96	6.78
Simpani-Mahatgauda	312	190	38	10	6	6.48	10.64
Hallanchowk-Kaseri	432	423	33	16	16	4.07	4.15
Bagar-Fewa Lake	208	215	36	7	7	9.40	9.10
Chhorepatan-Bagar	300	474	38	10	15	6.75	4.27
Harichowk- Chhorepatan	258	426	36	9	14	7.60	4.60

Table 7. Calculation of service frequency and time interval of 10 routes in reverse direction.

Routes	Corridor Capacity		Vehicle Capacity	Effective Service Frequency (Vech/Hr)		Time interval (min)	
	Peak hour	Off-peak Hour		Peak hour	Off-peak Hour	Peak hour	Off-peak Hour
Lamachour-Chhorepatan	494	518	46	13	14	5.06	4.82
Harichowk-Majheripatan	215	186	43	6	5	10.69	12.35
Manipal-Belghari	199	99	39	6	3	10.51	21.05
Housing-Khaltey Masina	261	168	36	9	6	7.49	11.63
Gufa-Fewa Lake	346	244	41	10	7	6.44	9.14
Simpani-Mahatgauda	282	341	38	9	11	7.17	5.94
Hallanchowk-Kaseri	362	281	33	14	11	4.85	6.24
Bagar-Fewa Lake	167	105	36	6	4	11.74	18.59
Chhorepatan-Bagar	342	330	38	11	11	5.92	6.14
Harichowk- Chhorepatan	244	294	36	8	10	8.03	6.66

3.6. Route Capacity and Anticipation of Serviceability of Routes

Different buses operate with different capacities; the average bus seat capacity was calculated by taking the passengers per seat as 1.25. The passenger demand comprises the total number of passengers that use the public buses on ten different routes in a day, which is also called the corridor capacity of that route. The capacity of each route per day was determined by using Equation 5. (National Academies of Sciences, Engineering, and Medicine., 2013)

$$\text{Passenger's Capacity} = (1340 \times \text{operational hours} \times \text{number of seats on a bus})/43 \qquad \text{(Equation5)}$$

In our case, the operational hours are 14 hours. As per the census of 2078, the annual population growth rate of the Pokhara Valley is 2.55%. (National Statistics Office, 2021) Using the geometric increase method, the period of capability of the routes serving up to their maximum limits was calculated.

Table 8. Anticipation of Serviceability of Routes

Routes	Passenger's Demand	Passenger's Capacity	Anticipated year
Lamachour-Chhorepatan	18998	32285	19.06
Harichowk-Majheripatan	5252	29667	66.76
Manipal-Belghari	4544	27049	68.85
Housing-Khaltey Masina	5936	25304	55.58
Gufa-Fewa Lake	8335	28794	47.23
Simpani-Mahatgauda	7816	26177	46.00
Hallanchowk-Kaseri	10397	22687	28.99
Bagar-Fewa Lake	4813	25304	63.91
Chhorepatan-Bagar	10284	26177	35.10
Harichowk- Chhorepatan	8768	25304	40.09

4. Results and Conclusion

4.1. Results

- During peak hours, both the Lamachour-Chhorepatan and the Manipal-Belghari routes served an average of 58 passengers, while the Chhorepatan-Bagar route served an average of 64 passengers in off-peak hours, which was also the highest. Similar to this, the Bagar-Fewa Lake route has an average of 50 passengers in both peak and off-peak hours.
- Maximum delays on the Mahatgauda-Simpani route were 24-minutes during peak hours and 25.5-minutes during off-peak hours, respectively. This route's running speed varied from 19.52 kmph to an average journey speed of 11.2 kmph due to the most extended delay period. The Belghari-Manipal route routinely faced a 21.5-minutes delay during peak and off-peak hours. The Majheripatan-Harichowk route had a minimum delay of 8-minutes during peak hours and 5-minutes during off-peak hours.
- In the reverse direction, the loading area at Srijanachowk can be suggested to serve a person capacity of 6541 per day. In contrast, the loading area at Prithivichowk Buspark needs to fulfill a person capacity of 4545 per day. The loading area at Chhorepatan must serve a capacity of about 7740 passengers in a day.
- In our study, the maximum corridor capacity per day per direction was found on the Lamachour-Chhorepatan route in the forward direction, which was 11891. Similarly, on the route Bagar-Fewa Lake, the corridor capacity per day per direction was found to be 1843, which was the minimum of all.

- The effective service frequency on the route Lamachour-Chhorepatan was found to be 22 at both peak and off-peak hours in forward direction. Whereas 12 at both peak and off-peak hours in the reverse direction, which is the same as the existing service frequency. The time interval is 2.95-minutes at both peak and off-peak hours in the forward direction. Similarly, the time interval is 5-minutes at peak and 4.85-minutes at off-peak hour; 13 and 14 buses are required at peak and off-peak hours in reverse direction, respectively. A considerable difference was found in the time interval on the route Manipal-Belghari. The time interval was 10.51-minutes at peak and 21.05-minutes at off-peak hours in reverse direction.
- The Lamachour-Chhorepatan route has a maximum passenger capacity of 32285 and a demand of 18998, indicating that the existing service quality is satisfactory. In addition, the least-frequented Manipal-Belghari route will reach its capacity after 68.85 years since demand is approaching it, and Hallanchowk-Kaseri can accommodate the demand for up to 35.75 years. However, it has the least passenger capacity.

4.2. Conclusion

Pokhara's current transport problem has been revealed through examining the city's transit system. After careful consideration, a number of major findings regarding the flow of passengers have been drawn, including the total number of passengers, journey time, delay time, running time, person capacity and corridor capacity on each route in various shifts. On the majority of the studied routes, the volume of passengers varies significantly between peak and off-peak hours. This indicates that in order to provide effective service, the service providers must adjust the service frequency accordingly rather than maintaining it constant throughout the operation hours. Despite being a popular destination for tourists and a fast-growing city, Pokhara's public transport options are busy and challenged by traffic, which has increased journey times. Passengers experience significant delays as a result of buses randomly stopping in locations other than bus stops and shelters. On some routes, like Simpani-Mahatgauda, it also happens that the delay time exceeds the running time and increases running speed, which is inconvenient for the passengers. The difference of average journey speed and running speed is low for Housing-Khalteymasina which indicates low delay and increases the overall efficiency of bus services. At stations where dwell time is found to be longer, a loading area is proposed. Three loading areas are proposed at Bagar, Chipledhunga, Prithivi Chowk Bus-Park Amarsingh, and Srijana Chowk in the forward direction. Similarly, stations with three loading areas are proposed at Fewa Lake, Chipledhunga, Bagar, Mahendrapool, Ranipauwa, and Chhorepatan in the reverse direction, having a passenger capacity ranging from 3000 to 7000 per hour, which is sufficient for the future. According to the study, the current capacity of Pokhara's routes is sufficient to fulfil passenger demand. Based on the calculation and analysis from Table 8, the capacity can satisfy demand for at least 19 years on all, considering at most 25 buses operating per hour per route. Overall, the study highlights the necessity of thorough application of rules against random stoppage, utilizing facilities like bus stops and shelters to reduce unnecessary delays and make Pokhara's transit system effective. By putting the suggested solutions about effective service frequency and loading areas into practice, the city may create a transit system that is more effective, dependable, and passenger-focused, satisfies the requirements of its citizens and visitors, and contributes to sustainable urban development and enhanced quality of life.

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