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Optimal Route Computation for Public Transport with Minimum Travelling Time & Travel Cost: A Case Study of Pokhara City

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ABSTRACT

In road networks, it is imperative to discover a shortest way to reach the final destination. When an individual is new to a place, lots of time is wasted in finding the destination. With the advancement of technology, various navigation applications have been developed for guiding private vehicles, but few are designed for public transportation. This study is solely concentrated on finding the possible shortest path in terms of minimum time and cost to reach specific destination for an individual. It requires an appropriate algorithm to search the shortest path. With the implementation of Dijkstra's algorithm, the shortest path with respect to minimum travel time and travel cost was computed. Public transportation network of Pokhara city was taken for the case study of this research. The results of this analysis indicated that when the "time" impedance was used by the algorithm, it generated the shortest path between the origin and destination along with the path to be followed. This study formulates a framework for generating itinerary for passengers in a transit network that allows the user to find the optimal path with minimum travel time and cost.

KEYWORDS *Dijkstra's algorithm, Optimal path, Public transport, Route computation, Shortest path*

INTRODUCTION

Public transportation plays an important role in urban areas to carry huge no. of passengers which helps to reduce traffic congestion. Nowadays, passengers in urban public transport systems do not only seek a shorter travelling time but they also ask for optimizing other criteria such as cost and effort (O. Dib, 2016). Time being one of the most valuable assets, people want to use their time in optimal way. An accurate and detailed public transport journey planner system can provide multi-modal public transport information on the internet, supports public access for pre-trip planning and optimal route searching. Users can search their optimal routes based on their own preferences such as shortest travelling time, least cost, least transfer, least walking distance or even a preferred mode of transport (Lilian S.C. Pun-Cheng, 2015).

Shortest path problem is the problem of finding a path between two vertices (or nodes) in a graph such that the sum of the weights of its constituent edges is minimized. The weights could be cost, distance, travel time, social economic values, etc. (Adhikari, 2014). An efficient routing system is an indispensable tool for any route network. Manual routing of even a small scale route is out of the realm of human capacity and is best left to computers. "Optimization" means finding an alternative with the most cost effective or highest achievable performance under the given constraints by maximizing desired factors and minimizing undesired ones (Lilian S.C. Pun-Cheng, 2015). **Route Optimization is the process of determining the most efficient route.** Route computation, being a branch of path finding, has largely been evolved from the graph theory of spatial computing. The basic concept of a routing algorithm is to model the specific problem in a suitable graph and solve it by computing shortest path (Geisberger, 2011). A graph refers to a collection of vertices or nodes and arcs that connect pairs of nodes. Nodes represent entities or places. An arc is a physical entity to connect two or more nodes together. It includes roads, bridges, tunnels, and so on. Also, an arc could be uni-directional or bi-directional to indicate the traffic flow along the arc (Lilian S.C. Pun-Cheng, 2015).

From the perspective of bus travelers, bus trip involves a variety of decision making. The purpose of a bus trip might be different, e.g., to reach destination in least cost, or to take a most comfortable line, or to traverse a sightseeing route. Travelers have to make choices on travel distance, travel time, number of transfers, and monetary cost. The existence of different trip objectives makes bus trip optimization a quite complicated issue. Therefore, there is a real need to develop a seamless routing application that provides passengers with efficient itineraries according to their needs and preferences (O. Dib, 2016).

The context of this research is the city of Pokhara in Nepal. The total area of Pokhara Lekhnath Metropolitan City (PLMC) is 464.24 square kilometers (PLMC, 2017) with 1,05,630 households and 4,02,995 populations (CBS, 2011). Since, Pokhara is in the rapid verge of immergence so the city is developing rapidly. Pokhara has annual population growth rate of 5.6%. In 2013, 45% population of Pokhara used private vehicles (Shakya, 2013). Pokhara is also recognized as one of the major destinations for adventure tourism in Nepal. The number of tourists visiting PLMC has been increasing from 2,30,000 in 2010 to 3,01, 200 in 2016 (DoT, 2016). Similarly, the growth of domestic tourists visiting PLMC is also in increasing trend. This indicates that there will be more number of passengers (locals and visitors) whose specific interest to visit specific place has to be responded by the public transportation. So, the tourists visiting Pokhara definitely want their time and money to be used efficiently. For a long history, Pokhara has relied on bus system. With urbanization and socio-economic sustainable development, the requirement of the urban public transport is increasing. As no any city is common to another, every city is unique in itself and has its own identity. So does Pokhara, it has its own nature of transport route network and facilitation of transportation system. To counteract the difficulties faced by commuters of Pokhara city, this study will focus on the development of model to find the optimum route among the network based on minimum travelling time and travelling cost.

METHODOLOGY

To conduct this research, the methodology has been divided into two main stages. The stages of methodology are discussed and highlighted one by one.

Stage One: Identifying the impedance of bus trip

First of all, the existing public transportation network of Pokhara was taken into consideration such that a node represented a bus stop/station and link between them represented a transport linkage. Since, the main variables of this research were travel time and travel cost. So, the field observation was carried out in order to note down the time taken to travel from each node to another node of each bus routes around Pokhara city with the help of stop watch. The field work for data collection was carried out from December 2017 to January 2018. Similarly, the travel fare data was collected from the respective bus service providers.

Stage Two: Analyzing the data and find the optimal bus route

During the bus trips, the travelers may prefer shortest travel distance and time including minimum bus fare. This has led to two different strategies in searching optimal bus trips, one is minimum travel cost oriented and another is shortest travel time oriented. As soon as the raw data were collected, they need to be processed. So, the time and cost required to travel from each respective node to others were classified. Since, the travel cost required to travel from each respective node to another respective node is same and vice versa but in case of travel time the case is not the same. Thus, the travel time was calculated by taking average value among the respective connecting nodes for each different trips. Once the travel time and cost were identified, a geographical network was prepared such that bus stops touching each other formed a link. Square matrix for each node in which time and cost as it's element was formed. A weighted graph was formed. The elements of matrix were imported to Microsoft Visual Studio 2017 as the input for each node. The bus trip optimization based on time and cost impedance was carried out with a looped procedure. With the help of Pseudocode for Dijkstra's Algorithm using C++, an optimal path in terms of minimum travel time and travel cost were achieved for each run.

Numerical Example

A numerical example is used to demonstrate the effectiveness and implementation of the algorithm to be used for this study.

For example, consider below graph and starting point (origin/source) as 0.

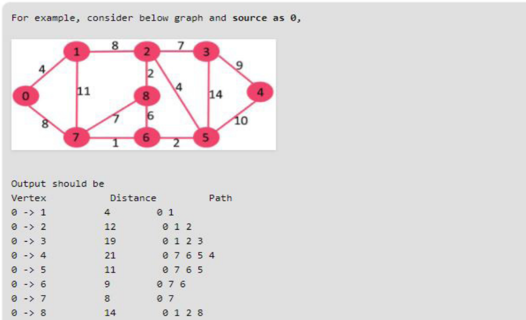

Figure 1. Example of Transport Network

(GeeksforGeeks, n.d.)

Data Analysis

Ranking of Bus Stops

For optimization of any road network, it should consist of ranking of nodes so that it will be easier to conduct and present the outcomes of research work. The bus stops (i.e. nodes) of Pokhara were ranked as follows:

Rank	Bus Stop	Rank	Bus Stop
0	Bagar	34	Titepani
1	Mahendrapool	35	Puranchaur
2	Chipedhunga	36	Raikar
3	Prithvi Chowk	37	Maidan
4	Birauta	38	Gufa
5	Lakeside	39	Riverdale School
6	Srijana Chowk	40	Jogimadi
7	Rastrabank Chowk	41	Tupke
8	Chorepatan	42	Ghattekunna
9	Hallanchowk	43	Chauthe
10	Zero KM	44	Bhotechautara
11	Sitaldevi	45	Majheripatan
12	Bajhapatan	46	Bagar Ward Office
13	Kahunkhola Chowk	47	Miyapatan
14	Sajha	48	Manipal
15	Kaseri	49	Ban Campus
16	Simpani	50	Tutunga
17	Harichowk	51	Belghari
18	Baglung Buspark	52	Bijaypur
19	Himalayan Eye Hospital	53	Buddhi Bazar
20	Int'l Mountain Museum	54	Arghaun Chowk
21	Mahatgauda	55	Tal Chowk
22	Amarsingh Chowk	56	Sisuwa
23	Rambazar	57	Begnas Tal
24	Kaji Pokhari	58	PU Chowk
25	Nirajan Chowk	59	Tamukh
26	Chinedanda	60	Satmuhane
27	Khalte Masina	61	Rupa Tal
28	Sundarfeed	62	Janata Ko Chautara
29	Engineering Campus	63	Phedi
30	Lamachaur	64	Rithepani
31	Akalaa Devi Temple	65	NEA Office, Malepatan
32	Bhunpare	66	WR Hospital
33	Besichowk	67	Saint Mary's School

Table 1. Ranking of Bus Stops

Optimization of Transport Network Based on Minimum Travel Time

For the preparation of the network, bus stops touching each were considered as the nodes and the geographical connection between nodes were considered as their links. The weights of the link between each node were the time required to travel to the respective nodes. The optimization was carried out for the nodes touched by the buses of respective bus service providers and was dealt individually.

Pokhara City Bus Service provides its service throughout the city and covers most of the parts of the city. It runs its bus service in 16 different routes with touching 52 nodes. Lekhnath City Bus Service provides its service focusing on major parts of Lekhnath and connects to Pokhara. It runs its bus service in 5 different routes with touching 19 nodes. Similarly, City Micro Bus Service provides its service on major parts of Pokhara. It runs its bus service in 6 different routes with touching 18 nodes. The weighted graph of respective bus service provider (i.e. Pokhara, Lekhnath and City Micro Bus Sevice) is shown in Figure 2.

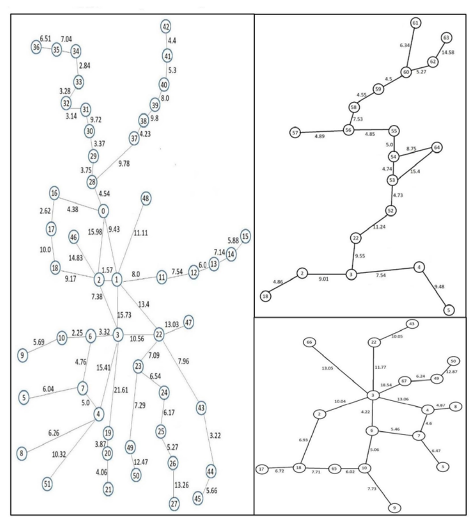

Figure 2. Weighted graph between the nodes

Since, the commuter can start their journey from any node/bus stop so the matrix for each node to be considered as starting point was formed.

Once the matrix was formed, it was then optimized using Dijkstra's Algorithm in Microsoft Visual Studio 2017 (C++ code) and the result was obtained.

Optimization of Transport Network Based on Minimum Travel Cost

In order to optimize the network based on minimum travel cost, the procedure will all remain same except the weights between the nodes had been replaced by travel cost instead of travel time. The weighted graph and matrix was introduced. The optimization in terms of min. travel fare was carried out for the nodes touched by the buses of respective bus service providers and was dealt individually.

RESULTS AND DISCUSSION

After the formation of matrix, it was optimized using pseudocode for Dijkstra's Algorithm with printing path in Microsoft Visual Studio 2017 (C++ code) and following results were obtained. Here, in the result box, the "vertex" indicates the origin to destination node where as "travel time" indicates the time required to travel from origin to destination and "path" indicates the nodes to be followed so as to reach the desired destination. For example, to travel from node "0" to node "5", the shortest path is: 0 à1 à2 à3 →6 →7 →5 and it takes 32.5 min.

Optimization based on minimum travel time for routes of:

Pokhara City Bus Service:

Result along with printing path:

From Node 0 (Bagar):

Vertex	Travel Time	Path
0 -> 1	9.430000	0 1
0 -> 2	11.000000	0 1 2
0 -> 3	18.380000	0 1 2 3
0 -> 4	31.460000	0 1 2 3 6 7 4
0 -> 5	32.500000	0 1 2 3 6 7 5
0 -> 6	21.700000	0 1 2 3 6
0 -> 7	26.460000	0 1 2 3 6 7
0 -> 8	37.720000	0 1 2 3 6 7 4 8
0 -> 9	29.640000	0 1 2 3 6 10 9
0 -> 10	23.950000	0 1 2 3 6 10
0 -> 11	17.430000	0 1 11
0 -> 12	24.970000	0 1 11 12
0 -> 13	30.970000	0 1 11 12 13
0 -> 14	38.110000	0 1 11 12 13 14
0 -> 15	43.990000	0 1 11 12 13 14 15
0 -> 16	4.380000	0 16
0 -> 17	7.000000	0 16 17
0 -> 18	17.000000	0 16 17 18
0 -> 19	39.990000	0 1 2 3 19
0 -> 20	43.860000	0 1 2 3 19 20
0 -> 21	47.920000	0 1 2 3 19 20 21
0 -> 22	22.830000	0 1 22
0 -> 23	29.920000	0 1 22 23
0 -> 24	36.460000	0 1 22 23 24
0 -> 25	42.630000	0 1 22 23 24 25
0 -> 26	47.900000	0 1 22 23 24 25 26
0 -> 27	61.160000	0 1 22 23 24 25 26 27
0 -> 28	4.540000	0 28
0 -> 29	8.290000	0 28 29
0 -> 30	11.660000	0 28 29 30
0 -> 31	21.380000	0 28 29 30 31
0 -> 32	24.520000	0 28 29 30 31 32
0 -> 33	27.800000	0 28 29 30 31 32 33
0 -> 34	30.640000	0 28 29 30 31 32 33 34
0 -> 35	37.680000	0 28 29 30 31 32 33 34 35
0 -> 36	44.190000	0 28 29 30 31 32 33 34 35 36
0 -> 37	14.320000	0 28 37
0 -> 38	18.550000	0 28 37 38
0 -> 39	28.350000	0 28 37 38 39
0 -> 40	36.350000	0 28 37 38 39 40
0 -> 41	41.650000	0 28 37 38 39 40 41
0 -> 42	46.050000	0 28 37 38 39 40 41 42
0 -> 43	30.790000	0 1 22 43
0 -> 44	34.010000	0 1 22 43 44
0 -> 45	39.670000	0 1 22 43 44 45
0 -> 46	25.830000	0 1 2 46
0 -> 47	35.860000	0 1 22 47
0 -> 48	20.540000	0 1 48
0 -> 49	37.210000	0 1 22 23 49
0 -> 50	49.680000	0 1 22 23 49 50
0 -> 51	41.780000	0 1 2 3 6 7 4 51

Similarly, the optimal path in terms of min. time for any trip starting from node (1-51) can be calculated.

Optimization based on minimum travel cost for routes of:

Here, in the result box, the "vertex" indicates the origin to destination node where as "fare" indicates the travel cost required to travel from origin to destination and "path" indicates the nodes to be followed so as to reach the desired destination. For example, to travel from node "0" to node "10", the cheapest path is: 0 à1 à10 and it costs NRs.

29. In this case, it also means that there is no any direct connection (bus route) between node “0” and node “10”, so node “10” can only be reached via node “1” which requires a transfer of vehicle at node “1”.

Pokhara City Bus Service:

Result showing along with path:

From Node 0 (Bagar):

Vertex	Fare	Path
0 -> 1	13	0 1
0 -> 2	13	0 2
0 -> 3	16	0 3
0 -> 4	22	0 4
0 -> 5	23	0 5
0 -> 6	16	0 6
0 -> 7	22	0 7
0 -> 8	23	0 8
0 -> 9	34	0 6 9
0 -> 10	29	0 1 10
0 -> 11	26	0 2 11
0 -> 12	31	0 2 12
0 -> 13	32	0 2 13
0 -> 14	37	0 2 14
0 -> 15	47	0 2 15
0 -> 16	13	0 16
0 -> 17	26	0 16 17
0 -> 18	26	0 16 18
0 -> 19	32	0 3 19
0 -> 20	35	0 3 20
0 -> 21	42	0 2 21
0 -> 22	19	0 22
0 -> 23	20	0 23
0 -> 24	24	0 24
0 -> 25	28	0 25
0 -> 26	29	0 26
0 -> 27	32	0 27
0 -> 28	13	0 28
0 -> 29	13	0 29
0 -> 30	14	0 30
0 -> 31	22	0 31
0 -> 32	26	0 32
0 -> 33	27	0 33
0 -> 34	28	0 34
0 -> 35	32	0 35
0 -> 36	36	0 36
0 -> 37	14	0 37
0 -> 38	19	0 38
0 -> 39	27	0 39
0 -> 40	28	0 40
0 -> 41	37	0 41
0 -> 42	41	0 42
0 -> 43	32	0 2 43
0 -> 44	41	0 22 44
0 -> 45	44	0 22 45
0 -> 46	26	0 2 46
0 -> 47	32	0 3 47
0 -> 48	28	0 1 48
0 -> 49	33	0 23 49
0 -> 50	36	0 23 50
0 -> 51	35	0 4 51

Similarly, the results of the nodes touched by Lekhnath and City Micro Bus Services were obtained.

CONCLUSIONS

With the advancement of technology, various navigation applications have been developed for guiding private vehicles, but very few are designed for public transportation. This study acts as a remedy to overcome this complication in case of public transportation of Pokhara.

The main aim of this research was to develop a model that generates itinerary for passengers / commuters in a public transportation network assuming that a passenger’s objective is to travel with minimum travel time and travel cost. So as to find the optimal route, the main data regarding travel time and cost of travel were collected. The data obtained were processed. Weighted graph and matrix for each starting node was constructed and analyzed with the help of Microsoft Visual Studio 2017 software using C++ code for Dijkastra’s algorithm which also provided the path to be followed. The code was run for each time for each starting node with its own respective inputs. Separate analysis was carried out in case of time and cost. The results of this analysis indicated that when the “time” impedance was used by the algorithm, it generated the shortest path between the origin and destination along with the path to be followed. Similarly, when the “cost” impedance was used, it generated the cheapest route. The results were cross checked with a different C++ code to solve the algorithm. From both the codes, the output obtained was same. The results obtained were completely unique and distinct for each individual node which was considered as starting point. Since, this research was able to develop a model to find an optimal path so the research objectives were met.

Though it is a challenge to practically implement the results of this study as the navigation practice is yet to be widely accepted by public in finding the location within Nepal but nevertheless it can definitely play a significant role in the field of optimization of public transport network in near future. It is believed that the methodology can be implemented in other cities as well to optimize the network as per their needs. Also, the nodes of the public transit network of Pokhara city touches almost all of the touristic destinations in the town.

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